Mixed Farming : Scope and Constraints in West African Savanna

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Mixed Farming : Scope and Constraints in West African Savanna

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Proefschrift

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Propositions

1. Only wealthier farmers can and will become mixed farmers.
   This thesis

2. Resource-poor farmers and semi-nomadic pastoralists must be stimulated to participate in technology development, so that they can influence the research agenda and be co-responsible for development and extension of technologies adressing their specific needs.
   This thesis

3. You can not sell a cow and drink its milk.
   A proverb

4. Appropriate credit facilities at farm level are a prerequisite for optimal animal production and undisturbed integration of crop and livestock production on mixed farms.
   This thesis

5. A cart should be considered more important in mixed farming than a plough.
   This thesis

6. Mossi crop farmers and Fulani herdmen use different strategies to cope with uncertainties such as unreliable rainfall conditions: Mossi increase control over scarce resources whereas Fulani increase mobility to track changes and find the scarce resources.
   This thesis

7. Mixed farming and population growth lead to a decrease in quantity and quality of animal feed for herds of Fulani herdsmen, and thus endanger their production.
   This thesis

8. A mixture of different farming systems, rather than an unique mixed farming model, is needed to satisfy the variety of societal needs.
   This thesis

9. Farming systems development is not so much explained by climatic conditions, soil type and other natural factors, but can be explained on the basis of differences in population density.
   Boserup, 1965

10. More people will imply smaller shares for each, not only in terms of food but also in terms of government services such as schooling and health care.
    Malthus, 1798

11. Classification of farming systems based on farm household characteristics is as difficult as making client profiles based on information on clientcards in supermarkets because it is very difficult to derive ones motives from ones behaviour.
Anonymus

12. Als mensen te gering in aantal zijn, lopen ze gevaar hun onafhankelijkheid te verliezen, en als ze te talrijk zijn, hun vrijheid.
Aristoteles

13. Het is niet te hopen dat de strijd tussen Kaïn en Abel als voorbeeld dient voor de relatie tussen Mossi en Fulani.

14. Onthaasten? Sorry, geen tijd voor gehad.
Rob van den Berg, in: Boeken, in NRC Handelsblad 31 december 1999

15. In future the only mobility left for Fulani may be the mobile telephone.

Propositions associated with the PhD thesis of Maja Slingerland: Mixed farming: Scope and Constraints in the West African Savanna.

Wageningen, June 2, 2000

To

- My parents Cor Slingerland and Gré Ros
- My partner Andi Tan
- The family of Dr. Adama Traoré

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Table of contents

1	General introduction: policy, crop and livestock production	1
2	Spatial and temporal heterogeneity of natural resources and land use in the study area (Kaïbo in Zoundwéogo province)	21
3	Institutional environment: Agricultural Knowledge Systems	37
4	Farming systems development in West African Savanna: criteria, concepts and drives	51
5	Financing role of livestock	88
6	Exploring the potential of animal traction in the North Sudan zone of Burkina Faso	157
7	Village territory land use for grazing and fuel wood	169
8	General discussion	213
9	Conclusions and recommendations	243
	References	251
	Summary	275
	Samenvatting	279
	Résumé	285
	Curriculum vitae	291

1 General introduction: Policy, crop and livestock production

Introduction

In West Africa, and in particular in the Sahelian countries, crop and animal production depend largely on factors that can hardly be influenced by farmers, researchers, extension workers or national politicians.

The main factor that determines annual agricultural output, and can not be influenced by man, is rainfall. Rainfall is very variable between and within years and locations, leading to heterogeneity of vegetation in time and space (Tucker and Nicholson, 1998; Grainger, 1992; Penning de Vries and Djitèye, 1982). Irrigation facilities need very large investments per hectare which are not within reach of farmers' possibilities, nor within the scope of the relatively poor governments. Most crop production occurs therefore in a system of rainfed agriculture. Rainfed crop production is risky and therefore not conducive for large investments (in fertiliser, high yielding varieties) without guarantees that sufficient water will be available to value them. Farmers have hardly any control over their environment. They can cope with the uncertainty of rainfall by using soils with very different properties, located at different positions in the landscape (toposequence). They can also use mixtures of crops that grow better under high rainfall with those tolerating low rainfall conditions. Finally, they can maximise seeding area and apply a system of selective weeding of only those soil-crop combinations that have the highest chance to succeed under the prevailing rainfall conditions. Years of food surpluses and years of deficiencies alternate in response to rainfall (Maatman *et al.*, 1992).

Most animal production depends on grazing of natural vegetation. Years of drought can lead to high mortality of livestock due to lack of fodder. Periods of severe droughts such as 1972-73 and 1983-84 have shown to have strong impacts on animal numbers and herd composition. Small ruminants start to breed at an earlier age, have shorter breeding intervals and have more young per litter compared to cows. Therefore, small ruminant herds can be built up much faster than cattle herds. This can be illustrated for Niger (Williams *et al.*, 1993), where the ratio of small ruminants to cattle had more than doubled between 1963 and 1991. In 1980, numbers for goats and sheep were much higher than in 1970, but for cattle they had not yet attained the 1970 level. After the 1984 drought, a very strong increase in small ruminant numbers compared to cattle has also been noticed in Yatenga province in Burkina Faso (INERA, 1993). Between 1984 and 1990 cattle numbers increased twofold and small ruminant numbers increased from 150.000 to 1.200.000 which is almost eightfold (INERA, 1993).

Another effect of drought can be degradation of vegetation and soils due to plant-soil feedback and overgrazing (Rietkerk, 1998). Although the nature of the soils must be considered as a given factor, its productive value can either decrease or increase in response to management. In the Sahelian countries, soils are generally poor in nutrients, especially in nitrogen and phosphorus, and fairly unstable in physical structure (Penning de Vries and Djitèye, 1982).

Topsoils can locally and temporarily be improved by amendments, such as animal manure, mulch or green manure, but the substrate remains essentially unchanged. Droughts, excessive trampling by livestock, overgrazing, etc. can, on the other hand, lead to crust formation of bare soils, making infiltration of rainwater impossible and killing most soil fauna (Hoogmoed, 1999; Mando, 1997).

A completely other level of factors that can hardly be influenced, is that of political decision making. Many decisions are made at global scale by the World Bank (WB), the International Monetary Fund (IMF), the United Nations (UN), World Trade Organisation (WTO), etc. National politicians have very little influence on these institutions and have to accept their decisions to obtain budget support or debt-reduction. National politicians have no influence on world market prices, except when they produce large quantities of a commodity that is scarce and valuable. Nigeria has, through its membership of OPEC (Oil Producing and Exporting Countries) for instance some influence on oil prices. Burkina Faso, although exporting large quantities of cotton and livestock, is just a small player on the world market.

Finally, many actual developments in a country depend on its history that must be accepted as given and can not be changed. The way in which to deal with history can, however, be influenced. The relation between France, the former colonial power in many countries of West Africa, and these countries changed for instance over time. The actual situation in these countries can only be understood when their history is known. The history of Sahelian countries in general, and Burkina Faso in particular, will therefore be discussed in relation to labour, crop and animal production, in the next sections (Massa and Madièga, 1995).

Colonial occupation, labour and crop production

During the first 20 years of colonisation of Africa, France aimed at development of economic activity (Duperray, 1984). France forced their colonies to become financially independent and to support all costs of the local administration (Kambou-Ferrand, 1993). The colonial powers introduced therefore taxes, forced labour and forced military services. Forced labour compensated lack of cash and served to construct infrastructure such as roads, bridges, railways, digging of wells and planting of trees.

In 1919, Upper Volta with its capital Ouagadougou was created. Ouagadougou was also the capital of the Mossi kingdom, hence the Mossi chieftancy became highly involved in colonial occupation. Mossi chiefs were used to collect taxes. Traders (Dioula) and pastoralists (Fulani) paid therefore higher taxes than (Mossi) farmers. Mossi chiefs arranged labour forces and were responsible for feeding administrators on field trips. They supported the introduction of cash crops, such as cotton for export and to make it easier for (their) farmers to pay their taxes. Cotton seeds were distributed free of charge either for communal fields of 10 acres per inhabitant or in quantities of one kg per farmer. French textile industries depended heavily on cotton from West Africa, because world market prices of cotton, mainly produced in the USA, doubled in 1920 and tripled in 1923. Cotton production for export was therefore, imposed on the French colonies in West Africa from 1924 through 1930. In 1928, three cotton farms were created on which experiments to improve cotton varieties were executed and farmers were trained in cotton production. In 1932, industrial separation of raw cotton into cotton and grains was possible at over 30 factories and other industrial processes such as milling of groundnut and karité[1] for oil extraction were introduced (Schwartz, 1995).

Upper Volta was considered as a labour reserve that could be used for work in neighbouring countries: railways in Ivory Coast, Senegal, Mali, etc. (Ouédraogo, 1985). In 1932, the country was divided among its neighbours and ceased to exist. The objective was to use its labour force for coffee and cacao plantations in Ivory Coast, for rice cultivation in the "*Office du Niger*" and to construct the railway Abidjan-Niger (Izard, 1968). Traditional Mossi leaders complained about this division, that also divided the Mossi kingdom. They achieved in 1947 that Upper Volta became a separate unit again within the 1932 borders. In the meantime, the crisis of 1930 in Europe and the USA had a very negative impact on all export crops and years of droughts and grasshopper invasions in Africa led to severe hunger. In 1937, colonial powers therefore instructed local administrators to stimulate local food production, but export crops such as karité butter, cotton, groundnut, sisal, sesame and ricinus oil were still promoted.

After World War II, 1940-1945, France added the concept of development to its relation with its colonies. Forced labour was abolished, but labour migration continued. Remittances from migration remained an important source of cash for Upper Volta. Another source of income was trade. Cattle and cotton were exchanged against kolas[2] from Ivory Coast and Gold Coast (Ghana), salt came from the Sahara. France tried to stimulate trade with Ivory Coast by decreasing transport costs by railway to Ivory Coast and increasing export taxes to Ghana. It also created corridors for cattle to pass without problems to Ivory Coast (Duperray, 1984).

To develop Upper Volta, two plans were developed for the period 1948-59 (La documentation française, 1960). Main objectives of the plans were intensification of food crop and export crop production, construction of irrigation infrastructures to open up land for crop production, improvement of animal production, water management and training of farmers. From 1948 onwards the two existing field stations were strengthened and three new ones were created, each with its own speciality. Breeding, selection and processing of oil crops (groundnut, karité) was done in Saria and Niangoloko, horticulture and experiments with legumes for gardening were the speciality of Kamboinsé and Banfora, whereas soil protection was emphasised in Farako-Ba. In 1949 the *Compagnie Française pour le Développement des Fibres Textiles* (CFDT) was created to cover the total production and processing chain of cotton. The CFDT was funded with 64 % of the capital coming from France and 36 % from societies of users and producers of cotton (Schwartz, 1995). CFDT was the predecessor of the current SOFITEX, that also covers cotton production, collection, transportation and processing.

[1] Kernel of the fruit of *Butyrospermum paradoxum* subsp. *parkii*
[2] Fruit of *Cola acuminata Schott & Endl.*

Just before independence in 1960, the results of the economic development activities were very modest although the railway reached Ouagadougou in 1954 and rice production increased significantly. Production of cash crops such as cotton and groundnut was only some thousands of tons and of sisal and sesame only hundreds of tons. Pilot farms were started by the first governor in 1923, re-established again by the agricultural service in 1930 and installed again as part of the second agricultural plan of 1953-1959. They were based on animal traction, incorporation of manure, and crop rotations of cotton-groundnut-millet. They were generally failures, because they were operated by chiefs and ex-military men, and not by motivated farmers (Belem, 1985). From 1957, pilot farms were replaced by 19 training centres, on gardening (9), cotton (7) and traditional crop production (3). Efforts with respect to animal production focused on animal health, leading to the creation of veterinary and vaccination centres and a school and a laboratory for veterinarians. Additional themes were pastoral water points and animal breeding. One of the former cotton farms was used for breeding experiments. In 1960, livestock constituted 50 % of the value of all exports. Whether this was the direct result of measures to improve animal production remains to be proven.

Import-export enterprises were all in the hands of French companies. Gold digging was done by foreign companies and not remunerative. Positive results were the establishment of many wells and small water holding reservoirs. Silos were constructed to store buffer quantities of cereals to be used in case of calamities. They replaced traditional grain reserves at farm level, that were exhausted during the hunger period, but also to pay taxes.

Social changes also occurred. Children of Mossi chiefs went to school and many people served in the military. Both groups learned French and this language facilitated communication between ethnic groups and became at the same time a means to spread Western culture and values. Education, but also commercial channels with France were responsible for the introduction of Christianity. Islam was present in Upper Volta through commercial activities with neighbouring countries, specially in the North. Both religions were vectors of change of culture and associated values. Finally, the introduction of hired (salaried) labour and the monetarisation of taxes caused a gradual shift from social to economic relations (Massa, 1995).

Demographic development in Upper Volta was very peculiar compared to its neighbouring countries. Between 1921 and 1960, annual population growth was only 0.9 % for Upper Volta, because of the high labour migration, compared to 2.5 % in Ghana during the same period (Goarnisson, 1984).

Policy options after independence

After independence, the relation with former colonial powers changed gradually from exploitation to trade. Local governments needed money and continued to export cash crops to France, often through semi-governmental agencies partly owned by France. An example is SOFITEX, the organisation currently responsible for cotton production, collection and export in

Burkina Faso, since 1984 the name of Upper Volta. The pathways for agricultural development initiated during the colonial period seemed adequate for the country. Emphasis on modern cotton production is maintained. Farmers now grow cotton voluntarily, because it generates revenues, that are invested in agricultural equipment such as animal draught power. Modernisation of cotton production has some spin-off on cereal production through the use of animal draught power, manure and fertilisers. Groundnut became also integrated in many farmers' cropping patterns and livestock is still one of the most important export products (Goarnisson, 1984).

During the last decades, agriculture in the Sahelian countries has changed considerably as a result of severe droughts (1972-73 and 1983-84), high population growth and slow economic development (De Ridder and Breman, 1993). Governments and foreign donors emphasised local food production and storage to increase food security with regard to unforeseen calamities such as droughts and grasshopper attacks. Donors from Europe and the USA sent food aid and discovered their responsibilities for this part of the world. After the periods of (emergency) aid, a strategy of funding development projects to support increase in local food production was implemented. At present in Sahelian countries a mixture of interrelated, sometimes conflicting and sometimes mutually supportive projects are executed, funded by many donors.

National policy makers have to deal with priority with the problem of increasing populations and their need for food. All calculations lead to the inevitable conclusion that efforts should be made to develop technologies leading to substantial increases in yields per ha and to promote adoption of these techniques. Within the group of policy makers (and researchers) two main streams can be distinguished with respect to the methods to realise an increase in production: Low and Heigh External Input Agriculture (LEIA and HEIA).

The basic principle behind LEIA is to optimise recirculation, to minimise losses and to prevent environmental pollution. A key process is recycling. Technical options are composting of household waste, use of manure on arable land, mulching, mixed cropping and rotational cropping, use of crop residues as animal feed, animal traction for transport and agricultural labour, biological pest management, etc. Integration of crop and livestock production is essential, because of the mutual benefits through manure, crop residues and animal traction. A reason to promote LEIA is its low capital cost which is very important to the large number of small subsistence farmers in developing countries with mostly very low purchasing power. As only few capital inputs are involved, financial risks are low. A disadvantage is that most proposed techniques are labour intensive, which becomes finally a bottleneck for the farm household. Furthermore, production levels are generally modest, but sustainable over a very long period, provided most elements of the system do not leave the farm. Participation of farmers in a market economy is hardly necessary from the input side. When the objective is to increase cereal production to feed the urban population, including government officials, market integration is necessary to allow agricultural surpluses to become available for these categories of the population.

The basic principle underlying HEIA is to maximise output by using high levels of external inputs. Environmental pollution is not a priori excluded, but considered an acceptable cost for development and modernisation. Technical options are crop production with inputs such as inorganic fertilisers and pesticides, monocultures, mechanisation with tractors and other machinery, livestock keeping with improved breeds, stall feeding with concentrates, intensive veterinary care, etc. Thus, HEIA requires import of inputs, which may claim a considerable part of the government budget, that is mostly already insufficient to cover the country's needs. HEIA tends to lead to specialised crop or animal production. The high capital costs make HEIA especially suitable for more wealthy farmers with a certain purchasing power and who can afford to take some risks. The high capital input entails high financial risks. Spectacular increases in production can be realised, but only under optimal conditions and environmental costs may be high. Furthermore, an adequate infrastructure is necessary: roads, markets, banking facilities, distribution channels for inputs and for production surpluses, etc.

The choice between LEIA and HEIA depends thus, among others, on the characteristics of the farm population in a specific country, its infrastructure, and its development model. A government has two extreme options. It may aim at a few very productive capital-intensive farmers (HEIA), that must be able to feed themselves and the remainder of the population active in the non-agricultural sectors of the economy. Or it may settle for many small basically subsistence farmers producing each a modest surplus (LEIA), enough to feed a small number of government agents. In the rainfed areas in developing countries of West Africa, such as Burkina Faso, local food production can not compete with cheap imports. Protected economic environments need therefore to be created for national diffusion processes with regard to LEIA, to occur. Under these conditions self-sufficiency in food may be ensured, even if other countries produce the same products cheaper. On the other hand, the Burkinabé government could aim at rapid agricultural growth through sophisticated technology (HEIA) and progressive farmer strategy, that might guarantee food security in an environment of free economic competition, but at the social costs of unemployment of large groups of former farmers.

National policy makers may also have other objectives than food security. Export of products is essential for the national budget and to balance the import of consumption goods not produced locally. In Burkina Faso, the main export products are cotton, gold, meat and live animals. These products were represented 39, 15 and 10 % of the value of total export (EIU, 1996). In this view, extension messages should lead to increased production of these commodities, if necessary with high external inputs (HEIA). The possibility to export agricultural products depends on the ability to offer a better product at a lower price at the right time, hence the HEIA approach is favoured. This means permanent innovation and thus high investments in research and efficient transfer of results to the farmers. Inefficient producers will be weeded out.

When reduced environmental degradation is a policy objective, HEIA also seems the better alternative. High external input agricultural production on a limited area causes less damage to natural resources than inefficient low input production on extended tracks of land which its associated soil mining, that may result in irreversible degradation. Highly controlled, intensive indoor livestock keeping is also less destructive to natural resources than low input uncontrolled free grazing with a tendency to excessive animal densities and the associated risk of rangeland degradation.

Another, mostly hidden, objective of politicians is to satisfy the constituency that forms their power base: the urban population, the civil servants, the military, the merchants and all those formally educated. These parts of the population are mostly not active in the agricultural sector. Consequently, they are not interested in high producer prices, but in low consumer prices for meat and cereals. When some are active in arable farming or in animal production, it is with an investment motive expecting a high return to capital. They will be interested in specialised cotton or intensive milk production (HEIA), but certainly not in labour intensive low output techniques (LEIA).

National policy makers can decide on subsidies for certain products such as inorganic fertiliser or animal drawn carts. They can also influence the distribution pattern of scarce locally produced commodities such as cotton seed cake. Finally, they set the national research agenda. Some research topics (for instance gender issues, natural resource management) and subsidies for certain commodities (for Burkina phosphate for instance) have to be accepted by politicians, because donors make them conditional for funding.

Animal production policy

General

Since colonial days, development programmes have been formulated and implemented to increase livestock production in West African Savanna. Since about 1910 interventions focused on veterinary care, aiming at eradication of various contagious animal diseases. Vaccination campaigns in the 1950s and 1960s created a continuous increase in livestock numbers, for instance at a rate of 2.8 % a year for cattle between 1963 and 1970 (De Leeuw and Tothill, 1993). Since about 1950, attention has been given to development of pastoral water points to extend the use of pasture. Water resources that were publicly financed were open to all, which led to serious over-grazing. They lacked the traditional management structures that linked watering rights to pasture use rights, thus avoiding over-exploitation of rangelands, and they were often constructed without considering the real production capacity of the pastures surrounding them. Only since about 1960 were studies on the pasture resource itself combined with the installation of water points, but attention for management structures was still limited. Periods of serious droughts showed the vulnerability of livestock production entirely dependent on natural pasture. The need became apparent for establishing criteria and ways for determining the carrying capacity of African rangelands (ILCA, 1975).

Politicians have always wanted to abolish transhumance and aimed at sedentarisation of the herdsmen. Nomads were depicted as uncivilised, primitive, living completely independently of the world around them and providing in their own subsistence. Sedentary people were, on the other hand, depicted as civilised, producers of works of art, living in relations of exchange or commerce with others. Sedentarisation was considered equivalent to progress and mobility was confused with chaotic movement, ignoring the valid reasons, either political, economic or ecological, for deliberate movement. The focus of nomads on their cattle was considered irrational, leading to excessively large herds, ignoring the advantages of large herds in an insecure (climate, war, diseases) environment (Bernus 1990).

Between 1970 and 1980 a policy towards ranching (Boudet, 1973) was promoted (by the World Bank) and used as a means to settle semi-nomad pastoralists and to increase the output of the livestock sector. Ranching was heavily based on models used in Europe and the USA, with the carrying capacity concept as key element. Ranching appeared not to match the Sahelian socio-economic and ecological conditions (Douma *et al.*, 1994). After the failure of the ranching strategy, so-called pastoral zones were created, where pastoral people would find certain services such as veterinary infrastructure, permanent water points, storage for agro-industrial by-products, etc. The creation of these zones was also part of the policies of sedentarisation, gradually forcing formerly dispersed pastoral people with their herds to settle inside the limited areas, respecting carrying capacities and selling their livestock "surpluses" (Douma *et al.*, 1994).

In response to the severe drought of 1973, the Club du Sahel and CILSS[3] were established, to co-ordinate the fight against desertification and to assist in formulating and implementing a range management programme. Unfortunately, many interventions had unpredictable, unintended, contradictory consequences. Creating water holes and controlling animal diseases led for instance to a substantial increase in livestock numbers (positive), that, unfortunately, in turn triggered disasters like overgrazing and erosion, and conflicts over grazing rights among livestock owners and between livestock owners and crop producers. One of the problems was that the authorities taking the measures often did not take into account nomads' knowledge of their environment and the associated practices. Even worse, the negative opinion about nomads was used as a justification to accuse them of destroying their environment through irrational use, as witnessed, for instance by the practice of cutting trees to feed their livestock or to make the few utensils they need, use bark for tanning their hides, etc. Only after opening up the pastoral zones and observing the sedentary population cutting wood and making charcoal for sale in cities, was it realised that the pastoral zones had been only lightly and conservatively exploited by pastoralists, compared to the destructive exploitation by non-pastoralists.

The droughts have led to a shift in livestock activity from the Sahelian zone to the savannas. The (semi) nomadic livestock owners lost substantial parts of their herds as a result of high mortality rates and also by forced sales caused by the deteriorating terms of trade between livestock and cereals. The number of livestock kept by arable farmers in the south has increased considerably, producing draught power and manure to improve stagnating or declining crop

[3] Comité permanent Inter-états de la Lutte contre la Sécheresse dans le Sahel (CILSS)

yields. Some wealthier citizens, the new livestock owners, regard livestock as an attractive investment, aiming at large numbers. Urban centres increase demand for meat and milk and lead to intensified milk production and fattening around cities (De Ridder and Breman, 1993). Livestock changed hands and occupies new territories. Farmers, becoming livestock owners adopt other production objectives such as traction and manure, than traditional pastoralists that are interested in meat and milk (Breman and Traoré, 1985).

Population growth, leading to increased pressure on the land has eagerly been used as a pretext to make pastoralists abolish their mobile lifestyle, depicted as outdated, chaotic and irrational. For the national governments, an important motive to sedentarise nomads was to increase control over a hitherto mobile population that escaped all state influence. Concomitant advantages of settlement put forward were the possibilities to provide infrastructure like schools, hospitals, etc., for the nomadic people, and to participate in the sector of intensive livestock production, generating national income and allowing collection of taxes.

Policy makers can deal much more easily with sedentary livestock keepers, which are in fact crop producers, than with transhumant or nomadic pastoralists. The mobility of the latter complicates tax collection, input distribution systems, contact between extension and user, etc. Mobility of herds and herdsmen has also serious consequences for the implementation of national development programmes such as "*Gestion de terroir villageois*" (GTV). How to decide to which village the herdsman and his herds belong? How to involve the pastoralists in natural resource management, when they are part of the year elsewhere, etc. Moreover, many conflicts between crop producers and herdsmen break out each rainy season. In addition, almost all politicians originate from the sedentary crop producer group and have no positive emotional link or built-in solidarity with transhumant herdsmen. Research issues and extension messages with respect to animal production are therefore connected to priorities and possibilities of crop producers: development of animal traction, investment in collection and use of manure, collection and use of crop residues, cultivation of fodder legumes for intensive animal production subsystems.

Finally, the environmental issue becomes increasingly important to policy makers. Studies indicate the rapid deterioration of natural resources which threatens the entire agricultural production capacity of the country. Moreover, foreign donors insist on programs with respect to natural resource management as conditions for loans (World Bank, IMF) and as conditions for financing bilateral projects (Directoraat General Internationale Samenwerking).

Animal production policy in Burkina Faso

In 1985, CILSS initiated a study on the livestock sector in Burkina Faso (Breman and Traoré, 1985). The study formulated among others, a strong recommendation towards mixed farming in the savanna zone of the country, as a means to improve livestock production. Mixed farming should be based on the use of external inputs such as inorganic fertiliser, rotation of cereals with legume (fodder) crops and animal traction. Sales of livestock, hence destocking, were recommended as source of cash needed for the purchase of external inputs needed in arable farming. High cereal yields were expected to result in reduced cereal prices, compared to livestock prices, hence improving the economic position of livestock keepers. These high cereal yields would increase at the same time the availability of crop residues as animal feed. Intensive crop production should reduce the pressure on the land for agriculture. This combination of measures should result in reduced pressure of livestock on natural grazing lands (Breman and Traoré, 1985).

The study also recommended to intensify animal production directly by improving the fodder situation through introduction of fodder crops based on fertiliser use, and the re-introduction of perennial grasses and legumes in natural pastures. Other recommendations included settlement of nomadic herds, opening of trypanosomiasis infested areas for livestock and emphasis on production of small ruminants that have shorter lifecycles than cattle. Mortality of livestock should be reduced by adequate veterinary care hence herd sizes could be reduced. Adequate construction and management of pastoral water holes should be part of the strategy to improve animal production based on grazing of natural pastures (Breman and Traoré, 1985).

Many conditions must be met to realise the recommended development towards mixed farming. Population growth should be limited through family planning. In the long run the number of livestock owners should decrease and alternative employment should be created. Research should be done to establish production potentials in dependence of availability and quality of the natural resources and their management, but also taking into account the potentials for production of fodder crops and improved pastures. In addition, livestock markets, clients and products should be identified and commercialisation of livestock should be stimulated by legislation and custom regulations at the country borders. Infrastructure, such as veterinary services, saving and credit institutions, effective extension services and distribution channels for inputs should be available or created (Breman and Traoré, 1985).

In Burkina Faso various factors influencing animal production are not under the direct influence of farmers or national policy makers but depend on international events and decisions. An example of an international activity damaging animal production in Burkina Faso is the supply of meat from Europe and Argentina against artificially low prices to countries on the West African coast (Rolland, 1994; Ruben *et al.*, 1994; Josserand, 1993; Klugkist, 1993; Wooning, 1992). Animal products can not be produced in Sahelian countries at these prices and certainly not be exported to the coastal areas for sale. The same holds for European milk powder that is cheaply available on Sahelian markets and hampers development of local milk production, collection and distribution systems (De Jong, 1996). Research and extension to increase milk and meat production in Burkina Faso are relatively useless, when prices on local export markets are controlled by outsiders.

Burkina Faso and most of the other former French colonies share the same currency, FCFA[4], that has a fixed exchange rate with the French Franc (FF). Therefore, these countries are, till today, linked to the monetary policies of France. A recent example to illustrate the impact of this link on animal production is the effect of the devaluation of the FCFA in 1994 on animal exports (CEBV, 1995; Ruben *et al.*, 1994; Quarles van Ufford, 1994). Following this devaluation, Burkina Faso could restore its export market. Compared to 1993, 5.5 times the number of cattle, 5 times the number of sheep and 9 times the number of goats were exported to Ghana in 1994. Also the volume on old markets increased: for example 18 % more cattle was exported to Ivory Coast (CEBV, 1995).

Crop-livestock integration and mixed farming

General

Landais and Lhoste (1990) attributed the start of the crop-livestock integration paradigm as leading development model for francophone Africa to Curasson (1947). Massa and Madièga (1995) and Gervais (1990) state that the mixed-farming model was promoted first by scientists and administrators during French colonial rule and later on, after independence, also by governmental services and development agencies. The model is based on concomitant intensification of crop and livestock production at the level of individual farms. Intensification of crop production consisted of mechanisation (animal traction) for deeper ploughing and more weeding and soil fertility management through the introduction of rotation with leguminous fodder crops and the use of manure and compost. Together, these techniques allowed permanent cropping and hence the elimination of fallow. Intensification of livestock production consisted of keeping draught animals in stables, producing (fodder crops) or collecting fodder (hay) to be stored for feeding these animals, fattening of the animals after their working period, allowing for the purchase of replacements in the form of young bullocks and generating revenue at the same time. The stables also allowed collection of manure.

Landais and Lhoste (1990) showed this model to be a myth, by comparing the development objective with reality over the period 1947-1990. In reality, animal traction has led mostly to extensification of crop production (as long as there was enough land), neglect of draught animals other than cattle (donkeys, horses), because of the fattening component of the model, abandonment of traditional techniques of fertilisation (*contrat de fumure*), leading to more unequal distribution of fertility, neglect of the transport function of draught animals due

[4] Franc de la Communauté Financière Africaine

to the emphasis on ploughing and weeding. The technique of keeping draught animals in stables, at least part of the year, and feeding them properly, was one of the few elements of the model that was widely accepted. In reality, the introduction of leguminous fodder crops was a complete failure. Techniques for the successful cultivation of the crops were insufficiently developed (damage due to pests and diseases, losses during harvest), while their fertilising aspects on-farm were insufficiently understood. Moreover, acquiring seeds was often difficult (not available) or very expensive, while establishment of the crop required high investments in fencing for protection of the crop against free roaming livestock. Finally, practices like fencing and planting of perennial crops created land tenure problems as they were interpreted as annexation of the land. For the use of manure, old practices were abandoned, although those were based on collective grazing of fallow and of harvested fields leading to a more or less homogenous restitution of fertility to the fields. The increase in cultivated area forced herds to be at least part of the year separated from the agricultural area. The territory- and village-level decision making aspect of fertilisation was not compatible with the farm household-level dictated by the model.

In addition, it was surprising that trees were absent in the model, while they are a dominant feature in African parklands and savannas. Trees were found to be alternative sources of organic material for soil fertility (complementary to manure), for livestock feed (protein-rich) and for protection against water and wind erosion. They provide food for humans, and as such they complement products from arable farming and animal husbandry. Trees provide fire wood, allowing crop residues to be used for animal feed and manure for maintaining soil fertility instead of being burnt to serve for cooking. On the other hand, trees growing in high densities may host tsetse and other animal disease vectors and they may limit growth of herbs under their canopies due to competition for light.

Crop-livestock integration experiences in Burkina Faso

In Burkina Faso several field studies have been executed on crop-livestock interactions and their developments, mainly towards mixed-farming. Mixed farming is only one form of crop-livestock integration but the two concepts are very often confused. The studies emphasised either economic behaviour of Mossi crop producers and Fulani herdsmen (Delgado, 1979), changing social relations between Mossi and Fulani (Breusers, 1998), or focused on technical aspects, such as nutrient management through crop residues, livestock and manure (Savadogo, 2000; Murphy and Sprey, 1980). The main findings of these studies will be summarised here, to highlight the remaining issues.

In Tenkodogo in East Burkina, Delgado (1979) found that the main problem for the mixed farming model was that of seasonal labour bottlenecks. Simultaneous production of cereals and cattle leads to a severe labour bottleneck in late July, when the second weeding in cereals should be performed and when herding of cattle on high quality pasture without damaging bush fields is very labour demanding. The labour required to look after a few head of cattle during the rainy season, has therefore significant opportunity costs in terms of foregone crop production. Mossi farmers, owning only a few head of cattle each, choose therefore to entrust their cattle to Fulani herdsmen and to concentrate on crop production and small ruminants. Labour data showed the existence of important economies of scale with increasing herds up to 40 animals. Fulani choose to keep a number of low-return entrusted cattle next to their own herd, and to cultivate millet in an extensive way (low labour, low capital inputs, large fields with low planting densities) leading to low yields. Fulani also cultivated very small fields with red sorghum and maize on which they achieved, despite low labour inputs, high yields through the judicious use of cattle manure. Fulani appeared to be fully incorporated in the market economy and attained much higher cash income than Mossi, mainly through livestock sales related to purchase of cereals to feed the family.

Specialisation was clearly advantageous to Mossi, provided they can entrust their cattle to Fulani. Specialisation was also advantageous to Fulani, provided that the returns to entrusted cattle remain at the same level or increase. There is no economic incentive for Fulani to become crop farmers, nor for Mossi to intensify cattle production. The traditional division of labour between Mossi and Fulani enables both groups to realise the advantages of specialisation, while in theory retaining the advantages of the integration of crop-livestock production. Grazing of crop residues by all Fulani cattle in return for manuring the Mossi fields is part of the deal.

Mutual trust is the cornerstone of the relationship found and described by Delgado (1979). Increased expansion of Mossi fields into the traditional grazing areas and fencing of lowland plots for gardening in the dry season increased the number of incidents concerning crop damage by livestock. Under the influence of Western values, such as individualism and materialism, the authority of Fulani elders is challenged by youngsters that have been to school or have returned from migration to Ivory Coast. Cases of youngsters selling cattle that have been entrusted to them by Mossi, have been reported. Both developments put the mutual trust under pressure, and undermine the complementarity between crop and animal production systems.

Delgado (1979) recommends that policy makers stimulate the complementarity between the systems. He concludes that there are many reasons and opportunities for promoting the integration of crop and livestock production through increased trade between Mossi crop specialists and Fulani herding experts. In Tenkodogo, the traditional situation evolved in this direction rather than in the direction of mixed farming within either of the production units.

Breusers (1998) neither supports the mixed farm approach. He demonstrates that although Mossi were involved in animal husbandry in Ziinoogo (Central Burkina Faso), integration of livestock and crop production at the level of the farm remained limited. The production specialisations of Mossi and Fulani continued to dominate their interrelations, in line with the findings of Delgado (1979) twenty years earlier in Tenkodogo. Earnings from migration enterprises in Ivory Coast led to accumulation of wealth in cattle among Mossi. This wealth remained separate from agricultural production, because these animals are for the larger part entrusted to Fulani neighbours. This practice makes it difficult to achieve crop-livestock integration at farm level, because livestock is often physically outside the farm area and part of its management is not in the hand of the cattle-owning crop farmer but left to the appreciation of the herdsman. Landais and Lhoste (1990) came to the same conclusions. Reasons for entrustment are secrecy (hiding wealth for others) and special friendship relations across ethnic boundaries, while in public debate Mossi and crops are opposed to Fulani and livestock. This public debate serves specific goals, such as to re-confirm the symbolic boundary of the Mossi community or to mask tensions and uncertainties within the community. The problem of increasing competition of scarce natural resources is, however very real. To narrow the analysis of this competition to an inter-ethnic conflict is supported by the public debate, but should be contradicted by the knowledge of the strong relationships between members of both ethnic groups.

Breusers (1998) supports the identification of labour as a key element in crop and livestock production. He argues that scarcity of labour prohibits expression of certain advantages of crop-livestock integration. Within the crop-livestock integration paradigm, the concept of sustainability has frequently led to the proposition of labour intensive practices, such as soil and water conservation and compost production. Despite high population growth, labour is however scarce because of seasonal and longer term migration by Mossi, mainly towards Ivory Coast. Although the remittances contribute to economic equilibrium of households in the home country, they are hardly ever re-invested in agriculture (Imbs, 1987; Benoit, 1982; Remy, 1973) and labour shortages strongly contribute to the stagnation of production and to extensification of land use. In a situation of labour scarcity, crop-livestock integration does not seem a feasible option.

Mobility within Burkina, mainly towards relatively unoccupied areas such as the eastern part and the parts where onchocerciasis was eradicated in 1973, appeared also important (Breusers, 1998). The *Autorité des Aménagements des Vallées des Voltas* (AVV) scheme recruited migrants from the northern provinces where agriculture was difficult due to low rainfall and low soil fertility aggravated by degraded soils (Murphy and Sprey, 1980). In the settlement zones migrants were supposed to work ten hectares of land, according to a blueprint entirely based on the crop-livestock integration concept of mixed farming. The proposed practices consisted of a cropping scheme based on rotations, use of external inputs, such as seeds and inorganic fertilisers, cultivation of cash crops such as cotton, cultivation of fodder crops to feed draught animals and the introduction of animal traction. All farm animals had to be fed with fodder and crop residues from the farm area. The programme was supported by credit facilities. The policy objectives of the AVV scheme were to bring in production the substantial resources of river valleys, to create zones of high agricultural productivity and to increase gross agricultural product for the agricultural producer (Republique de la Haute Volta, 1963-64).

The AVV settlement zones might have served as examples for mixed farming. Many spontaneous migrants came to the zones, but they were excluded from the programme and suffered from the general problems underlying the crop-livestock integration approach (Landais and Lhoste, 1990), such as lack of credit facilities and lack of external inputs such as seeds, fertiliser and equipment for draught animals.

Breusers (1998) mentions land tenure as another constraint to crop-livestock integration. Despite laws reforming land ownership, land tenure remains very uncertain and in practice customary land tenure arrangements are followed even in the AVV settlement zones. In this framework, farmers have a tendency to adopt low cost soil-mining land use practices and mobility of fields, instead of permanent cropping with adequate fertilisation with manure requiring a lot of labour, or with inorganic fertiliser being expensive in terms of capital. In addition, farmers attempt to maximise claims on land through farming an area as large as possible, leading to low labour and low capital inputs per hectare and high land use per capita.

In a climate of economic liberalisation and retreating government, the tendency grows to establish legislation favouring individual private property in land (Hesseling and Ba, 1994), which according to neo-classical economic theory should result in optimal allocation of resources (Lambert and Sindzingre, 1995). Individual land titling has, however, not proven to provide land holders with sufficient incentives to conserve and develop their lands (Shipton and Goheen, 1992). Land is often subject to multiple and overlapping claims, shifting and merging over time, for instance over the family life cycle or following seasonal fluctuations (Lambert and Sindzingre, 1995; Shipton and Goheen, 1992; Fauré and Le Roy, 1990), which makes attribution of land titles to individuals a tricky business. In Burkina Faso, and in particular in the Central Region, Mossi retain customary control of the very large majority of the land and this land is used everywhere by Fulani too, either for pastoral or for agricultural uses or both.

Sustainable land use and crop-livestock integration appear to require complete sedentarisation of both crop and livestock production. The "*Gestion de Terroir*" approach, initiated by the Burkinabé government in 1986 (*Programme National de Gestion des Terroirs Villageois*), strengthens this tendency by aiming at a reduction of movement of crop production and livestock. The approach disregards the difference in perception about land ownership between Mossi and Fulani (Benoit, 1982), but is based on the Mossi concept of a village territory. Breusers (1998) showed that mobility has always been an essential element of land use and livelihood practices in Burkina Faso and doubts whether mobility can be reduced. On the other hand, Breusers (1998) supports the "*Gestion de Terroir*" approach, because it seems a multi-level approach, taking into account the farm, the village, and when needed, the region in accordance with the integrated spatial approach promoted by Landais and Lhoste (1990). The approach indeed is based on regional planning, but focuses heavily on individual farm enterprises that are conceived as autonomous, purely technical entities and it fails to take into consideration the social relations and organisation that, to a large extent, determine land use management (Rabot, 1990). At farm level, a transformation of production systems is once again pursued following the mixed-farming model. Interventions at village level seem to aim mainly at realisation of (physical) conditions considered indispensable for successful interventions at farm level. The zoning of the village territory according to different production activities (crop production, animal production, forestry) threatens to marginalise animal production as practised by the Fulani so far. Inhabitants of villages that have land rights, and hence a say in the matter, are Mossi and they tend to favour crop production over livestock production and to attribute preferably marginal and degraded land to extensive animal production. Zoning also implicitly means settlement because it limits shifts between crop land and grazing land in response to season and inter-annual rainfall conditions. Additionally, the approach seems to consider villages as homogeneous social entities whose populations can be expected to reach consensus on matters related to zoning of space. The approach thus tends to underestimate differences and conflicts within the group of sedentary farmers and to accentuate polarisation between crop and livestock producers.

Although the narrowly interpreted crop-livestock integration model has been demonstrated to be a technocratic myth (Breusers, 1998; Landais and Lhoste, 1990), it continues to shape development projects and government policies in Burkina Faso, for instance through the "three fights against desertification" (*Les Trois Luttes*, 1985, Government of Burkina Faso) and the "*Gestion de Terroir Villageois*" (GTV) approach. The concept has been given new impetus in the sustainability debate, that started already after the severe droughts in the 1970s and 1980s, focusing on prevention of degradation by assuring maintenance of soil fertility, mainly through application of soil and water conservation techniques and the use of manure, and by protecting areas against overgrazing by livestock. For the collection of manure, and to protect the environment, animals have to be stallfed with for instance crop residues. The concept continues to motivate researchers to search for sustainable nutrient cycling through optimal management of crop residues, livestock and its manure (Savadogo, 2000). Explicitly or implicitly, all those following the crop-livestock integration model aim at reducing mobility of crop production and livestock, towards a system of permanent cropping and stall feeding. Those explicitly supporting mixed farming seem to concentrate their efforts on efficient nutrient cycling, but many realise now that the use of external inputs can not be avoided (Savadogo, 2000; Powell *et al.*, 1996; Van Keulen en Breman, 1990; Breman and Traoré, 1985).

Research questions

The proposed crop-livestock integration concept appears to be reduced too often to a mixed farming model, aiming at arable farmers in order to increase crop production to feed the growing population. The assumption that livestock keepers, such as Fulani herdsmen, could also better develop into mixed farmers was based on premises with respect to environmental degradation through livestock and low productivity of their herds (Bernus, 1990). The model was presumed to be suitable and attractive for both formerly extensive crop producers and formerly extensive and mobile animal producers. In addition to all the criticism already expressed, the crop-livestock integration (CLI) model contains several inadequacies that have to be addressed, specially because it is still guiding development of farming systems.

1. The CLI model focuses on the scale of the farm and considers a farm to be independent of any context

Various issues, however, can not be treated at household level, but must be considered the domain of village decisions (water points, manuring fields by herds) or regional levels (seasonal transhumance, use of protected areas). In fact, the development of relations between crop and livestock production should be placed in wider contexts, such as increasing population density, cropping density, livestock density, sedentarisation of livestock producers, modification of the terms of trade between cereals and livestock, policy measures and the research-dissemination-client system. A production unit in the African context can not be considered independently of social structures. These structures may impose certain behaviour on individual production units and for instance limit their freedom to react to certain opportunities. Social relations and status within the village hierarchy may influence the reaction of production units to innovations and may explain why seemingly comparable households do not respond similarly to proposed techniques.

2. The CLI model presumes complementary (economic) relations

Complementarity in the CLI model is mainly focused on nutrient balances, with soils as study subject and farm area as research scale. System components (crop residues, manure) should be managed in such a way that losses, especially of nutrients, are minimised, and farm income will automatically increase. Livestock plays, however, a role in social relations among families, including the practice to entrust animals to family and friends outside the village territory. These entrusted animals have no access to family fields of the actual livestock owner, due to geographical distance. This practice makes technical complementarity between crop and livestock production in many cases physically impossible.

Economic complementarity has always been very important, but primarily related to farm household budgets and only secondary to increased income because of reduced losses. Animal production was frequently associated with crop production, mainly because of its security (buffer) function: income from both cereals and livestock being necessary for household survival in a very variable environment (climate, season: crop failures versus crop surpluses) and capitalisation in livestock being a pre-requisite for future investments. The financing function of livestock has mostly been neglected and hardly ever quantified.

3. Competition is assumed to be absent (as it is neglected) in the CLI model

Competitive phenomena are entirely neglected in the CLI model. Competition is, however, likely to occur with respect to the allocation of two production factors: labour and land. Application of the CLI model has probably led to changes in land use, increased competition and modified access to fodder. Such changes can only be assessed at territorial level, while the CLI model considers only the farm level. At higher spatial scales, competition can for instance occur between national (urban) needs for fuelwood and village scale land management practices.

In the context of highly unpredictable rainfall and generally unfertile soils in the West African Savanna, combined with global decision making about research subjects and world market prices, the main question that arises is:

"Is crop-livestock integration or mixed farming a suitable model for farming systems development leading to guaranteed food security and socio-economic survival for all social entities of the rapidly increasing population in Sahelian countries, without endangering their resource basis?"

Outline of this thesis

Re-considering 40 years of research and development activity aiming at crop-livestock integration, shows that the suggested technical model of crop-livestock integration contains at least three major flaws that need attention (Landais and Lhoste, 1990). In our thesis we will address these flaws in the context of a rapidly growing population. Burkina Faso, Zoundwéogo province, and the village of Kaïbo Sud V5 in particular, will serve as study area and generate examples for the relevant issues. Kaïbo Sud V5 has been chosen because it is a village created within the AVV settlement scheme, benefiting from exceptionally intensive assistance from government, research and extension, and therefore in a relatively favourable position to develop into a model of mixed farming. Additional data were collected in Sanmatenga (Section 5.4) province and in *Forêt Classée de Nazinon* in Ziro province (Section 7.3).

In Chapter 2 the research area will be presented. Its heterogeneity in terms of landscape, soil, vegetation, livestock, crops and cropping techniques will be described. With the village level model SHARES and the farm level model HOREB, different scenarios such as maximisation of income or cereal production, under different constraints such as food security or sustainability, will be explored and their outcomes will be compared.

In Chapter 3, the place of the farm household in society as a whole will be discussed using the concept of the agricultural knowledge system. Interactions between research, extension and policy makers will be treated and the attitude of the farmer as client or subject of these powers will be discussed in general and within the context of Burkina Faso.

In Chapter 4, a framework will be developed in which discrete farming systems are described and development pathways are discussed for Sahelian countries with special emphasis on Burkina Faso. Literature data and own field work will be analysed to provide criteria for a distinction among discrete farming systems. Case studies and field studies will be used to build up the general framework and to provide examples of discrete farming systems. The processes of change will be analysed to determine the main driving forces behind change and the actors supporting these forces.

In Chapter 5, the financing function of livestock for mixed farm households in Burkina Faso will be highlighted. The interaction between the financing function and production function of livestock will be explored through a market study (Section 5.1). The importance of financing through livestock will be related to alternatives in formal and informal financial markets (Section 5.2). Quantification of the financing function of livestock will be theoretically discussed (Section 5.3) and partly operationalised (Section 5.4).

In Chapter 6, the potential for animal traction development will be explored, as a key factor in farming system development, specially when aiming at integration between crop and livestock.

In Chapter 7, the relations between man, livestock and the environment will be discussed through analysis of the grazing system. Differences among farming systems and related grazing management of goats, sheep (Section 7.1) and cattle (Section 7.2) will be highlighted and the changes related to crop-livestock integration will be discussed. Impacts of urbanisation and the associated demands for fuelwood will be discussed in relation to grazing potentials (Section 7.3) and possibilities of crop-livestock integration at village scale will be discussed. The results will be confronted with theories on vegetation-herbivore interactions and related to changes in abiotic factors such as climate (Section 7.4).

In Chapter 8, the impact of the prevailing crop-livestock integration concept under high population growth will be discussed. The issue of economic complementarity through the financing function of livestock (Chapter 5) related to CLI will be treated. The possibilities for increased animal traction (Chapter 6), as needed in mixed farming, and its consequences will be discussed. The impact of crop-livestock integration on the environment, through changes in grazing systems, will be discussed (Chapter 7), in relation to theoretical concepts about the relation between grazing, climate and vegetation. Theories and studies on the impact of population growth on agricultural development will be used as references (Tiffen *et al.*, 1994a and 1994b; Mortimer and Turner, 1993; McIntire *et al.*, 1992; Boserup, 1965; Malthus, 1798).

2 Spatial and temporal heterogeneity of natural resources and land use in the study area (Kaïbo in Zoundwéogo province)

Introduction

In Burkina Faso (Figure 2.1) a multidisciplinary research program called "Management of Natural Resources in the Sahel", has been executed as a joint activity of Wageningen University the Netherlands, and Ouagadougou University, Burkina Faso (1992-1998). Interdisciplinary research was conducted in two provinces, Sanmatenga and Zoundwéogo, and mainly in three villages in each province. Our research was therefore also conducted in Zoundwéogo and in particular in its village Kaïbo Sud V5 and surroundings. Results of various studies on land use are summarised here to sketch the context for our own research.

Population

In 1988 the population of Burkina Faso was about 8,546,000 with an average density of 29 km^{-2} (INSD, 1989). The variation in population density was high with about only 10 inhabitants km^{-2} in the eastern provinces Gourma and Tapoa and the northern province Oudalan, but with 60-80 inhabitants km^{-2} in Oubritenga and over 80 km^{-2} in Sangui province. The latter provinces are situated on the central Mossi plateau, surrounding the capital Ouagadougou. Our study sites, Sanmatenga and Zoundwéogo provinces, are also part of this highly populated plateau (Figure 2.2). The national population increases at a high rate. Between 1975 and 1985 total population increased by 41 %, and from 1985 with 2.7 to 2.8 % annually. In 1998 population was estimated at 10,900,000 persons (World Bank website, 1998). Urbanisation also increased. In 1975 only 6.4 % of the population lived in urban areas, which had increased in 1985 to 12.7 %, with Ouagadougou and Bobo-Dioulasso amongst the fastest growing cities. These cities more than doubled in population between 1975 and 1985 (INSD, 1989). World Bank (1998) reported that 17 % of the population lived in cities in 1998. The population is very young with 54 % below 19 years of age in 1985. More than 80 % of the population over 15 years of age is illiterate (World Bank website, 1998).

In 1993 the population of Zoundwéogo province was estimated at 185,400, based on a census from 1985 (INSD, 1989) and an annual population growth of 2.2 % (PDI/Z, 1993). The total area of the province is about 345,300 hectares of which 22 % was cultivated in 1993 (PDI/Z, 1993). Hence, population density was 54 persons km^{-2} for the total area and 239 persons km^{-2} for the cultivated area. For the village territory of Kaïbo Sud V5, a population of 572 persons on 503 hectares of land leads to a density of 114 persons km^{-2} for all land and 316 km^{-2} for the cultivated area that was 36 % of all land (Leenaars, 1998b).

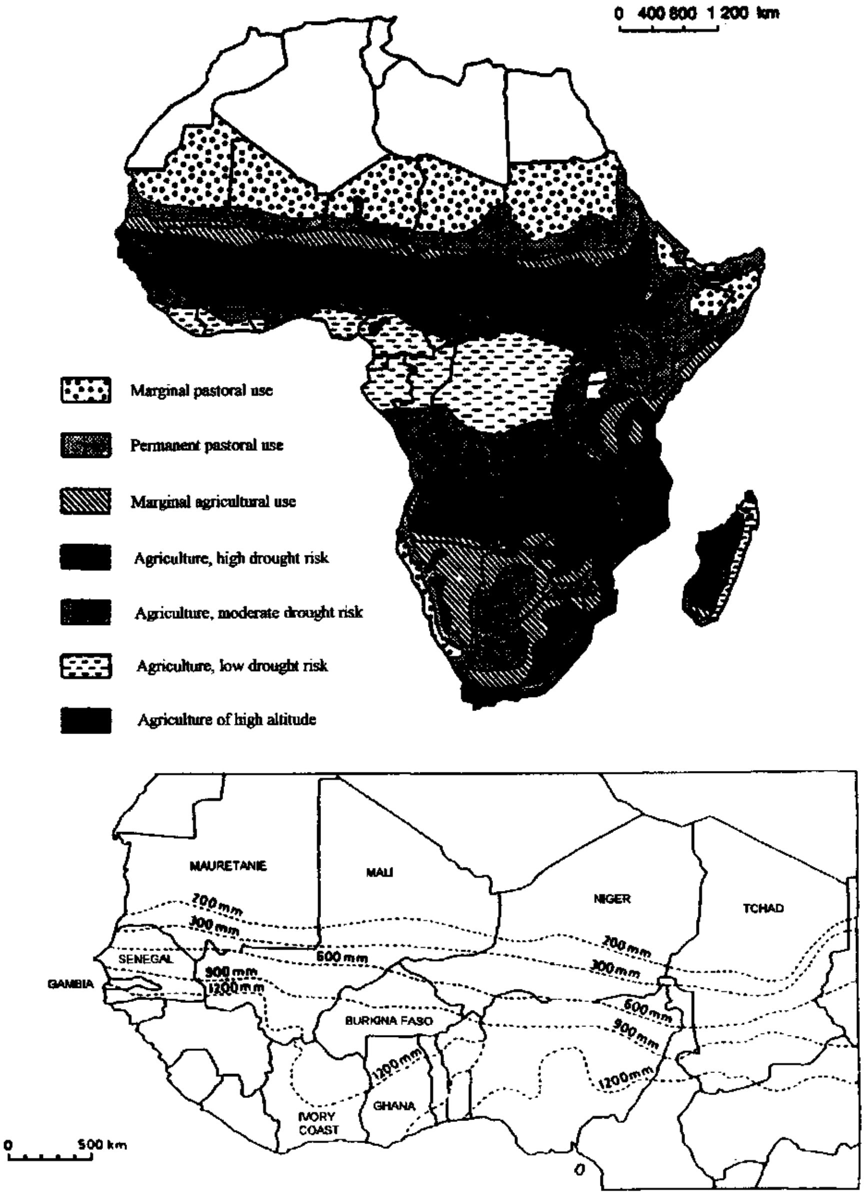

Figure 2.1 Location of Burkina Faso in Africa and in the Sahel rainfall zone.
Sources: Pieri (1989); Klaver (1982)

Rainfall

Burkina Faso is located between 9° 20' and 15° 05' northern latitude and 2° 20' eastern and 5° 30'western longitude. Its area of 274,000 km^2 can be subdivided in four agro-ecological zones (Figure 2.2). The Sahelian zone, located in the north of the country, is characterised by annual rainfall ranging from 200 to 400 mm during 2-3 months. The Sub-Sahelian zone receives 400 to 800 mm rain in 4-5 months. The North-Soudanian zone receives 800 to 1000 mm and the South-Soudanian zone more than 1000 mm, both in about 6 months. Rainfall increases from 200 mm in the north to 1100 mm in the south of the country.

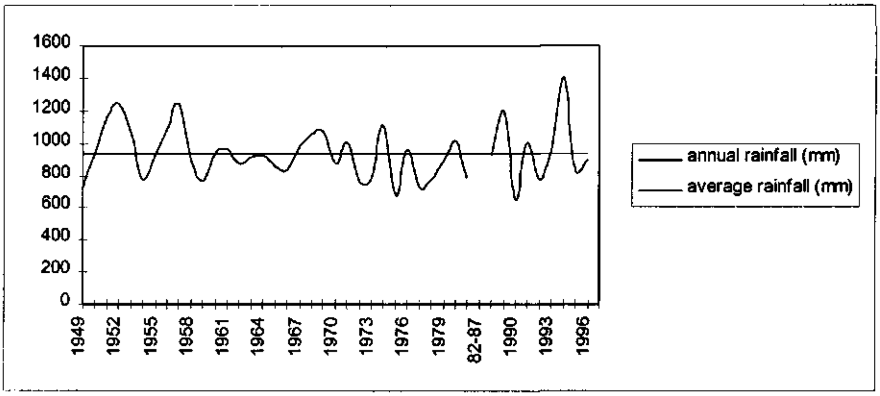

Figure 2.3 Annual rainfall data for period 1949-1996 and average over the total period, for Manga weather station. Data for 1982-1987 are missing.
Source: Direction de la Météorologie Nationale

Zoundwéogo province is located between 11° and 12° northern latitude and part of the North Soudanian climatic zone, characterised by a mean annual rainfall of 750 to 1000 mm and a mean temperature of 28 °C (Kessler and Geerling, 1994). Data from the weather station in Manga, the capital of Zoundwéogo province, show an yearly average rainfall of 935 mm falling in 63 rain showers for the period 1949-1996 (Figure 2.3). The rainy season lasts about four months from June to September in which about 80 % of all rain is recorded. In August, the highest monthly average of 260 mm is recorded in about 15 rain showers. In 1994, a weather station was installed in Kaïbo Sud V6. Daily data are available for 1994-1998 (Figure 2.4). Rains started early in 1995 and 1997. About 100 mm was recorded for March, April and May together, for each of those years. In 1994 and 1996 rains were persistent with about 50 mm in October of each year. Rains generally fall at irregular intervals, heterogeneously distributed in space and very variable in amount of water per shower.

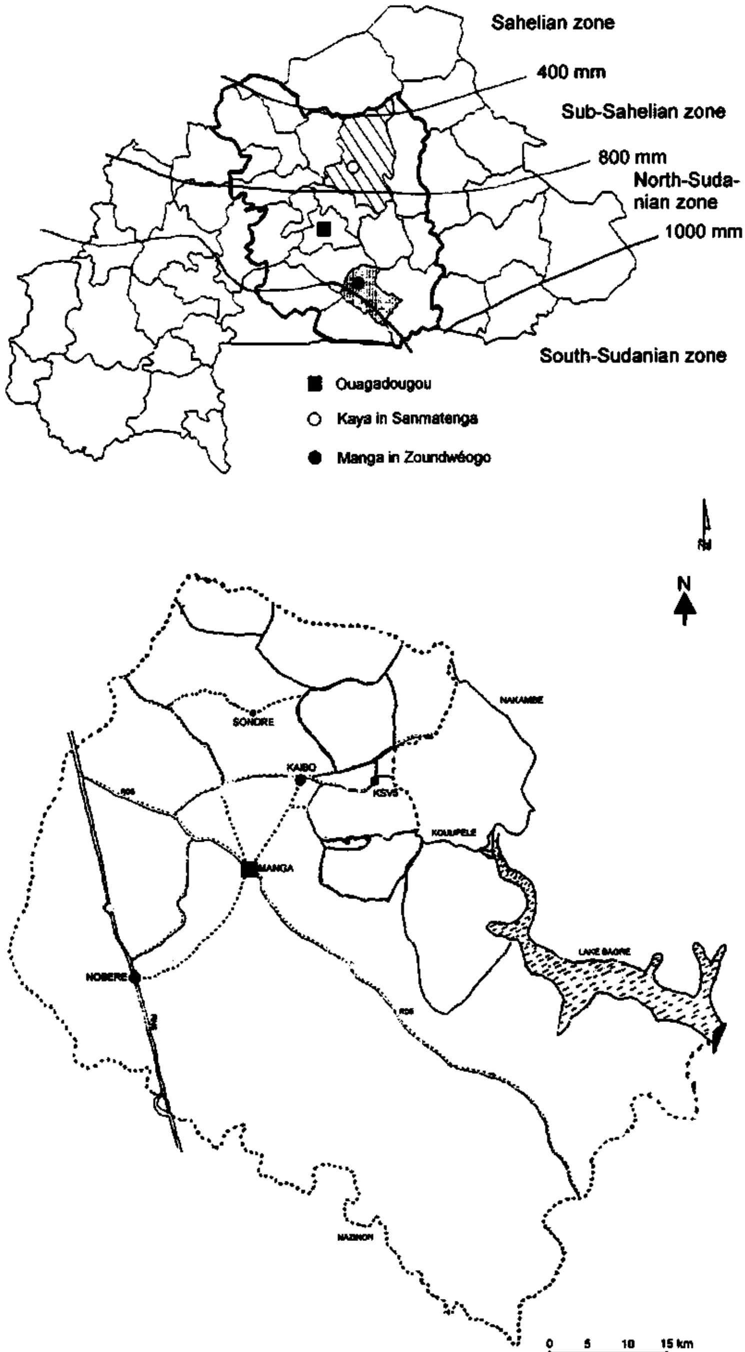

Figure 2.2 Situation of agro-ecological zones, Central Mossi Plateau and Sanmatenga and Zoundwéogo provinces in Burkina Faso (a) and situation of Kaïbo Sud V5 (KSV5) and Manga in Zoundwéogo province (b). Sources: Savadogo (2000); Breusers (1998); Atlas du Zoundwéogo (1997)

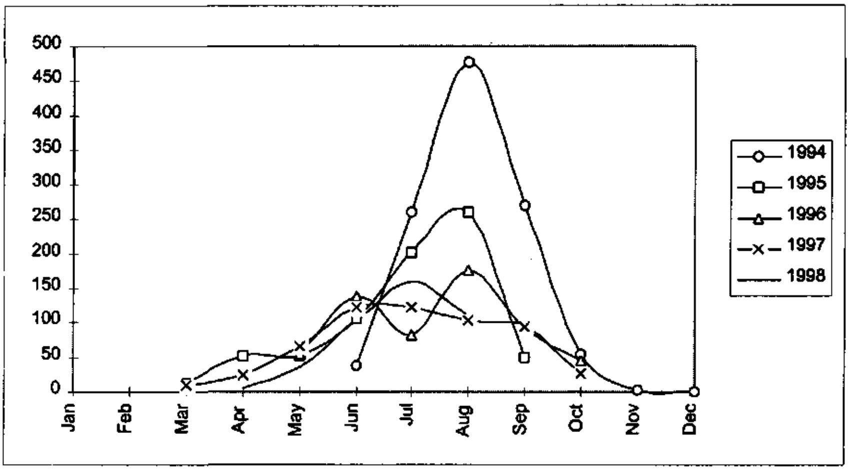

Figure 2.4 Monthly rainfall data for 1994-1998 for Kaïbo Sud V6 weather station
Source: W. Hoogmoed, Antenne Sahélienne

To get insight in the range of production possibilities in Zoundwéogo province, rainfall data from Manga weather station from 1949 to 1998 have been analysed. A ranking was made based on the rainfall in the months of June, July, August and September, covering the growing period. In that ranking, the years with rainfall with a probability of exceeding of 90 (dry), 50 (average) and 10 % (wet) were chosen. Two or three years around these probability points were assessed in more detail with respect to distribution. Years with exceptionally uneven distribution were then excluded. Following this procedure, for Zoundwéogo province, the years 1997 (706 mm), 1996 (882 mm) and 1974 (1038 mm) were selected as dry, average and wet years, respectively (Hoogmoed *et al.*, 2000).

Landscape and vegetation

The landscape in Zoundwéogo province can arbitrarily be divided in cultivated areas (fields), fallow (recently cultivated) and bush (never or long ago cultivated). The cultivated areas present themselves as so-called parklands, characterised by scattered adult trees and absence of the herbaceous and bush layers. The main food crops are sorghum (*Sorghum bicolor L. Moench*) and millet (*Pennisetum typhoïdes*), whereas cotton (*Gossypium hirsutum)* and groundnut (*Arachis hypogaea L.*) are the main cash crops. The most important tree species of the parkland are *Adansonia digitata* (Baobab), *Butyrospermum paradoxum* (karité or shea butter tree), *Parkia biglobosa* (néré or locust bean tree), *Tamarindus indica* and *Lannea microcarpa* (Raisinier), all important for their fruits. *Faidherbia albida* is a parkland tree that is famous for its fodder and its contribution to soil fertility. Fallow is characterised by the combination of a herbaceous layer and bushy vegetation. Dominant shrubs are *Combretum glutinosum*, *Guiera senegalensis* and *Piliostigma spp.* Adult and young parkland trees are also present on this land use unit. The older the fallow, the more it looks like bush. Bush is dominated by three physionomic unities: shrub savanna, tree savanna and forest galleries, the latter essentially close to rivers. The tree layer of bush comprises trees of all age classes and heights. Several species of annual and perennial grasses can be present.

Village history

The village Kaïbo Sud V5 is one of the 14 villages that have been established in Zoundwéogo province during the early seventies in the framework of the *Autorité des Aménagements des Vallées des Voltas* (AVV) settlement scheme. This scheme was established after elimination of river blindness in the Nakambé (White Volta) river area. According to an agro-economic study conducted by De Graaff (1993-1996), Kaïbo Sud V5 is a village with an average of 572 inhabitants (census of 1993), comprising 52 settled Mossi households and a variable number of semi-nomadic Fulani households. At the beginning of the settlement scheme, each settled Mossi household has been alloted 10 hectares of arable land, composed of one hectare around the farm buildings and six small plots scattered throughout the village territory. One third of this land was supposed to remain fallow. In 1996, land was redistributed, resulting in three larger plots of three hectares each per household, while the compound area was maintained. Fulani have not been given any land in Kaïbo, as the settlement scheme provided land for them in the pastoral area of Sondré-Est (16,500 ha), created in 1979. They were supposed to move to this area, as soon as the settlement scheme started. Many of them remained however on the village territory of Kaïbo Sud V5.

Soil types

Local classification of land units in the Kaïbo area is based on topography and texture of top soils. A study by Zerbo *et al.* (1998), based on satellite images, topographic maps, aerial photos (1:20.000 and 1:50.000) and field observations, distinguishes landscapes subdivided into physiographic segments like plateaux, slopes and valley bottoms. Each segment is individually described for soil characteristics such as colour, stoniness, texture, etc. A combination of both classifications is used to identify six classes of soil types. Interpretation of aerial photographs covering Kaïbo Sud V5 (1:10.000) was combined with information about the geographical boundaries of the village and geo-references of certain fixed objects (church, school, etc.) on the village territory. On that basis the village territory of

Kaïbo Sud V5 was distributed over the six defined classes (Table 2.1) by Leenaars (1998a).

Valley bottoms are very fertile, but suffer often from stagnating water thus reducing their suitability for crops that can not tolerate water logging. Valley bottoms and clay soils are difficult to cultivate by hand. Sandy soils are easier to cultivate and subject to natural drainage, which makes them suitable for almost any crop but their chemical fertility is limited.

Table 2.1 Names of soil type classes based on local and "scientific" soil classification, and their contribution to the Kaïbo Sud V5 village territory in percentages (Leenaars, 1998a).

English name	Local name (Maure)	Part of village territory of Kaïbo Sud V5 (%)
Hill	Tanga	19
Plateau	Rassempo	8
Slope	Zegdega	6
Sand	Bissiga	13
Clay	Bole	45
Valley bottom	Baongo	9

Land use

Land use categories

Results from studies of Marchal (1983), Prudencio (1983) and Dugue (1989) were combined with observations and interviews in the village, resulting in the identification of seven land use units for the Kaïbo territory. These units were defined on the basis of a combination of soil cover (bush, field, bare soils) and land use purpose (grazing, tree plantation, fallow, bush field, village field, compound field). Combining field information and the soil type map resulted in a land use map for 1993 with a legend conform the seven selected units (Leenaars, 1998b).

Table 2.2 Land use categories for Kaïbo Sud V5 village territory in hectares and percentages for 1993 (Leenaars, 1998b).

Land use purpose	Hectares	Percentages
Compound fields	34	7
Village fields	119	24
Bush fields	29	6
Young fallow	96	19
Pasture and older fallow	114	23
Pasture	104	21
Pasture and wood collection	7	1

With the use of a Geographic Information System (GIS) the total surface area within the village boundaries and the distribution over the distinguished land use units was estimated (Table 2.2).

The area of Kaïbo Sud V5 was estimated at 503 hectares of which 36 % was cultivated. The arable land area per person was 0.88 hectare of which 0.32 hectares were cultivated and thus 0.56 was available for grazing (Leenaars, 1998b). Of the households 44 % used manure or compost, and also 44 % used inorganic fertiliser, mainly on the cotton fields. Of the households 20 % park cattle on their land for *in situ* fertilisation. On 15 % of the cultivated area stone rows have been constructed and on 3 % grass strips (De Graaff, 1995).

Crops and management

A very large proportion of the cultivated land is used for the production of staple food, especially sorghum (Table 2.3). Farmers judge soils with respect to water retention and nutrient supplying capacities, which in turn depend on topography and top soil texture. These aspects are taken into account when deciding which crops to cultivate on certain soil types. The decision depends also on the development of the rainy season. Maize (*Zea mays*) has a short growing cycle and can be harvested before other cereals. It is mostly cultivated around the homestead on soils that have been enriched with household wastes, because it needs relatively fertile soils. Mixed cropping of drought tolerant cereals with cereals that support water logging, is a strategy of farmers to cope with unreliable rainfall. Millet/sorghum, but also sorghum/rice (*Oryza sativa*) combinations can be found. Changing from cereals to groundnut in years when rains are late is a strategy to anticipate on a short growing season.

Table 2.3 Distribution of crops (%) over cultivated area for Kaïbo Sud V5 village territory in 1993 (De Graaff *et al.*, in prep.).

Crop	Area in % of total cultivated area	Distribution over soil types
Sorghum	57	All
Sorghum/millet/cowpea	7	All
Maize	7	Slope, sand, clay
Cowpea	4	Slope, sand, clay
Cotton	10	Slope, sand, clay
Vegetables and tobacco	15	Mainly valley bottom

Mixed cropping of cereals and cowpea (*Vigna unguiculata L. Walp.*) is a means to provide nitrogen to the soil and to the cereal growing on the same field. Cowpea is a dual purpose crop: its beans are used for human consumption and its leaves serve as high quality fodder for livestock. Pure millet can be cultivated on all soil types, except for valley bottoms because it is very sensitive to water logging. Although groundnut was not cultivated in 1993, it was cultivated in other years and then only on sand and slopes. Cotton is cultivated as cash crop and receives most external inputs.

Traditionally, crops are cultivated in a fallow system in which soil preparation, sowing, weeding and harvesting are done manually. Neither soil and water conservation measures were taken, nor manure or inorganic fertilisers are applied. Crop residues are left in the field. This management level is called T0. Crop production in Kaïbo Sud V5 knows seven alternative management levels. Level T1 differs from T0 in that crop residues are harvested, stored on farm and used as animal feed in the dry season. The next three levels are similar to T1 but include traditional soil and water conservation such as stone rows (T2), mulching (T3) or both (T4). Level T5 equals level T2 but adds the use of animal traction for ploughing and weeding, and application of about 4000 kg manure per hectare. Level T6 equals level T5 but has a lower manure application rate of about 2000 kg per hectare, and additional inorganic fertiliser application up to 95 kg N per hectare. As an alternative management level installation of vegetation bands such as grass strips (T7) is proposed. Not all combinations of crops and management levels are actually found on the Kaïbo territory. The most common ones are given in Table 2.4.

Table 2.4 Combinations of crops and management levels for four major crops in Kaïbo Sud V5, Burkina Faso (personal observation).

	T0	T1	T5	T6
Sorghum	Yes	Yes	Yes	No
Cowpea	No	Yes	No	No
Maize	Yes	Yes	Yes	No
Cotton	No	No	No	Yes

Animal production

Several livestock species are present in the village territory (Table 2.5). Cattle are used for ploughing and weeding by sedentary Mossi farmers, but also for milk and meat production by semi-nomadic Fulani, living part of the year in the village territory. Most households own small ruminants for financing purposes. In addition, some Mossi farmers keep sheep in semi-intensive production units in which they are fattened for sale on the market and for Muslim feasts (Savadogo, 2000). Donkeys are kept by Mossi farmers and used to draw carts. Every household owns some poultry (chickens, guinea fowl, pigeons, ducks) for sacrifices, gifts, and financing of small expenses. Pigs are absent for religious reasons.

Although on average all Mossi households owned a number of cattle, 10 of these households did not own draught animals, 34 no milking cows and 32 did not own any other cattle. For small ruminants, 18 Mossi households did not own sheep, whereas eight Mossi and two of the other households did not own goats. In total, only four households did own neither goats nor sheep. Numbers of small ruminants per Mossi household vary among and within years, because many may be sold in case of crop failure or in case of unforeseen cash needs and many may be bought in case of crop surpluses. Numbers of draught animals and donkeys are more stable within and over years.

Table 2.5 Average livestock numbers per household per ethnic group in Kaïbo Sud V5 (survey 1998).

Ethnic group	Mossi	Silmimossi*	Fulani	All
Sample size	49	4	2	55
Animal Species				
Cattle	9	43	84	14
- draught	3	0	0	3
- milk	2	15	36	4
- other	4	28	48	7
Goats	10	9	10	9
Sheep	9	19	31	10
Donkeys	1	1	0	1

* Silmimossi are Mossi that have assimilated many characteristics of Fulani which is amongst others reflected in livestock ownership

Ruminants can feed on crop residues or graze sylvo-pastoral land. Fodder of sylvo-pastoral land consists of annual and perennial grasses and forbs, but also of twigs and leaves of shrubs and trees (browse). Grazing management influences fodder availability, therefore schematically three grazing systems are distinguished (Breman and De Ridder, 1991): All season free Grazing (AG), in which the availability of fodder for animal consumption is 35 % of total dry matter (DM) production at the end of the rainy season; Dry season free Grazing (DG), in which the availability of fodder is equal to that in AG; Wet season free Grazing (WG), in which the availability of fodder is 50 % of DM production at the end of the rainy season.

The use of crop residues depends on their production, the capacity of the farm household to transport the residues to the compound, and the feeding strategies applied per animal species and per production category. The feeding value of legume straws is higher than of cereal straws in terms of digestible protein, energy and overall digestibility (Savadogo, 2000). Quality classes of crop residues and grasses for animal feed are distinguished on the basis of digestibility and N contents. Cereal stems and in particular sorghum stems have on average a digestibility of 45 % and 6-8 g N per kg DM (Q4). Cereal leaves and in particular sorghum leaves fall in Q6 with an average digestibility of 50 % and $8<N<10$ g per kg DM. For Q8 and Q9 digestibility becomes 55-60 % and $N>13$ g per kg DM (Hengsdijk *et al.*, 1996).

Potential cereal and straw yields

Combinations of rainfall regimes, soil qualities, crop species and cropping techniques lead to a wide variety of crop yield potentials (Table 2.6). From sorghum stover, 80 % consists of stem, of which only 30 % can be eaten by livestock. The remaining 20 % consists of leaves that can completely be eaten by livestock. Stems have lower digestibility and CP contents, hence quality class Q4, than leaves which can be found in quality class Q6. Under the influence of fertiliser application, the quality of cereal leaves can increase to class Q8. The lowest grain yield is associated with straw yields of 980 kg ha^{-1} of which 235 kg of Q4 and 196 kg of Q6 are available for animal feed. The highest grain yield is associated with straw yields of 7493 kg ha^{-1} of which 1499 kg of Q8 is available for animal feed. For cowpea, about 75 % of its straw can be used for animal feed. Many leaves are lost during ripening of the pods and collection and transport of the straw.

Table 2.6 Calculated highest and lowest grain and straw yields for sorghum and cowpea under various circumstances in Kaïbo territory.

Rainfall	Technology	Soil type	SORGHUM (kg DM ha^{-1})				COWPEA (kg DM ha^{-1})		
			Grain	Stover	Q4	Q6/Q8	Grain	Straw	Quality
Dry	T1	Slope	245	980	235	196	157	295	Q8
Wet	T6	Sand	3330	7493	1798	1499	2138	4008	Q9

Land use models

Two land use models have been developed for the study area: SHAred RESources (SHARES, Van Rheenen *et al.*, in prep.) and Household level Optimal crop REsidue allocation in Burkina Faso (HOREB, Savadogo, 2000).

SHARES takes into account the entire village territory of Kaïbo Sud V5 and its inhabitants. The inhabitants are organised in 66 households of which 12 are Fulani pastoralist households. A population of 904 is used in the model. This differs from the counted population of 572 in 1993 because of population growth of sedentary Mossi and addition of Fulani households to the village territory. SHARES distinguishes between five types of actors, each with specific endowments such as available land, available technology (animal traction), etc. The total village area was re-estimated at 512 hectares (503 ha in 1993) of which 282 ha is private land meaning that farm households have private use rights on this area. The remaining 230 hectares are permanent common land to which each actor has access. In the model, Fulani have priority access to these lands compared to Mossi households. SHARES distinguishes the soil type classes given in Table 2.1, and takes into account their quality, the nutrient and water requirements of crops, and their dependence on several cultivation techniques in order to calculate a range of grain and straw yields. In SHARES, animal production is based on crop residues and grazing of fallow and other non-cultivated land (such as common land), but supplementation with cotton seed cake is possible assuming that farmers can buy it against pre-set market prices.

HOREB is a Multiple Goal Linear Programming model describing an average farm for Zoundwéogo province. Such a farm is characterised by 6.2 hectares of available land, with 210 mandays of labour available each month, choice between sorghum, groundnut and cowpea crops, and various cropping techniques. Animal production, in the current version of the model, is limited to semi-intensive sheep production based on crop residues fed in the dry season. Families with and without a cart are distinguished, assuming that those owning a cart can transport 86 % of legume and 80 % of cereal straw to their compound, whereas those without a cart do not use crop residues in sheep feeding. A cart is also crucial for the amount of manure that can be returned to the crop lands.

Scenarios

Both land use models can be used for scenario studies. Crop-livestock integration is currently the leading development model, therefore it has been used as a leading concept in defining the different scenarios. In the actual situation, most farmers have very low purchasing power and hence practice low external input agriculture (LEIA), aiming at food security. The impact of the use of alternative technologies was explored with the models.

With SHARES five scenarios have been run for an average rainfall year for the whole village territory (Table 2.7). All crop management levels, as defined before, are used in the SHARES model. T0-T4 represent thus cropping techniques based on fallow for the restoration of soil fertility. Farmers are supposed to have very low purchasing power, hence animal traction and use of external inputs is excluded. Technologies T5-T7 allow for permanent cropping with the use of animal traction and external inputs. With these techniques fallow can be abolished. Scenarios 1 and 2 aim at maximum cereal production using either set of management techniques. In scenarios 3 and 4 farmers are considered as *homo economicus,* i.e. maximising income with the use of either set of techniques, but without constraint on food security or sustainability. In scenario 5 the territory must produce sufficient cereals to feed its population. The option to aim for 100% self-sufficiency in food with T0-T4 cropping techniques, appeared unfeasible and is therefore not included in the table. For all scenarios gross margin (GM) was calculated.

In scenario 1, only 58 kg of cereals per inhabitant is produced using only traditional cropping techniques, appreciably below the annual needs of 190 kg (Schweigman *et al.*, 1988). In scenario 2, the use of improved cropping techniques makes it possible to achieve a cereal production of 261 kg per inhabitant which represents a surplus of almost 40 %. Income from livestock production is high. The result of scenario 3 show that cereal production is economically not very interesting as no cereal activities are selected. Main sources of revenue in this scenario are wood (in plantations), groundnut and milk. In scenario 4, the use of external inputs such as fertiliser and animal traction on crops leads to a production of about 106255 kg of cereals, substantially below annual needs. Considering expected population growth rates (2.64 %, Atlas du Burkina Faso), total cereal requirements in 10 years would be 222889 kg for the village as a whole. Main sources of income in this scenario are wood, groundnut, meat and milk. In scenario 5, optimisation of gross margin was constrained by cereal-sufficiency and hence, when compared to scenario 4, gross margins are reduced. More than doubling the food production leads to only 16 % reduction in gross margin so the trade-off seems not so bad.

Table 2.7 Scenarios for land use under average rainfall conditions for the village Kaïbo Sud V5 (SHARES model, Van Rheenen *et al.*, in prep.).

Scenario	1	2	3	4	5
Optimisation	Cereal production	Cereal production	Gross margins	Gross margins	Gross margins
Techniques	T0-T4	T5-T7	T0-T4	T5-T7	T5-T7
Demands	none	none	none	none	100% food
Cropped (ha)	79	150	282	282	166
Fallow (ha)	203	8.7	0	0	0
Cereal (kg)	52786	235956	0	106255	222889
Meat (kg)	1948	10277	2720	7465	10604
Milk (kg)	636	21453	8908	20292	28857
Soil loss (t)	610	580	1051	554	636
N balance (kg)	- 988	294	484	1622	950
Income from livestock (FCFA)	604434	2289960	601043	1648539	2343500
GM (FCFA)	3561970	18163120	19231243	27989656	23459769

With HOREB four scenarios have been studied, for combinations of crop production in the rainy season and sheep production in the dry season (Table 2.8). In the first one, Food Security I (FSI), sheep roam freely during daytime and are housed at night. Semi-intensive livestock production is not possible in this scenario, because the households do not own a cart and hence can not transport crop residues to their compound nor transport manure to their fields. The main objective is maximisation of staple crop production. The second Food Security scenario (FSII) supposes that a cart is present, hence livestock production based on crop residues and crop production with manure input are possible. In this scenario, purchasing of external inputs is allowed to a maximum of 14000 FCFA for fertiliser and 3000 FCFA for cotton seed cake as concentrate. Households aim at maximisation of Gross Margin under the constraint of food security.

The third (SPI) and fourth (SPII) scenarios are so called Sustainable Production scenarios. They aim at optimum Gross Margin under food security with the constraint of sustainable production in terms of balanced organic matter (OM) or both OM and nitrogen (N) budgets. In these scenarios fullest crop-livestock integration is attained, through the use of crop residues as animal feed and the use of refusals plus manure as organic fertilisers on crop land.

Table 2.8 Four scenarios for land use under average rainfall conditions for an average farm in Zoundwéogo province (HOREB-model, Savadogo, 2000).

Scenario	FSI	FSII	SPI	SPII
Optimisation	Staple crop	Gross Margin	Gross Margin	Gross Margin
Techniques	LEIA, grazing sheep	LEIA, crop residues fed	LEIA, crop residues fed	HEIA
Constraints	Cereals > 2.9 t No cart	Cereals > 2.9 t Fert. <14.000 F Conc.< 3.000 F	Cereals > 2.9 t OM = 0	Cereals > 2.9 t OM = 0, N = 0
Cropped (ha)	5.1	5.7	5.1	5.3
Fallow (ha)	1.1	0.5	1.1	0.9
Crops (ton)	3.2	3.5	3.1	4.7
Cereals (ton)	3.2	3.3	3.0	4.5
Livestock (no)		19	26	23
LWG (kg)	0	246	149	382
Feeding level		1.7 M	1.3 M	2.0 M
OM balance (kg/ha)	- 344	- 175	0	0
N balance (kg/ha)	- 21	- 15	- 18	0
P balance (kg/ha)	- 1.8	- 1.2	- 1	1
GM (FCFA)	253000	369000	291000	367000

LEIA = Low External Input Agriculture; HEIA = High External Input Agriculture; M = Maintenance level; LWG = Live Weight Gain; OM = Organic Matter; N = Nitrogen; P = Phosphorus; GM = Gross Margin; 100 FCFA = 1 FF

It appears that labour needed for collection and storage of crop residues is the major constraint for the use of crop residues for stall feeding of sheep. Farmers aiming at maximising animal numbers generally select chopping of crop residues and feeding sheep at maintenance level. That practice leads to the highest output in terms of manure. In FSII and SPI 16 to 18 mandays of labour are needed to store crop residues and 108-114 mandays a month to feed the animals in the period December to May. In SPII 61 mandays are needed to store crop residues, because many more animals are needed to achieve balanced nutrient and OM budgets.

When working capital would be available, urea could be purchased to improve the feeding value of the chopped feed. At current urea prices, however, excess feeding is the most economic feeding strategy in all scenarios, because it requires less labour than chopping and allows for selection within the roughage, increasing animal production.

Maximum crop gross margins are always associated with soil mining. Different runs of the model for wet and normal years respectively, indicated that 200-344 kg OM, 15-21 kg N and 1.5-1.8 kg P per ha are lost annually from the system under extensive grazing systems (FSI). These losses could be reduced to 192-175 kg OM, 12-15 kg N and 1.1-1.2 kg P under systems based on crop residue feeding and manuring of crop fields (FSII) for wet and normal years. Intensive management of crop residues and manure in integrated crop-livestock farming does not result in maintaining soil nutrient status, when food security has to be guaranteed. For sustainable production, external inputs are needed, either in the form of concentrates for animal feed or inorganic fertilisers on crops. Current price ratios of fertiliser and grains do not favour fertiliser use. Use of concentrates is remunerative but due to lack of working capital they were hardly ever purchased.

Conclusions

The high variability in rainfall in the study region exerts a strong impact on possibilities for crop production and food security. Farmers can select combinations of soil type and crops that have the highest chance to succeed under rainfall conditions expected during the cropping season. Interruption of rainfall can lead to abandoning of certain fields and/or intensive weeding of others. Early season failure of cereal crops can lead to seeding of groundnuts instead, when the remaining lenght of the growing season would be very short. Excess rain can lead to abandoning of fertile valley bottoms because of water logging risks. The heterogeneity of the resource base of the village of Kaïbo Sud V5 therefore creates opportunities for on-farm management of resources in response to unpredictable and erratic rainfall.

SHARES and HOREB were run for a normal rainfall year. SHARES showed that at village scale sustainable production, in terms of nutrient budgets, would never be achieved when gross margin was optimised, because soil mining was and is a very cheap way to produce. SHARES has a timeframe of one year, hence long term consequences of soil mining on production are not taken into account. SHARES indicates that improved cropping techniques T5-T7 are needed to achieve 100 % self-sufficiency in food, because it was unfeasible with traditional T0-T4 cropping techniques.

HOREB tested crop-livestock integration as a basis for sustainable production, in terms of nutrient and OM budgets, at farm scale. Crop-livestock integration, based on the use of crop residues for sheep feeding and on returning manure to the fields, appeared to contribute only to a limited extent to improvement of sustainability of production systems. Without the use of external inputs, such as fertiliser and concentrate feeds, nutrient and organic matter budgets remained negative. The most important limitation for crop and livestock production appeared to be cash availability at farm level to provide means of transportation for improved crop residue and manure management, and to purchase external inputs.

The myth that fully integrated crop-livestock farming (crop residues, manure, animal traction) would lead to sustainable land use, was shown to be false in average rainfall years. Crop-livestock integration could not prevent negative organic matter and nutrient budgets, neither at village level nor at farm level. Food security at village level, even when negative nutrient budgets are allowed, is not possible without the use of external inputs. In dry years it will even be much more difficult, if not impossible, to attain the desired level of food security.

3 Institutional environment: Agricultural Knowledge Systems

Introduction

The institutional environment for farmers consists of various components, including markets, roads, banking facilities, etc. The environment discussed in this chapter is the agricultural knowledge system (AKS), its components and its most important processes. The AKS framework is subsequently used to evaluate the role of policy, research and extension in the process of adoption of innovations in animal production in Burkina Faso. The interaction between the crop-livestock integration concept and research and extension subjects is explored. When weaknesses for successful innovation of animal production and natural resource management can be identified, they will be made explicit so that they can be treated in the next chapters of this thesis.

Theoretical framework

Much has already been written about extension (Röling *et al.*, 1994; Van den Ban and Hawkins, 1988; Rogers, 1983). With respect to development and adoption of innovations, four questions are often heard from the different actors:

Extension agents:	Why don't my clients (farmers) do what I want them to do?
Farmers (2x):	Why don't they (extension agents) offer me solutions to my problems?
	Why don't they (government, extension agents) offer me the means to adopt innovations?
Policy makers:	Why does overall production not increase?

Farmers not adopting innovations, are often accused of being traditional, conservative, resistant to innovation/change, ignorant of the benefits associated with innovations, irrational, etc. (Rogers, 1983). In short, the farmer is entirely and only to be blamed for the failure of accepting innovations: individual blame (Caplan and Nelson, 1973, quoted in Rogers, 1983). When it is recognised that farmers are part of a system, other elements of the system may be considered. The other extreme is then to put the blame entirely on the circumstances created by society (system blame), in which individuals are nothing more than marionettes, passively responding to changes in circumstances and at the same time without means to influence these circumstances.

To study the complex relations among different actors involved in the process of adoption of innovation in animal production, some concepts have first to be defined.

System

Systems are limited parts of reality with well defined boundaries (Rabbinge and van Ittersum, 1994). A system is a construct with arbitrarily defined boundaries serving as a basis for discussion about complex phenomena to emphasise wholeness, interrelationships and emergent properties (Röling, 1994).

While Rabbinge and van Ittersum (op. cit.) look at models of systems as constructs, Röling (op. cit.) considers the systems themselves as constructs. The definition of Röling will be referred to any time the word system is used in the following text.

Knowledge system

A knowledge system is a system in which knowledge generation, transformation, transfer, testing, utilisation and feedback function synergistically (Röling, 1985b). It comprises the articulated set of actors, networks and/or organisations, expected or managed to work synergistically to support knowledge processes that improve the correspondence between knowledge and environment, and/or the control provided through technology use in a given domain of human activity (Röling and Seegers, 1991, quoted in Röling, 1992)

Agricultural Knowledge System (AKS)

Agricultural knowledge systems are deliberately designed knowledge systems. Designed for extension science, they include a research sub-system, a dissemination sub-system and a user sub-system (Nagel, 1980).

To guarantee initiation and perpetuation of the information flow process, the system must perform six basic functions (Nagel, 1980):

1. identification of knowledge needs at the producer level
2. generation of innovations
3. operationalisation for utilisation
4. dissemination
5. utilisation
6. evaluation of experiences

The model emphasises the flow of information from users, both on needs for knowledge and evaluation. It illustrates an interactive process, not a one way flow. In most AKSs the generation and dissemination functions are very strong, but needs identification, operationalisation, utilisation and evaluation are weak. AKSs suffer frequently from the institutional separation of research and extension. In addition, users are often not active enough to make the system work effectively .

In the next paragraphs, this model is applied to the animal production sector in Burkina Faso, taking into account actors' opinions about the actual situation.

A schematic representation, based on Havelock's linkage model (Havelock, 1969), combining the subsystems and the basic functions (Nagel, 1980), is given in Figure 3.1 (Röling, 1985b).

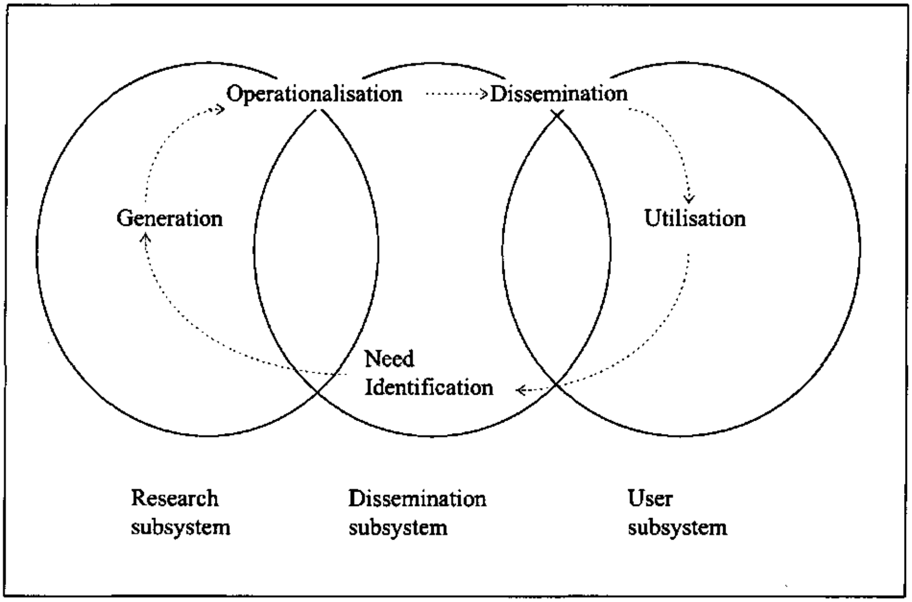

Figure 3.1 Basic elements of the agricultural knowledge system
Source: Röling, 1985b, based on Nagel, 1980, and Havelock, 1969

Research sub-system: organisation and research messages

Generalities

Scientists are supposed to generate knowledge and identify areas for growth of agricultural production and human expansion. Their knowledge must be transferred to be utilised. Research-extension linkages have become a focus of concern, as scientists become increasingly convinced that most of the world's problems would be solved if only the knowledge that is already available would be effectively used. This concept may be called the transfer of technology model (TOT) (Chambers and Ghildyal, 1985). This model however, hardly matches the needs and conditions of resource-poor farm families. In response to this problem, the TOT model has been adapted and extended through multi-disciplinary farming systems research (FSR), including on-farm trials (Fresco, 1984; Shaner, 1982). This response however, leaves the power in the hands of scientists. Information is obtained from farmers and processed and analysed to identify what might be good for them (Chambers and Jiggings, 1987).

Research Institutes in Burkina Faso

In Burkina Faso national research in the field of agriculture is supervised by the National Centre for Science and Technology Research (CNRST)[1], and mostly executed by the Environmental and Agricultural Research Institute (INERA)[2], and the University of Ouagadougou, including the Rural Development Institute (IDR)[3]. Only one specialised international research centre, CIRDES[4], dealing with animal production research, is based in Burkina Faso. Various donor-funded development projects are involved in applied research, directly aimed at their own programmes. These projects are integrally supervised by the Ministries of Agriculture, Animal Resources and Planning. This supervision includes research, planning, execution and impact of the projects' programmes. Research efforts of these projects are not subject to CNRST supervision.

National research on animal production is concentrated in the Animal Production Programme (APP) of INERA. A donor-funded project called "Optimisation of animal production in Burkina Faso"[5] has been formulated to support this programme. Following a period entirely devoted to on-station research, a tendency towards on-farm and more participatory research is developing. This means at the same time a shift from more fundamental towards more applied research (Tyc *et al.*, 1997).

INERA also had a programme dealing with farming systems: *Recherche de Systèmes de Production (RSP).* In theory, this programme identified farmers' needs and encouraged the sectoral programmes, like APP, to develop technical answers to these needs. The RSP programme was also responsible for the dissemination of technical packages to the farmers (TOT). In reality, the linkages between sectoral programmes and RSP were weak. During the reorganisation of INERA, in 1995, the RSP programme has been eliminated. The sectoral APP program has been maintained and even increased in importance, as it became one of three sectoral departments: Animal Production, Crop Production and Forestry Production. The fourth department is called Management of Natural Resources. It is totally unclear how a systems approach can or will be implemented within this new structure.

Research messages in Burkina Faso

CIRDES focuses mainly on impact and treatment of trypanosomiasis in the sub-humid tropics, hence their results only apply to the south of Burkina Faso. APP focuses on subjects related to optimal use of animal feed to maximise animal production. The level of research is usually an animal sub-system like sheep fattening, steer fattening, milk production or conditioning of draught animals. When feed rations have been developed, they must be

[1] CNRST = Centre National de Recherche Scientifique et Technologique
[2] INERA = Institut d'Etude et de Recherche Agricole (since 1996: Institut National de l'Environnement et de Recherche Agricole)
[3] IDR = Institut de Développement Rural (since 1 october 1997: Université Polytechnique Bobo-Dioulasso)
[4] CIRDES = Centre International de Recherche-Développement sur l'Elevage en zone Subhumide
[5] Optimisation de l'Elevage au Burkina Faso

transferred (TOT) to the livestock owners that have to adopt the technical packages. Adapted messages or additional conditions (priority access to certain scarce inputs, for instance) are not included for farmers that lack the means to adopt the packages. For example, a ration containing cotton seed cake is of no use to most farmers, as its availability is limited and uncertain and its price high. Moreover, no advice is available with respect to strategies to follow when less cake is available than necessary for the proposed maximum output. Should the farmer shorten the fattening period and feed the same ration or should he feed smaller rations for the whole period? If research does not address this type of practical questions, many messages can not and will not be adopted, especially not by resource-poor farmers.

Currently, most development projects and research programmes, especially those funded by foreign development organisations, focus on management and utilisation of natural resources. Thus, animal production research must also deal with the impact of livestock on natural resource utilisation and management. From the scientific literature, it appears that scientists tend to focus on cattle, as they constitute by far the largest group in terms of livestock units in the Sahelian region. Vegetation surveys, specially of the herbaceous layer, are carried out as a basis for calculation of the carrying capacity[6] of a certain area. In such calculations, complications, such as differences between grazers (cattle, sheep) and browsers (goat), and the seasonal use of parts of the area, are generally ignored, as are different production levels of livestock. The carrying capacity concept (Buttersworth and de Ridder, 1984), based on Tropical Livestock Units (TLU)[7], ignores animal selectivity which, at lower stocking rates may already seriously damage the vegetation by overgrazing of preferred species. A certain number of TLUs, entirely composed of cattle may be completely harmless to an ecosystem, while the same livestock density in terms of TLUs, consisting of goats may for instance lead to complete destruction of the woody vegetation. The fact that different animal species use different components of a habitat should thus be taken into account in describing interaction between vegetation and livestock (see Chapter 7).

Another issue in natural resource management is the integration of crop and livestock production. Research messages refer to collection, storage and use of crop residues for animal feed, but also to collection of manure. Optimal use of crop residues in cattle feeding, either treated with urea or supplemented with bran or cotton seed cake, has mainly been determined through feeding experiments with sheep and goats, as these animals are cheaper and easier to handle than cattle.

The former "small ruminant network" (ILRI)[8] was one of the few attempts to emphasise research on sheep and goats. It acknowledged that small ruminants may have other functions for farmers than cattle. Especially resource-poor farmers will keep small ruminants instead of cattle.

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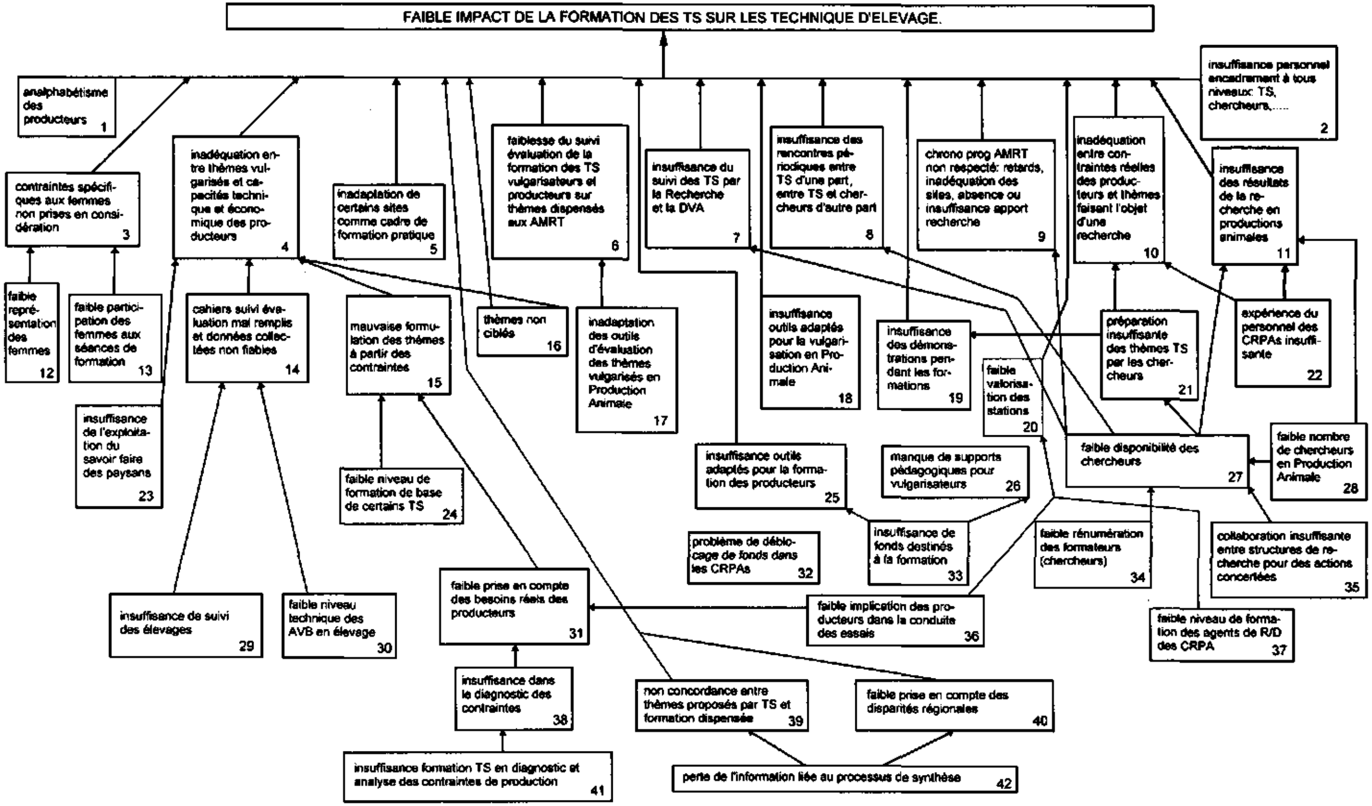
[6] Carrying capacity = the maximum stocking rate possible without inducing damage to the vegetation or a related resource (American Society of Range Management, 1964)
[7] TLU = a hypothetical animal of 250 kg liveweight, fed at maintenance
[8] ILRI = International Livestock Research Institute



TS = *Technicien Supérieur*
DVA = Direction Vulgarisation Agricole

Figure 3.2 Problem tree made during a training of "Techniciens Supérieurs"

Extensionists' opinions on the research sub-system

In July 1995, the project "Optimisation of Animal Production" organised a workshop with the objective to evaluate the training of technical agents (actors) with respect to extension of animal production messages to farmers (INERA, 1995). As a result of the workshop a 'tree' of problems has been identified (Figure 3.2). This tree will serve to illustrate some of the concepts discussed with respect to the AKS on animal production in Burkina Faso. The boxes of the tree are referenced in brackets: tree plus number (e.g. tree 1).

The tree of problems shows that technical agents consider the results of research unsatisfactory (tree 11), the research messages partly inadequate with respect to farmers' problems (tree 10, 15) and the transfer of results to technicians inadequate (tree 21, 27). In addition, research capacity is considered insufficient (tree 28) and research staff underpaid (tree 34).

Intermediate conclusion

The research sub-system is very science driven, based on the TOT model and leading to extension messages of little interest to resource-poor farmers. Research to increase understanding is more important than to solve farmers' problems. Research on grazing systems is almost entirely restricted to cattle and carrying capacities. All other research focuses on systems based on the use of external inputs, directed to livestock kept by crop producers in line with the crop-livestock integration concept.

Dissemination sub-system

Generalities

Research has demonstrated empirically that new ideas, once introduced into a social system, gradually spread in that system from one decision making unit (individual, household, committee or village group) to the next (Röling, 1985a). This process of diffusion takes place rather autonomously in social systems, without any intervention (Rogers, 1983; Havelock, 1969). In case of introduction of innovations, diffusion is often the automatic multiplier of the innovations impact.

Farmers adopting many innovations relatively early, tend to be favourite target clients of extension workers. These so-called progressive farmers, in turn actively solicit the services of extension workers. The described process will be called progressive farmer strategy. Another strategy, the so-called commodity strategy, focuses all services and support on a specific commodity, e.g. cotton. The focus on commodities was particularly strong as a result of the colonial political and economic pressure to supply crop and livestock products that satisfied the demands of growing Western industrialised societies (Sumberg, 1998; Massa and Madièga, 1995; Schwartz, 1995). The progressive farmer strategy is underpinned by the theory that extension is faced with a so-called homogeneous population of farmers, similar in every important aspect. All members of the population produce the same product and neither can influence individually its price. More "entrepreneurial" farmers are early adopters of new ideas, so they increase their profits which is an incentive for others to follow. Thus, the extension effort is effortlessly multiplied. This theory is based on successful diffusion of innovations, but how about imperfections in the diffusion processes?

According to Röling (1985a), populations are never perfectly homogeneous. Homogeneity must be expressed relative to the purpose of the intervention. Heterogeneity may originate from: psychological characteristics, access to information or access to resources. Access to resources such as land, capital, inputs, credit and labour. determines to a large extent whether innovation is feasible, as it requires not only knowledge, but also the means to implement innovation. Access to resources or to institutions controlling them, greatly varies among farmers. Progressive farmers generally have better access to resources than others (Rogers, 1983) and can therefore more easily adopt innovations. They can, in general also afford to run the associated risks. In Havelock's linkage model (1969), capacity is presented as an important factor in knowledge dissemination and utilisation. Capacity combines the characteristics wealth, education, power, status, intelligence, etc. which are all invariably good predictors of successful innovation and utilisation. Those who are already well-endowed, have the best chances to get more, because they have the "risk capital".

When a population is not homogeneous in important aspects related to the innovation introduced, that innovation is not identical for each farmer, and it may not be appropriate for everyone. Hence, non-adopters are not necessarily ignorant, traditional and/or conservative (personal blame), but the innovation was not relevant to them (Rogers, 1983) or they could not afford the risk.

There is also a difference in rewards for innovation between later and early adopters. As adoption spreads, the limited elasticity of demand for agricultural products almost invariably leads to lower prices. In a rapidly changing environment, farmers, thus have to innovate to maintain their income level. The so-called laggards, facing deteriorating prices, finally have to join the adopters, but in the meantime the rewards have fallen considerably. At the bottom end of the distribution, rapid agricultural innovation processes lead to a continuous expulsion of farmers out of the sector (Bordenave, 1976, quoted in Rogers, 1983). Diffusion processes may thus become key mechanisms in furthering inequity (Rogers, 1983) and social differentiation. Furthermore, innovations are usually developed to match the conditions of progressive farmers. Extensionists, farmers' representatives, policy makers and researchers tend to have only contact with progressive farmers, thus any targeting is based on their situation.

If a different future for agricultural and rural areas is aimed for, than the one following from the progressive farmer strategy, a target category-oriented strategy is called for. In this strategy, relevant variables have to be identified to segregate a heterogeneous population in categories in such a way, that variance in those variables is maximised between categories and minimised within (phase 1). It analyses each category on aspects important to decision making about interventions (phase 2). Content and strategy of the intervention should be designed based on the information collected in the first two phases. Interventions should be tested in close collaboration with representatives of these categories and extension programs should address the target categories selectively. This strategy is essentially used in marketing (Kotler, 1975).

Extension in Burkina Faso

In Burkina Faso, government extension services are assumed to communicate their messages to the farmers according to the TOT model. The messages are formulated at national level. The extension agents are trained per message and provided with leaflets (*fiches techniques*) containing a summary of the practical aspects of the message. The messages are disseminated nation-wide, irrespective of regional differences in agro-ecological conditions, religious traditions, infrastructure, etc. Extension agents consider this absence of regional differentiation a problem (tree 40). In 1995, CNRST has acknowledged the importance of regional differentiation, and the country was divided in five regions. For the animal production program (APP), regionalisation is based on numerical importance of species and on agro-ecological characteristics (CNRST, 1995). Knowledge dissemination is assumed to follow the diffusion process as extension agents can only reach a limited number of farmers. The easiest way to proceed, from the extensionist's point of view, is to focus on the farmers interested in the message, i.e. those with access to the necessary resources, and to call these early adopters: "demonstration or model farmers". This is the very example of the progressive farmers strategy. No special attention is given to the non-adopters, neither in assisting them to gain access to necessary resources, nor in adapting the message to their options and constraints, as also expressed by extension agents (tree 4, 10, 3, 31 and 38). The extension agents have, in theory, also the function to facilitate farmers' access to credits and agricultural inputs such as inorganic fertiliser for crop production and/or cotton seed cake for livestock feeding. In reality, their role is limited, as distribution of inputs is poorly organised, for instance leading to serious delays in supply. This is acknowledged by Kaboré *et al.* (1996) in their synthesis of the animal production program as executed by the regional agricultural extension services (CRPA[9]). They identify various problems in program execution, for instance, shops being out of stock for long periods for veterinary products and feed supplements such as mineral blocks, etc. Seeds for fodder crops and agro-industrial by-products are available in insufficient quantities to cover the requirements of livestock farmers in Burkina Faso and at high prices only[10].

The synthesis (Kaboré *et al.*, 1996) shows that all messages refer to animal production systems aiming at maximising meat output (fattening). Intensive animal production with high labour input for cultivation of fodder crops, collection and storage of hay and stall feeding is promoted. A certain level of capital inputs is also promoted such as buying and feeding concentrates (cotton seed cake), construction and equipment of stables and/or corrals and complete veterinary care. Moreover, it is concluded that farmers are blamed for non-adoption of

[9] CRPA = Centre Régional de Promotion Agro-pastoral

[10] ruptures prolonguées de l'approvisionnement en intrants vétérinaires et zootechniques, semences fourragères et Sous Produits Agro-Industriels (SPAI) insuffisantes et chères

the messages. They are called "resistant to innovation"[11].

For cotton, one of Burkina Faso's main export products, a commodity strategy is used. The *Société Burkinabè des Fibres Textiles* (SOFITEX), a semi-government organisation, provides all necessary inputs (seeds, fertiliser, insecticides, credit facilities, animal traction for land preparation and weeding) and also organises the marketing of the final product. Inputs are provided on credit, to be repaid directly after harvest. The moment the cotton is paid to the farmers, all debts are collected by SOFITEX agents. Many farmers face difficulties paying their debts (Kaboré *et al.*, 1996), especially when their cotton crop failed or when they used the inputs on other crops. SOFITEX stimulates extension messages aiming at increased output of animals used for traction. Output is expressed in terms of crop production and not in terms of meat production.

Intermediate conclusion

The adoption rate of many extension messages on animal production in Burkina Faso is low, either because they are not attractive for certain farmers or because the farmer lacks the means to adopt the innovation. The TOT model and the diffusion theory and, therefore, the progressive farmers strategy dominate the dissemination system. Messages on animal production focus on sedentary farmers, owning some livestock and managing them in line with the crop-livestock integration concept.

User sub-system

Generalities

Users frequently appear passive consumers of research findings disseminated to them by extension. The active user sub-system comprises the more progressive elements within the agricultural sector (Nagel, 1980). Farmer training and research services have often failed to adequately diagnose the specific needs of different subgroups of farmers in different areas (tree 3,4, 15, 23, 31, 38, 40, 41). There has been a tendency to formulation of "standardised messages", assuming that they would match the conditions of all farmers and areas. In fact, only progressive farmers constitute the active clientele of the knowledge system. Tendler (1982) concluded that a strong constituency is an important element in intervention success, and that many poor people do not form such a constituency, while moreover influential "elite" groups discourage or even prevent them from exerting influence. Progressive farmers mostly form a constituency allowing them to demand research and extension messages according to their needs. Leeuwis *et al.* (1990) highlight this aspect as an important criticism on knowledge systems theory and methodology, that 'can only deal poorly with issues of power and social conflict....'.

[11] "résistance à l'innovation" and "barrières et résistance socio-économique"

The agricultural knowledge systems approach implicitly assumes that the contacts between "intervenors" and clients take place in an atmosphere of positive expectations and harmonious participation, whereas we know, according to Leeuwis *et al.* (op. cit.), that differences in interest, resources and perceptions may interfere. Two possible solutions present themselves: (i) define the system (AKS) boundaries in such a way that the possibilities of mutual agreements are maximised: this implies identifying homogeneous target groups or specific institutions dealing with knowledge dissemination/utilisation and thus excluding other actors or more informal social arrangements; (ii) adopt a view of the situation that is acceptable to the most powerful participants. A more actor-oriented perspective, with emphasis on human agencies and the concept of multiple knowledge networks is promoted by Leeuwis *et al.* (op. cit.). This perspective implies that analysis must be based on a "detailed ethnography of specific empirical contexts to come to understand specific actors' life-worlds interests and representations of the world around him" (Leeuwis *et al.,* 1990).

To implement such an approach for a whole country would require many highly competent sociologists and/or anthropologists to identify the many specific actors, each with its own needs. At national level, this degree of detail can not be managed. It is impossible to develop specific extension messages for each individual separately. To guide research and extension, these actors have to be classified again, so that in practice the actor-oriented approach is not very different from the knowledge system approach with its target groups.

Users in Burkina Faso

In Burkina Faso, most farmers aim at self-sufficiency in cereals and the production of some surpluses to be able to buy household necessities. As crop production is entirely rainfed, farmers have very little control over yield. They have difficulty building up sufficient reserves for financing and for investments. These farmers' strategies will be low-input risk-avoiding, rather than early adopting high-input innovations.

In Burkina Faso, farmers are organised in village groups (VG). Such groups are presided by the village chief and the influential elders. Functions like secretary and treasurer are in the hands of the few people that can read and write (tree 1), thus the progressive villagers. Within these village groups, various committees can be formed, dealing with specific subjects. In certain villages a *Gestion de Terroir Villageois (GTV)* committee exists that is responsible for co-ordinating all activities with respect to the village territory. Other committees, organising certain producers like livestock owners or vegetable growers, can also exist. These committees may be considered target groups in the AKS. Extension messages, but also other interventions, pass through the village group and its committees. Demonstration farmers are "selected" by extension agents, and supposed to participate in on-farm trials (tree 36). This selection is not based on a set of objective criteria defined by the extension agent, but rather on self-selection within the village group or the committee: farmers that want to participate and express their willingness are subsequently selected. This leads invariably to the selection of the influential members and farmers that can bear risks. The result of the self-selection process shows that the progressive farmer strategy is coming to the fore, irrespective of the approach to work through specialised committees. Committees, in fact, do not function as target groups as defined in the AKS approach.

Only a limited group of livestock owners can adopt extension messages related to animal production, e.g. on cultivation of fodder crops or feeding rations with cotton seed cake (tree 4). Adoption of the first message requires e.g. additional arable land, additional labour, access to seeds and materials to construct enclosures, and transport facilities to bring the product to the stable. Only "rich" farmers can afford these inputs. Adoption of the second message requires a strongly organised group or persons with a far reaching network to secure access to cotton seed cake. Messages on sheep fattening are only useful when marketing of these sheep can be guaranteed, thus to livestock owners near main roads or livestock markets. Messages on milk production are relevant only, when demand for milk exists in the immediate surroundings of the herd.

In addition, all messages in Burkina Faso seem to be directed towards arable farmers keeping livestock or to specialised livestock keeping units from absentee farmers (civil servants or private employees) and not to Fulani, the traditional livestock keepers. Their farming system comprising substantial numbers of animals and a limited area of arable land, makes messages on cultivation of fodder crops and collection and storage of crop residues largely irrelevant.

Finally, the special role that small ruminants may have in farmers' households, compared to cattle, is ignored by extension. Management of small ruminants differs from that of cattle as a result of farmers' objectives and animal species' potentials. Messages aiming at high-input sheep fattening are of little use to farmers keeping small ruminants as a capital asset that is easily convertible in cash in case of financial needs (see Chapter 5).

Intermediate conclusion

Progressive farmers strategy dominates the users sub-system. Only rich sedentary farmers can form a constituency and therefore receive extension messages that are beneficial to them. They are also the only ones that can bear the risks involved when implementing an innovation.

Conclusions and recommendations

Agricultural innovation appears to occur in highly inter-connected systems that allow interactions among users, researchers, extensionists, agricultural media and institutions for supply, distribution and marketing. In successful systems, users often have considerable control over the whole process, which ensures expression of its synergistic functions and prevents inefficiency and lack of co-ordination. Moreover, many linkages operate among the different elements (Röling, 1985b). Systems, aiming at deliberate agricultural innovation are called Agricultural Knowledge Systems (AKS). Targeting such systems at homogeneous categories of users is difficult, as progressive farmers tend to form their constituency. This is not a problem when the system is equitable in terms of farmers' access to resources, but that is seldom the case. Targeting of AKS has thus two components:

- developing technical innovations that are attractive to designated target groups
- human resource targeting, i.e. creating conditions for different or additional categories of farmers to become constituents of AKS.

While the first considers farmers as instruments to increase efficiency and productivity of resource use, the second focuses on the rural population itself and on the social system in which it functions.

In Burkina Faso, the AKS does not function satisfactorily, as each of its elements suffers from lack of influence. For instance, extension being institutionally separated from agricultural research and policies, has only limited influence on identification and formulation of research messages. Extension mainly translates research results in messages that subsequently are transferred to the farmers. Moreover, farmers are not strongly organised and not represented at government level, hence they have very limited influence on national agricultural policy. Mobile livestock owners, such as Fulani herdsmen, are even less organised and not at all connected to research and extension. For the same reason (lack of constituency), neither herdsmen's needs nor farmers' needs are conveyed through extension to research. Summarising, the interactions among different components of the AKS in Burkina Faso can be characterised by:

- TOT between research and extension
- progressive farmer strategy between extension and user
- no influence of farmers or herdsmen on policy makers, hence neither on research issues nor on extension messages

It has been shown that farmers can not be considered as one homogeneous group. They have different objectives and means to realise them. Animal production systems are dynamic under the influence of national and international policies, demographic pressure, quality and quantity of available natural resources, research and extension efforts, etc. To properly react to farmers' objectives, government objectives and natural resource endowments with respect to animal production, major adaptations are necessary.

First of all it is suggested that a framework for classification of farming systems with a livestock component be developed that represents development pathways, and livestock farmers are stratified according to their objectives and means (Chapter 4). The driving forces behind farming systems development must be identified (Chapter 4) in order to understand the direction and rate of change. Relations between farmers objectives and management may explain why certain farmers do not respond to certain extension messages (Chapter 5). For the same reason different roles of livestock, such as financing (Chapter 5) or animal draught power (Chapter 6) for different categories of farmers need to be understood and where possible quantified. Finally, the impact of farming systems development on the use of natural resources needs attention (Chapter 7). These subjects, that are part of the technical targeting, are treated in the remainder of this thesis.

4 Farming systems development in the West African Savanna: criteria, concepts and drives

Introduction

Crops and livestock are interactive components of rainfed farming systems in Burkina Faso. In the past, interaction was mainly based on complementarity. Crop producers and livestock owners (pastoralists) lived side by side (Van Raay, 1975). Sedentary arable farmers allowed livestock of mobile pastoralists to graze their crop residues in exchange for manuring their fields. Milk was bartered against grain. In fact, two separate systems were present: an extensive crop system and an extensive livestock system, both characterised by low external input (LEIA). Gradually, integration between the two systems takes place: pastoralists start to cultivate small plots of land and crop producers acquire some small ruminants and even some cattle. Both systems develop into agro-pastoral (mixed) systems, characterised by a certain level of integration between the two (now called subsystems), with management in one hand.

Understanding the dynamics of interactions between crops and livestock, both in separate and in mixed systems is important to interpret resource degradation, sustainability and productivity trends in farming systems operated by smallholders. As the characteristics of systems differ, so do their development pathways. Although farming systems form some sort of a continuum, a taxonomy or map of discrete farming systems should be developed, as a basis for understanding change and where desirable, designing interventions (Mortimer and Turner, 1993). To develop such a map, and to distinguish between farming systems, a set of explanatory and discriminating variables must be identified. Moreover, research on the development pathways for each system and the possible change in their relative importance in time is necessary. Furthermore, management objectives, available technologies and available resources of specific farming systems must be known to formulate relevant and acceptable recommendations for farmers. The same information can serve to underpin the expected (anticipated) dynamics of farming system development.

Farming systems

To develop a typology of farming systems in a research area, useful discriminating criteria must be identified and a certain number of constructs must be defined. Criteria can be found in literature and derived from field studies. Some constructs that are useful for the argument in this chapter will be defined here. Most definitions are based on the ICRA textbook by Mettrick (1993) and on Amir and Knipscheer (1989).

Household: The farmer and other members of the family who form a consuming and producing unit and a social organisation. Households are often under the management of a single person, but sometimes operate collectively. Members normally live and sleep in the same place, share meals, and divide household duties (Amir and Knipscheer).

Farm: An organised decision-making unit within which crop and livestock production is carried out for the purpose of satisfying the farmer's goals (Amir and Knipscheer).

Farming system: A unique and reasonably stable arrangement of farming enterprises that a household manages according to well-defined practices in response to physical, biological and socio-economic factors and in accordance with household goals, preferences and resources (Shaner *et al.*, 1982).
An alternative definition of *farming system* comes from Byerlee *et al.* (1980): The total of production and consumption decisions of the farm household, including choice of crop, livestock and off-farm enterprises and food consumed.

Farming Systems Research (FSR): An approach to agricultural research and development that: (1) views the whole farm as a system, (2) focuses on the interdependencies among the components under control of members of the farm household and on their interactions with the physical, biological, and socio-economic factors not under the household's control, and (3) aims at enhancing the efficiency of farming systems by improving the focus of agricultural research in order to generate and test better technologies (Shaner *et al.*, 1982). The FSR approach involves selecting target areas and farmers, identifying problems and opportunities, designing and executing on-farm research, and evaluating and implementing the results. In the process, opportunities for improving policies and support systems affecting the target farmers are also considered.

Farming Systems Analysis (FSA): A research activity within FSR, consisting of a quantitative analysis of an existing farming system whose objective is to understand the structure of interactions within the system and to quantify stocks and flows (Merrill-Sands, 1986). The typical product of this research is a model of the system. The farm is subject of research.

Participatory research techniques increase farmers' involvement in research, making farmers active participants and actors, instead of subjects (Farrington and Martin, 1987) and they may as such be an useful addition to FSR. The interpretation of results is not taken out of farmers' hands, but is an interactive process. These research techniques aim at developping technology that is possible for farmers to adopt, both in terms of economic profitability and resource availability and attractive for farmers to adopt in that it matches with farmers' perceptions of their needs (Merrill-Sands, 1986).

FSR often does not consider the place of the farming system in its broader context of the economic and policy environment. Lack of adequate supporting services and infrastructure may render an otherwise appropriate technology useless. An approach that does take these aspects into account is for instance Recherche-Développement (RD).

Recherche-Développement (RD): Experiments in the actual social and physical environment, on the possibilities and conditions for technical and social change (Jouve and Mercoiret, 1987).

RD pays special attention to the fact that many of the constraints that the farmer faces can only be tackled at a higher level than the farm and depend on policy decisions or development actions rather than further research. Farmers can not be considered as isolated entities in society. They are, for instance, part of an Agricultural Knowledge and Information System (AKIS; Chapter 3) with other actors like researchers, policy makers, including village chiefs, and extension agents.

AKIS: The interlinked system of institutions and individuals involved in the generation, transfer and utilisation of knowledge and information for agricultural improvement (Röling, 1989).

When extension and research are based on the concept of AKIS, farmers' objectives, farmers' strategies and farmers' networks, but also factors influencing decision making, are important research objects. The farmer is subject of and actor in research. Hence, technology development and human resource development are focus of research (Röling, 1989). The AKIS approach implies that additional information is necessary on the context in which farmers live and work: infrastructure (roads, markets, schools), information (extension services, radio, television, newspapers), incentives (subsidies on inputs, minimum prices for outputs).

A farming system, as defined above, comprises two subsystems: a cropping system and a livestock system. Although our main interest is in livestock systems, the cropping system will also briefly be treated, because the systems interact at the level of the farm and the farm household.

Crops: Plants that are planted and managed for economic purposes, producing a physical product for the farm's use or sale (Amir and Knipscheer, 1989).

Cropping system: Crop production activity of a farm, comprising all components required for the production of the set of crops and their relationships with the environment. These components include physical and biological factors, technology, labour, and management (Zandstra *et al.*, 1981).

Cropping Systems Research (CSR): Research concentrating on crops, cropping patterns, and interactions between crops, between crops and other enterprises, and between the household and environmental factors beyond the household's control (Amir and Knipscheer, 1989).

Livestock systems

To characterise livestock systems, livestock, livestock system and livestock systems research should be explicitly and unequivocally defined, and the different roles of livestock must be known.

Livestock: Animals raised for home use and profit.

Livestock system: Subsystem within the farming system, consisting of a set of one or more animals and comprising all components required for their production, including the interactions among the animals, other household enterprises, and the physical, biological, and socio-economic environments (Amir and Knipscheer, 1989).

Livestock Systems Research (LSR): A process similar to cropping systems research but with procedures that reflect the inherent differences between cropping and livestock systems (Amir and Knipscheer, 1989).

The role of livestock

For arable farmers, livestock is a means to maintain household viability (Bayer and Waters-Bayer, 1991). Livestock can be sold for financing households' foreseen and unforeseen expenditures. It can be seen as investment capital, available for use in contingencies, that is relatively divisible. In case of crop failures, livestock offers various economic options in support of smallholder resilience. Crop surpluses can be sold and the cash invested in livestock that will increase in number by reproduction and in weight by growth. Livestock can thus present considerable wealth. It can be used to support crop production with energy (traction) and manure (McIntire *et al.*, 1992; Powell, 1986). Animals can also be used for transport.

For pastoralists and agro-pastoralists, milk, meat and other products provide recurrent food and income. For pastoralists, livestock is the basis of their production system, thus food production and accumulation of wealth are the major objectives of their livestock keeping. For both pastoralists and agro-pastoralists livestock serves to maintain social relationships. Animals can be offered to family and friends as presents on specific occasions like marriages, funerals, religious ceremonies, etc. (Adamou, 1991). Animals can also be involved in more formal arrangements: pastoralists that herd animals for crop growers or civil servants (absentee farmers) against remuneration (Delgado, 1979).

In general, ruminant livestock is one of the few means to value natural vegetation (grasses, tree leaves) and crop residues by transforming them into meat and milk, suitable for human consumption. Grazing livestock around villages during the wet season reduces combustible standing biomass and reduces the risk of uncontrollable fires during the dry season (Waters-Bayer and Taylor-Powell, 1986).

The three pole model

Lhoste (1984) describes livestock systems by means of a three pole model: territory, herd, and man. Each level comprises certain elements and has certain characteristics (Figure 4.1). The structure, production and use of natural vegetation are main elements at territory level. Properties such as digestibility, biomass quantity and quality represent its characteristics. Structure, dynamics, animal physiological status, animal production are main elements at the herd level. Measurable parameters like species, sex and age composition of herds but also reproductivity and health status of animals are its characteristics. Finally, ethnic group, socio-economic requirements and relations with others are main elements at the human level. Lhoste (op. cit.) argues that it is important to examine the interfaces between the different levels of the system. An example is the balance between feed resources available on the territory and feed requirements of the herd. Another example is the balance between animal production and farmers' needs.

Tourte (1984) uses the same model, calling the level of man the management unit (farm, household) and adding an intermediary level: the community. Landais (1992) also uses the three pole model. He argues that livestock systems are characterised by the activities (pasture management, herd management, transformation of livestock products, etc.) that man undertakes with respect to his animals, based on the available resources. He defines resources much wider than territory (Lhoste, 1984), including financial and labour resources, but also sources of information.

Some authors using the three pole model put too much emphasis on one of the levels. Bosma *et al.* (1992) characterise a livestock system in Mali by the following elements: farmers' objectives and selling strategies, animal feeding schemes and animal production parameters, and available and used natural resources. They concentrate on animal production parameters (herd level) and neglect the other two poles. Dollé (1984) and Moulin and Tillard (1993) also concentrate on the herd level. The analysis of the latter results in a performance profile per animal and per herd that subsequently is used to classify livestock systems. On the other hand, Boudet (1984) concentrates entirely on the territory level with his diagnosis of ranges and their management.

The three pole model seems to cover all factors, but it leaves some fundamental questions. One pertinent question relates to the subject/unit of study. Studying at territory level means that the subject is a certain unit of land, that can be used by several stakeholders,

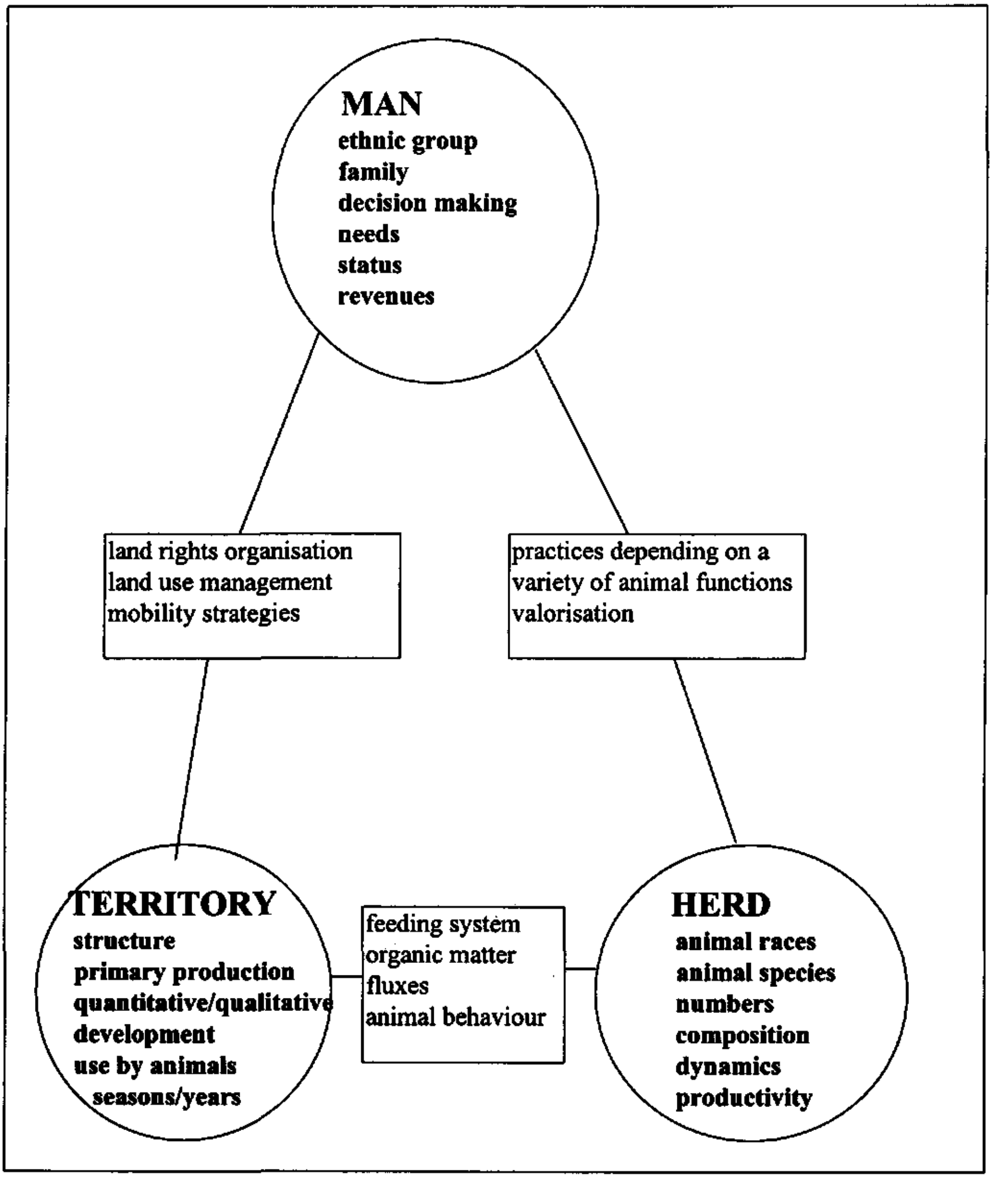


Figure 4.1 The three pole model
Source: adapted from Lhoste 1984 in Landais 1992

some of which are livestock owners and others are not. From the point of view of environmental management, this level of analysis is appropriate. From a systems typological point of view, the extent of heterogeneity among systems that may exist in a single territory is unmanageable, and therefore the community level is preferable (Tourte, 1984). Studying at the level of man means that the unit is the household, using its resources (finances, labour, land) for different activities of which animal production is only one. The level of the single management unit is only appropriate when crop-livestock integration is complete and the use of common or "open access" resources insignificant (Tourte, 1984). Studying at the level of herds is complicated, as herds may be composed of animals from different stakeholders and the herdsman may or may not be one of the owners of the animals.

Available typologies and their distinguishing criteria

Different farmers have different possibilities and needs. To take these into account, Byerlee *et al.* (1980) define the concept of recommendation domain: a roughly homogeneous group of farmers under similar circumstances for whom more or less the same recommendation can be made. Recommendation domains can be defined in terms of both natural factors (rainfall) and economic factors (farm size). Recommendation domain has been called target group by other authors (Röling, 1985b).

A typology aims at grouping production systems that function in a similar way, reflecting a similarity of objectives, strategies and limiting factors. Typologies aim generally at maximising differences among types and minimising variability within types. They should pay attention to the decisions that farmers take, given their constraints and their behaviour in the face of climatic fluctuations and the changing socio-economic situation.

First, criteria used in developing typology of livestock systems will be presented from general literature. Subsequently, Burkina Faso will be taken as a case and criteria found in literature on this country will be presented.

Criteria for typologies from general literature

According to Mortimer and Turner (1993), available typologies are generally based on five criteria: functional farming systems (1), economic specialisation (2), patterns of movement (3), livestock ratios (4) and animal traction (5). The relevance of these criteria for farming systems typology will be discussed.

Functional farming systems

Ruthenberg's (1980) classification of farming systems considers cropping systems and livestock systems separately. Cropping systems are classified from less to more intensive, but the level of intensification is not taken into account for livestock systems. Although animal species is not explicitly defined, limiting livestock systems to (semi-)nomadic and ranching grazing systems, implicitly considers only cattle. Mixed systems are absent in his classification. Jahnke (1982) proposes five types of livestock production systems, three specialised: pastoral range, ranching, landless livestock production, and two mixed: crop-livestock systems in lowlands and highlands.

Economic specialisation and values

Wilson *et al.* (1983) base their classification on the contribution of livestock-related activities to household revenue and food energy. Pastoral systems are defined as systems in which more than 50 % of gross household revenue or more than 20 % of food energy is derived from livestock. Agricultural systems are systems in which less than 10 % of gross revenue, is derived from livestock production. All other systems are called agro-pastoral. Monicat *et al.* (1992) also use household revenues from crop production, animal production and off-farm activities as the basis for a detailed typology of livestock systems.

Fricke (1979) distinguishes four main types and 23 subtypes of cattle-keeping systems in Nigeria. It appeared impossible, however, to relate these types empirically to identifiable groups. The main types are: full time cattle keeping enterprises, mixed enterprises, part-time enterprises, special types. The classification seems to be based on two discriminating factors: household time spent on the livestock component and the presence of other components in the enterprise.

According to Baxter (1977), pastoral peoples can be grouped in three classes. These include two subtypes of pure pastoralists, not involved in cultivation: those fully and those marginally involved in a market. Secondly, some primarily pastoral people, frequently transhumant, who cannot subsist on their stock alone and cultivate some crops (agro-pastoralists). Finally, some primarily arable people who maintain strong pastoral values (agro-pastoralists). It is important to realise that households may shift between classes as they loose or reconstitute their herds through time.

Classifications based on the degree of dependence on livestock (Monicat *et al.*, 1992; Wilson *et al.*,1983; Fricke, 1979; Baxter, 1977) may yield important insights in the choice of economic options at household level. They do, however, not address relations between livestock and crop production subsystems nor the impact of management practices on the environment.

Patterns of movement

Van Raay (1975) distinguishes four types of Fulani livestock owners, based on mobility: nomadic, semi-nomadic, semi-settled and settled. Kirk (1991) also distinguishes between nomads and transhumants as opposed to sedentary livestock keepers and crop farmers using animal traction. Mobility is used as a characteristic for the household and not for the different herds of various animal species that are managed by the household.

Movements of cattle may for instance be different from those of small ruminants.

Livestock ratios

Ratios between cattle and small ruminants are indicators of household wealth, movement patterns and specialisation. They are relatively sensitive to short-term dynamics in animal ownership, responding to cycles of impoverishment and restocking, following periods of drought-induced mortality or de-stocking. Monicat *et al.* (1992) use the ratio between cattle and goats as basis for a typology of livestock systems in Zimbabwe. Cattle numbers are significant indicators of wealth for crop producers and also of the relative importance of the livestock component for the household. Crop producers with a high off-farm income for instance, own many cattle and few small ruminants, while animal production specialists with off-farm income own large numbers of both species.

Animal traction

Use of animal traction seems important for classifying mixed farming systems. However, McIntire *et al.* (1992) could not establish a general correlation between adoption of animal traction and other techniques. Kirk (1991) argues that crop farmers using animal traction are an important category of livestock owners to be distinguished when introduction of technology and change are important issues. Vall's (1992) analysis results in the distinction of three types of farms with animal traction. The differences appear essentially based on factors related to farm size: total cultivated area, number of active household members and number of livestock. He observes that farmers can shift among categories, but was unable to identify a development pathway from one type to another in time. Fauré (1994) also shows that farms varying in level of mechanisation differed in farm size, use of fertiliser and insecticides, yields per hectare, cropping pattern, net annual revenue, numbers of cattle, etc. In South Mali, four farming systems are distinguished using the level of mechanisation as main discriminating factor, expressed as the number of draught animals and the tools involved (Sanogo *et al.*, 1991).

Intermediate conclusion

It appears that none of these five mentioned criteria provides a satisfactory basis for a classification of discrete farming systems based on the three poles (Lhoste, 1984) : man, animal, environment.

Criteria for typologies derived from literature on Burkina Faso

For Burkina Faso, various authors have tried to describe the different livestock systems. For evaluation of INERA[1]'s Animal Production Program a synthesis has been made of animal production research in Burkina Faso (INERA, 1994), in which three criteria for classification have been identified:

(1) ethnographic or anthropological (Kintz, 1992; Benoit 1982; Barral 1970)
(2) geographic or agro-climatic (Touré *et al.*, 1985)
(3) animal (re)production, management and exploitation of herds (Rondo, 1986)

These criteria can also be found in Figure 4.2 (Landais, 1992a and 1992b), identifying the disciplines necessary in the analysis of livestock subsystems. A very brief summary of each of the criteria is given.

Ethnographic or anthropological

Till the end of the seventies, application of the first criterion led to recognition of two distinct systems (Benoit, 1982; Barral, 1976):
- a pastoral Fulani system, based on mobility of at least part of the people and livestock of a household, at least part of the year;
- a sedentary system that is common for other ethnic groups, such as Mossi, Bissa, Lobi, Bobo, Gourounsi, Gourmantché, all mainly crop producers.

Kintz (1992) described in detail the origin and political power of Fulani families in Burkina Faso, especially in Sissili province. She compared their livestock keeping to that of other ethnic groups in the same province. De Boer and Kessler (1994) also started from ethnic group (Fulani, Mossi, Gourounsi) to describe livestock systems in Sissili province.

Geographic or agro-climatic

The geographic or agro-climatic approach considers the Sahel, the Northern part of Burkina, as the cradle for livestock production, while the Southern, Sudan zone, is considered only marginally suitable for animal production. In 1983 (Rondo, 1986; Touré *et al.*, 1985), more than 30 % of the Burkinabé herd was concentrated in the Sahelian zone, which represents only 17 % of total national area. The same two main systems as in the preceding paragraph are distinguished (Touré *et al.*, 1985; Delgado, 1982):
- pastoral, semi-nomadic, in the North, based on *Bos indicus* (Zebu cattle)
- sedentary, agro-pastoral, in the centre and the South, based on small ruminants, with some *Bos taurus* cattle

Since 1983, this situation has changed considerably. During the droughts, many Fulani in the North of Burkina lost part or all of their animals, making it impossible for them to make a living on livestock production. They were left with three alternatives: live on cropping, become an employee (herdsman) of other livestock owners or look for work outside the

[1] INERA = Institute Nationale de l' Environnement et de Recherche Agricole

agricultural sector. Several Fulani thus became sedentary mixed farmers even though their objective remained to rebuild their herds as soon as possible, to become mobile pastoralists again (Kirk, 1991). Other Fulani fled with their herds to the South, to Zoundwéogo province for instance, where they remained after the droughts. On the other hand, various arable farmers in the center and south of the country started livestock keeping, even cattle. One third of all cattle currently is found in the cotton zone, the South-West of Burkina Faso (Badini, 1991).

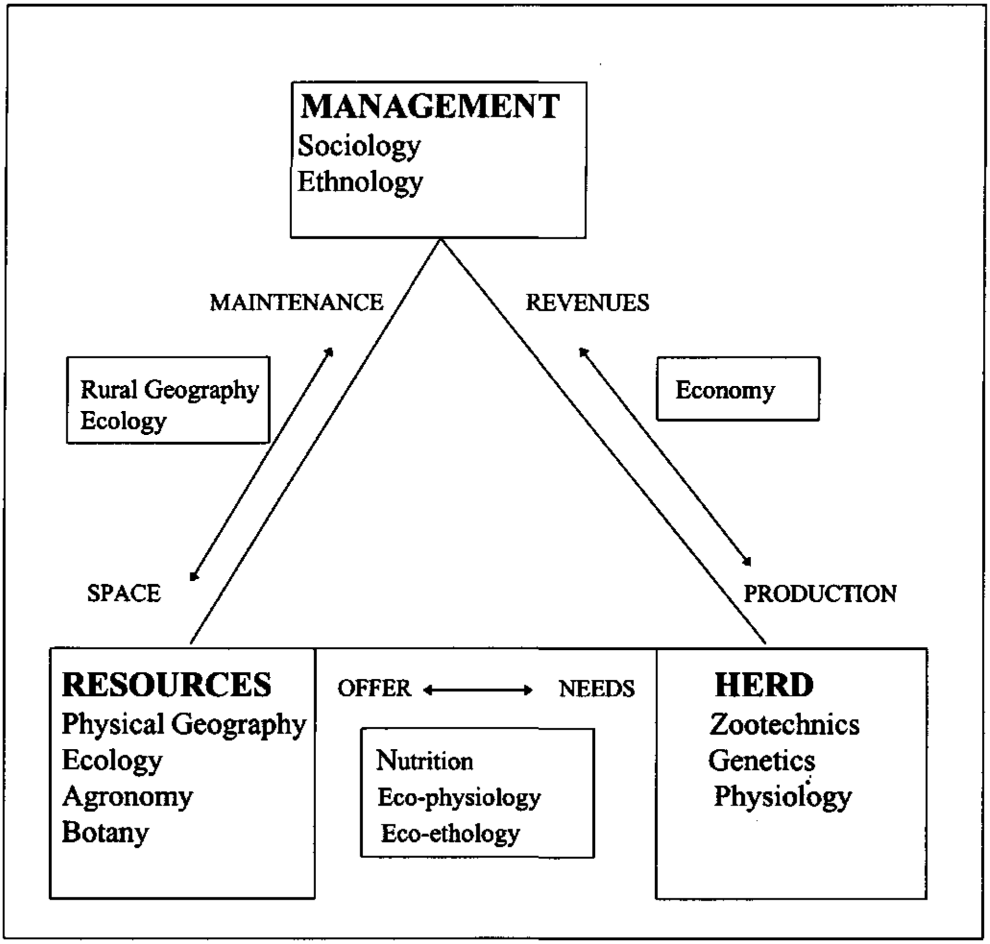


Figure 4.2 Disciplines involved in pastoral systems research in accordance with the three pole model
Source: adapted from Balent and Gibon, 1987, in Landais 1992

Animal (re)production, management and exploitation of the herd

Animal production systems can be distinguished according to production goal, and to grazing system and mobility.

Production goal. The opinions about Fulani livestock production systems differ. Some authors suggest that status is the pastoralists' one and only objective, leading to large herds that are hardly exploited. Others think that milk production is the Fulani's main objective, while the animals represent the pastoralists' wealth and saving account that guarantees household survival in difficult times (Ouédraogo, 1991). Young cattle remain in the herd, instead of being sold, because they are not considered meat products but as replacement of stock and contribution to the growth of the herd (Rondo, 1986). Delgado (1982) points out the economic (saving, capital accumulation, financing in time of crisis) and social (gifts, slaughtering at ceremonies, status) roles for both Fulani and sedentary livestock. For agro-pastoralists, livestock can be considered a support for agricultural production (manure, traction), but also as investment of the revenues from the cropping component (De Boer and Kessler, 1994; Gnoumou 1992; Lalba and Gnoumou 1992; Felix, 1985).

Table 4.1 Characteristics of Fulani and Mossi livestock systems in Burkina Faso.

Ethnic group	Fulani	Mossi/Bissa
Main produce	livestock	crops
Main production factor	labour	land
Mobility of people	mobile	sedentary
Herding	year round	rainy season
Mobility of cattle	mobile	entrusted
Mobility of small ruminants	mobile	tethered
Cattle breed	*Bos indicus* (Zebu)	*Bos taurus*
Main species	cattle	small ruminants
Cattle production goal	milk, capital	capital
Small ruminant production goal	financing	financing

Grazing system and mobility. All systems are based on natural pastures. Fulani herds in the North move frequently in search of water and feed. The animals are herded and cover large distances. The main incentive for this mobility is the wellbeing of the animals. Crop fields are scarce and easily avoided (Benoit, 1980). Agro-pastoralists from the South are concerned with the need to keep their animals away from the crop fields in the rainy season. They thus have to entrust their herds to herdsmen to take them far away. Another option is to tether some small ruminants and draught bullocks on nearby fallows. In the dry season animals are left to wander on their own.

Some small-scale, intensive livestock production is practised in which animals are stallfed. This system is so far only used for fattening of rams for Muslim holidays and for fattening of steers after their working career (Kiema, 1992; Badini, 1991; Sawadogo, 1986; Felix, 1985).

Intermediate conclusions

Mobility, animal breed and animal production goals appear directly linked to ethnic groups. All criteria combined lead to two distinct systems, present till the eighties (Table 4.1).

Additional criteria for typologies

Analysis of recent studies in Burkina Faso from literature

Four studies will be analysed to derive additional criteria to be used in farming systems typology: the national livestock study (1988), the national agricultural study (1993), a project study in Sanmatenga province (1994) and in Bam province (1994).

National livestock survey

In 1988 a national survey was executed to collect baseline data on animal production in Burkina Faso (DEP, 1990). The sample comprised 1465 villages, proportionally distributed over small, medium and large villages. A total of 43307 households, both pastoralists and arable farmers, was selected for the interviews. Agricultural extension, at the time, was provided by CRPAs (*Centre Régional de Promotion Agro-pastorale*), each covering one or more provinces. Results were analysed per CRPA, per province, per ethnic group, and per animal species. Most cattle and goats were present in CRPA-Sahel. About 70 % of all animals in Burkina Faso were owned by Fulani and Mossi. Fulani pastoralists owned over 50 % of all cattle. Mossi arable farmers, owned almost 50 % of all small ruminants and 62 % of all donkeys.

In the CRPA comprising Zoundwéogo province, both ethnic groups owned small herds of small ruminants. Mossi owned 24 % of all cattle, 63 % of all sheep and 72 % of all goats in this CRPA. Most households owned a combination of animal species. Only 12 % of the Fulani owned pure cattle herds.

National agricultural survey

A national agricultural survey has been conducted among sedentary farmers in Burkina Faso in 1993 (DSAP, 1996a; b). Data were collected on household characteristics, cropping activities, livestock ownership, mechanisation and use of external inputs, household expenditures and revenues. Fifteen selected variables were used for analysis, which led to distinction of three household types:

Type 1: Households practising low external input agriculture (LEIA) for subsistence, having no savings in cattle, some small ruminants and a very low degree of integration in markets. Livestock serves as buffer: it is sold when crop production is insufficient to feed the family, and bought in exchange for crop surpluses. Use of external inputs and investments in soil and water conservation are low, because they are not remunerative in terms of increased production of subsistence crops. This type represents 96 % of all Burkinabé farm households.

Type 2: Households cultivating cash crops (mainly cotton), and therefore highly integrated in the market for inputs and outputs. This type is characterised by high external input agriculture (HEIA) and a high degree of mechanisation. Livestock is necessary for traction and in addition serves as a savings account. At higher cash crop production, lower livestock sales occur, with the exception of fattened draught animals at the end of their working life. This type represents 1.3 % of all households.

Type 3: Households based on livestock production. A certain degree of subsistence farming is present but market integration is based on cattle. This type represent 2.4 % of all households.

The results showed that households that normally produce sufficient cereals to feed their members, had a tendency to maintain their way of farming. They were not very receptive to extension messages, did not invest in external inputs nor in soil and water conservation techniques or in animal traction. Knowledge of extension messages alone apparently was not sufficient for adoption. Household financing capacity appeared a vital characteristic for adoption, except for soil and water conservation measures, probably because some subsidies were involved.

Project study in Sanmatenga province

Within the framework of the PEDI-project in Sanmatenga province in Burkina Faso, 221 households in three villages have been studied to identify target groups for the projects' extension messages (Barning and Dambré, 1994). An in-depth study has been performed for 30 households to elucidate possible linkages between household characteristics and farmers' motives for certain activities.

Farming types have been discriminated by ethnic group (Mossi-Fulani), bush fields as % of total farm area (>75 %) and main source of income (animal production, crop production, off-farm activites). Table 4.2 summarises qualitative characteristics of each group.

This classification not only considers activities, but also farmers' perceptions. Traditional crop and livestock producers, for instance, consider themselves crop producers, as they are Mossi, but in reality their main source of income is animal production. Also, only professional crop and animal producers are optimistic and have confidence that their success depends on their personal efforts and work. This category of farmers is receptive to extension messages and adopts innovations. Traditional farmers do not believe in someone's personal

Table 4.2 Characteristics of household types in Sanmatenga province (adapted from Barning and Dambré, 1994)

Household type Characteristics	Traditional crop producer	Traditional crop producer and livestock owner	Professional crop producer	Professional agro-pastoralist	Traditional pastoralist	Herdsman
Ethnic group	Mossi	Mossi	Mossi	Mossi and Fulani	Fulani	Fulani
% of households	34 %	14 %	8 %	11 %	14 %	19 %
Perception	poor, no resources	poor, no resources	dynamic,work hard	dynamic,work hard	rich, free	poor
Objective	self sufficiency (cereals)	self sufficiency (cereals and sales of livestock)	self sufficiency (cereals) and (CP and AP) revenues	self sufficiency (cereals) and (AP) revenues	self sufficiency through revenues of AP	contract work build a herd
Future	pessimistic, fatalistic	pessimistic, fatalistic	optimistic, personal responsibility	optimistic, personal responsibility	optimistic	optimistic to become rich
Activity	work on land	AP	CP with AP complementary	AP with CP complementary	AP with some CP	AP
Integration AP and CP	absent	absent	important	important	absent, but manure (AP) used for CP	absent
AP	extensive	semi-intensive	intensification: hay, SPAI, veterinary care	intensification: hay, SPAI, fodder crops, bran, stables, lick blocks	extensive, transhumance and permanent herding	herd belongs to others
AP	buffer	revenue	revenue	revenue	revenue from cattle	revenue from milk and herding
CP	extensive	neglected	intensification	intensification	absent	absent
Adoption of new techniques	absent	absent	many	many	absent	absent
Techniques used on crop land	mulching, fallow	absent	manure pits, SWC, animal traction	manure pits, SWC, animal traction	absent	absent
Perspective	migration	animal production	improvement of farm	improvement of farm	increase of cattle herd	build a herd

* CP = crop production * AP = animal production * SWC = Soil and Water Conservation * SPAI = concentrates

contribution to his future, but relate their degree of success to fate only.

Project study in Bam province

Within the framework of the PATECORE-project in Bam province in Burkina Faso, a household typology was based on a socio-economic analysis and on the impact of extension on soil and water conservation measures (Kunze, 1994). The study covered three phases:

- preliminary typology based on 5 villages and 279 households
- test of this typology at provincial level, 27 villages and 349 households
- in-depth study in 6 villages and 90 households

The main characteristics of the distinguished types are presented in Table 4.3.

Intermediate conclusions

The national livestock study supports the concept that ethnic and agro-climatic criteria shape livestock systems and that livestock ratios also play a role. Fulani own large cattle herds, Mossi own mainly small ruminants and livestock is concentrated in the Northern part of the country.

The national agricultural study provides insufficient information as a basis for livestock systems typology. The criteria used, were among others mechanisation, household budgets and livestock ratios. Ethnic identity of the households was not recorded and mobile households were not included in the sample. The three types distinguished are very interesting as such, but the fact that 96 % of all households are of the same type (type 1) makes the results of the analysis not suitable for targeting of extension messages.

The typology used in Sanmatenga province is based on ethnic identity (Fulani/Mossi), level of intensification of cropping (% bush fields) and on economic specialisation (main source of income). It does not address the issue of development pathways, although some information is given on perspectives and goals. Professional crop and livestock producers are shown to invest in both activities and to emphasise their integration. They will improve their farming enterprises. Traditional farmers appear not to invest. They rely on off-farm income from migration or even quit farming to move to cities to earn some money. Pastoralists have been shown to continue investing in increased numbers of cattle, thus increasing their dependence on the scarce natural resources.

The typology used in Bam province appears rather exhaustive, taking into account farmers' livestock, cropping and non-agricultural activities, but also degree of subsistence and use of "modern" technology. Criteria such as economic specialisation (revenues off-farm), animal traction (cart and oxen) and intensification (compost, fertiliser), but also ethnic group (Fulani) play a role. Missing is information on farmers' objectives and strategies. Moreover, development pathways have not been analysed and any reflection is missing on whether households might change from one category into another, and if so under which circumstances.

Table 4.3 Characteristics of household (hh) types in Bam province, Burkina Faso (adapted from Kunze, 1994)

Household type	Fulani	Small families	Vegetable farmers	Crop farmers	Agro-pastoralists	Pastoralists
% of households (hh)	9	2	7.7	9.9	29.6	41.8
persons/household	9.2	3.0	13.7	9.5	11.7	15.1
% of hh owning cart	2.4	12	52	14	21	58
% of hh owning oxen	2.4	8	38	0	0	46
livestock value (CFA)	450000	49000	185000	9000	71000	473000
area/full time labourer (ha)	0.5	1.0	1.1	0.9	0.8	0.8
revenue/person* (CFA)	24600	20500	26300	9400	11600	21000
% revenu non-agric.**	3.5	19.7	1.3	5.3	11.1	6.7
% hh using SWC***	38	60	67	48	61	68
% hh using fertilizer	10	0	29	45	18	40
% hh fattening sheep	38	0	32	14	18	25
% hh with compost pit	14	0	36	5	10	25

* revenue from crop component, livestock component and non-agricultural activities combined for 1992/1993

** revenue from non-agricultural activities as % of total revenues for 1992/1993

*** SWC = Soil and Water Conservation techniques

Additional field studies in Zoundwéogo province, Burkina Faso

In the scope of the multidisciplinary research programme "Management of Natural Resources in the Sahel" research was conducted at the *Antenne Sahélienne*, the outreach station of Wageningen Agricultural University, in Ouagadougou, Burkina Faso. Field work was conducted in Sanmatenga and Zoundwéogo provinces. Under the supervision of M.A. Slingerland several MSc students of Wageningen Agricultural University conducted studies in Zoundwéogo province and in Kaïbo Sud V5 in particular. Zoundwéogo province is part of the central plateau of Burkina Faso. The province is characterised by a Sudanian climate and is dominated by agro-pastoral systems, dominated by small ruminants (Gnoumou, 1992; Felix, 1985; Benoit, 1982) and is part of the Sudan climate zone.

Detailed results of the studies can be found in the students' theses, that have all appeared in a series of project documents. Some of these studies will be analysed with respect to their value for farming systems typology: animal traction study (Van Waveren, 1996), sociological study (Suurmond, 1994), small ruminants study (Elskamp, 1995; Van den Berg, 1994) and cattle study (Meuldijk, 1997).

Animal traction study

A study has been conducted to compare households with and without animal traction equipment. In each of 30 villages two equipped and two non-equipped farmers were interviewed, of which 96 were able to answer all questions. Their answers were analysed with the students t-test (Van Waveren, 1996).

Equipped households were significantly ($p < 0.05$) larger than non-equipped ones: 9 versus 5 persons per family. Equipped households cultivated a significantly ($P < 0.05$) larger area: 5.5 versus 3.6 ha. They also owned significantly ($P < 0.05$) higher numbers of livestock other than draught animals: 10 versus 4 small ruminants and 7 versus 2 head of cattle.

Sociological study

In this study, 41 households have been interviewed, equally distributed over four Departments (Suurmond, 1994). Villages created within the framework of the AVV[2] settlement scheme were excluded from the study. The respondents were all head of an extended family comprising on average 25 persons. They were on average 57 years of age. Two main types of livestock keepers emerged: traditional and innovative (Table 4.4).

For both farming types, the majority of the households owned a cart (64 %). Innovative households slightly more often owned a plough (91 versus 84 %), owned more often compost pits (64 versus 58 %) and more often bought agricultural inputs (68 versus 53 %). The main differences refered to training. Of the innovative farmers 77 % of the households frequently followed training, compared to 26 % of the traditional ones. More

[2] AVV = Autorité des Aménagements des Vallées des Voltas

recent innovations such as cultivation of fodder crops or participating in an extension programme on demonstration herds, were adopted by 64 and 36 % of the innovative households against 16 and 5 % of the traditional ones.

Table 4.4 Characteristics of traditional and innovative livestock keepers in Zoundwéogo province (Suurmond, 1994).

Type	Traditional (n = 19)	Innovative (n = 22)
% of households with:		
Main revenue from livestock	53	91
Main revenue from cash crops	32	0
Number of cattle/household (all households)	23	42
Number of cattle/ household (only Mossi households)	9	22
Origin cattle	inherited	personal buying and breeding
Role cattle	saving	manure, traction, investment
Role livestock on farm	absorbs surpluses of crop production	supports crop production
Labour input in livestock	almost none	high
Other inputs in livestock	vaccination	vaccination, selection, cultivation of fodder crops, purchase of cotton cake
Intensive animal production	no	fattening of sheep or cattle
Participation in extension meetings	none	frequent

The traditional households generally indicated that they could not maintain their herds. They started from a large number of animals through inheritance around 1960 and increased herd size with limited inputs of labour or capital. At present, grazing land is scarce and crop land abundant, which prevents free roaming of the animals. On one hand, because damages to crops are easily inflicted in the rainy season, on the other because fodder supply is limited and should be actively searched for, both in the dry and in the rainy season. On the other hand, innovative livestock keepers, that started from a small number of animals around 1960, are very confident and actively maintaining and increasing their herd through adoption of extension messages and cultivating and buying of fodder. They also use their animals actively to support crop production (manure, traction).

A third category, not included here, is that of absentee livestock owners, mostly merchants and civil servants, who use livestock as investment and for speculative purposes.

They pay a herdsman and their objective is minimising cost-benefit ratios of inputs and outputs.

Small ruminant study

In Kaïbo Sud V5, a village in the AVV settlement scheme in Zoundwéogo province, Fulani and Mossi livestock owners have been interviewed and their practices with respect to small ruminant management observed. Between March and August 1994, herds of different systems have been observed once every two weeks (Elskamp, 1995; Van den Berg, 1994).

Small ruminant production systems in Kaïbo can be classified in:

- agro-pastoral dominated by crop production
- agro-pastoral dominated by animal production
- semi-intensive

For the crop dominated and the semi-intensive systems the head of household was Mossi, for the livestock dominated system Fulani. The research focused on production and reproduction characteristics of grazing herds. Goats in the Fulani system appeared to have more, but smaller, litters than goats in the crop dominated system. Sheep were more prolific, both in number and size of litters in the crop dominated system.

The study also paid attention to the interactions between herdsman, animal species and pasture. For both Mossi systems, sheep and goats were tethered on fallow, while in the Fulani system goats grazed wastelands outside the cropping area. In the semi-intensive system sheep were stallfed in the dry season (see further Section 7.1).

In the crop dominated system small ruminants were kept for saving and reserve for calamities. The main investment consisted of vaccination against contagious diseases. In the Fulani system, small ruminants were exchanged against food grains. Investments were generally absent. In the semi-intensive system, sheep were fattened with a commercial objective: maximisation of sale price. Each year over 20 % of the herd was sold. Investments consisted of adequate vaccination, collection and feeding of crop residues, and occasionally cultivation of fodder crops.

Cattle study

The households sampled in the small ruminant study, in Kaïbo Sud V5, were selected for a cattle study (Meuldijk, 1997). Quantitative data were monitored only once, while qualitative data were collected during a series of interviews within a six months period. Subsequently, specific herds were selected for on-pasture research (See Section 7.2), of which the results, however, did not contribute to the definition of a typology. The three distinguished types of cattle owners varied in animal production related characteristics (Tables 4.5 and 4.6).

Table 4.5 Main characteristics of three animal production systems in Kaïbo Sud V5 in Burkina Faso. Averages per household (hh) and standard deviations accounting for differences among households (Meuldijk, 1997).

Farming system Ethnic group (no. of hh)	AP* crop Mossi (6)	AP animal Fulani (4)	Semi-intensive Mossi (4)
Number of crop species cultivated	5.5 ± 1.2	2.0 ± 0.8	5.5 ± 2.4
Number of sheep	10.8 ± 8.9	74.8 ± 46.7	12.5 ± 8.5
Number of goats	11.7 ± 10.1	14.3 ± 23.8	10.5 ± 6.6
Number of cattle	5.7 ± 2.4	105.5 ± 94.2	29.3 ± 28.1
Number of donkeys	1	0	1
Number of draught bullocks	2	0	2
Number of compost pits	2	0	2

* AP = Agro-Pastoral

In Table 4.5, quantitative features are summarised. Judged by the average number of cattle, semi-intensive Mossi are wealthier than AP crop Mossi households. Table 4.6 considers management aspects. All households owned *Bos indicus* (Zebu) cattle.

Table 4.6 Main characteristics (percentage of households) of three animal production systems in Kaïbo Sud V5 in Burkina Faso (Meuldijk, 1997).

Farming system Ethnic group (no. of hh)	AP* crop Mossi (6)	AP animal Fulani (4)	Semi-intensive Mossi (4)
Use of sorghum bran	67 %	75 %	all
Ram fattening	67 %	none	50 %
Cultivation of fodder crops	33 %	none	50 %
Hay making	none	none	50 %
Veterinary care small ruminants	33 %	none	50 %
Veterinary care cattle	50 %	75 %	75 %
Bush grazing rainy season	none	all	25 %
Night grazing	50 %	all	none
Transhumance	67 %	all	50 %
Selling animals to pay for veterinary care	33 %	all	50%
Bos taurus	33 %	none	50 %
Crossbreds	17 %	none	50 %
Housing for livestock	hangar	parc	enclosure

* AP = Agro-Pastoral

Intermediate conclusions of studies in Zoundwéogo

The animal traction study suggests that ownership of animal traction equipment is a discriminating characteristic among livestock keeping households. It is strongly correlated to other household features such as family size, farm area, and livestock ownership. The results of this study are similar to the findings of Vall (1992) and Fauré (1994).

The results of the sociological study can be compared to those of the study in Sanmatenga (Barning and Dambré, 1994). The traditional livestock keepers from Zoundwéogo correspond to the first two types in Table 4.2 for Sanmatenga. The innovators from Zoundwéogo can be compared to the two types of professional producers in Sanmatenga. A strong point of the study is that it shows that Mossi and Fulani livestock keepers are not homogeneous groups, and that farming systems should be characterised beyond ethnic differences. An additional feature of the study is that it pays explicit attention to farming systems development and to different perspectives among livestock owners.

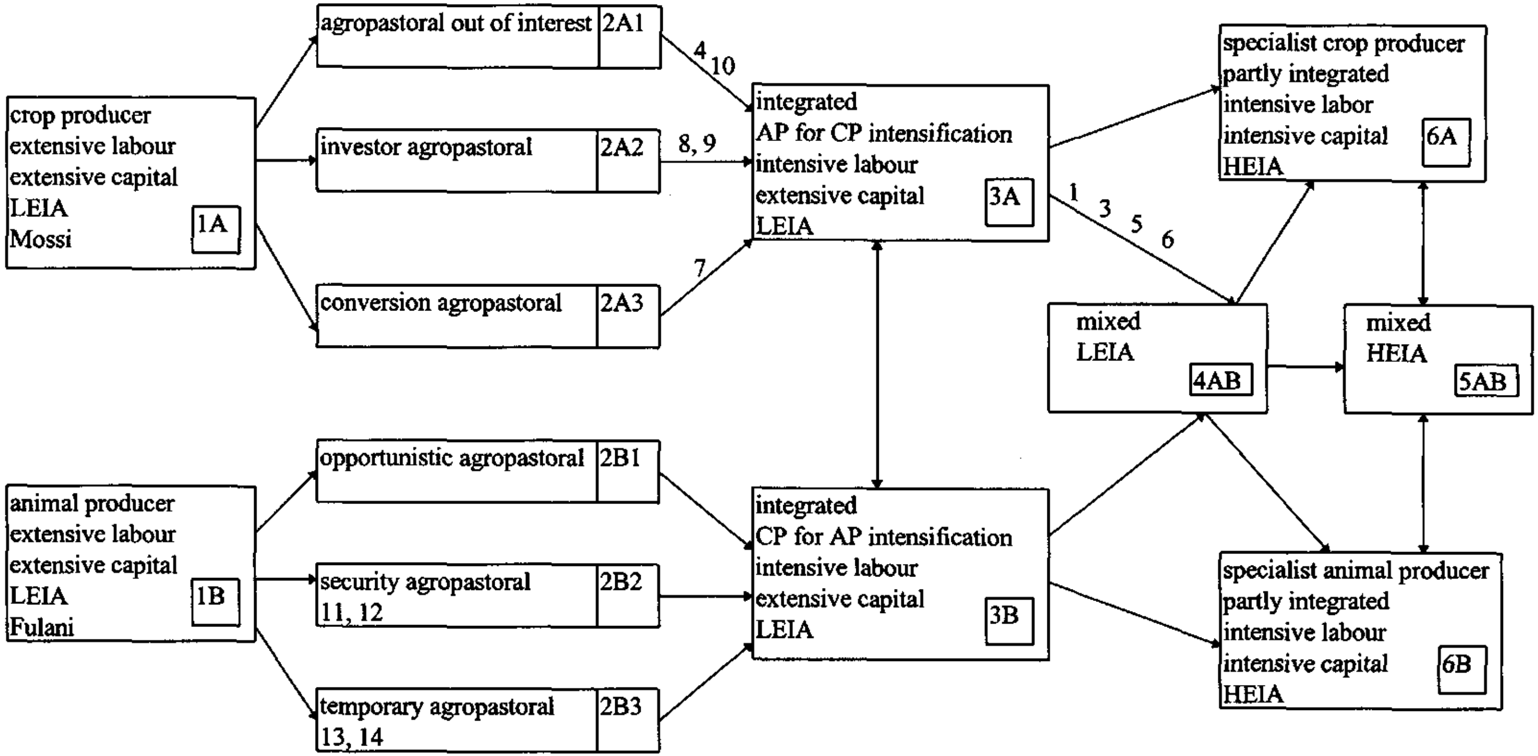
The small ruminant study paid attention to all poles of the three pole model (Lhoste, 1984): man (farmers' motives, % sales), herd (production and reproduction) and territory (grazing behaviour). It ignores, however, the cropping component of the farming system of the livestock owners.

Data from the cattle study could be used to distinguish farm households with respect to aspects, such as intensification of livestock and of crop production, but with respect to integration of both. It combines information on on-farm management of livestock and crops.

A new typology: a framework of discrete farming systems

Comparison of criteria from different existing classifications, both general and specific for Burkina Faso, with recent studies in Burkina Faso shows many similarities. In the framework of the "Use and Management of Natural Resources in the Sahel" programme additional field work has been carried out in Zoundwéogo province. The overall tendency appears to be a typology based on static or descriptive properties of farming systems. Most studies treat just one aspect of the three pole model. Only the small ruminant and cattle studies comprised a grazing area component (the territory or resource pole) and treated the farm household level (man pole), although they concentrated on herd level (animal pole).

Discrete farming systems are presented in Figure 4.3. The figure is based on CORAF (1993) and modified on the basis of the criteria from literature and research in Burkina Faso. Each farming system combines crop and livestock production to different degrees. The three components suggested in the three pole model, i.e. men, herd and territory (natural resources) will be discussed for each discrete farming system presented. Secondly, it will be examined whether the discrete farming systems presented in the framework can be recognised in the farming systems encountered in the field studies in Burkina Faso. The sequence in which the farming systems are presented in Figure 4.3 suggests a development pathway from one farming system to another. The main concepts and drives behind these transitions will be discussed.



AP = Animal Production, CP = Crop Production, LEIA = Low External Input Agriculture, HEIA = High External Input Agriculture

Figure 4.3 Framework with discrete farming systems (1AB-6AB) for west African savanna
Numbers (1-14) refer to farm households from study in Kaïbo Sud V5 (Meuldijk, 1997)
Source: adapted from CORAF, 1993

Discrete farming systems

Specialised crop production (1A) and specialised animal production (1B)

Both specialist systems aim at subsistence and neither uses external inputs. In accordance with rainfall conditions, animal production is based in the North and crop production in the South. Crop production is extensive, based on fallow to restore soil fertility, hence it uses large surfaces of land for the production of food. Livestock production is extensive, based on free grazing of natural pasture. Crop producers generally own some small ruminants as a buffer, while pastoral systems are based on large herds of cattle. Pastoral households may be involved in some cropping, but as they are generally very mobile, cropping activities are virtually incompatible with their lifestyle. Both systems aim at the largest possible herd (small ruminants in 1A and cattle in 1B) without too much attention for the production per head, and are typical representatives of low external input agriculture (LEIA). There is exchange between the two systems, notably of cereals against milk and crop residues against manure.

As long as there is enough space, and governments do not interfere with traditional rights on water points and grazing (Bernus, 1990), the systems are complementary and can exist side by side. Both systems are entirely based on extensive use of natural resources. Low population and animal densities should be maintained to prevent their degradation.

Agro-pastoralism (2A and 2B)

Bonfiglioli (1990) stated that agro-pastoralism is omnipresent in Sahelian countries and suggested the following six types:

Agro-pastoralist out of interest (2A1). The crop producer owns a few head of cattle as a savings account. He does not invest in them, has no expertise in livestock production, and only guards them from straying into crops in the fields. The animals are not integrated within the farm. The objectives at herd level are maximum animal numbers through maximum survival. Crop production remains the only productive activity of the farm household.

Agro-pastoralist-investor (2A2). The crop producer owns more animals and entrusts them to a herdsman against remuneration. The herdsman has the necessary expertise and guarantees that the investment pays off. The crop producer is fully occupied by crop production, but secures his livestock production via herdsmen (outside the farm household). The objective at herd level is maximum animal numbers through survival.

Agro-pastoralist in the process of conversion (2A3). The crop producer owns a large number of cattle, hence commands much capital. He must act accordingly, i.e. by modifying the relations between crop and livestock production within his farm household. In some cases, the farm household can integrate into a pastoral society, i.e. by increasing its mobility (transhumance) and changing some cultural characteristics. Another option is to become "businessman" and hire a manager for the farm who manages both crop and livestock production. Objectives at herd level are maximum production of meat and milk for sale.

Opportunistic agro-pastoralist (2B1). Livestock owners are locally engaged in crop production. The benefits of this type of agro-pastoralism are not based on integration, but on complementarity of specialisation. A polarity exists between the North, characterised by bush, livestock production, mobility and independence and the South, characterised by the village, cereals (fields), sedentarity, dependence and markets. The system is based on cattle. Fulani women prefer milk production and Fulani man aim at high animal numbers.

Security agro-pastoralist (2B2). Crop production is important for survival of these livestock owners. The main output of cattle herds is offspring for draught animals. Small ruminant herds are large and cattle herds are small. Mobility of herds is reduced. Specialisation is replaced by integration. Reduction in cattle herdsize and increasing production per animal may be objectives of animal production in this system.

Temporary agro-pastoralist (2B3). Pastoralists use crop production as a means of restocking to start pastoral life again. The objective at herd level is maximum reproduction and survival of animals to increase herdsize as fast as possible.

Agro-pastoralism is representative for low external input agriculture (LEIA). Livestock of agro-pastoralists is generally not very mobile, leading to high intensity of land use for grazing and the risk of overgrazing and degradation of natural resources. Crop producers do not use much manure on their land, hence depletion of soil fertility may occur when required length of fallow periods are not respected.

Integrated crop and livestock production, on-farm (3A and 3B)

Type 3A represents intensification of crop production, mainly based on increased labour input without use of external inputs. Labour is for instance used to apply soil and water conservation measures, such as construction of stone rows or mulching. Animal production is integrated with crop production and supports it through animal traction and manure.

Type 3B represents intensification of livestock production, based on increased labour input with limited use of external inputs. Labour is for example used to make hay from natural pasture grasses. Crop production is integrated with livestock production: Crop residues serve to feed the animals and its grains to feed the household, thus avoiding forced sales of livestock to buy cereals.

Crop and livestock components of farming may benefit from each other's 'wastes' (outputs). Integration of crops and livestock allows farming without the use of external inputs, although fully closed systems cannot exist (Savadogo, 2000). Exchanges through bartering are, however, progressively replaced by purchase and sale against money. Cereals and crop residues can be sold to animal producers, while they in turn can sell manure and animals to crop producers. Exchange of services also takes place. Livestock producers may herd animals from crop producers, while the latter may rent their animal traction unit to livestock producers.

Environmental implications of both farming types may be negative, due to the incomplete integration of crop and livestock production. In type 3A, livestock may remove nutrients from pasture during grazing. When the manure of these grazing animals is only applied to crop fields, chemical degradation of pasture may occur. The use of animal traction can lead to an increase in cropping area without sufficient labour and manure to maintain soil fertility on all fields. In type 3B, removing crop residues from the fields to use them for animal feed can lead to severe soil degradation on the now unprotected fields, especially when no efforts are made to restore soil fertility by the use of manure on the crop fields.

Mixed farming system (4)

Type 4 is called mixed farming and is a representative of a more complete integration between both production components at farm level, aiming at optimum use of farm resources and recycling of outputs between sectors. Crop residues produced on-farm are collected and stored to be fed to animals on-farm. Draught animals are stallfed on crop residues and hay, while their manure is transformed into compost to fertilise the crop fields. Output of crops and livestock is equally important. The use of external inputs is all but absent, labour input is high.

Environmentally, the system seems beneficial, because more permanent cropping is possible thanks to the use of manure that partly prevents soil fertility problems and ends the occupation of (excessively) large areas of land for cropping. On the other hand, the risk of degradation of natural pasture exists, because nutrients, in the form of hay, are transferred from these areas to the compound where animals are stallfed, and subsequently to the crop lands in the form of manure.

High external input mixed farming (5)

Type 5 depends on availability of labour and capital. It is a fully integrated mixed farming system, based on high external inputs (HEIA), the final phase anticipated on the basis of the crop-livestock integration concept (Landais and Lhoste, 1990). External inputs such as inorganic fertiliser, pesticides and improved seeds for crop production, concentrates for animal feed, veterinary products for animal health care, and agricultural equipment, such as tractors and carts are purchased. Complete integration between crop and livestock production is maintained to limit losses of nutrients and thus expenditures on external inputs.

Environmentally, this system seems sustainable, because nutrients are replenished using fertiliser and concentrates, which is combined with judicious management of crop residues and manure. A risk may, however, be pollution of the environment and of the food chain by unskilled or uncontrolled use of pesticides and veterinary products.

High external input specialised crop (6A) and livestock (6B) farming systems

Specialised crop production (6A) with high external inputs, such as fertiliser, pesticides and mechanisation, leaves no room for livestock production. Animal traction is no longer an option and livestock serves at best for capital accumulation. Food production for these farm households has lost priority, as the revenues from the cash crop, often cotton, allow purchase of grain. Crop producers do not use fallow, because it is incompatible with high annual production per hectare. Cultivation of cash crops requires investments in soil and water conservation measures, fertilisation, organic matter build-up, etc. These investments have to be repaid from yields of several years. Therefore access to these fields must be guaranteed and permanent.

Specialised livestock production (6B) has specific production objectives such as high milk production per cow, high meat production per animal (fattening) or the production of draught animals. External inputs comprise improved breeds, both preventive and curative veterinary care and purchase of concentrates to provide balanced high energy and high protein diets. The highest production can be reached when feed intake of the animals can be controlled and losses due to diseases, theft, etc. can be minimised. Keeping animals in stables is therefore easiest, but is labour-intensive, especially for stallfeeding. It is impossible to keep large herds in these systems. Animals of specialised livestock producers depend less on grazing of natural pasture, because the quality and quantity of livestock feed from communal pasture can not easily be guaranteed or influenced. Only hay making from communal pastures seems feasible in this system. Animal fodder is produced on farm.

The specialised crop system may be sustainable in terms of nutrients. Inorganic fertilisers can, however, lead to crop damage (burning) in low rainfall situations. Inorganic fertilisers are not efficient, without sufficient organic matter in the soils. When judicious management of crop residues and manure with respect to crop production is neglected, the system may not be sustainable in terms of nutrients, despite addition of nutrients from external sources. Livestock can not be fed on concentrates alone. Roughages, such as crop residues or natural pasture are necessary for rumen digestion. Although the use of external inputs reduces the risk of chemical depletion and degradation of the environment, efforts must be made to appropriately manage crop residues and manure. The systems have also some disadvantages, in terms of risk of pollution of the environment or the food chain, as a result of improper use of external inputs.

Burkina Faso studies reconsidered

To examine whether the discrete farming systems presented in the constructed framework can serve as a basis for farm household classification in practice, all studies presented earlier in this chapter are reconsidered.

In Sanmatenga six household types were distinguished (Table 4.2; Barning and Dambré, 1994). Traditional crop producers can be classified as specialised crop producers (1A), while traditional pastoralists are equivalent to specialised animal producers (1B). Traditional crop and livestock producers are agro-pastoralists (2A). Professional crop producers can be classified as integrated farming households (3A), either moving directly to specialised HEIA crop producers (6A) or passing through mixed farming (4). Professional agro-pastoralists can be classified as integrated farmers (3A or 3B), some developing in the may move towards mixed farming (4), when the crop-livestock integration concept is implemented to its full extent with draught animals fed on-farm. alternatively, the household may develop into integrated LEIA animal production (3B) or even specialised HEIA animal production (6), when animal production is more strongly emphasised. The fact that adult men herd the cattle also indicates that livestock production is very important to this household.

All Fulani households consume milk and meat from their own herds. They practice night grazing for their cattle (Ayantunde, 1998), and semi-nomadism for part of the year. All animals are herded year-round. These households do not intensify livestock production: fattening, purchase of external inputs such as cotton seed cake, production of fodder crops, collection of hay, are all absent. Veterinary care is restricted to vaccination against cattle pest and pneumonia. They hardly practice crop production, hence draught animals and compost pits are absent. They do benefit from the manure of the animals by cultivating the area enriched by animal excreta during the night in the dry season. Crop residues are collected there, to feed them to animals that are unable to graze, because they are too young, too old, too weak or too sick. Households 13 and 14 own a relatively small number of cattle and are typical temporary agro-pastoralists (2B3). They aim at becoming specialised animal producers again (1B), but might also develop in the direction of integrated animal producers (3B). The animal production component of household 13 is strengthened by cattle entrusted by family. Households 11 and 12 are security agro-pastoralists (2B2), households distinctly moving in the direction of integrated animal producers (3B).

Drives and concepts behind transition among farming systems

Transition from one farming system to another

Transition from one type of farming system to another is not an autonomous development, but affected by many externalities, combined with conscious choices of the actors. The numbers in brackets refer to the farming systems presented in Figure 4.3.

Specialised systems (1A en 1B) develop into agro-pastoral systems (2A and 2B) through diversification. The transition from crop producer (1A) to agro-pastoralist has been described by Bonfiglioli (1990). Livestock ownership increases through accumulation of the surplus revenues from the cropping systems. The first investments are in small ruminants, but as wealth increases, also in cattle. Crop producers do not integrate cattle into their farming system, but entrust them to herdsmen. Cattle serve just as savings account (2A1) or a way to invest money (2A2). When the cattle herd increases beyond a certain size, it becomes economically interesting to convert from crop producer to livestock producer (2A3), because the returns to labour through animal production are higher than through crop production (Savadogo, 2000). A progressive change from small ruminants to cattle occurs during the transition from 1A to 2A2 and 2A3.

The transition from pastoralist (1B) to agro-pastoralist has also been described by Bonfiglioli (1990). Because of loss of livestock due to droughts or other disasters, pastoralists may be temporarily forced into crop production to survive (2B3). This serves only one objective: reconstitute a herd to start the life of a pastoralist again. Often they do not succeed, due to environmental limitations, market price fluctuations, etc., so that finally many become permanent agro-pastoralists (2B2). The increase in population density and the associated decrease in available space (grazing land), may also force pastoral people to change their way of live drastically and permanently towards agro-pastoralism (2B2), if only for survival of the group. Within this process crop production gains in importance, transhumance has a tendency to become more restricted and animal production becomes often a very commercial activity, producing draught animals for agriculture. Large cattle herds are very difficult to feed in sedentary systems, therefore cattle is partly replaced by small ruminants, as can be seen in the transition from 1B to 2B2 and 2B3.

Only permanent security agro-pastoralism (2B2) is a case of mixed farming. Generally, agro-pastoralism combines crop and livestock production without operational integration. All agro-pastoral systems are based on natural pasture and low external inputs (LEIA).

Transition from specialised cropping (1A) to systems in which animal production is partially (3A) or entirely integrated (4) occurs when land becomes scarce leading to the need for more permanent cropping. Permanent cropping creates the need for manure management and improved soil tillage, for instance by animal draught power. Scarcity of grazing land restricts mobility, creates a need for alternative animal feed sources, and leads to reduced cattle herds. Transition from specialised animal production (1B) to partial (3B) or total integration (4) with crop production will be the result. As a consequence of reduced mobility of the livestock producers, replacement of cattle by small ruminants will continue.

Transitions from LEIA mixed farming (4) to the three HEIA types (5, 6A and 6B) will only occur when markets and monetary infrastructure are available. For investments, pre-financing may be needed in the form of credits, while returns on investments are only guaranteed through participation in an extensive and open marketing system, allowing sales at low transaction costs. To facilitate the transition to HEIA systems, extension services must be able to provide sufficient technical information and all necessary inputs must be available on local markets.

Reconsidering the studies in Burkina Faso, it must be concluded that none of the studies explicitly considered transitions from one farming system to another, nor the drives behind them. Only in Sanmatenga (Barning and Dambré, 1994) and the sociological study in Zoundwéogo (Suurmond, 1994) briefly touched the issue by asking farmers about their past, their future and their way of farming.

Drives and concepts behind transitions

The general drive for the transition from specialised crop producer to agro-pastoralist appeared to be the accumulation of wealth (Bonfiglioli, 1990). Hence, this transition is a positive choice from the farm household involved. The general drive from the transition from specialised pastoralist to agro-pastoralist is poverty and disaster (drought, animal diseases). This transition is thus not a choice made by the households, but an inevitable consequence of externalities beyond their control.

Identified drives behind scarcity of land are population growth and the two most recent periods of severe droughts (1973/74 and 1984/85). Population growth increases food requirements and hence the need for crop land. Crop producers move further North in search of arable land, thus occupying possible wet season grazing land and also, when vegetable cropping is started around permanent water points, dry season water sources of livestock. Droughts generally lead to migration of population and herds to higher rainfall areas in the South and increased human and livestock densities, increasing the demand for crop land and grazing land at the same time. In the South, only marginal soils are left for grazing and, to avoid damage to the crops, herds are excluded from the cropped area with its fallow during the rainy season. Food production increases, may lead to demands for draught force and manure leading to still higher animal numbers.

Two processes come to the fore in the transition from specialised LEIA to specialised or mixed HEIA systems:

- Progressive monetarisation of inputs and outputs replaces traditional bartering. Manure, crop residues, hay, all can be and must be paid for. Crop producers may even buy their cereals, when they produce mainly cash crops like sesame or cotton (specialisation).

- Progressive privatisation of inputs and outputs replaces communal use of resources. Crop residues are no longer left in the fields to be grazed by any livestock, and grasses from common grazing land are transformed into hay. Both feed resources are collected and stored on-farm to feed the livestock of the crop producer. Privatisation of resources increases due to their scarcity and associated high monetary value.

The possibility for any farming type to occur, depends to a large extent on the quality of the agricultural knowledge and information system (Röling, 1989; Chapter3). The crop-livestock integration concept (Landais and Lhoste, 1990) has influenced the research agenda and extension messages for an extended period of time (Chapter 1 and 3). Quality and quantity of infrastructure influence the ease and degree of specialisation through markets and banking facilities. Government policies, providing credit for certain activities, for instance acquisition of animal traction units or purchase of fertiliser to promote cotton production, may influence the development of certain farm types as well.

To characterise the discrete farming systems and to determine their sequence in the framework (Figure 4.3), some basic concepts and their relations have implicitly been considered. The relations between some of these concepts and the farming systems under study have been examined through additional studies on human-related factors, such as ethnic identity or sex. These factors may have been important in selecting between either investment in intensification of crop and livestock production or migration to other parts of the country (Van Veen, 1996; Van Dongen, 1995). First, the concepts will be defined and examples presented. Next, the relations, between the concepts will be explored and results of the additional studies presented when contributing to the discussion.

Intensification of crop production

Increase over time in labour and/or capital inputs per hectare of cultivable land, including temporary fallows and permanent or temporary grazing areas.

Example: Application of soil and water conservation measures and chemical fertiliser on existing plots.

Intensification of animal production

Increase over time in labour and/or capital inputs per unit of livestock.

Example: Stall feeding with balanced rations and adequate veterinary care with the objectives of high milk production or fattening of animals for sale.

Crop-livestock integration

Combining crop and livestock production to mutual benefit. Integration is considered more complete when output from one production component serves as much as possible as input for the other and vice versa. Full integration of crop and livestock production with both crop and livestock management the responsibility of one farm manager, is called mixed farming. Integration can also be based on exchange or trade between crop producers and livestock owners, each specialised in their own production sector.

Example: Cattle used for manure and traction, while crop residues and sometimes even cereal surpluses are used to feed livestock. Purchase and sale of cereals and livestock are complementary and frequent, and both serve household survival.

Specialisation

Emphasis on one production component, using all inputs to maximise its output. If two production components are present on one farm, one mainly serves the other.

Example: Cotton farmers own cattle for ploughing, for manure production and for saving purposes. They are not interested in animal production as such.

Example: Fulani herdsmen produce some cereals, but only to prevent the sale of cattle to purchase food for the family. They are not interested in crop production as such.

Identity

Social identity is that part of a self-concept or self-image of a person that results from membership of a social group and the value and emotional significance that the individual attaches to this membership (Van Dongen, 1995). Mostly, people pursue a positive identity by comparing their own group (ingroup) to other groups (outgroup). A form of social identity can be ethnic identity based on membership of an ethnocultural group. Aspects of identity can be common language, symbols of cultural relevance, participation in certain group events, agreement on common characteristics.

Example: Mossi acknowledge the Moro Naaba as their king, submit themselves to his traditional power, participate in funerals in the honour of village chiefs, and speak one common language.

Next, relations among these concepts are explored to highlight their relevance for the typology.

Specialisation, intensification and integration

Specialisation, aiming at maximising output in the field of specialisation, may need integration with other production components to a certain extent. To increase output higher inputs are generally necessary. This increased input level has been defined earlier as intensification. Under capital scarcity, e.g. inputs must be created with the limited means available, mostly labour. Another important strategy to increase production is to increase the efficiency of recycling of by-products or wastes in the farming system to minimise losses. Recycling in general is labour-intensive. Specialisation in livestock production may thus stimulate cultivation of fodder crops, collection of crop residues and production of hay, all to be used as animal feed. Specialisation in crop production may stimulate livestock production to provide power for ploughing and for transportation of inputs and products. Livestock also provides manure, that is used as fertiliser on the fields.

Identity and crop and animal production

Economic reality can be in conflict with the concept of identity. In the PEDI study in Sanmatenga province (Barning and Dambré, 1994), traditional crop and livestock producers considered themselves crop producers as they were Mossi, even though their main source of income was livestock production. On the other hand, Fulani that lost all their cattle during the droughts of the 70's or 80's, thus being forced into crop cultivation for survival, still identified themselves as livestock producers even when they had not one animal left (Bonfiglioli, 1990). Identity, in Burkina Faso, appeared mainly based on ethnological considerations (Van Dongen, 1995). Both, Mossi and Fulani identified strongly with their own ethnic group and were proud of its common history and traditional values. Fulani appeared to be very reluctant to participate in activities that were traditionally considered Mossi ones. They were specifically negative towards crop production related activities and did not want to share meals with Mossi although they lived as neighbours. Mossi also were not eager to participate in Fulani activities, but harboured a less negative attitude (Van Dongen, 1995). Fulani men tend to stay away from modern society, while Mossi men tend to integrate (children go to school). Women from both groups showed a tendency to assimilate, probably because they benefit clearly from it in daily life, through availability of medicines, sale of products such as milk and butter on the markets (Van Dongen, 1995).

Intensification of crop production and crop-livestock integration

Higher population density leads to shorter cultivation cycles and a tendency for the fallow period to become shorter, calling for alternative methods of soil fertility maintenance, among which the use of animal manure is the most widespread. Intensifying the cultivation cycle means at the same time a reduction in available grazing land, forcing farmers to feed their livestock at least partially from their crop lands (i.e. on crop residues). An alternative strategy to cope with population increase and thus increased demand for food, is to try to reduce risks of crop failure. Under conditions of capital scarcity, increased labour input (application of soil and water conservation techniques) seems to be a solution that is highly compatible with population growth. The reasoning presented here, based on Pingali (1987), McIntire *et al.* (1992) and Mortimer and Turner (1993), suggests that higher population density automatically leads to intensification of crop production and a certain integration between crop and livestock production. Mortimer and Turner (1993) analysed 500 references in both English and French and found only 43 cases sufficiently complete to test the argument that population density is the driving force for intensification which is closely linked to crop-livestock integration. Their results support the argument .

Both, Mossi and Fulani populations in Zoundwéogo province have been interviewed on their motivation for intensification of crop and livestock production, respectively (Van Veen, 1996). A distinction was made between rich Fulani, living in a protected pastoral area (Sondré-Est), rich Mossi, living in a settlement scheme (Kaïbo Sud V5) with guaranteed land rights on 10 hectares each and cultivating cotton, poor Mossi, living in a traditional village (Yakin) with only small areas of land and poor Fulani, living as neighbours of rich Mossi (Kaïbo Sud V5), surrounded by arable land with nowhere to go. The qualifications poor and rich are relative and fully based on access to land.

All Mossi showed to have a positive attitude towards intensification of crop production, but many claimed to lack the necessary financial means to buy a plough, to construct a compost pit or to construct soil and water conservation structures. Some also claimed that many proposed techniques (stone rows) require hard work and are time-consuming. Within the Fulani group, men and women had opposite opinions. Fulani women, especially those of the poor group, were very interested in intensification of animal production to increase milk yield per cow. As women are entitled to the benefits from the sales of milk, this comes as no surprise. Fulani men in the poor group were significantly less interested (P (χ^2) < 0.01) in intensification of animal production. In fact, all Fulani men preferred large herds, even though production per animal is low. They profit from the sale of animals. For large herds, intensification is complicated, because labour requirements to cultivate fodder are high, capital requirements to buy agro-industrial by-products are high, and the work for stall feeding for a herd of as many as 200 animals is prohibitive in view of the available work force (Van Veen, 1996).

The same populations have been interviewed on their motives to start a complementary activity, i.e. to create an integrated (mixed) farm. For Fulani, men from the poor group were more positive than men from the rich group ($P(\chi^2) < 0.05$). Women from the poor group were very negative towards the idea of starting crop production. Traditionally, it is a disgrace for a Fulani, and especially for a Fulani woman, to work the land. Poor women were more negative than rich women ($P(\chi^2) < 0.01$), probably because rich ones may just hire people to do the actual work. Men could be more positive, because they would let the women do all the work. Poor men already cultivated crops, so they could not express a very negative opinion, without emphasising their misery (Van Veen, 1996).

Intensification of crop and livestock production and crop-livestock integration

The original crop-livestock integration concept was based on concommittant intensification of crop and livestock production in mixed farming systems. Intensification of crop production consisted of mechanisation (animal traction) for deeper ploughing and more intensive weeding and soil fertility management through the introduction of rotation with leguminous fodder crops and the use of manure and compost. In combination, these techniques allowed permanent cropping and hence the elimination of fallow. Intensification of livestock production consisted of keeping draught animals in stables, producing (fodder crops) or collecting fodder (hay, crop residues) to be stored for feeding these animals. Fattening of the animals after their working period, allowing purchase of replacements in the form of young bullocks and generating revenue at the same time, was also an important means of intensification. The stables allowed collection of manure. Even though the concept of crop-livestock integration was shown to be very rigid and to neglect important aspects of reality (Landais and Lhoste, 1990), agro-pastoralism is omnipresent in Sahelian countries (Bonfiglioli, 1990).

The concepts defined and discussed here, add to the understanding of farming systems development. A very strong traditional relation between ethnic identity and production type appeared to exist: Mossi are crop producers, Fulani are livestock producers (Van Dongen, 1995). Ethnic identity and gender appered to be intertwined with production goals and labour distribution, and hence with motives towards intensification and integration of crop and livestock production (Van Veen, 1996; Van Dongen, 1995).

They indicate that higher population density stimulates intensification of crop production and a certain degree of integration between crop and livestock production (Mortimer and Turner, 1993; McIntire *et al.*, 1992). Specialisation can be considered an example of intensification, and specialisation needs integration under conditions of capital scarcity. Under these conditions, increased labour input seems, a solution that is highly compatible with population growth (McIntire *et al.*, 1992).

Discussion and conclusions

Discrete farming systems have been identified, based on criteria for farming systems typology derived from literature and field studies. Farming systems identified, included specialised LEIA crop or livestock producers, agro-pastoralists, integrated LEIA crop or livestock producers, LEIA mixed farmers, HEIA specialised crop or livestock producers and HEIA mixed farmers. Important criteria were agro-climatic conditions (North/South), ethnic group (Fulani/Mossi), production goal, ratio of cattle to small ruminants, use of bullocks for animal traction, and use of external inputs (LEIA/HEIA).

The discrete farming systems have been incorporated in a framework that adds to the understanding of the transitions from one system to another. The framework takes into account important concepts related to change and illustrates the drives of transitions. The most important concepts appear to be crop-livestock integration, intensification, specialisation and identity. Drives appear to be linked to ethnic group and gender. For Mossi crop farmers, wealth appears a strong drive towards mixed farming. For Fulani animal producers, poverty due to externalities such as droughts and animal diseases is a main drive towards mixed farming. Another important factor shaping farming systems development appears to be land scarcity due to population growth and periods of droughts.

In the reality of Burkina Faso, households recognisably corresponded to the described farming systems and development pathways. The framework needs however some additional comments.

The transition from one farming system to another can strongly be influenced by policy measures and the research-extension-users system (Chapter 3). Crop-livestock integration, the leading development model since colonial times (Massa and Madièga, 1995; Landais and Lhoste, 1990), and biases against mobile livestock producers, expressed since tax collection became important (Bernus, 1990), both favour the LEIA mixed farming model (Figure 4.3; Type 4) for all farmers. This model is based on integration of crop and animal production by settled farm households. Research and extension, operating according to the transfer of technology model (Chambers and Ghildyal, 1985) supply recommendations and technical packages aiming at the development of all farming systems towards this unique mixed farming system. Mixed farming is also favoured by the recent sustainability debate, because it is supposed to minimise nutrient losses through adequate management of crop residues and manure.

Lack of purchasing power at the level of the actual farm population prevents widespread introduction of HEIA farming. The progressive farmers strategy (Chapter 3), focusing on relatively well-endowed farmers (Rogers, 1985; Röling, 1985), and the application of the commodity strategy with respect to cotton production, could however lead to the development of some mixed (Figure 4.3; Type 5) or specialised (Figure 4.3; Types 6A and 6B) HEIA farming systems. Cotton sales may generate sufficient cash to purchase external inputs needed for successful HEIA farming. HEIA farming systems need extension services, credit facilities, infrastructure such as roads and markets, but also a distribution network of inputs. Subsidies on inputs or guaranteed prices for outputs can easily promote the development of these farming systems and influence the choice of their products (Sissoko, 1998). When households are hardly integrated in markets, their farming system depends less on policy and is mainly shaped by farmers' decisions.

Although the framework does not explicitly allow for reverse developments, this option should be included. When, for instance, world market prices for cotton decrease, mixed farming based on this cash crop will probably temporarily shift towards mixed farming based on food crops to guarantee survival of the household. When prices are restored the first system may gain importance again. Another example is provided by the animal producers, that settled in the South of Burkina Faso in the seventies and substantially reduced herd mobility. Recently they took up transhumance again because grazing lands contracted due to increased cropping in the rainy season. Baxter (1977) already noticed that households may shift between classes as they loose or rebuild their herds through time. Mortimer and Turner (1993) point at the same dynamics when they state that "livestock ratios are indicators of wealth, movement patterns and specialisation, sensitive to short-term dynamics in animal ownership, responding to cycles of impoverishment and restocking, following periods of drought-induced mortality or de-stocking".

The framework does not include a time scale, because it is not deterministic: developments can take place in all directions. The framework was constructed to increase understanding of farming systems development. It succesfully represents the criteria that shape discrete farming systems and the concepts and drives of the transition from one system to another.

CHAPTER 5 The financing role of livestock

5.1 The small ruminant subsector in Zoundweogo province: household financing restricts remuneration of animal production 91

Maja Slingerland[1,3] and Teunis van Rheenen[1]

5.2 Animal production and rural financing: the case of Zoundwéogo province, Burkina Faso 107

Maja Slingerland[1] Teunis van Rheenen[1] and Jan Willem Nibbering[1]

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5.3 Assessing the financing and insurance capacity of livestock in mixed farming systems 125

Jan Willem Nibbering[1,2], Teunis van Rheenen[1] en Maja Slingerland[1,3]

5.4 Livestock and short term financing for mixed farming households in Burkina Faso: Zoundwéogo and Sanmatenga provinces 141

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5.1 The small ruminant subsector in Zoundwéogo province: household financing restricts remuneration of animal production

Abstract

In Zoundwéogo province of Burkina Faso, West Africa, sheep and goats are present in high numbers and their population is growing at 3% annually. The exploitation rate of small ruminant herds (sales, home consumption, presents) varies between 11 and 28 %, depending on animal production systems and animal species. Farmers' selling strategies depend on one hand on animal species, sex and weight, and on the other hand on periodically varying cash requirements. On the market, significant correlations were found between animal liveweight and price for each species, and each sex within species per season. Prices were usually established on the basis of observation rather than by weighing. If only meat production is taken into consideration, selling time for an animal is not optimal. Not only are animals sold before reaching adult liveweight, but also before generating the potential number of offspring in the case of young females. At small ruminant markets, it could be observed that 56 % of the ewes and 63 % of the does were sold at liveweights inferior to liveweight at first conception, and 95 % of all animals sold had not reached adult liveweight yet. Revenues from small ruminants might be greatly improved when farmers could concentrate on animal production and have viable alternatives for financing. Revenues could increase even more, when seasonality in prices would be exploited through seasonal fattening and selling.

KEYWORDS: Burkina Faso, exploitation, marketing, small ruminants, motivation, selling strategy, price negotiation, seasonality, animal weights, economic losses.

Introduction

The numbers of sheep and goats in Zoundwéogo province of Burkina Faso were 87000 and 81800, respectively in 1994 and both showed an annual growth of 3 % (DSAP, 1995). Small ruminants are kept by Mossi farmers and by Fulani herdsmen. Both animal production systems are extensive, based on grazing natural vegetation, with low input of labour, no supplementation and only marginal veterinary care. Animals are kept for meat and manure production. Their importance for rural households partly derives from their role as a source of cash for planned and emergency expenses (Slingerland *et al.*, 1998; Bayer and Waters-Bayer, 1991). They also play a role in maintaining social relations and are regularly slaughtered at religious and other ceremonies (Breusers, 1996; Höfs *et al.*, 1995;). Some Mossi households started a semi-intensive sheep fattening unit, based on crop residues, supplemented with purchased agro-industrial inputs like cotton seed cake. Such an unit can be operated within a household next to a traditional herd, the first as meat production unit, the latter to meet other demands.

Animal prices show strong seasonal patterns, with trends opposite to cereal prices. Under conditions of cereal shortages, cereal prices go up. To finance the purchase of cereals, many animals are offered for sale, and consequently animal prices drop. Seasonal prices also fluctuate for rams that are needed for ceremonial slaughterings during Muslim feasts. In these periods prices for rams increase considerably and some farmers fatten sheep specially for these occasions. Prices not only fluctuate within years, but also between years because of fluctuations in crop yields due to variations in rainfall or for instance grasshopper attacks.

Animal production from sheep and goats in these systems depends on production and exploitation strategies of their livestock owners. The financing functions of small ruminants seem to interfere with the objective to maximise revenues from the animal production sector. To investigate this hypothesis, a monitoring study was executed to determine exploitation rates and reproduction parameters of small ruminant herds in the different systems. Information on motives for buying and selling, and on characteristics of sold animals was collected from markets and slaughterhouses.

Methodology

A herd monitoring study (equal to small ruminants study from chapter 4) and a market study were conducted. Data on slaughtering were collected from the Regional Animal Production Service in Manga, the capital of Zoundwéogo province.

Herd monitoring study

From January to December 1994, 15 small ruminant flocks were followed from the villages Kaïbo-Center and Kaïbo Sud V5. Production, reproduction and exploitation data were monitored. The sample included three goat and three sheep herds, managed by Mossi, and two goat and three sheep herds, managed by Fulani, under extensive management conditions. Additionally, four Mossi sheep herds kept under semi-intensive management conditions were followed. Twice a month all herds were visited, non-pregnant animals were weighed and records per animal were updated for births, mortality and exploitation (Elskamp, 1995; Van den Berg, 1994).

Market study

From September 1994 to September 1995, the principal markets for small ruminants in Zoundwéogo province were surveyed at least once a month: Kaïbo-Center, Nobéré and Manga.

Some smaller markets were visited occasionally to verify certain trends: Gogo, Bilbalogo.

All animals offered on the market were tagged individually for the period that they were on the market. All individuals offering animals for sale were interviewed on the animals' age, sex, species and breed, reasons for selling an animal at that moment and reasons for selecting that specific animal. The sold animals were weighed when leaving the market with their new owners, who were interviewed on the animal they bought, reasons for buying and animal prices. Also the profession of the buyer was monitored.

Analysis of variance (ANOVA) and T-tests were used to evaluate the significance of the factors sex and species with respect to animal weight and all three factors with respect to the sales price. ANOVA was also used to evaluate possible significant differences in prices between seasons.

Slaughterhouse data

For 1994 and 1995, the numbers of animals that were officially slaughtered, were collected at the Regional Animal Production Service per slaughterhouse: Manga, Nobéré, Bindé, Guiba and Gogo. From these data the total number of animals slaughtered per month, per animal species and per slaughterhouse was calculated.

RESULTS

Exploitation rates and reproductive performance of small ruminants

Animals can leave a herd for various reasons. Mortality, thefts, etc. are considered involuntary losses and do not contribute to exploitation or offtake. Exploitation is defined here as all animals leaving the herd as a result of a decision of the farmer: sales, slaughtering for home consumption, or presents to third parties. Offtake is defined as the maximum number of animals that may leave a herd without reducing the (re)productive capacity of the existing herd. In many studies offtake is considered equivalent to exploitation.

The monitoring study (Table 5.1.1) of goat herds revealed exploitation rates of 11 % for Fulani and 19 % for Mossi herds. For Fulani herds, exploitation equalled sales, as home consumption is not involved. Mossi did slaughter some animals for consumption during ceremonies. For sheep, exploitation rates of 15 % for Fulani and 28 % for both extensively and semi-intensively kept Mossi herds were found. Fulani did not consume sheep of their own herd, but some animals were given away. Mossi also gave away some sheep and slaughtered some during ceremonies. When exploitation is expressed as percentage of the total number of animals in the herd, sheep are exploited more intensively than goats and Mossi herds more intensively than Fulani herds.

Table 5.1.1 Exploitation and reproduction data for Mossi and Fulani goat and sheep herds in Kaïbo Sud V5, 1994.

Production system	Offtake (%)	Sale (%)	Consumption (%)	Gifts (%)	Number of kids born yearly per reproductive female	Sale/birth annually (%)
Mossi goats	19	14	4	1	1.24	29
Mossi sheep	28	18	5	5	1.03	41
Mossi sheep fattening	28	21	4	3	0.95	56
Fulani goats	11	11	0	0	1.63	17
Fulani sheep	15	10	0	5	0.68	33

Source: Antenne Sahélienne, Monitoring Study (January-December 1994)

Exploitation can also be considered in relation to reproductive performance (Table 5.1.1). Both, ewes and does kidded only once during the monitoring study, thus intervals between parturitions were at least one year. First parturition took place at the age of 15 to 16 months. On average 1.03 lamb and 1.24 kid were born annually per female in the reproductive age class for Mossi herds, against 0.68 lambs and 1.63 kids for Fulani herds. Herd dynamics, expressed in sales as percentage of births, varied per system, being highest for the sheep fattening unit with 56 % and lowest for Fulani goat herds with 17 %. Again, sheep appeared to be most intensively exploited, while Mossi exploited more intensively than Fulani.

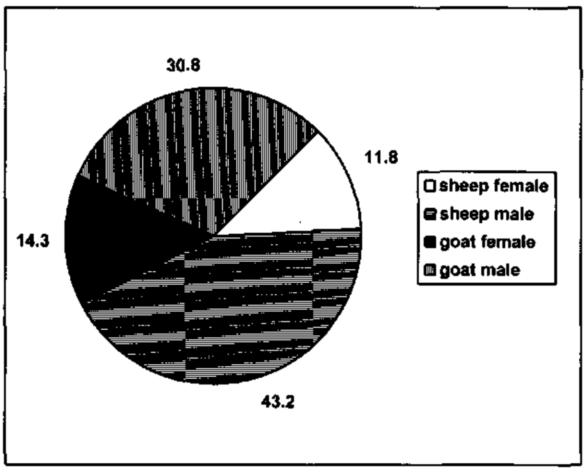

Figure 5.1.1 Sex and species of animals marketed (%)

Characteristics of marketed animals

Breed, sex and species

The total population of small ruminants in the sample was 1579. Most animals were of the Djallonké breed, with a few Bali Bali sheep and some animals of mixed races. Bali Bali is a Sahelian breed, originating in the North of the country. It is imported into Zoundwéogo province exclusively for fattening for Muslim feasts. These animals were left out when analysing the data on animal weight and prices, as the adult weight of Bali Bali is considerable higher than of Djallonké. Of the marketed Djallonké almost 75 % were male of which about 60 % were sheep (Figure 5.1.1). Less than 1 % of the animals were castrated.

Animal weight

Normally, marketed animals are not weighed, but for the market study they were. The average weights of animals presented on the market varied between 12.5 and 15.3 kg, depending on species and sex (Table 5.1.2).

Table 5.1.2 Average weights for small ruminants per sex and species, for animals sold on livestock markets in Zoundwéogo province.

Species and sex	Number of animals	Average weight (kg)	Standard deviation
Buck	352	12.5	5.35
Doe	133	15.3	8.42
Ram	575	14.7	7.08
Ewe	149	14.7	5.66

Source: Antenne Sahélienne, Livestock Market Survey (September 1994-September 1995)

Average weight was highest for castrated animals, 20.5 kg for sheep ($n = 4$) and 23.8 kg for goats ($n = 5$), but these have not been included in the data in Table 5.1.2, as their contribution to the sample was very small. A T-test showed that the average weight was 15 % higher for does than for bucks, which was highly significant ($P < 0.0005$).

The liveweight of bought animals varied with respect to their destination (Figure 5.1.2). Those sold in Ouagadougou (sO) and Guelwango (sG) were significantly heavier ($p < 0.05$) than those to be slaughtered (sl). Those to be slaughtered at Tabaski (Ta) were the heaviest ($p < 0.05$) as requested for this religious ceremony. For other ceremonies (C) like funerals significantly smaller ($p < 0.05$) animals were selected. Slaughtering of animals at these specific occasions is an obligation, but animal weight non-significant.

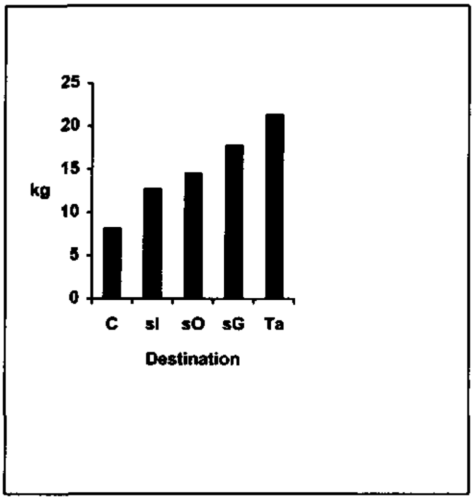

Figure 5.1.2 Average animal weight (kg) at sale differentiated per destination
C = ceremony, sl = slaughter, sO = sold in Ouagadougou, sG = sold in Guelwongo,
Ta = Tabaski

The distribution of animals over weight classes in the market study showed that more than half of the animals had liveweights below 15 kg (Table 5.1.3). Only 1 % of all sheep sold had liveweights equal to or exceeding 30 kg, while only 2.4 % of all sold goats had liveweights equal to or exceeding 25 kg.

Table 5.1.3 Percentage of sold animals per weight class on markets in Zoundwéogo province.

Animal species and animal sex	Percentages of animals (%) in each liveweights class (kg)		
	0 - 10 kg	10.1 - 15 kg	15.1 - 20 kg
Buck	34.0	42.9	17.9
Doe	22.5	40.7	25.5
Ram	24.3	35.4	24.5
Ewe	20.3	35.3	23.5

Source: Antenne Sahélienne, Livestock Market Survey (September 1994-September 1995)

Reasons for buying and selling

Mossi and Fulani women are not allowed to sell animals on the market, so they had to ask a man as intermediary. The majority of the sellers were farmers, selling from their own herd because they needed cash. At the market place, professional intermediaries assist in the negotiation process for a small fee per animal. In total, 450 people were recorded as buyers during the survey period. Almost half of them were merchants, buying for further trade and 36 % were butchers.

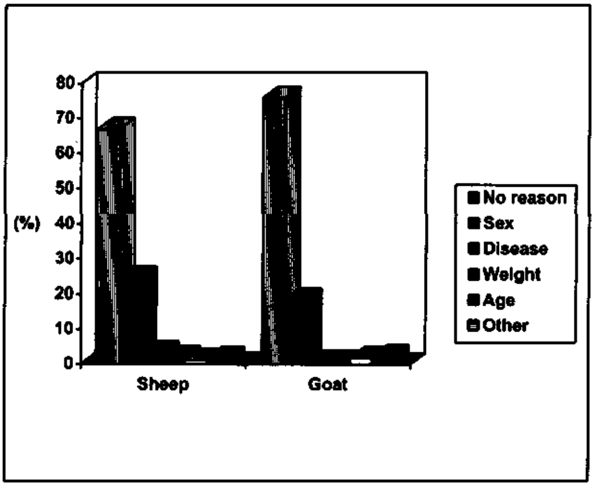

Figure 5.1.3 Reasons for selling specific animals

Various reasons were mentioned, for selling a specific animal (Figure 5.1.3). Some people sold their oldest or heaviest animal, others one with a disease or poor reproductive performance. The most important criterion appeared to be sex: males were more often selected than females.

Many animals were sold to cover foreseen or unforeseen cash requirements. Throughout the year animals were sold to buy cereals. In January and February it was the reason for only 11 % of the sales, because enough cereals were left from the last harvest. Between April and the next harvest in September, it became the most important reason for sale (Figure 5.1.4).

In the rainy season, June-September, cash was needed for agricultural inputs. In each of the months May and July, 7 % of both animal species was sold to buy agricultural equipment and improved seeds. In August, 8 % of goat sales was necessary to repay part of the loans used to buy ploughs.

In December, February and April, 9, 14 and 12 % of all sales was necessary to pay for vaccination of cattle (Fulani). In September, 21 % of the sales of both sheep and goat was necessary to pay school-related expenses; in October, this accounted for 8 % of all sales. Only Mossi sent their children to school.

Unforeseen and emergency cash needs appeared related to medical care, ceremonies like funerals and marriages of family members, but also to repair of means of transport, roofs of houses, etc. Foreseeable high cash needs were related to religious ceremonies such as Christmas, Tabaski and Ramadan.

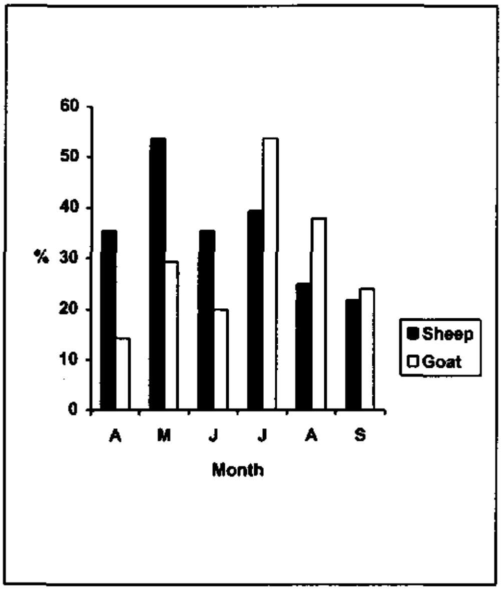

Figure 5.1.4 Percentage of sheep and goats sold to buy cereals, April-September 1994

Prices

Sale prices, the outcome of negotiation, were determinated per head and not based on weight. For sheep, average prices and average weights could not be differentiated between sexes. For ewes and rams Eqn. 1 and 2, respectively describe the correlations ($p < 0.05$) between prices (P) and liveweights (LW):

Ewe (N = 183)	$P = -1291 + 434\ LW$	$r = 0.83$	[1]
Ram (N = 676)	$P = -1885 + 491\ LW$	$r = 0.79$	[2]

The slope is higher for rams. The price is identical at about 11 kg, beyond that rams are more expensive.

For goats, average weight of does was significantly higher than of bucks ($p < 0.05$), as was the average price ($p < 0.05$). For does and bucks Eqn. 3 and 4, respectively describe the correlations ($p < 0.05$) between prices (P) and liveweights (LW):

Doe (N = 288)	P = - 979 + 420 LW	r = 0.81	[3]
Buck (N = 475)	P = -1175 + 429 LW	r = 0.80	[4]

Both the slope and the intercept are similar. The price is identical at 24 kg, beyond that bucks are more expensive. The higher prices for smaller does could be associated with their reproductive value.

Seasonality

Average prices per kg liveweight were calculated per month for each combination of animal species and sex, except for some months in which no monitoring took place (Table 5.1.4). ANOVA analysis showed that season contributed significantly ($p<0.01$) to price differences for all categories. Prices were generally high in December and January, when all farmers want to buy animals to invest earnings from sales of cereal surpluses, and low in August and September, just before crop harvest.

Animal destination

Of the animals bought, 52 % were sold again and 34 % were slaughtered. Another 9 % were bought by farmers with the revenues from the sale of cereals and cotton. Of the animals sold again, 70 % were sold outside Zoundwéogo, in Po, possibly for export to Ghana or Ivory Coast, and in Ouagadougou, the remainder in the province, in Kaïbo, Gomboussougou, Manga, Nobéré, Guelwango or elsewhere.

Animal breed, sex and species

Of all animals bought, 13.5 % was of mixed breed, most of which were bought to be sold again. Animal destination varied between breeds: 30 % of local and 21 % of mixed breed were slaughtered and 2 % of local and 5 % of mixed breed were used for breeding. For all ceremonies other than Tabaski, only the local race was used.

Of all animals bought, 26 % was female. Males were more often bought to be used in ceremonies especially Tabaski and funerals. Females (7%) were more often intended for breeding.

Almost 50 % of the sheep and 40 % of the goats was destined for Ouagadougou, for both species about 30 % to be slaughtered and 65 % to be sold again. Only 2 % was used for ceremonies, goats mostly for funerals and sheep for Tabaski.

Table 5.1.4 Monthly* average prices (FCFA[1] per kg liveweight) per animal species and sex at livestock markets in Zoundwéogo province

Species and	January		February		April		May		August		September		November		December	
sex	Price	N[2]	Price	N	Price	N	Price	N	Price	N	Price	N	Price	N	Price	N
Goat male	345	39	348	42	519	15	306	35	275	63	291	121	312	23	307	13
Goat female	331	20	400	11	581	6	329	20	289	41	286	19	274	12	310	4
Sheep male	341	87	347	55	616	28	365	41	279	44	296	231	292	40	343	48
Sheep female	332	15	371	28	447	3	326	12	263	27	295	53	298	9	-	-

* No data recorded for the months March, June, July, October.

[1] FCFA = Franc de la Communauté Financière Africaine, 100 FCFA = 1 FF = US$ 0.2

[2] N = numbers of animals

Source: Antenne Sahélienne, Livestock Market Survey (September 1994-September 1995)

Slaughterhouse

Data for different slaughterhouses in Zoundwéogo province, as collected in the study, are given in Table 5.1.5. The number of animals accounted for about 70 % of the nationally registered number of slaughterings for the province. The number of goats slaughtered was about five times as high as that of sheep.

Table 5.1.5 Average number of animals officially slaughtered monthly at slaughterhouses in five villages in Zoundwéogo province in two years.

Year	1994		1995	
Village	Sheep	Goats	Sheep	Goats
Bindé	120	310	n.a.	n.a.
Gogo	11	59	15	55
Guiba	19	122	13	101
Manga	64	441	34	439
Nobéré	14	129	20	110

Source: Direction Régionale de l'Agriculture et des Resources Animales, Manga
n.a. = not available

Export and slaughtering data for Zoundwéogo province as a whole, are given in Table 5.1.6 (DSAP, 1995 and 1996).

Table 5.1.6 Export and slaughterings of sheep and goats for Zoundwéogo province (numbers) for two years.

	1994		1995	
Animal species	Export	Slaughter	Export	Slaughter
Goats	364	17469	262	15129
Sheep	322	3912	390	3065

Source: Direction des Statistiques Agro-Pastorales (DSAP), 1995 and 1996

Between 1994 and 1995 export of sheep increased with 21 % and of goat decreased with 28 % . In both years, export of sheep was much more important than that of goats. For Zoundwéogo province, sheep were preferably exported and goats were mostly slaughtered.

Discussion

The importance of small ruminant sales for purchase of cereals and for agricultural inputs, observed in the market study, is consistent with results reported (Bosma *et al.*, 1992; Debrah and Sissoko, 1990; Dumas and Raymond, 1975). The exploitation rates observed in the monitoring study for goats, 11-19 % exploited and 11 - 14 % sold, are rather low for Burkina Faso. Dumas and Raymond (1975), for instance, studied flocks during the drought of the seventies, when offtake, necessary to buy cereals, was high compared to years with normal rainfall. They found offtake rates of 32 % for Mossi sheep, 38 % for Fulani sheep, 37 % for Mossi goats and 43 % for Fulani goats. For Mossi, 53 % of their marketed small ruminants were sold to purchase cereals and for Fulani 34 %. Data for Zoundwéogo and Nahouri provinces (DEP, 1990) derived from just one interview with each of the animal owners in the sample, thus depended entirely on farmers' memory. Exploitation rates of 31.7 and 35.2 % were found for sheep and goat respectively. These data were on average much higher than monitoring data found in literature for neighbouring countries, such as 10-19 % sales for goat in Nigeria (Bosman, 1995), 14.1 % sales and 16.6 % exploitation for goat in Mali (Bosma, 1992) and 10-12 % sales and 19.3 % offtake for goat and 18.5-19.6 % sales and 26.8 % offtake for sheep in Mali (Wilson, 1986). The results for sheep in the monitoring study were also somewhat lower than in literature. In general, a relatively large proportion of the animals were given away or consumed at home during ceremonies. Exact exploitation rates were therefore difficult to establish in studies with large intervals between observation periods.

In a reproductive herd, only a few adult males are necessary for breeding. Therefore, young (light) males can be sold without endangering the herd. Young rams were frequently offered at the market, which resulted in relatively low prices. Adult rams had additional value for religious ceremonies, which is reflected in the steep curve (Eqn. 2) representing the relation between price and liveweight. Does and ewes were as much as possible kept for reproduction, except when the animal had specific problems. As young ewes were thus offered at the market, their prices were high relative to their weights. Adult ewes were generally viewed with suspicion with respect to their health and reproductive performance, hence their low prices. For goats, there was very little differentiation between the sexes as illustrated in Eqns. 3 and 4. When all males in the herd had been sold already and more cash was needed, healthy female were occasionally sold. Hence, males represented more than 50 % of all animals marketed and these males were generally younger and lighter than females. In the market study, only 1 % of all sheep sold had a liveweight exceeding 30 kg while only 2.4 % of all goats sold exceeded 25 kg.

Can an optimum weight or age at sale be derived? An optimum can be expressed in terms of animal growth depending on factors such as animal breed, feeding system, infection with parasites or any other diseases, climate and season, etc. (Carles, 1985; Provost, 1980), or in terms of cash benefits depending on price differences between inputs (labour, drugs, feed) and outputs (meat). Here we consider animal growth under prevailing management, without the use of external inputs. For goats, the monitoring study showed a linear increase in weight till the age of 5.2 months, followed by a decline in growth rate. At that age males were about 14 kg and females about 10 kg. For sheep, liveweight increased linearly till at least 6.4 months of age, at liveweights of 18 kg for Mossi and 20 kg for Fulani herds, both under extensive management. No data for older animals were recorded, but normally animals still increase in weight even though at a lower rate. Hence, animals sold on the markets at average weights of 12.5 to 15.3 kg (Table 5.1.2) were still in the linear growth phase.

Wilson (1986) found that average daily weight gain decreased after one year of age. Asymptotic weights were attained in sheep at about 3 years and for goats at almost 4 years old. It therefore seems economic to sell male animals when growth rates start declining between 1 and 3 years of age. Many authors found similar growth curves (Carles, 1985; Provost, 1980; FAO, 1977)

For female animals weight at conception is an important parameter to determine whether an animal is sold too early. In Mali, average weights at first conception were 16.6 kg for goats and 22.8 for sheep, while conception did not take place below 10 kg for goats and 15 kg for sheep (Wilson, 1986). Hence, on the market in Zoundwéogo, 63 % of the does and 56 % of the ewes are sold before having reached the weight of possible first conception (Table 5.1.3). For these animals all offspring is lost to the farmer that bred the animal and even lost to society when the animal is slaughtered after sale. The practice of sales at low weights thus is associated with serious financial losses to the animal production sector.

In Burkina Faso, the age at first parturition (birth) averaged from 13 (Damiba, 1989; Pitroipa, 1983; Bourzat, 1979) to 16.6 months (Nianogo,1990) for Mossi sheep, from 12 (Damiba, 1985) to 15 months (Bourzat, 1979) for Fulani sheep and 13 months (Bourzat, 1979) on average for Fulani goats. The results of the monitoring study were within these ranges.

Prices

In Burkina Faso, statistics are regularly collected for 11 livestock markets at national level, none, however, in Zoundwéogo province. For rams a standard of 30 kg liveweight is used to evaluate prices for fattened animals. For 1995, market prices varied between 8400 and 15000 FCFA[1], with an average of 12190 (DSAP, 1996). For rams of 30 kg, the equation derived from the market study results in a price of 12835 FCFA, comparable to the national average. For bucks, a standard of 25 kg liveweight is used. For 1995 prices varied between 6700 and 11900 FCFA with an average of 9218 (DSAP, 1996). For a buck of 25 kg, the equation derived from the market study results in a price of 9544 FCFA, also comparable to the national average. This suggests that the correlation between animal liveweight and prices derived from the Zoundwéogo markets may also be applied to other small ruminant markets in Burkina.

[1] FCFA = Franc de la Communauté Financière Africaine

Estimated opportunity costs

Losses due to premature sales comprise elements of production (meat) and of reproduction (offspring). The correlation functions between liveweight and prices show that 1 kg liveweight represents values of 429 and 491 FCFA for bucks and rams, respectively. Average weights of bucks and rams at sale on the market were 12.5 and 14.7 kg (Table 5.1.2). Putting these weights in eqn. 2 and eqn. 4, they represent 4188 FCFA and 5333 FCFA for rams and bucks, respectively. When the animals would have been sold at adult weight, 30 kg for rams and 25 kg for bucks, 12845 FCFA would have been generated for rams and 9550 FCFA for bucks. The loss incurred per average ram and buck animal sold is thus 7512 and 5362 FCFA, respectively.

The loss in offspring can only be calculated in numbers. The age of female animals at first parturition is about 1.5 years, 95 % of all females in the herd are younger than 6 years (DSAP, 1992), and the interpartum interval is about one year (DEP, 1990; DSAP, 1992). Therefore, for each ewe or doe sold before first parturition, about 6 parturitions are foregone. For Mossi ewes, with an average of 1.03 lambs per parturition (Table 5.1.1) this is equivalent to 6.2 lambs. For Fulani does, with 1.63 kids per parturition (Table 5.1.1), 9.8 kids are foregone. Taking into account the fraction of females that is prematurely sold, the loss in offspring per 100 does or ewes equals 617 kids (63 x 9.8) and 347 lambs (56 x 6.2). Foregone revenues will be even higher when second generation offspring would be taken into account.

Losses can also be incurred due to the choice of the period of sale. Prices varied from 262 to 447 FCFA/kg for ewes, 280 to 616 FCFA/kg for rams, 274 to 581 FCFA/kg for does and 275 to 519 FCFA/kg for bucks (Table 5.1.4). Selling at the month with highest prices means doubling the revenues. Unfortunately, sales for financing can mostly not be optimally timed. Financing to buy cereals in August and September, the period with the lowest prices for animals due to the large supply, is necessary. On the other hand, fattening of rams can be planned with respect to Muslim feasts and fattening of other animals can also be planned with respect to a sale date with highest prices. When these animals are not needed for emergency financing, they can generate attractive revenues thanks to this planning.

Losses for the livestock sector due to the role of animals for financing are thus threefold (meat production, offspring, seasonality) and very substantial. Daily wages for farm labour are between 500 and 1000 FCFA depending on seasonal demands. Foregone income due to premature sales of livestock represent the value of between 20 and 25 days of work.

Conclusion

Both, Mossi farmers and Fulani herdsmen, use small ruminants as assets that are easily convertible in cash. Their selling strategy is based on choice of animal and periodic cash needs. For goats, males are sold first, preferably at one year of age. Does are only sold when all available bucks have left the herd or when they suffer from a reproduction or health problem. Therefore, does are older and heavier at sale than bucks. Goats are seldom slaughtered for home consumption, but sold to butchers and only seldomly exported. For sheep, the situation is more complex because of their importance for certain religious and other ceremonies. Fattening of sheep, especially Bali Bali, takes place for sales around Muslim holidays. Preferably males, as heavy as possible, are sold, either on local markets or for export. Ewes are only sold when infertile or sick. Sheep are regularly slaughtered for home consumption during ceremonies. Sheep are exploited more intensively than goats.

Both, Mossi and Fulani, sell small ruminants in the rainy season to buy cereals. Fulani, keeping large herds of cattle, also sell small ruminants to generate cash to pay for their vaccinations. Mossi sell at particular periods to buy agricultural inputs and pay for school expenses for their children. Emergency cash needs for medical care or funerals are also covered by selling small ruminants. Mossi exploit their small ruminants more intensively than Fulani.

The market system is based on expert judgement to visually estimate an animal's value. For both, sheep and goats, the market data showed highly significant correlations between animal liveweight and animal price per sex. Weighing of animals seems not necessary as consistent prices per kg can be reached without. Professional buyers, butchers and merchants, select animals on the basis of their final destination: Heavy ones for sale, small ones for slaughtering. Farmers offer the number and type of animals they consider sufficient to generate the necessary money.

The market study showed that most female animals are sold before their productive life started or was finished. Also many animals were sold at very low liveweights, thus while still growing. Finally, sales of animals appeared to be seasonal, leading to low prices. These three factors lead to considerable financial losses for the livestock sector. Apparently, small ruminants are so important for financing that animal production optima are not reached. It is therefore highly recommended to policy makers to provide alternatives for financing in rural areas to increase meat production from small ruminants.

5.2 Animal production and rural financing: the case of Zoundwéogo province, Burkina Faso

Abstract

Almost 90 % of the population of Burkina Faso live in rural areas and depend on farming for their livelihood, and livestock is of great economic importance for rural households. In Burkina Faso, as in so many other developing countries, rural banking services do not function properly. Due to social inhibitions monetary saving is difficult and often absent, and due to technical and psychological inhibitions saving through formal financial institutions hardly exists. These inhibitions are illustrated for Zoundwéogo province in Burkina Faso, where despite numerous efforts, rural banking services have failed. Particularly in the Sahel, where households are confronted with unpredictable rainfall and hence the risk of crop failure, there is a need to deal with temporary crop surpluses and shortages. Rural households seek alternative ways to finance their foreseen and unforeseen needs. A rural financing multiple criteria matrix has been developed to evaluate and compare the alternatives. Livestock rearing proves to be the most interesting alternative because of its accessibility, security, liquidity and profitability. In the future it should be necessary and useful to quantify this function of animal production to allow it to be compared to other benefits of livestock. The rural financing multiple criteria matrix may prove to be useful in assessing different methods to finance the needs of rural households.

Introduction

Almost 90 % of the population of Burkina Faso live in rural areas and are economically dependent on agriculture and hence rural development is placed high on the policy agenda of the national government. To stimulate rural development a financial market is necessary, both to absorb and invest savings and to provide loans. The absence of formal financial markets such as banking institutions will force the rural population to seek informal alternatives (Bosman and Moll, 1995). In Burkina Faso, as in other Sub-Saharan countries, livestock functions as an alternative to formal financial markets (Bosman and Moll, 1995; Toulmin, 1993).

This paper will seek answers to the following questions for Zoundwéogo province in Burkina Faso: (i) why are rural banking facilities not functioning; (ii) which alternatives are available; (iii) is livestock rearing the most interesting alternative with respect to saving and financing; and (iv) and if so why?

Animal production by rural households will be highlighted and formal financial markets will be evaluated. Alternatives for financing, used by rural households will be discussed and compared with respect to their accessibility, security, liquidity and profitability by means of a rural financing multiple criteria matrix.

Table 5.2.1 Studies executed in Zoundwéogo province in the framework of the research programme "Management of Natural Resources in the Sahel".

Study	Characteristics	Research sites	Period	Methodology	Sample
Farm economics	Inventory of household activities and available resources	Yakin Barcé Kaïbo Sud V5	1993-1996 every dry and rainy season	Interviews with farmers and measurements of inputs and outputs	159 households 90 households 62 households
Markets	Inventory of reasons for selling small ruminants	Kaïbo Gogo Bilbalogo Nobéré	1994-1995 twice a month every market during one year	Interview with each buyer and seller	ca. 450 buyers and sellers
	Inventory of market prices and their relations with season and/or animal characteristics	Idem	Idem	Measurements and observation of each animal	ca. 1500 animals
Formal financial institutions (FFI)	Inventory of all formal financial institutions in the province	Zound-wéogo	1994	Literature review and interviews with key persons	
	Financial evaluation of CECC and COOPEC	Manga Bilbalogo Nobéré	1994	Analysis of financial administration	1 CECC and 2 COOPECs
	Evaluation of clients' appreciation of COOPEC	Bilbalogo Nobéré Kaïbo Gombous sougou	1994	Interviews with clients	50 clients
Informal financial markets (IFM)	Inventory of farmers alternatives for financing and their appreciation of each option	Kaïbo Sud V5	1994 September-December	Interviews with heads of households and one of their wives	10 Mossi and 10 Fulani households

Since 1992, Wageningen Agricultural University, the Netherlands, and the University of Ouagadougou, Burkina Faso, work together in the context of the research project "Management of Natural Resources in the Sahel". The project operates in Sanmatenga and Zoundwéogo provinces in Burkina Faso. Senior research staff and students participating in the project have conducted field studies from which information, in particular on Zoundwéogo province, has been derived for this paper (Table 5.2.1). In addition to field data, this paper also draws on a number of studies which have been published elsewhere.

The position of livestock in farming

In developing countries livestock performs several roles for rural households. Milk and meat are the most important products. Livestock also enhances cropping activities with manure and animal draught power and play a role in social and cultural life (McIntire *et al.*, 1992). In Sahelian countries which are characterised by erratic rainfall, livestock often serve to absorb grain surpluses and to compensate grain deficits (Bayer and Waters-Bayer, 1991).

On the Central Plateau of Burkina Faso, both Fulani livestock owners and Mossi farmers, increasingly show a tendency towards mixed farming. Due to population growth at a national rate of 2.7 % per year between 1985 and 1994 (World Bank, 1996) pressure on croplands has increased (McIntire *et al*, 1992; Bayer and Waters-Bayer, 1991). The decline of fallow leads to an increasing need for manure to restore soil fertility in the fields. The availability of crop residues for crop cultivators increases. The use of animal traction in land preparation can raise crop yields. It has thus become advantageous for crop growing farmers to own cattle. When farmers grow cash crops, especially cotton, the revenues are generally invested in cattle (Lallemand, 1977). For Fulani herdsmen the grazing area has decreased both in quantity and in quality. In order to have access to crop residues, Fulani households have to take up crop cultivation. Cropping is also practised as a device to claim a portion of land (McIntire *et al.*, 1992). Fulani especially took up crop cultivation when their herds became too small to support their families. Herd size may have decreased due to animal diseases or severe droughts. In this view, Fulani are supposed to convert crop surpluses into livestock as fast as possible in order to reconstitute their herds (Adamou, 1991; Cissé, 1980). Also, during the droughts of the 1970s and 1980s, herds were appropriated by crop growing farmers because the balance between grain and livestock prices was advantageous for the crop producers (McIntire *et al.*, 1992). For both groups, diversification of production is a strategy to cope with climatic and political risks (Toulmin, 1993; Bayer and Waters-Bayer, 1991; Cissé, 1980). However, in Burkina Faso, some specialisation takes place in the form of sheep or oxen fattening. These practices serve commercial meat production. Commercial milk production around cities has also started.

In Burkina Faso, 70 % of all ruminants are owned by the two mentioned ethnic groups, Fulani herdsmen and Mossi farmers (ENEC, 1990). In the Sudan zone, in which Zoundwéogo province is located, the number of livestock has increased substantially since the 1970s. During the last twenty years, the number of cattle has doubled and the number of small ruminants even quadrupled (IEMVT, 1991). Small ruminants with their short life cycles were used to rapidly reconstitute the herds that had been decimated during the 1972 and 1973 droughts (Adamou, 1991). Population growth resulting from the increase of the local population and immigration from other areas of Burkina Faso, has been accompanied by an increase in livestock numbers in Zoundwéogo province. The sedentarisation of former transhumant Fulani families with their herds coming from the North of the country has contributed to the increase of livestock in the south of the country.

Livestock density in the rural areas of Burkina Faso is high. For Zoundwéogo province livestock density increased from 29.3 TLU km^{-2} in 1988 to 33.3 TLU km^{-2} in 1995. Due to a population growth of 2.2 % yearly (INSD, 1989), average livestock numbers per capita remained 0.6 for cattle, 0.5 for sheep and 0.5 for goats (ENEC, 1990). Total numbers of cattle, goats and sheep in 1995 (Table 5.2.2) were calculated from the ENEC figures (1990) by multiplying them with their annual growth rates (DSAP, 1996a).

Table 5.2.2. Livestock dynamics in Zoundwéogo province.

Species	1988[1] (x 10^3)	Annual growth[1] (%)	1995[2] (x 10^3)
Cattle	101	2	114
Sheep	75	3	90
Goats	72	3	84
Donkeys	12	2	14
TLU[3]	101		115

[1] ENEC, 1990 [2] DSAP/MARA, 1996a [3] Tropical Livestock Unit (250 kg)

Fulani herdsmen who are traditionally dependent on animal production only, own 65 % of all cattle in the province. Seventy per cent of these cattle is present in herds containing over 40 head per household. Fulani women sell the milk of the cows and can freely spend their revenues thus obtained. Small ruminants and cattle are sold by Fulani men for family and personal expenditures. As Fulani cultivate only small areas they are obliged to sell animals or milk to buy grain every year.

Mossi farmers, who are traditional cereal growers, own 63 and 72 % of the total number of sheep and goats in the province respectively. Both the ENEC survey (1990) and the farm economics study (Table 5.2.1) held by the project showed that most of the herds of cattle, sheep and goats kept by Mossi farmers consisted of less than ten animals per household. Most households keep small ruminants only or a mixture of small ruminants and cattle (Table 5.2.3). The larger the household, the larger the number of cattle and small ruminants kept, particularly sheep. There is also a positive relation between the number of livestock kept and area cropped (DSAP, 1996b).

Table 5.2.3 Percentages of households (hh) by type of ruminants kept*.

Village in Zoundwéogo	Number of households	hh with cattle only (%)	hh with small ruminants only (%)	hh with both (%)
Barcé[1]	99	8	26	53
Yakin[1]	173	9	31	40
Kaïbo V5[1]	63	19	13	62
Kambo[2]	115	4	50	36
Ouda[1]	157	1	45	31

[1] Data from farm study (1992)

[2] Data from additional inventory (1993)

*The remainder hh without ruminant livestock

Mossi use their cattle mostly to support crop production by using draught power, obtaining manure or both. The percentages of households with donkey or bullock traction can be found in Table 5.2.4.

Table 5.2.4 Percentages of households in Zoundwéogo villages with animal traction*.

Village	Number of households	Percentage of households with animal traction	
		Bullocks	Donkeys
Barcé[1]	29	45	76
Yakin[1]	25	40	56
Kaïbo V5[1]	25	52	32
Kambo[2]	115	36	58
Ouda[2]	157	18	56
Centre-Sud[3]		38	41

[1] Data from farm study (1992)

[2] Data from additional inventory (1993)

[3] Data from a national survey executed in 1993 by DSAP/MARA (1996b); Centre-Sud covers three provinces: Bazega, Nahouri and Zoundwéogo

* Some hh have both species

The development of animal traction is impressive as in 1991 there were 54 % more ploughs and 52 % more draught oxen than in 1985. Transport with animals, especially carts drawn by donkeys increased in the same period about threefold (PDI/Z, 1993). The results from the farm economics study (Table 5.2.1) are similar to the findings of ENEC (1990) and DSAP (1996a) for the whole province.

The use of livestock dung to fertilise the fields has become important. This can be illustrated by the fact that in 1991, 12 % of all farming households had constructed one or more manure pits in Zoundwéogo province. The total number of pits increased from 258 in 1984 to 4900 in 1993 (PDI/Z, 1993). Also all farmers interviewed with respect to their saving behaviour mentioned manure as an important benefit of livestock (IFM and FFI studies cf. Table 5.2.1).

Livestock is also known to play an important role in social and cultural life. For the Fulani, cattle are very much part of their life, but for Mossi farmers they fulfil important social functions as well. Sheep are sacrificed during Muslim ceremonies but may also be slaughtered at marriages and funerals. Imbs (1987) found that within one year, 52 % of the goats and 30 % of the sheep of 19 households in the Mossi village of Kumtaabo were consumed at funerals or other ceremonies. In some societies in Burkina Faso the possession of horses is the exclusive right of chiefs and is thereby directly linked to power and social rank. Presents of animals are important when establishing or maintaining relations between individuals, families, villages and even ethnic groups (Breusers, 1996).

The market study conducted by the project (Section 5.1) showed that small ruminants are sold only when either the animal has a low performance or the owner needs money or both. For female small ruminants found on the market, 25 % appeared to be sold because they were ill, 21 % because they were old and another 20 % because they were infertile. In each of the months of May, June and July (1995) 10 % of the marketed animals were sold to generate money to buy agricultural inputs. More than 20 % of the small ruminants offered on the market in September were sold to raise money for the payment of school fees. Other reasons for selling livestock were to buy medicine and to make contributions to ceremonies. From May to September 35 % to 55 % of the marketed sheep were sold to buy cereals. These figures prove that small ruminants fulfil a security and financing function.

The present section showed the importance of livestock for farm households in Burkina Faso and in Zoundwéogo province in particular. In the next section an evaluation of financial markets in Burkina Faso, and in Zoundwéogo province, will be presented. The data of both sections combined will show that the importance of livestock is related to poor functioning financial markets and explain why financing through livestock plays such a crucial role in the province.

Rural financial markets in Burkina Faso

Burkina Faso has been struggling with the immensely complicated task to finance rural development. Complicated, because there hardly exists any form of infrastructure, such as formal rural financial institutions in this country.

A rural financial market consists of relationships between buyers and sellers of financial assets who are active in rural economies. The relationships are based on transactions that include borrowing, lending and transfer of ownership of financial assets (Von Pitschke *et al.*, 1988).

In Burkina Faso, two systems of formal rural financing developed independently: the commercial banks and the Decentralised Financial Systems (DFS) (Kaboré, 1994). The commercial banks will be discussed for Burkina in general. With respect to formal DFS a study was undertaken for Zoundwéogo province (FFI study Table 5.2.1).

Commercial banks

When commercial banks operate in the agricultural sector, they preferably do so by granting consortium loans to organisations that cover production, industrial transformation and commercialisation of a certain product. Examples of such organisations in Burkina Faso are *Société Burkinabè des Fibres Textiles* (SOFITEX) for cotton and *Société Sucrière de la Comoé* (SOSUCO) for sugar (Bosch *et al.*, 1994). Between 1975 and 1983 only 5 % of total bank credits were allocated to the agricultural sector (Slangen, 1986).

Banking institutions in Burkina Faso attach relatively little importance to participating in rural financial markets. The management of small accounts is too costly and clients often cannot be given loans because they have no collateral. In addition, the low literacy level of potential clients complicates access to these institutions. Bank representatives are not sufficiently present in rural areas which makes regular use of these institutions almost impossible (Kaboré *et al.*, 1995; Lelart, 1992). This situation is characterised by Chanard (quoted in Lelart, 1992) as *technical inhibition.*

To strengthen bonds of solidarity, monetary surpluses earned by the rural population are mostly distributed among relatives or fellow villagers. Lallemand (1977) describes a specific case of the spending pattern of youngsters returning to their Mossi village after having worked abroad. They spent their money immediately on consumption goods and presents for relatives and friends. Society stimulates them to do so, rather than invest or save money. Stability of Mossi society is based on a certain hierarchy in age and possessions. The concern with maintaining egalitarian relations in West-Africa and in Mossi communities in particular has been pointed out by several authors (Kohler, 1971). The youngsters who have returned are a potential danger to this stability until they have spent all their money and have reintegrated into society resuming their normal status. Very little money is thus left for saving in formal financial institutions. This situation is characterised by Chanard (quoted in Lelart, 1992) as *social inhibition.*

In 1993, several banks, amongst which the *Banque Nationale de Développement* (BND) in Burkina Faso, were closed. Consequently, many clients lost all their savings overnight (Bosch *et al.*, 1994). In January 1994, the *Franc de la Communauté Financière Africaine* (FCFA) was devaluated against the French Franc (FF) and the purchasing power of savings was reduced with about 30 %. These events cause rural savers to have strong doubts about the security of their money in the hands of formal financial institutions, which receive their instructions from the urban centres, such as Ouagadougou. People also doubt the reliability of the so-called "bank-secret", which guarantees that no one has access to information concerning the client's account and his financial transactions. Many financial institutes have in the past lost people's confidence due to incompetent and sometimes even criminal management of their funds. Chanard (quoted in Lelart, 1992) calls this lack of confidence *psychological inhibition.*

The three mentioned inhibitions contribute to the fact that many banking institutions in Burkina Faso play a minor role in rural development.

Decentralised Financial Systems in Zoundwéogo province

Decentralised financial systems are different from central banks in that they do not have central headquarters in the capital. Each region has its own institutions which are not necessarily present in other parts of the country. Many decentralised financial systems have no formal status.

In Zoundwéogo province, the experience with formal banking programs has not been very positive. Most financial institutions that entered the rural market were subsidised by the government or a donor agency. Their activities were entirely focused on the provision of loans. These institutions have proven not to be sustainable. When sponsors withdrew their contributions, activities also ceased, mainly due to the low repayment levels.

SOFITEX, for instance, provided loans to farmers growing cotton through the *Caisse Nationale du Crédit Agricole* (CNCA). CNCA, established in 1980, was the only development bank in Burkina Faso to provide financial services in rural areas. It provided credits to village groups, but withdrew when repayment levels dropped to 54 % in the 1985/86 season. In Zoundwéogo province, farmers growing cotton are mostly found in the villages established under the *Autorité des Aménagements des Vallées des Voltas*[1] (AVV) program. When CNCA withdrew, SOFITEX had to rely on the *Centre Régional de Promotion Agro-Pastorale* (CRPA) in Manga to facilitate the provision and recuperation of loans. Consequently, many loans could not be recovered, as neither farmers nor extension workers felt responsible for repayment of loans as the loan provider, CNCA, was no longer present.

In 1989, a *Cellule d'Epargne, Crédit et Commercialisation* (CECC) was created as part of the *Projet de Développement Intégré au Zoundwéogo*[2] (PDI/Z) in Manga, the capital of Zoundwéogo province. CECC provides credit and saving facilities to the population of the province. Between 1992 and 1995 CECC created five saving institutions, *Coopératives d'Epargne et de Crédit* (COOPEC), in villages in the province.

Saving

There are three main reasons why people become clients of DFS's in Burkina Faso: (i) *security*, (ii) *accessibility* and (iii) ease with which *membership* can be acquired (Bosch *et al.*, 1994).

In the FFI clients study conducted in Zoundwéogo province, *security* was mentioned by 66 % of the clients as an important advantage of saving at the COOPEC. People want their savings to be safe. At COOPEC and CECC unauthorised access to one's account is prohibited and the money is save from destruction by fire, termites, etc. Security very much depends on confidence and, therefore, it is important that clients know the other members and those who are responsible for handling their funds. For COOPECs a member must be represented by a

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Banking institutions in Burkina Faso attach relatively little importance to participating in rural financial markets. The management of small accounts is too costly and clients often cannot be given loans because they have no collateral. In addition, the low literacy level of potential clients complicates access to these institutions. Bank representatives are not sufficiently present in rural areas which makes regular use of these institutions almost impossible (Kaboré *et al.*, 1995; Lelart, 1992). This situation is characterised by Chanard (quoted in Lelart, 1992) as *technical inhibition*.

To strengthen bonds of solidarity, monetary surpluses earned by the rural population are mostly distributed among relatives or fellow villagers. Lallemand (1977) describes a specific case of the spending pattern of youngsters returning to their Mossi village after having worked abroad. They spent their money immediately on consumption goods and presents for relatives and friends. Society stimulates them to do so, rather than invest or save money. Stability of Mossi society is based on a certain hierarchy in age and possessions. The concern with maintaining egalitarian relations in West-Africa and in Mossi communities in particular has been pointed out by several authors (Kohler, 1971). The youngsters who have returned are a potential danger to this stability until they have spent all their money and have reintegrated into society resuming their normal status. Very little money is thus left for saving in formal financial institutions. This situation is characterised by Chanard (quoted in Lelart, 1992) as *social inhibition*.

In 1993, several banks, amongst which the *Banque Nationale de Développement* (BND) in Burkina Faso, were closed. Consequently, many clients lost all their savings overnight (Bosch *et al.*, 1994). In January 1994, the *Franc de la Communauté Financière Africaine* (FCFA) was devaluated against the French Franc (FF) and the purchasing power of savings was reduced with about 30 %. These events cause rural savers to have strong doubts about the security of their money in the hands of formal financial institutions, which receive their instructions from the urban centres, such as Ouagadougou. People also doubt the reliability of the so-called "bank-secret", which guarantees that no one has access to information concerning the client's account and his financial transactions. Many financial institutes have in the past lost people's confidence due to incompetent and sometimes even criminal management of their funds. Chanard (quoted in Lelart, 1992) calls this lack of confidence *psychological inhibition*.

The three mentioned inhibitions contribute to the fact that many banking institutions in Burkina Faso play a minor role in rural development.

Decentralised Financial Systems in Zoundwéogo province

Decentralised financial systems are different from central banks in that they do not have central headquarters in the capital. Each region has its own institutions which are not necessarily present in other parts of the country. Many decentralised financial systems have no formal status.

In Zoundwéogo province, the experience with formal banking programs has not been very positive. Most financial institutions that entered the rural market were subsidised by the government or a donor agency. Their activities were entirely focused on the provision of loans. These institutions have proven not to be sustainable. When sponsors withdrew their contributions, activities also ceased, mainly due to the low repayment levels.

SOFITEX, for instance, provided loans to farmers growing cotton through the *Caisse Nationale du Crédit Agricole* (CNCA). CNCA, established in 1980, was the only development bank in Burkina Faso to provide financial services in rural areas. It provided credits to village groups, but withdrew when repayment levels dropped to 54 % in the 1985/86 season. In Zoundwéogo province, farmers growing cotton are mostly found in the villages established under the *Autorité des Aménagements des Vallées des Voltas*[1] (AVV) program. When CNCA withdrew, SOFITEX had to rely on the *Centre Régional de Promotion Agro-Pastorale* (CRPA) in Manga to facilitate the provision and recuperation of loans. Consequently, many loans could not be recovered, as neither farmers nor extension workers felt responsible for repayment of loans as the loan provider, CNCA, was no longer present.

In 1989, a *Cellule d'Epargne, Crédit et Commercialisation* (CECC) was created as part of the *Projet de Développement Intégré au Zoundwéogo*[2] (PDI/Z) in Manga, the capital of Zoundwéogo province. CECC provides credit and saving facilities to the population of the province. Between 1992 and 1995 CECC created five saving institutions, *Coopératives d'Epargne et de Crédit* (COOPEC), in villages in the province.

Saving

There are three main reasons why people become clients of DFS's in Burkina Faso: (i) *security*, (ii) *accessibility* and (iii) ease with which *membership* can be acquired (Bosch *et al.*, 1994).

In the FFI clients study conducted in Zoundwéogo province, *security* was mentioned by 66 % of the clients as an important advantage of saving at the COOPEC. People want their savings to be safe. At COOPEC and CECC unauthorised access to one's account is prohibited and the money is save from destruction by fire, termites, etc. Security very much depends on confidence and, therefore, it is important that clients know the other members and those who are responsible for handling their funds. For COOPECs a member must be represented by a

[1] AVV = a settlement scheme carried out in the Volta river valley after control of river blindness
[2] PDI/Z = An integrated rural development project in Zoundwéogo province, financed by the Netherlands

president of a village group, live in the department in which the COOPEC has its office and have the Burkinabè nationality. This guarantees that members know each other.

Accessibility appeared another important consideration for people to become members of DFS's. In general, people in the rural areas have very few transportation facilities thus a DFS must not be too far from their homes. For the COOPEC in Bilbalogo (Figure 5.2.1), 34 out of 50 members lived in the village itself and 20 out of these 34 members even lived in the direct neighbourhood of the COOPEC. In Nobéré (Figure 5.2.1), which lies close to the only tarmac road in the province, most members live within five kilometers from the COOPEC. Here, accessibility appears to be closely related to distance.

Finally, *membership* must be easy. Irrespective of gender, age and ethnic background, people must be allowed to become a member (Soulama and Zett, 1994). It must also be inexpensive to become a member. The study showed that it is the case with the COOPECs and CECC in Manga. Members must pay 1000 FCFA[3] for individuals and 3000 FCFA for groups, which is refunded when the account is closed. Furthermore, a non-refundable entrance fee of 300 FCFA must be paid to obtain a membership card and an annual contribution of 200 FCFA for the administration costs. The minimum deposit is 200 FCFA.

The COOPECs are open on all market days, and deposits can always be made between 6.00 a.m. and 5.00 p.m. The ease with which money can be withdrawn from one's account was mentioned by 15 % of the clients as an advantage of saving at a COOPEC. The low transaction time is one of its most appreciated characteristics.

Savers at CECC of Manga consist mainly of village groups. About 329 account holders of which 236 village groups and only 21 individuals possessed a savings account at CECC in Manga in December 1994, with total savings amounting to 86 million FCFA. Individuals appear to deposit income from small trade and from sale of vegetables (egg plant, hibiscus, etc.). Village groups deposit income from communal enterprises like the exploitation of a mill, income of a grain bank, income from sales of the harvest of communal fields, etc. Village mills, grainbanks, water pumps, etc. are often installed in a village on the condition that a bank account is opened in which the villagers regularly deposit money for repairs and also for the replacement of the goods after technical obsolescence.

The value of deposits on saving accounts does not increase with time as no interest is given so far. As a result, immediate monetary benefits from saving are absent. In fact the net value of the deposits decreases due to inflation.

Borrowing

Loans can only be acquired in the town of Manga. CECC applies the concept of *moral guarantee.* It forces village groups to repay their loans, even when some individual group members do not. When a village group does not repay, it looses its moral guarantee and thereby any future access to loans for any of its members. For the villagers, however, the advantage of

[3] Franc de la Communauté Financière Africaine, 100 FCFA = 1 FF = US$ 0.2

this concept is that even those without any personal possessions can get a loan if they are part of a group that has been accepted by CECC.

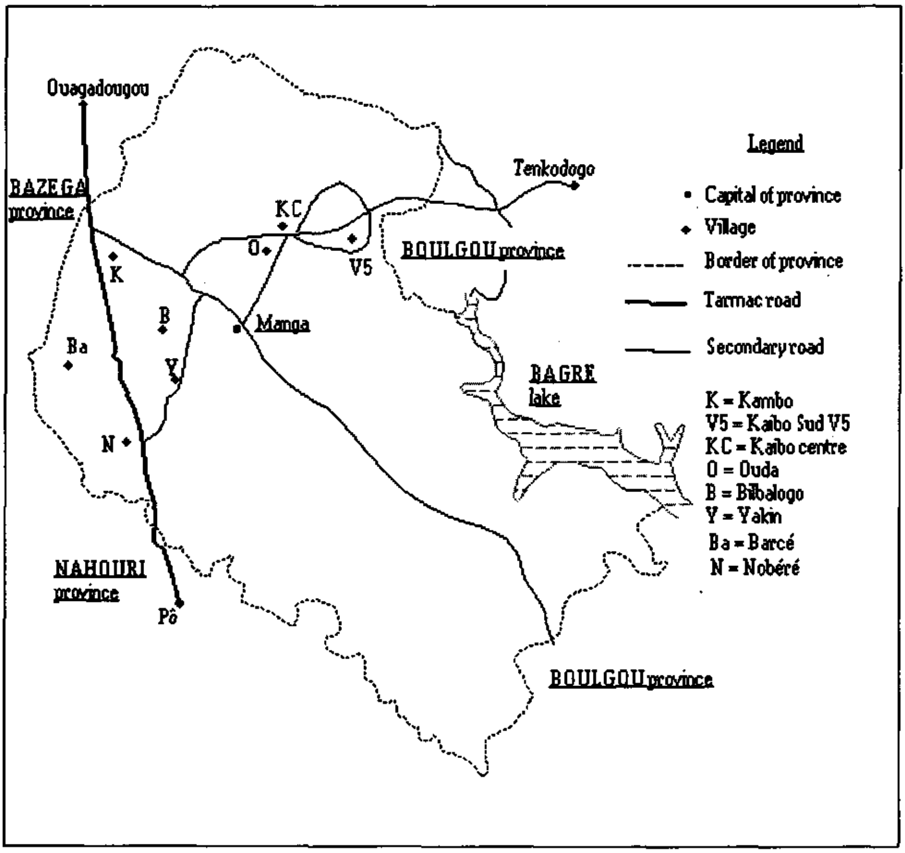

Figure 5.2.1: Zoundwéogo province with the studied villages

CRPA[4] helps village groups to write a credit request and provides the agricultural inputs and equipment while CECC judges the requests, provides the loans and is responsible for debt recovery. Due to the conditions on loans set out below, village groups dominate borrowing activities.

Four types of credit are available at CECC in Manga. These are for (i) financing the activities of male groups and collective economic enterprises such as mills, grain banks, shops,

[4] CRPA = Centre Régional de Promotion Agro-pastorale

(ii) female groups engaged in processing of agricultural produce, (iii) purchasing agricultural inputs, and (iv) financing small enterprises for individuals only.

Only clients without debts are considered for loans. Village groups must have a savings account at CECC or a COOPEC on which at least 10 % of the sum applied for is deposited. An annual interest rate of 12 % is charged. For loans to individuals, annual interest rates are 15 % and the applicant must submit a written application accompanied by a feasibility study on the profitability of the activity. One must have a legal pledge of 150 % of the amount applied for and a deposit of 25 % of the desired loan. The deposit must be placed at least six months prior to the loan application.

Viability of CECC and the COOPECs

With the existing conditions, loans may be provided that are several times higher than the savings held by the applicant. After repayment of the loan, the client generally spends the remaining benefit immediately, not depositing additional money in his account (Bosch *et al.*, 1994). The data presented in the rest of this paragraph results from the IFF evaluation study on CECC and the COOPECs (Table 5.2.1).

For CECC in Manga, about 50 % of the women's saving groups showed a balance of less than 10,000 FCFA a year in April 1995. About 80 % of the total of 213 saving groups showed a balance smaller than 50,000 FCFA a year. Of the 50 saving groups in Bilbalogo, 68 % of the men and 74 % of the women had a balance of less then 10,000 FCFA. For the 140 saving groups in Nobéré these figures were 81 and 66 % for men and women, respectively. These figures show that both CECC and the COOPECs reach many groups and individuals, each with only a very small contribution to the total savings volume. Although CECC recovers most of the loans, it will have difficulty to expand the volume of its capital, as most clients do not accumulate capital and do not deposit substantial amounts of money on savings accounts. This is confirmed by Soulama and Zett (1994) who generally observed in Burkina Faso a difficulty to mobilise and cumulate savings and consider it as a major development constraint.

PDI/Z is a donor-funded project and sooner or later it will end. As part of the project, CECC operates in a legal vacuum. To survive, CECC must become independent of the project and develop into a *caisse populaire* with the legal status of a co-operative, operating under the government charter. As such, it may continue the transaction of financial contracts with only little government supervision. To become independent of the PDI/Z project will be difficult, as CECC owed more than 63 % of its liabilities to the project at the end of 1994.

When only lending costs are considered, CECC should have required an interest of 23 % on each outstanding loan to cover these expenses. When operating and capital costs are also considered, with an inflation rate of 10 %, an interest of about 35 % would be necessary. The actual interest revenues on loans over 1994 were only 5.7 % of the outstanding loans. This is no problem as long as the project pays the lending, operating and capital costs. The calculated interest rates could decrease in the future when the loan volume increases, the fixed administration costs decrease and the capital utilisation percentage increases. Also low inflation rates can improve CECC's financial performance. However, lower repayment levels due to, for example, several years of low yields in a row, could endanger the financial position of CECC.

Although CECC clients in Manga consider the institution accessible, its market penetration is low. For loans, 10,125 adults out of the total of 90,000 in Zoundwéogo province are reached, i.e. 11 % only. For savings, CECC in Manga and the COOPECs together reach a penetration level of 9 % . Considering the lack of alternatives, these figures mean that about 90 % of the adult population is not reached by either financial institution. In addition, all savers show very low saving capacity with balances smaller than 10,000 FCFA.

The majority of farmers in Zoundwéogo province is not involved with COOPECs and does not have sufficient monetary resources to use their services. Most respondents stated that their savings only depended on their means of earning money, and not on interest rates. As the actual interest rate on deposits is zero, it will not motivate people to save much anyway. Under the circumstances, people prefer direct consumption over saving.

Considering the actual low market penetration and the low economic viability of the COOPECs and CECC, for both saving and the provision of loans, rural households apparently continue to rely on informal alternatives to these formal rural financial institutions.

Alternatives to formal financing

Farmers and herdsmen on the Central Plateau of Burkina Faso accumulate capital mainly in the form of grain stocks, livestock or both (Kaboré *et al.*, 1995; Slangen, 1986). These grain stocks and livestock are not only used as a source for consumptive expenditures and as investments, they also serve to insure the family against minor and major economic setbacks. These are not the only ways in which rural households attempt to achieve security. They can also do this, for instance, through social contacts with family, age groups and neighbours (Cashdan, 1985). Money, however, only plays a modest role in daily life, and livestock constitute a source of easily convertible capital for financing purposes.

According to Raijmakers (1993), also in Zoundwéogo province, non-monetary savings are at the same time a source of investment and an insurance. As such, they determine the farmers' management strategy. The IFM field study (Table 5.2.1) showed that Mossi households in Kaïbo Sud V5, a village in the AVV zone of Zoundwéogo province, distinguished four sources of finance: (i) accounts at CECC or COOPECs; (ii) loans from family, friends and neighbours; (iii) cereal production and storage and (iv) livestock keeping. Formal saving through CECC and COOPECs has already been described earlier in this paper. In the present section the three other forms will be discussed.

The IFM and FFI studies (Table 5.2.1) and the study of Bosch *et al.* (1994) showed that four important criteria have to be considered in choosing sources of finance: accessibility, liquidity, security and profitability. Accessibility means that the asset is within immediate reach: the saver can have it at his disposal at any time, at a short distance or both. Liquidity is a measure for the ease with which savings can be monetarised. Security implies that the asset cannot be taken by others without authorisation of the owner or be destroyed by fire, diseases or insects. With respect to loans, security from the borrower's point of view means the extent to which the borrower can be certain that he can obtain a loan from a money lender or a money lending institution whenever he needs it. From the money lender's point of view, security implies that the borrower has a collateral that can be monetarised or a moral guarantee. Profitability is the degree to which an asset increases in value or the interest rate on loans. In the next sections these criteria will be used to evaluate each source of finance.

Loans from family and friends

The IFM field study revealed that loans from family and friends are common. Access to this kind of financing is easy, as potential "moneylenders" are living nearby and are mostly already part of the social network (Breusers, 1996; Lallemand, 1977). Security from the borrower's point of view is fairly high as the borrower makes an appeal on solidarity and creates the prospect of reciprocity. Security from the lender's point of view is guaranteed, as people who do not respect agreements may be penalised by social isolation. There is no net benefit; transactions are based on reciprocity and interest is never charged. In case of calamities befalling individuals or individual households, everyone can and will contribute according to one's means either in kind or in cash. In this way a security in terms of insurance is provided. Reciprocity is a way of sharing risks, not a way of reducing it. It can only protect against an individual risk or a local scarcity in a situation in which the community or the region has not suffered the same problem (Cashdan, 1985). Reciprocity will e.g. not work when there is general crop failure in a vast region due to lack of rainfall or attacks of locusts.

Normally, only small amounts can be asked for, up to 1000 FCFA. These types of loans for larger amounts of money are not very popular, because the debtor will accept great social obligations to his creditor, such as the obligation to render certain labour services, and there is always the risk that a quarrel will start. Raijmakers (1993) mentions that small urgent cash needs, such as money needed for public transportation or for medicines, could be met through loans from neighbours, but that less urgent cash needs had to be covered by selling poultry or small ruminants.

Nowadays, society is increasingly monetarising: school fees, taxes (Imbs, 1987) but also medical care must be paid for in cash. When high monetary inputs are required, it will be more and more difficult to solve problems through social networks. Cashdan (1985) showed that in moments of crisis, solidarity tends to be restricted to the closest kin within families. Loans from more distant relatives and friends are extremely difficult to obtain in those situations.

Cereal production and storage

In the IFM field study, cereal production and storage were mentioned as another alternative source of finance. The practice of keeping grain stocks or savings in family or village stores is a long standing tradition in Burkina Faso (Slangen, 1986). As self-sufficiency in grain is the main objective of most farm households, grain can only be sold in case of crop surpluses (Kaboré *et al.*, 1995). Cereal cropping is hard work and in rainfed farming there is only one crop yield a year in Burkina Faso. All households have access to the means required for cereal production: land, labour and knowledge of the crops, in various degrees. Due to erratic and often insufficient rainfall and low and declining soil fertility, grain crop surpluses are generally small or absent. Each year between 1975 and 1988 for instance, cereal production on the Central Plateau of Burkina Faso was insufficient to feed its population (Schweigman *et al.*, 1988). Grain stocks have become insufficient to meet food demand in the slack season due to consecutive droughts (Slangen, 1986). Financing from grain is therefore fairly insecure. Grain storage can incur losses of as much as 10 % (Yonli, 1987), caused by rats and insects. Nevertheless, it is claimed that white sorghum can be conserved for as long as seven years without much loss. Buying up grain at harvest time to sell it later in the year, when prices have risen, is traditionally done by some women, producing small revenues. It is even possible for women to get a loan to undertake such an activity. Reasons for selling grain are sudden monetary needs to finance the purchase of medicines, ceremonies, travel expenses, etc. (Imbs, 1987). As other regular revenues or convertible products are absent, farmers tend to sell grain, even though they are aware that they will run out of food later on.

In order to make households less dependent on the grain market, they are encouraged by development projects to start a grain bank in their village. The bank buys grain from the villagers just after harvest, when prices are low. This grain is stored in the bank. When prices go up, villagers participating in the bank can buy grain at prices below the prevailing market price. After subsequent year's harvest, the bank buys again from the villagers to replace the stock sold. Another system allows villagers to borrow an amount of grain from the bank, under the condition that they replace the same amount after the next harvest. Grain banks are only successful when good and bad harvests alternate. Grain banks do not serve as a source of finance for different needs of individual households. They only provide relatively cheap cereals throughout the entire year and as such their existence does increase food security for households. The modest revenues from a grain bank might be used to finance community infrastructure or ceremonies.

Livestock keeping

In traditional livestock rearing in the Sahel, livestock increase in number and weight without high investment costs. It was for this reason that households, interviewed in the village of Kaïbo Sud V5, considered the risks of theft or death of livestock acceptable. Moreover, all livestock can be sold at any time in the village or to ambulant buyers and a livestock market is held every third day at only nine km from the village. Women cannot sell livestock themselves. They have to rely on mediation by a man, for which they have to pay a modest sum of 200-400 FCFA per small ruminant. Mediation not only adds some costs, but in general it also adds some risks as one is never sure to receive the full sale price. Livestock has other benefits, such as production of manure, milk and draught power. Delgado (1978) undertook a cost-benefit analysis of investments in cattle, including all benefits (reproduction, milk, manure) in the small town of Tenkodogo east of Zoundwéogo province. He calculated an internal rate of return of 20 % for cattle entrusted by Mossi farmers to Fulani herdsmen and rates varying between 25 and 33 % for cattle kept by the Mossi farmers on their own farms. On the financial market, ordinary investments never generate such high returns. Only high risk investment on stock markets or in real estate may generate comparable returns, but both options are absent in rural Burkina Faso.

Ten Mossi households, interviewed in the IFM study kept on average 14 small ruminants. In 1994, an average of 12 small ruminants per household were born. The interviewed Fulani households owned 56 head of cattle and 21 small ruminants on average. In 1994, 15 calves and 9 small ruminants were born on average per household. Herds appeared to have increased considerably with relatively little labour and without capital input, which suggests substantial profitability.

In Mossi society, cattle constitute accumulated wealth. Wage or trade income of family members, as well as income from migrants are often used to initiate or increase the family herd (Cissé, 1980). Displaying one's wealth is dangerous, as one could arouse another person's envy and run the risk of being cursed. By entrusting cattle to Fulani herdsmen, one's wealth can be hidden from fellow-villagers (Monod, 1975), but also from tax collectors (Cissé, 1980). An advantage of livestock is its mobility (Cissé, 1980). When rains are insufficient, herds can be moved to areas with sufficient fodder.

Discussion

The four criteria used to evaluate each form of financing will be combined in a rural financing multiple criteria matrix. With this matrix, the strengths and weaknesses of the various forms of financing can be compared and evaluated. In Table 5.2.5 the matrix is presented in which the various forms of financing are ranked from low (=1) to high (=4) for each criterion. Different forms of financing can have the same ranking for the same criteria. The ranking is based on the authors' subjective interpretation of the information presented in the preceding section.

Every household has access to grain and livestock, as these can be produced and bought freely. Everybody also has access to family and friends, but they form only a small circle and there may be no money available in this group. Access to the COOPECs and CECC is limited to those living in the same administrative region. Access to loans is subject to certain conditions. When one is member, access to savings is easy, but only on the days the offices of the co-operatives are open. Consequently, they rank lowest on accessibility.

Table 5.2.5 Rural financing multiple criteria matrix for four types of financing.

Criterion	Accessibility	Liquidity	Security	Profitability	Total
CECC & COOPEC	1	2	4	1	8
family & friends	2	1	3	2	8
cereals	4	3	1	3	11
livestock	4	3	2	4	13

Source: Judgement of the authors based on all presented data (1 = low, 4 = high)

Grain and livestock can always be sold on market days, either in the village or elsewhere. They have medium liquidity because markets are kept only once every three days and sales at a favourable price are not guaranteed. CECC and the COOPECs have less liquidity, because the COOPECs are open only one day a week for withdrawals. Withdrawals of large sums of money with the COOPECs have to be announced in advance because the money is safeguarded at CECC in Manga. Liquidity may therefore be a temporary problem. Borrowing from family and friends gives the lowest liquidity. Money is not always available, neither to give loans nor to repay loans. In fact, in most transactions only small amounts change hands.

Investing money in livestock is not very secure, due to the possibility of theft and mortality. An advantage is, however, that livestock can be moved to be hidden from fellow villagers. Therefore, it has intermediate ranking. Stored grain can be attacked by insects and claimed by relatives and friends. Moving the stock is difficult. Therefore, grain ranks lowest on security. Family and friends may try to escape their responsibility of helping out. They may also not respect promises made in better times. Therefore, one can never be completely sure to get a loan from them. However, as social control and reciprocity are strong, the risk of being turned down can be considered low. The COOPECs and CECC are fully secure.

Profitability of livestock is highest as internal rates of return can easily reach 20-30 % . Family and friends do not charge interests on loans, thus their ranking is intermediate. Grain does not increase in quantity by itself, but it might increase in value due to price fluctuations. Therefore, grain scores somewhat higher on profitability. CECC and the COOPECs give no interest on savings, but charge substantial interests on loans. Therefore they have the lowest ranking.

When scores are totalled for each alternative, giving equal weight to each criterion, it turns out that savings in livestock must be considered the most interesting option (score 13). The outcome can be fine-tuned in the future by using different scales per criterion and by giving the criteria different weights. Some farmers' statements (from the IFM study) may illustrate that they give a higher priority to investing in livestock than to depositing money in a bank account. According to them, before putting money in a bank, a number of goals have to be achieved first, as the following examples may illustrate: *"a number of animals and no debts; ten head of cattle plus money plus the perspective to make money in the future; having a good harvest and enough cereals to feed the family; a maximum number of animals and all problems solved; having enough to eat and surplus money as reserve".*

The same field study showed that farmers' attitudes towards CECC and the COOPECs were very positive, but as there were only five COOPECs in the province and many farmers were not well informed about their functioning, actual use of these institutions was low.

When, in 1980, 78 families in the AVV-Kaïbo zone were asked what they would do if they had a large sum of money at their disposal, 40 % mentioned investment in livestock (Murphy and Sprey, 1980). In general, surpluses from grain production and cash crops, such as cotton are invested directly in draught animals and additional cattle, as a means of capital accumulation (Lallemand, 1977). Small ruminants are regularly sold and their numbers in a household fluctuate enormously (Imbs, 1987, Lallemand, 1977). They are used for ordinary expenses, while cattle are only sold or slaughtered in extreme cases. Farmers invest (save) regularly in small ruminants, until they have a number which is sufficient to generate the money necessary to buy a head of cattle.

Conclusions

The rural financing multiple criteria matrix shows that livestock keeping is of considerable importance for the financing needs of rural households. In the absence of functioning formal financial markets, livestock keeping proves to be the most interesting alternative in Zoundwéogo province.

The formal financial market in rural areas might gain importance when the number of CECC and COOPECs in the province increases and when both their saving and credit services are available for more days a week, which would improve their accessibility and liquidity. However, they are only economically viable when the saving volume increases. Therefore they should try to attract more savers by informing them better and by offering interest on deposits, thereby improving their profitability. Clients may also be encouraged to increase their savings when they become aware that they can get a credit which is directly related to the amount of their savings on an account at CECC or COOPEC.

The value of grain stock as saving asset may be increased by better storage conditions. When infrastructure exists for transporting grain rapidly at low costs to areas where prices are high due to temporary deficits, general interest in grain stocks might increase further, because of their greater profitability.

The rural financing multiple criteria matrix is a useful tool to obtain a comparative picture of the strengths and weaknesses of the various forms of rural financing. The matrix may be used as a policy-guiding tool. Future research should focus on the fine-tuning of the approach.

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5.3 Assessing the financing and insurance capacity of livestock in mixed farming systems

Abstract

Keeping livestock may be a secondary activity in mixed farming systems in the tropics; it is nevertheless important, not only for its productive functions, but also because it provides a suitable means for financing expenditures for consumption and investments and for insuring against contingencies. It can perform this function thanks to its capacity for asset diversification, asset accumulation, liquidity, resistance to inflation and accessibility for household members. Although the importance of this function is widely acknowledged, little has been done to assess its contribution in a systematic way. In this article costs and benefits associated with this function are quantified and the contribution of livestock to the farm household's financial strength is qualified by means of indicators derived from those commonly applied in financial analysis of enterprises. The presented approaches are expected to achieve a more transparent and comprehensive appreciation of the financing and insurance function of livestock in farm household management.

Keywords: Livestock; Financing; Insurance; Liquidity; Balances; Stocks

Introduction

Livestock provide various physical outputs. Through these outputs, however, livestock have also assumed socio-economic and socio-cultural functions other than mere production, such as capital accumulation, risk management, ceremonial functions and prestige. These functions are frequently listed and described in various terms in the literature on farming systems in which livestock play a role (Höfs *et al.*, 1995; Lhoste *et al.*, 1993; McIntire *et al.*, 1992). Whereas production and income from livestock raising have been extensively studied, quantified and modelled (Brouwer and Steenstra, 1994; Zemmelink and Brouwer, 1991; Dahl and Hjort, 1976), so far very little has been done to get a conceptually better underpinned and more quantitative grasp of the importance of these other functions, the work of Bosman *et al.* (1997) being a notable exception (see further below). Roeleveld (1996) mentions one of the most probable reasons for this persistent omission, when he states that such functions are difficult to measure and value. Yet, as argued by Jahnke (1982), in many cases they contribute much more to the understanding of livestock production systems than the production of meat and milk or the provision of farm inputs and traction.

In this article[1], a conceptual framework is presented, based on the ideas developed by Nibbering (1992), for the analysis of the socio-economic functions of livestock other than direct income generation. The existing terminology to describe these functions is diverse. We adopt, with Bosman *et al.* (1997), the terms *financing* and *insurance* to describe these functions, as they come closer to the financial nature and purpose of the operations involved than, for instance, saving or risk balancing. Financing involves conversion of part of the flock into disposable income (and vice versa) to enable households to regulate income and expenditure over time; insurance involves the maintenance of a capital stock embodied in livestock as a guarantee for offsetting shortfalls in earnings and unforeseen expenses in the future.

First, it will be shown that for assets to be suitable for financing and insurance operations they require certain qualities. Livestock in mixed farming systems appear to score generally well with respect to these qualities. The lower assets score on these qualities, the higher the cost when using these assets as a means for financing and insurance. The implications for a cost-benefit analysis of using livestock in financing and insurance will be discussed in the third section of this paper. In addition to these costs and benefits, one also wishes to assess the farm household's overall capacity for financing and insurance and the role of livestock therein. In the fourth section a number of balances and ratios are proposed to serve as indicators for this capacity. The paper concludes with some remarks on the use of the proposed approaches in research and development activities. The paper focuses on livestock in mixed farming systems in the tropics.

Qualities required for assets used in financing and insurance in mixed farming systems

In mixed farming systems, crop production and livestock production interact to a large extent and in a mutually beneficial fashion within a farm (Steinfeld and Mäki-Hokkonen, 1995). In these systems livestock may provide agricultural inputs, such as draught power and manure, and render the enterprise more productive and more secure, by using residual capacities of production factors with low opportunity costs such as non-arable land, excess labour and child labour, by converting crops and crop residues into high value animal products and by balancing production and market risks (Jahnke, 1982). Crop production, however, usually constitutes the core of the system. Mixed farming systems occur everywhere in the tropics varying from agro-pastoral systems with labour- and land extensive cattle raising in Africa and Latin America, to labour-intensive agricultural systems with zero-grazing in densely populated regions in Asia (Ifar, 1996; Mohammed-Saleem, 1995; McIntire *et al.*, 1992; Ruthenberg, 1980).

Assets to be used for financing and insurance in mixed farming systems require various qualities: liquidity, resistance to inflation, capacity for asset accumulation, capacity for

[1] We would like to thank Gerrit Zemmelink for his comments on an early version of this paper and Herman van Keulen for suggesting many editorial improvements in the text.

production differentiation, accessibility and controllability.

Liquidity relates to a firm's (household's) capacity to generate sufficient cash to meet its financial commitments as they become due, without disrupting its business operations (Penson and Lins, 1980; Hopkin *et al.*, 1973). This concept comprises two aspects: the possibility to withdraw resources from the system without disturbing it, and the facility with which these resources can be bartered, or converted into cash without significant price discount to obtain the required necessities. The resources that appear to meet these conditions best in mixed farming systems are livestock. Withdrawal of other assets such as land, equipment or housing would disrupt the farming business too much and markets for these assets may be less active, too much decentralised, or even non-existent. Their sales prices would not be favourable anyway because of the pressure of rapid liquidation. Food crops would be no alternative either. Both, crops and livestock usually have established markets and are easily converted into cash. In areas with little or inadequate infrastructure, markets for cattle may even be better organised, giving livestock an advantage over crops (Vale *et al.*, 1996). Most importantly, however, small subsistence oriented farmers producing no or small food crop surpluses will prefer not to part with their crop produce, as long as they have other assets at their disposal, because to store food crops is usually the safest way to achieve food security. In contrast, livestock products in mixed farming systems are generally not of prime necessity for households and livestock can therefore be withdrawn more easily. However, if too many animals are sold and not replaced soon enough, liquidation of the herd may have severe repercussions for the productive capacity of the farm system, because of the intermediate role livestock often plays in farm production by providing manure and draught power. Therefore, also livestock rarely have complete liquidity. Livestock is also *resistant to inflation*, a quality which is obviously not shared by cash and sometimes not even by bank savings under conditions of high inflation as often prevalent in developing countries.

If assets possess a *capacity for value increase* over time, they become more attractive for financing and insurance. Livestock have this capacity which is embodied in the growth and reproduction of animals. Annual crop production does not share this feature. Annual crops attain their value only within the limits of one fixed period in the agricultural season, i.e when the crop has reached maturity. Before maturity, the crop has little or no value, and when it is left in the field too long after maturity, it will deteriorate. Also, leaving aside price speçulations, storage will generally not add any value to the crop. This and the risk of storage losses make it desirable that, as an asset, the harvested crop be converted into a more durable, and if possible, more productive asset (Vale *et al.*, 1996). The increase in liveweight of livestock over time and its capacity for reproduction, however, provide farmers with a means to gradually and continually accumulate their assets. There are other farm activities that share this quality, such as timber production, but its value increase over time is much slower (Chambers and Leach, 1987). Raising livestock is also often found to be superior to saving money on a bank account, because net annual returns from livestock are higher than interest rates in the bank. Saving in the bank may even be less attractive when transaction costs, and other obstacles, farm households may experience in dealing with formal financial institutions are taken into account (Slingerland *et al.*, 1998).

If generation of certain assets can contribute to *asset diversification,* this would also strengthen the farm household's financing and insurance position. In mixed farming systems, keeping livestock does just that (Toulmin, 1993; Ruiz, 1982). Perhaps not in all, but at least in some respects, does livestock depend on production and marketing conditions that are different from those on which crop production depends. Therefore, when crop production is adversely affected by production or market disturbances, animal production may not be affected, or to a lesser degree. In other words, raising livestock side by side with crop production serves to spread production and marketing risks for the farm household, and thus renders its asset position more secure.

A high degree of *accessibility* and *controllability* of assets are equally prerequisites for being used in financing and insurance. Livestock are relatively accessible and controllable by farm households, or even by their individual members. Cattle sharing systems, such as found on Java, for instance, enable farmers without capital of their own to engage in animal production and obtain livestock (Solichin Abdul Wahab, 1996). Property rights on livestock are often more individualised than those on land resources or stocks of staple crops. There is less social pressure to share or to give away livestock than to share food or cash. Moreover, by entrusting livestock to other farmers or herdsmen, livestock owners can conceal their animals to prevent demands from others to share their wealth. The controllability of livestock as an asset may also compare favourably with that of savings in bank accounts. Here, complicated procedures, restrictive conditions and lack of transparency may reduce actual farmer's control of his or her assets (Slingerland *et al.*, 1998).

Apparently, the various qualities of livestock make them a relatively suitable means for financing and insurance for smallholders practising mixed farming. Compared to other assets, capital can be kept safely without losing its value, its value can even increase over time. Subsequently, it can be sold easily to acquire funds for investments or for consumption or for contingencies, allowing farm households to continue their operations without interruption. Inversely, livestock can be purchased easily when there is a need for conversion of less durable or less productive assets.

Disturbances in the farm household economy can, of course, be overcome by other strategies than through the liquidation of assets, for instance, by maintaining good relations with neighbours, relatives or patrons whose support may be relied on in times of need, or by having a relative, working in town in a permanent job, who sends remittances. The way in which a farm household system is run determines to what extent farmers actually need to reserve special resources for contingencies. Well-managed farms with good production strategies need to reserve less assets of high liquidity for security reasons than poorly managed farms. The latter have to withdraw more assets from productive investments or consumption or both.

Costs and benefits of using livestock for financing and insurance

If one is only interested in animal production and the associated income, a conventional cost-benefit analysis can be performed, taking into account the various intermediate and final livestock products and their services. Future costs and benefits can be discounted, based on prevailing time preference rates. The attractiveness of the enterprise can then be assessed on the basis of such criteria as Net Present Worth or Internal Rate of Return. There is extensive literature dealing with cost-benefit analysis of animal production (Dillon and Hardaker, 1980; Delgado, 1978).

However, these assessments do not consider the specific value livestock may have as a means of financing and insurance. Bosman *et al.* (1997) pay explicit attention to these functions and propose two ways for valuing the special benefits from financing and from insurance, respectively. The extra benefit derived from financing may be estimated by considering the costs of alternative ways of saving or of obtaining credit other than through the outflow of livestock, such as costs of operating a savings account, losses incurred when consumer goods, such as grains, are stored, or the costs of informal credit. For insurance, they propose that the capital embodied in the flock present on the farm, constitutes a potential to pay expenses, which must be seen as a form of security. The security value of livestock can then be considered equivalent to the insurance premium to be paid in situations where an insurance market exists. Estimation of this rate not only requires understanding of the household's perceptions of its future and thus uncertain financial obligations and its abilities to meet these, but also assessment of alternative insurance options. The financing and insurance benefits respectively, can be represented as follows (Bosman *et al.*, 1997):

$$B_f = b_f \, x \, (outflow \; x \; P_{meat})$$
$$B_i = b_i \, x \, (average \; stock \; x \; P_{meat})$$

in which:

b_f	=	financing benefit factor
b_i	=	insurance benefit factor
P_{meat}	=	price of meat

This idea of farmers saving money, by using their own resources instead of externally acquired resources, is theoretically sound, but in reality it may not be applicable and, moreover, in our view it is incomplete. Firstly, it may well be that the alternatives, on the basis of which these extra benefits are calculated, are not really considered by farmers for various reasons. The alternatives may not exist, are not perceived by the farmers or are rejected for reasons other than their estimated costs. If an alternative is not seriously taken into consideration, it ceases to be an alternative and should not be treated as such. The question of what rates to apply, then becomes irrelevant. Secondly, Bosman *et al.* (*op. cit.*) tend to treat the foregone costs of borrowing from the bank or taking out an insurance policy as benefits that can be added to the production value of livestock. This seems not very realistic. Foregone costs are real, in the sense that farmers take them into account in the decision process; they do no represent attainable income.

Most importantly, however, assessment of the benefits from financing and insurance by means of livestock, on the basis of foregone costs alone (Bosman *et al.*, 1997) seems incomplete. Using livestock for financing and investment may also entail extra costs that farmers would not incur, if they kept their animals for production only. These costs should also be taken into account. We would argue that both, the price of alternatives, if applicable, and the costs incurred when using livestock, have to be considered to properly assess the real gains (and losses) in using livestock for financing and insurance. Farmers may incur loss of production and income when they liquidate assets, such as livestock, for the purpose of financing or insurance. Five types of such costs can be distinguished, related to the qualities assets require to be useful for financing and insurance, as defined in the preceding section.

Liquidity costs may be incurred when the withdrawal of assets adversely affects farm production. For livestock the reason might be, for instance, that the sale of animals reduces the reproductive capacity of the flock or the capacity for animal traction and production of manure, reducing crop production. Farmers may adjust to the new situation, for instance by buying manure or using more manual labour, and thus avoid some of the damage, but in most cases they will nevertheless suffer net income losses. These losses constitute the liquidity costs of the asset. Clearly, these costs should be determined for a well-defined period, for instance one year, because in the long run, with more opportunities for adjustment, the farmer is likely to restore his initial asset situation. In the case of complete liquidity, liquidity costs would be zero, but this is a hypothetical situation, not likely to occur with any asset.

Timing costs refer to the quality of asset accumulation. These costs are incurred when assets with this quality, such as livestock, are used for investment and insurance, and not disposed of, given constant market prices, at the moment coinciding with maximum production benefits. The income thus foregone represents timing costs. Farmers are often willing to accept higher timing costs when livestock prices are increasing, because of their financing and insurance functions. Doran *et al.* (1979) found, for instance, that a rise in livestock prices induced a negative supply response. Optimal selling times vary from one situation to another, depending on relative resource scarcities at the farm and market prices.

Opportunity costs are connected with the condition of asset diversification. They comprise the income foregone when farmers could have allocated their resources more profitably to another activity than keeping livestock or any other activity. Under certain conditions, farmers may prefer to keep livestock for the sole purpose of availing of a source for financing and insurance, even if that would be suboptimal for them in terms of income earning. Note that keeping livestock for a longer time than necessary to obtain optimum production benefits, may also involve opportunity costs. However, in most cases opportunity costs of keeping livestock are likely to be small, as in mixed farming systems, the livestock component tends to use residual capacities of production factors. Opportunity costs of keeping livestock can be determined by calculating the loss (or gain) in income that would be associated with withdrawal of the resources required for financing a given good or service with livestock, from the livestock keeping activity, and made available for an alternative asset generating activity.

Market exchange and *inflation costs* account for losses due to changes in market prices and loss of real value. Livestock may be relatively safe from inflation, while keeping money in a savings account in the bank is not. Livestock, however, is not free from market price fluctuations and the terms of trade with staple crops may at times be very unfavourable for livestock, particularly when the former are scarce due to crop failure. Market prices may also be subject to other disturbances: while on the one hand market integration isolates livestock from local conditions, thereby enhancing the security value of animals, on the other hand it may subject livestock prices to large shocks caused by shifts in urban demand and exports (Fafchamps and Gavian, 1997). Here there are gains associated with using one asset and losses by using another. Also in the long run there may be changing terms of trades favouring one asset over another. Whereas with high market prices for livestock farmers may incur timing costs, with low prices they are liable to market exchange costs. Lastly, one could add *controllability*, *security* or *storage costs*, which refer to the costs of losses incurred by theft, insect or rodent damage, spoilage, etc.

The various costs incurred in financing and insurance can be looked at from two different perspectives, a short term perspective and a long term perspective. When looked at from a short term perspective, the production and asset situation of the farm household is considered fixed. Hence, we are only concerned with financing proper and the question is, what is the most efficient way of financing, selling available assets or resorting to external sources. The question to what extent farm households could undertake activities producing other or more assets which are more suitable for financing and insurance is not considered. In other words, only liquidity and timing costs are taken into account in the assessment; opportunity costs, inflation and market exchange costs, and security costs are not. This is the appropriate level for comparing the costs of financing by means of livestock with the costs of obtaining a loan from the bank. When looked at from a long term perspective, however, the farm household's production and asset situation is no longer considered fixed. In this situation we are concerned with capital accumulation or asset generation for financing and insurance. The central question now becomes what activities farmers could pursue to improve their financing and insurance position. Here, in addition to liquidity and timing costs, opportunity costs, security costs, inflation and market exchange costs become relevant. At this level one can compare capital accumulation through livestock with savings in a bank account or taking out an insurance policy.

Let us first look more closely at the short term perspective. To determine the efficiency of using livestock for financing, the costs incurred in using livestock for this purpose should be compared with the costs incurred in using alternative farm assets, or the interest payments and transaction costs if these sources are derived from outside the farm, such as credit. We may call this difference in costs, the Net Financing Benefit or Cost of livestock. Clearly, in this cost comparison approach, the purpose of financing is given and therefore not assessed.

Theoretically, in the case of a contingency, one should also include the zero-option, i.e. the costs associated with the damage caused to the household, would it not have (or use) any assets to cover the necessary expenses. It is assumed, however, that in the event of a major contingency, farmers will take action and will select the least cost option. Moreover, potential damage to the farm household economy is difficult to measure quantitatively, and does not make sense if this 'damage' would involve total collapse of the farm household.

The Net Financing Benefit or Cost (F_l) of livestock (l) compared to another farm household asset (a) can be expressed as:

$$F_l \quad = (L_a + T_a) - (L_l + T_l) \qquad [1]$$

in which:

L = liquidity cost

T = timing cost

The Net Financing Benefit or Cost (F_l) of livestock (l) compared to an external asset (such as credit, e) can be expressed as:

$$F_l \quad = (P_e + A_e) - (L_l + T_l) \qquad [2]$$

in which:

P = interest payments and administration costs

A = transaction costs

Now let us take the long term perspective. To determine the efficiency of using livestock for capital accumulation with the aim of financing and insurance, a similar comparison can be made, including the opportunity costs. The opportunity costs of an activity, generating a certain amount of asset A, consist of the increase in net income from the activity generating asset B, for which resources have been re-allocated from A to B. Instead of comparing costs, it is more convenient to take the direct approach of comparing net income differences of two asset-generating activities, after subtracting liquidity and timing costs for each. We may call the resulting balance the Net Saving Benefit or Cost (S_l) of livestock (l) which for comparison with an alternative farm household asset (a), can be expressed as:

$$S_l \quad = \quad (\Delta I_l - L_l - T_l) - (\Delta I_a - L_a - T_a) \qquad [3]$$

in which:

ΔI = difference in net income before and after re-allocation of resources, under optimal timing

The Net Saving Benefit or Cost (S_l) of livestock (l) compared to an external asset (savings in a bank account, e) can be expressed as:

$$S_l \quad = \quad (\Delta I_l - L_l - T_l) - (\Delta I_e - P_e - A_e - T_e) \qquad [4]$$

Generally, the larger the Net Saving Benefit of livestock, the more attractive it is for farmers to use livestock as a means of capital accumulation.

So far, it has been assumed that the costs incurred are actual costs and, therefore, the Net Saving Benefit or Cost expresses the actual gain or loss of asset sales by which farmers solve their financing and insurance problems. However, we are perhaps even more interested in how farmers arrive at their decision. Hence, productivity risks, storage risks and market risks need to be incorporated in the balance. Productivity risks refer to the probability of crop failure; it can be calculated on the basis of stochastic yield distributions. Storage risks refer to the risk of losses due to spoilage or theft. Market risks refer to the risk of inflation and price fluctuations. In this way storage, market exchange and inflation costs, defined in the preceding section, are also incorporated in the balance. Productivity risk and storage risk affect net income differences. Liquidity is also affected by these risks, because with increasing productivity and storage risks, the chance that the farm household will be confronted with liquidity costs becomes smaller. Market and inflation risks only affect net income differences and timing costs and do not affect liquidity costs, because these are not so much related to the value of the asset, but to its functions in the farm household system. The two types of risks can be introduced using probabilities. For each asset-generating activity, a number of output levels and market price levels (states of nature) can be distinguished. Each level is multiplied by a probability. Probabilities vary between 0 and 1. If a probability equals 0, the income or cost level concerned does not occur. If it is 1, only that level occurs. For each activity, the sum of the probabilities is always 1. The risk-adjusted Net Saving Benefit or Cost (S'_l) of livestock (l) compared to an alternative farm household asset (a) is:

$$S'_l = \sum_j \sum_k ((\Delta I_{jkl} - T_{jkl})m_j - L_{kl})p_k - \sum_q \sum_r (\Delta I_{qra} - T_{qra})m_q - L_{ra})p_r \qquad [5]$$

in which:

ΔI = difference between net income from livestock before re-allocation of resources and net income from livestock after re-allocation of resources under optimal timing

p = productivity and storage probability for livestock (k) and an alternative asset (r) respectively

m = market exchange and inflation probability for livestock (j) and an alternative asset (q) respectively

In the case of livestock the summation of k possible productivity and storage levels will produce a probability factor of 1 and the summation of j possible market exchange an inflation levels will also produce a probability factor of 1. In case of an alternative asset the summation of r possible productivity and storage levels will produce a probability factor 1, and the summation of q possible market exchange and inflation levels will produce a probability factor of 1 as well.

A similar comparison can be made between livestock and assets from external sources. Evidently, it only becomes meaningful to incorporate risk in the balance, if it differs considerably between livestock and the alternative asset. Many different rules and theories have been developed to provide ways of ranking the resulting income distribution (Hazell and Norton, 1986). It is beyond the scope of this article to deal with this subject. It suffices to indicate how risk could be incorporated in the assessment.

To what extent keeping livestock for insurance purposes compares favourably with taking out an insurance policy, depends on the Net Insurance Benefit or Cost (S^i_l) presented below. For the sake of simplicity, it is assumed that farm households have no access to savings accounts.

$$S^i_l \quad = \quad (Vyn - V - L_l - T_l) - (Vyn - rn) \; = \; rn - V - L_l - T_l \qquad [6]$$

in which:

V = size of liquid reserves needed without insurance
y = annual rate of return, if invested in livestock
r = annual insurance premium
n = number of years passed until contingency occurs

The Net Insurance Benefit or Cost should be interpreted as follows: annual returns from the liquid reserve (Vy), livestock in this case, would have to exceed the annual premium (r) for an insurance policy to become interesting in the first place. Investing in livestock for the purpose of insurance is more profitable than taking out a policy, when total earnings from livestock after subtraction of liquidity costs, timing costs and the costs necessary to reconstitute the flock after the contingency, exceed net benefits gained by taking out an insurance policy during the same period. Note that in this equation the incremental effect of re-investment of income into the asset, generating capital, has been ignored. The Net Insurance Benefit or Cost expresses the expected gain or loss in using livestock for insurance. Risk can be introduced similarly into the Net Saving Benefit or Cost equation. In addition to probabilities for production output and market prices, probabilities also need to be included for the contingency.

Financing and insurance costs of livestock may vary according to the timing of the sale of the asset for instance. This is particularly true for livestock. In the optimal situation, all these costs may be nil for livestock. This may give livestock an additional advantage over those alternative assets that will always incur costs, when used for financing and insurance, stocks of staple crops for instance, the selling of which would involve high liquidity costs, if farm households have no surpluses. It certainly gives livestock an extra advantage over external assets, for the latter will always involve transaction costs.

Assessing the contribution of livestock to the farm household's overall capacity for financing and insurance

In the literature, diversification of farm activities as a risk spreading strategy has been treated extensively. When yield and price probabilities of each activity, the correlation between the yield and price probabilities of all activities, the farmer's risk attitude and the farm household's resource endowments are known, it is possible to estimate how much the farmer should invest in each activity (Upton, 1996) to minimise the overall production risk. It does not, however, address the issue of the capacity of farm households to deal with setbacks, *when they occur*, by selling off assets.

The sale of assets is only one of the measures that add to the farm household's risk bearing capacity for financing and insurance. Other possibilities are the ability to borrow, the ability to enter into agreements or contracts, and the ability to reduce operating and living expenses (Murray and Nelson, 1961). However, in the following discussion we will confine ourselves to the sale of assets and the farm household's asset position. We distinguish two main assets, livestock and grain stock. We use the term grain stock as shorthand for stored staple crops: it may also include tuber crops, for instance. Grain stock, however, is not only an asset; it is also the principal object of livelihood security which has to meet a basic need of the farm household. Therefore, in a way of speaking, grain needs share the character of what in financial analysis is deemed a 'liability', which has to be met. It is a liability a farm household has to itself. In the following we will treat it as such.

Generally, the more livestock a farm household can keep with a given amount of grain stock, the greater the contribution of livestock to its capacity for financing and insurance. A simple indicator of the role of livestock in this respect could then be the livestock/grain stock ratio. However, this would not be very informative, because farm households showing the same ratio may still show a wide range in total asset value. A meaningful way to examine the farm household's capacity for financing and insurance, based on its asset position, is to introduce a balance sheet -also called net worth statement or finance statement- comprising the farm household's assets (crops, livestock) and liabilities (food needs, cash needs), and comparing them by means of ratios. The use of ratios is common practice in financial analysis, where they serve as vital signs in monitoring the financial strength of the enterprise. Ratios can be used to judge the development of an enterprise by comparing its present ratio value with values at earlier stages of its development or they can be used to compare a given enterprise with similar enterprises. Finally, they could also be used as indicators of the farmer's position with respect to some norm, although the desired norms and acceptable deviations are less well defined for mixed farm enterprises (Penson and Lins, 1980).

The contribution of livestock to the farm household's liquidity position

It is common practice in financial analysis to distinguish between short term and long term assets and liabilities. In our case this distinction also seems useful. The short term or current assets and liabilities hinge on the liquidity position of the enterprise and thereby on its capacity for financing, and so it does for farm households. Current assets include cash, grain stock in excess of a minimum held for security, and added value of livestock. Added value of livestock is defined as that portion of livestock that can be sold without jeopardising the viability of the herd, and, what is more important in mixed farming systems, without jeopardising the productivity of crop cultivation to which livestock contributes indirectly. The current liabilities largely consist of food needs and other recurrent needs, such as cash for paying taxes and school fees. Food needs can be satisfied either by on-farm cereal production or by purchasing grain.

A balance sheet comprising all assets and all liabilities of the enterprise is made at a fixed point in time, usually at the end of the year. However, the usefulness of a balance sheet is generally quite limited in agriculture, because the food produced and cash generated from sales of products during the year, which are therefore not in inventory at the beginning of the year, usually by far exceed the cereal, cash and other current assets that farm households hold at the beginning of the year. Likewise, most of the needs, if not all of them, that have to be satisfied by the farm household, in the course of the year, are not included in current liabilities at the beginning of the year. Even if another date would be chosen for drawing up the balance sheet, the problem would remain basically the same. Hopkin *et al.* (1973) state that under such circumstances a cash flow projection would be a more useful tool in liquidity analysis. In our case this could be a current asset flow projection, cumulative in nature, that starts out from the present asset position and subsequently projects the generation and flows of grain, cash and other current assets during one agricultural year. The situation at the end of the year would result in what is often called a pro forma balance sheet comprising the farm household's likely asset position. Comparison of the two balance sheets would indicate whether the farm household's asset position is likely to change. However, apart from examining how the farm household's asset situation will develop, we also need the asset flow projection to assess what the role and capacity of livestock in managing the farm household's liquidity position will be in the course of the balance year. On the basis of the current asset flow projection, a balance can be drawn up which we will call the Liquidity Balance, comprising current assets in stock, added value of livestock and other current assets produced during the year minus current needs. The assets used and the needs satisfied are valued in cash. Food needs satisfied from the farm household's own production (and the assets used for this) need not be valued in monetary terms, as on the balance their outcome is zero. The final balance shows the farm household's asset position at the end of the year (the pro forma balance sheet). Two ratios can be derived from the Liquidity Balance indicating the farm households' *relative* liquidity position *at the end* of the year and the contribution of livestock to the farm household's liquidity *in the course* of the year.

Liquidity Balance =

current assets in stock[a] *+ added value livestock*[b] *+ current non-livestock assets produced*[b] *- current needs*[b]

Current Ratio =

(current assets in stock[a] *+ added value livestock*[b] *+ current non-livestock assets produced*[b]*)/current needs*[b]

Livestock Production Ratio =

(current assets in stock[a] *+ current non-livestock assets produced*[b] *- current needs*[b]*)/added value livestock*[b]

[a] at the beginning of the year; [b] in the course of the year

When the Liquidity Balance is positive, it might be considered the farm household's working capital at the end of the year. It represents the farm household's capacity for investment and for dealing with minor contingencies. The problem with this balance is, that needs and quantities of assets produced and prices are not known beforehand with certainty and should be estimated. This could be done on the basis of last year's production, taking into account any factors expected to cause differences. Another difficulty is to establish at which price or prices assets in the balance, not used for liabilities should be valued. The best solution would probably be to use average prices calculated over one year. When the balance is negative, it could mean that the farm household might consider using some of its long term assets (livestock, land) to finance current needs, which may negatively affect the productivity of the farm.

Whereas the Liquidity Balance gives an indication of the absolute values of either a surplus or a deficit of current assets vis-à-vis current needs after one year, it does not relate these values to the farm household's total current assets. For this purpose the Current Ratio can be used, that allows comparison of the farm household's relative liquidity with that of other farm households. For instance, farm household A which has a large negative liquidity balance may still have a higher Current Ratio than farm household B, because A's total current assets exceed those of B.

The Livestock Production Ratio is an indicator of the contribution of livestock to the farm household's liquidity base during the year under consideration. When the Livestock Production Ratio is negative, it means that the household will at any rate be dependent on part or all of the added value of their livestock to cover current needs, while the value of the ratio indicates what portion of the livestock will be required. If the ratio is positive, livestock will not necessarily be required to meet current needs, and the value of the ratio indicates how much of the other assets -expressed as a proportion of the added value of livestock- may be lost before that is required. The more positive the ratio, the more freedom the farm household will have in using its livestock.

The contribution of livestock to the farm household's food security position

In financial analysis, the long and medium term assets and liabilities affect the solvency of the enterprise. The basic issue for semi-subsistent farm households in mixed farming systems in the tropics is of course not solvency, but food security, and on this basis assets and liabilities have been defined. In the long run, the household's food security position may be treathened severely by crop failure. So, it is about the farm household's capacity to cope with such a disturbance, or, in other words its capacity for insurance against it. Therefore, a Food Security Balance has been conceived, in which current assets as well as long term assets are presented, including grain reserves and unsold cash crops farm households may have kept in stock, and the total asset value of livestock, rather than added value. Certain long term assets, such as land, have not been included, because often no market exists, and where they could be sold, their sale would mean a severe disruption of the farm household. Other long term assets such as luxury goods or equipment can be included. The long term liabilities only consist of food needs as other requirements are unimportant in times of great stress. Contrary to the farm household's liquidity position, a balance of long term assets and long term needs at a fixed point in time is meaningful. The long term needs, however, are defined as food needs during one year. The most appropriate time for drawing up the balance would be just before the main harvest, because this indicates to what extent the farm household will be able to cope with crop failure. The following balance and ratios can be defined:

Food Security Balance =
grain stock + cash crop stock + livestock asset value + other long term assets - food needs

Food Security Ratio =
(grain stock + cash crop stock + livestock asset value + other long term assets)/food needs

Livestock Capital Ratio =
(grain stock + cash crop stock + other long term assets - food needs)/livestock asset value

The interpretation of the balance and ratios is similar to that of the liquidity balance and ratios. The value of food needs should of course be that associated with crop failure (soaring food prices).

The major problem with these liquidity and food security indicators is, that households with less assets will scale down their needs and vice versa as part of their risk-coping strategies. As all indicators, they only cover part of the farm household's socio-economic situation, and one should always keep an open eye and mind for factors that cannot be covered.

Conclusion

We have proposed a more objective and comprehensive assessment of the role of livestock in financing and insurance. These functions can only be accurately assessed, by not only looking at foregone costs of external sources of financing and insurance, but by also taking into account the costs incurred when livestock is used for financing and insurance and compare them either with the costs of those external sources or -and this will usually be more likely- the costs incurred when farm households use other assets. For assets to be suitable for financing and insurance, they need to have a number of qualities. Livestock combines these qualities to a large extent. Hence, livestock has relatively low financing and insurance costs compared to other assets. This explains why animals are such a popular means in financing and insurance operations.

In addition to proposing an approach to assess the costs and benefits of individual financing and insurance operations, a framework has been designed to assess the overall capacity of farm households for financing and insurance and the contribution of livestock to this capacity. The socio-economic context in which it will be used should be well-known and it should not discourage users from examining other factors that may influence the risk-coping capacity of farm households.

The two approaches should be used as tools in trying to better grasp how farm households are dealing with their resources, and with livestock in particular. They can also be used to diagnose problems and give clues to possible solutions in the area of financing and insurance. They may help to detect ways to better balance income generation, investment and security, taking into account the probability of contingencies, and the perceptions about and attitudes of farmers to the associated risk. Clearly, the next step would be to actually try to apply these approaches to test their relevance. Operationalisation of the various costs and concepts, such as added value of livestock, however, entails various problems and may sometimes have to be solved arbitrarily. If this is done in a transparent and consistent manner this does not matter: the final outcome may still be more useful than merely descriptive comparisons. We would like to invite interested researchers and development workers to take up this challenge.

Even when the proposed approaches appear difficult to apply, at least this should have become clear: although from a production point of view, keeping livestock may seem to be uneconomic, this may be only because livestock is also used as a means of capital accumulation, financing and insurance. In the context of the whole farm system and its social, economic and institutional environment, livestock management may be the most sensible and most effective way, and it may be the best method to keep the farm household economy going in the long run. To ignore that livestock has other functions than production is to ignore farming reality. To treat livestock only as an isolated economic enterprise, without trying to come to grips with the more strategic roles of livestock in farm household economies will hamper understanding of the dynamics and therefore the performance of those farm household economies.

5.4 Livestock and short term financing for mixed farming households in Burkina Faso: Zoundwéogo and Sanmatenga provinces

Abstract

The importance of livestock in mixed farming systems - particularly in the Sahel - is being stressed continuously. Farm households in these systems particularly appreciate the role of livestock for financing of their foreseen and emergency cash needs. However, very few attempts have been made to actually quantify the value of livestock in the framework of a whole farm analysis. This paper quantifies two conceptional approaches to assessing the role of livestock for farm households in Burkina Faso: (i) by comparing financing through livestock to financing through loans from financial institutions. The main concepts in this comparison are liquidity and timing costs, (ii) the contribution of livestock to cash flows and assets of various household types is quantified. Results presented in this paper suggest that taking a loan at a bank is preferable to using livestock for financing, but farmers often have no choice, but use the latter. The applied sales strategy showed that farmers realise the differences in costs to the total farm when selling different categories of animals. The relative importance of livestock to cash flows and assets varied considerably between Fulani and Mossi households, but also among different types of Mossi households.

Introduction

In developing countries, livestock plays various roles for rural households. Milk and meat are the most important products, but livestock also play a role in social and cultural life. In mixed farming systems, common at many places in the world, livestock may provide agricultural inputs, such as draught power and manure (Ifar, 1996; McIntire *et al.*, 1992). It may render the enterprise more productive and more secure by using residual capacities of production factors with low opportunity costs, such as non-arable land, excess labour and child labour. Livestock can also convert crop residues into high value animal products and allow an enterprise to balance production and marketing risks (Jahnke, 1982). When farmers grow cash crops, such as cotton in Burkina Faso, revenues are generally invested in cattle which than serve as a kind of savings account (Lallemand, 1977). In the Sahelian country Burkina Faso, with its erratic rainfall, livestock also serve to absorb grain surpluses and to compensate for grain deficits (Bayer and Waters-Bayer, 1991).

Functions of livestock for crop production

In Burkina Faso, pressure on croplands has increased (McIntire *et al.*, 1992; Bayer and Waters-Bayer, 1991) due to a population growth rate of 2.7 % per year in the period 1985-1994 (World Bank, 1996). The decline in fallow periods leads to an increasing need for manure in soil fertility management of the fields. The use of draught animal power can lead to higher crop yields (Nicou and Le Moigne, 1991) and hence contribute to feeding the growing population. In Zoundwéogo province in Burkina Faso, Mossi arable farmers are increasingly engaged in mixed farming, involving in particular draught bullocks and small ruminants. The number of compost pits in the province increased for instance from 258 in 1984 to about 4900 in 1993 and the number of ploughs and draught bullocks increased with 53 % between 1985 and 1991 (PDI/Z, 1993). In Zoundwéogo province, an average Mossi household without draught animals comprises 5 persons, cultivating 3.6 hectares of land, of which 0.2 ha cash crops. These households own 4 small ruminants on average. Mossi households with draught animals comprise on average 9 persons, cultivating 5.5 hectares of land of which 0.7 ha cash crops. These households own about 10 small ruminants and 7 head of cattle (Van Waveren, 1996). In Zoundwéogo province, Fulani herdsmen owned 65 % of all cattle and Mossi farmers owned 63 and 72 % of the total number of sheep and goats, respectively (ENEC, 1990). For Burkina Faso as a whole, average livestock numbers per capita remained 0.6 for cattle, 0.5 for sheep and 0.5 for goats (ENEC, 1990) between 1988 and 1995, despite the rapid population growth.

Function of livestock for financing

Almost 90 % of the population of Burkina Faso lives in rural areas and is economically dependent on agriculture. To stimulate rural development, a financial market is necessary, both to absorb and invest savings and to provide loans. The absence of a formal financial infrastructure, such as banking institutions in rural areas will force farmers to look for informal alternatives (Bosman and Moll, 1995).

In Zoundwéogo province, rural households distinguished four sources of finance: borrowing from family and friends, cereal production and storage, decentralised saving and credit co-operatives and livestock keeping. When these alternatives were compared with respect to their accessibility, security, liquidity and profitability, livestock appeared to be the most interesting alternative (Slingerland *et al.*, 1998). In this paper, the value of the financing function of livestock will be estimated in two ways.

Firstly, the costs incurred in exercising this function of livestock will be determined theoretically, after which these costs will be quantified and compared to those associated with taking a loan from a co-operative. The conceptual basis for these quantifications has been derived from a working document by Nibbering (1992). Secondly, the contribution of

Table 5.4.1 Studies executed in the Zoundwéogo province in the framework of the research programme "Management of Natural Resources in the Sahel".

Study	Informal Financing	Formal Financing	Animal Traction (AT)	Animal Production	Animal Market	Budget	Rural Market
Staff or student	A. de Ruiter	G.J. Prins	W. van Waveren	F. Elskamp	M.A. Slingerland	G. Tapsoba	J. de Graaff
Characteristics	Inventory of alternatives for financing, farmers' appreciation of each option	Financial evaluation of credit co-operatives	Inventory of characteristics of farmers with AT and without AT	Monitoring of production and reproduction of small ruminants	Inventory of prices related to animal species, sex and liveweight	Monitoring of household revenues	Monitoring prices of agric. products
Research site	Kaïbo Sud V5	Manga, Nobéré, Bilbalogo	30 villages in Zoundwéogo	Kaïbo Sud V5	Kaïbo, Nobéré, Gogo, Bilbalogo	Tagalla, Sidogo	Tagalla, Kaya, Manga, Nobéré
Period	1994 Sept-Dec	1994	1995	1994-95, once per 2 weeks	1994-95, 3 times a month per market	1997-98, once per 2 weeks	1993-96 3 times a year
Method	Interviews with heads of households and one of their wives	Analysis of financial administration	Interviews with heads of households	Interviews, observations, measurements	Interviews, observations, measurements	Interviews, observations	Measurements, interviews
Sample	10 Mossi and 10 Fulani households	3 co-operatives	Every village 2 hh with AT and 2 without AT	14 herds, 3 livestock systems	1500 animals 450 persons	22 households	10 women per product/market

livestock to a households' cash flow and asset position will be established and compared to the contribution of cereals. Data from several studies executed by the Wageningen University Research Outreach Station in Burkina Faso (Antenne Sahélienne) will be used (Table 5.4.1).

Costs incurred by using livestock as a means for financing

Using livestock for other functions than meat and milk production may adversely affect total farm production. Transforming livestock into money (liquid) may entail some costs, referred to as liquidity costs in this study. The sale of an animal can, for instance, reduce the reproductive capacity of a flock or the capacity for animal traction and the production of manure which may restrict crop production. The sale of animals also entails direct transaction costs. Timing costs are incurred when livestock is used for financing and for that reason sold at a time that, given constant market prices, would not be optimal from a production perspective. Other means of financing may also entail costs. Looking from a short term perspective, costs of financing by means of livestock (l) can be compared with costs of obtaining a loan from the bank (b) using the following financing balance(see section 5.3: [2]):

$$F = (P_b + A_b) - (L_l + A_l + T_l) \qquad [1]$$

Where:
F = financing balance
P = administration costs
A = transaction costs
L = liquidity costs
T = timing costs

Liquidity costs

Research in Zoundwéogo province, has shown that households, when money is needed, sell male or non-productive female small ruminants first, when they have a choice. These animals are not essential for reproduction of the herd and their absence has no influence on farm productivity. Only when a large sum of money is needed at short notice or no small ruminants are available or both, cattle other than draught animals will be sold (Section 5.1). Only in the most extreme cases draught bullocks will be sold (De Ruiter, 1995).

Farmers practising mixed farming in Burkina Faso, normally own two draught bullocks of about 250 kg liveweight each. An animal of 250 kg liveweight fed at maintenance level is defined as a Tropical Livestock Unit (TLU). About four months a year these animals are herded by Fulani herdsmen on waste land, implying a loss of 579 kg of manure for crop production (Table 5.4.2). The other months they are tethered on-farm and they graze either on fallow or on stubble land. The amount of manure produced in this period, 1097 kg, is considered available for crop production (Table 5.4.2), although 10 % may be lost during transport.

Table 5.4.2 Seasonal herding and feeding systems for draught cattle and their contribution to manure availability for cropping.

Period[1]	Months[1]	Herding and feeding system[1]		Excretion[2]	Manure[3]
	Number	Daytime	Night	g kg $LW^{-0.75}$	kg
Post harvest	2	Crop residues (field)	At home in paddock	47.2	357
Dry season	4	Natural vegetation	With Fulani	38.3	579*
Early rainy season	2	Crop residues (home) and on fallow	At home in paddock	37.4	283
Rainy season	4	Fallow	At home in paddock	30.2	457
Total for crop production	12				1097

[1] Field study
[2] Lhoste and Richard (1993)
[3] Assuming that a farmer owns two bullocks each with a liveweight (LW) of 250, thus $LW^{-0.75}$ of 63 kg
* 579 kg not available for crop production

A review of research in Burkina Faso has shown that application of 1000 kg of manure increased cereal production on average by 70 kg per ha (Sedogo, 1981; Dupont de Dinéchin, 1969). Thus, manure excreted by two Tropical Livestock Units (TLU) increases cereal production by 70 kg. Hence, manure of one goat, equivalent to 0.1 TLU increases cereal production by 3.5 kg. With average cereal prices between 1993 and 1996 of 80 FCFA[1] per kg for the main cereals, the additional production can be valued at 5600 and 280 FCFA, respectively.

[1] 100 FCFA = 1 FF = 0.16 US$

Table 5.4.3 Additional yields per crop due to the use of animal traction for soil preparation.

Crop	Product	Number of experiments	Additional yield[1]		Distribution[2] of crops on farm	Total gain[3] of grain per farm	Average price per kg (1993-1996)[4]	Total gain per farm
		N	kg ha^{-1}	%	%	kg	$FCFA^{5}\ kg^{-1}$	FCFA
pearl millet	grain	55	225	18	52	644	89	57,316
sorghum	grain	84	464	27	35	893	73	65,189
maize	grain	56	1089	54	1.4	84	66	5,544
rainfed rice	paddy	29	969	71	0.7	37	ND*	ND
cotton	grain	26	236	17	1.5	19	ND	ND
groundnut	pods	79	215	20	4.5	53	114	6,042
TOTAL					100			134,091

* ND = no data available

[1] Nicou and Le Moigne (1991)

[2] Estimated crop surfaces in Zoundwéogo province for the 91/92 season (PDI/Z, 1993)

[3] Total = 5.5 (ha) x area (%) x additional yield (kg); 5.5 ha is the cultivated area for households owning AT equipment

[4] Study on rural markets (cf. Table 5.4.1, De Graaff): Prices for Manga

[5] 100 FCFA = 1 FF = 0.16 US$

A review of experiments in Burkina Faso has shown that animal traction increased cereal production by 17 to 27 % (Nicou and Le Moigne, 1991). A pair of bullocks can plough 5.5 hectares annually. In Zoundwéogo province, ploughing leads to an average increase in income of 134,091 FCFA per farm, given the average farm plan and crop value in the area (Table 5.4.3).

Liquidity costs for two bullocks can be estimated as loss of manure, 5,600 FCFA, and loss of animal traction, 134,091 FCFA, thus 139,691 FCFA in total. Liquidity costs for one bullock will be half this amount, assuming that one bullock can plough and weed half the surface of two bullocks. Liquidity costs for a small ruminant entail the loss of manure, i.e. 280 FCFA. The calculated liquidity costs are in fact maximum values, as farmers may restrict the losses by hiring or borrowing draught bullocks or buying fertiliser. Liquidity costs are calculated for one year, because farmers in the Sahel tend to plan per cropping season.

Direct transaction costs for selling are 1000 FCFA for a cow and 200 FCFA for a sheep or goat (study on animal market cf. Table 5.4.1).

Timing costs

It is assumed here, that sales price equals net benefits. No costs are involved in keeping animals, because they have free access to common grazing lands, and herding and watering of the animals is done by family members, mostly children, whose labour has no opportunity costs. Veterinary costs are negligible, consisting of one vaccination per animal at most. Sick animals are left to heal or die, or they are slaughtered.

From March 1994 through March 1995 fourteen small ruminant herds were monitored (Elskamp, 1995). Culling policy within these herds can be considered appropriate, since for the age class 0-6 months the male-female ratio was still 1, whereas it was between 0.1 and 0.2 for the age class 6-18 months. Four herds had only one adult ram and six herds had none. The few animals that might have been culled earlier were herded with other animals, which therefore did not entail extra herding costs, and no other inputs were provided. Costs associated with delayed sales can therefore be ignored.

Costs associated with premature sales, because of foreseen or unforeseen cash needs are, however, important. Adult liveweight for sheep and goats was 35 kg. A market study from September 1994 through September 1995 (cf. Table 5.4.1) indicated that average weight at sale was only 15 kg and that the relation between animal liveweight and prices for sheep could be represented by equations 2 and 3 (see section 5.1: Eqns [1] and [2]).

$$\text{Ewe Price} = -1291 + 434\ \text{LW}\ (N = 183, r = 0.83) \quad [2]$$

$$\text{Ram Price} = -1881 + 491\ \text{LW}\ (N = 678, r = 0.80) \quad [3]$$

Prices for animals of 15 kg liveweight were 5200 and 5500 FCFA, and prices for 35 kg animals 13900 and 15300 FCFA for ewes and rams, respectively. Early sales can thus entail timing costs of 8600 and 9800 FCFA per ewe or ram, respectively, based on liveweight only.

An alternative way to calculate timing costs is to take into account animal age, mortality rates and animal weight. Efdé (1996) quoting Brody (1937, 1945) uses equation 4 to describe the relation between age and liveweight as a function of adult liveweight.

$$W = W_a \times \left(1 - \frac{0.67}{e^{0.78(y-0.5)}}\right) \qquad [4]$$

in which:

W = actual liveweight

W_a = adult liveweight

y = age in years

The national livestock service quotes average mortality rates per age class of 17.4 % for year one, 7.5 % for year two and 10.9 % from year three onwards (DEP, 1990). Combining equations 2, 3 and 4 allows to link animal age to sales price. Table 5.4.4 gives the relations between age, sales price, mortality and real revenues for rams and ewes.

For sheep, 15 kg of liveweight is attained at an age of about 9 months (0.75 year) with a sales price, corrected for mortality, of 4580 FCFA for rams and 4367 for ewes. At four years of age real revenues decline due to mortality, thus animals should be sold before that time. At three years of age optimum benefits would be realised at a sales price of 9302 FCFA for rams and 8496 for ewes. Maximum timing costs would then amount to 4722 FCFA for rams and 4129 FCFA for ewes.

It must be realised, that these calculations are only valid when there are no constraints on input availability as in the situation of Burkina Faso. When availability of fodder or labour for herding is, for instance, a constraint, it is much more attractive to keep three young male animals for one year than one animal for three years, because young animals grow fast and require low feed inputs for maintenance, whereas older animals grow slower and are more expensive in terms of maintenance level. The sales prices are 18,600 (3 x 6200) for three animals at one year of age and 9300 FCFA for one animal at three years. The three young ones can also be herded together taking one year of labour input whereas the old one would take three years of labour input.

Finally, female reproduction rate can be taken into account in the calculation of timing costs. For ewes, sale of an adult animal, still in the reproductive stage, can be considered premature. The age of females at first parturition is about 15 months. As many as 95 % of all females in the herd is younger than 6 years and they give birth to on average 1.03 lambs per ewe per year (Elskamp, 1995). Timing costs are now defined as missed offspring due to early sale. As an estimate for the value of offspring the price at six months of age, calculated with equations 1, 2 and 3 is proposed. The values are 3725 FCFA for female and 3784 FCFA male offspring or an average of 3755 FCFA. Average timing costs for loss of offspring then equal 1.03 x 3755 or 3867 FCFA for the households in the study. These timing costs are calculated for one year, because it is unrealistic to extend these costs to the x^{th} generation and because costs (and benefits) in the far future have generally lower value than in the near future.

Table 5.4.4 Expected revenues for rams and ewes based on growth, mortality rates and market prices for 1994 -1995.

Age (years)	Sex	Sales price[1] (FCFA[4])	Mortality[2] (%)	Perc. alive (%)	Real[3] revenue (FCFA)	Loss (FCFA)
0.75	ram	5480	17.4	82.6	4580	900
1	ram	7497	17.4	82.6	6200	1300
2	ram	11715	7.5	76.5	8962	2753
3	ram	13647	10.9	68.2	9302*	4345
4	ram	14536	10.9	60.8	8838	5698
0.75	ewe	5280	17.4	82.6	4367	913
1	ewe	7013	17.4	82.6	5863	1150
2	ewe	10748	7.5	76.5	8222	2526
3	ewe	12458	10.9	68.2	8496*	3962
4	ewe	13245	10.9	60.8	8053	5192

[1]Study on animal market (cf. Table 5.4.1) from September 1994 through September 1995 in Zoundwéogo province

[2]DEP(1990)

[3] Real revenue = sales price x fraction alive (for whole years)

[4] 100 FCFA = 1 FF = 0.16 US$

* Highest revenues (inflection point)

Costs involved in loans from banks

To make use of services provided by a local credit and savings co-operative one has to be a member. Costs involved are 1000 FCFA to open an account (only once), 300 FCFA for a membership card (only once) and annual administration costs of 200 FCFA (Prins, 1995). Thus, P_b in equation 1 equals 1500 FCFA when farmers take out membership of such a co-operative to apply for a loan in the same year. Interests on loans are 15 % a year for individuals. The client must have a deposit of 25 % of the loan and a legal pledge for 150 % of the amount applied for.

Examples

In Table 5.4.5 a summary of all results is given to elucidate the following examples.

Table 5.4.5 Summary of the results of the calculations (in FCFA[1]).

Animal species and sex	Ewe	Ram	Draught bullock (a pair)
Liquidity costs			
* direct transaction costs	200	200	2000
* indirect costs:			
- loss of manure	280	280	5800
- loss of animal draught power			134091
Timing costs			
- based on weight and prices at sale	8600	9800	Not Calculated
- based on weight, age, mortality and price	4129	4722	
- based on loss of offspring	3850		

[1] 100 FCFA = 1 FF = 0.16 US$

Example 1

Suppose that a household needs 12,000 FCFA to buy cereals. It may sell two rams of one year of age and about 15 kg each. The balance equals:

$$F = \{P_b \quad + (A_b \qquad)\} - \{(L_l \quad) + (A_l \quad) + (T_l \quad)\}$$
$$F = \{1500 + (15\,\% \times 12{,}000)\} - \{(2 \times 280) + (2 \times 200) + (2 \times 4722)\} = -7{,}104 \text{ FCFA}$$

When no rams are available two ewes must be sold. The balance equals:

$$F = (P_b \quad + A_b \ ) - \{L_l \quad + A_l \quad + (T_l)\}$$
$$F = (1500 + 1800) - \{560 + 400 + (2 \times 4129 + 2 \times 3867)\} = -13{,}652 \text{ FCFA}$$

Example 2

Suppose that 140,000 FCFA is needed to pay for medical expenses. Either 10 adult (4 years of age) or 20 younger (1 year of age) small ruminants can be sold, if available. However, herds of small ruminants for average farm households in Zoundwéogo province comprise 5-10 animals, of which many are young. Their sale will therefore not generate the necessary amount of cash. When no money can be found through other channels, such as loans from family and friends or sales of cereals, the only option is to sell a draught bullock. The balance is then:

$F = \{P_b \quad + (A_b \qquad\qquad)\} - \{(L_l \qquad\qquad\qquad) + A_l \quad + T_l\}$
$F = \{1500 + (15\ \% \times 140{,}000)\} - \{(0.5 \times 5600) + (0.5 \times 134{,}091) + 1000 + T_l\} =$
$- 48{,}345$ FCFA

T_l is set to zero in this example, as the bullock is sold for financing, while the animal is at an age and liveweight that it can work well, representing the maximum value at sale. Timing costs associated with early sale are therefore not incurred.

When a bullock is still very young at sale, its working performance would be below maximum. The loss of crop production due to loss in traction will therefore be less. A younger animal will also produce less manure. On the other hand, its value will increase in time thanks to growth. In this case, timing costs may be involved, associated with early sales ("missing" liveweight) but yield loss due to loss of traction and loss of manure will be lower. It is assumed that these effects compensate each other.

Formally speaking, the pledge of 150 % must be included in the balances as transaction costs for taking a loan at the bank. In that situation, all balances are advantageous for financing through sales of livestock. Most farmers, however, do not have such a pledge therefore it has not been included.

Contribution of livestock to household cash flow and asset position

To assess the role and capacity of livestock in managing the farm household's liquidity position during a year, a so-called asset flow projection may be used (Hopkin *et al.*, 1973). An asset flow projection is cumulative in nature, starts from the present asset position (current balance sheet) and subsequently the generation and flows of grain, cash and other current assets during one agricultural year are estimated. The situation at the end of the year then is given as a pro forma balance sheet representing the household's likely asset position. Comparison of the two balance sheets would indicate whether a household's asset position is likely to change. To establish current stock at any moment in time is however very difficult. Livestock numbers and cereal stocks often are, at least partly, hidden from tax collectors and from family and friends desiring loans in kind. Both cereal and livestock production are difficult to monitor as many transactions are involved. However, a budget study (Tapsoba, 1998) may shed some light on the farm household's liquidity position in the course of a year (September 1997-September 1998).

Such a study was carried out for 22 households in the villages Tagalla and Sidogo in Sanmatenga province. Once every two weeks all household members were interviewed with respect to their cash earnings and expenditures. The results for various categories of Mossi households and for Fulani households are given in Table 5.4.6.

The asset position at the end of the study period was established for livestock and non-agricultural assets, such as means of transport, radios and houses with iron sheet roofs. For nine households in Tagalla, livestock was monitored at the end of the study and the situation at the start was calculated from the transactions recorded during the year of study (Table 5.4.7). For Mossi the number of cattle was unknown, but none of these households traded cattle during the survey.

Table 5.4.6 shows that the various categories of households in these villages spent more on food than they earned, and have on the other hand a positive income-expenditure balance for livestock.

Table 5.4.6 Average cash income (Inc) and expenditures (Exp) by 22 households (hh) over a one year period (1997-98)[1] in 1000 FCFA[2].

	Mossi (3 hh)		Mossi (3 hh)		Mossi (7 hh)		Mossi (5 hh)		Mossi (18 hh)		Fulani (4 hh)	
hh category	TRADERS		LARGE		SMALL		RICH		ALL		ALL	
hh size	18 persons		21 persons		5 persons		11 persons		11 persons		12 persons	
	Inc	Exp	Inc	Exp	Inc	Exp	Inc	Exp	Inc	Exp	Inc	Exp
Staple food	873	991	2	87	15	55	42	221	163	262	0	147
Δ^3 staple		- 118		- 85		- 40		- 179		- 99		- 147
Animals	49	22	136	83	37	32	193	74	99	50	335	7
Δ animals		+ 27		+ 53		+ 5		+119		+ 49		+ 328
Other	971	1821	315	489	128	154	462	595	393	611	122	335
Total	1893	2834	453	659	180	241	697	890	655	923	457	489
Staple/total (%)		35		13		23		25		28		30
Animal/total (%)	3		30		21		28		15		73	

[1] Budget study (Tapsoba, 1998) and De Graaff *et al.* (1999)

[2] 100 FCFA = 1 FF = 0.16 US$

[3] Δ = Income - Expenditures

For Mossi households that are heavily involved in trade, cash flow was substantial and the cash flow balance at the end of the year was negative. Trade included all kinds of commodities such as petrol, local beer and cereals. At the end of the budget study, these households owned several motorcycles, bicycles, radios, houses with iron sheet roofs, a donkey cart and one or more ploughs, all signs of wealth (and investment) in Burkinabé society. They also owned considerable numbers of livestock (Table 5.4.7). Staple crops comprised 35 % of all expenditures, whereas livestock generated only 3 % of all income.

For large Mossi households, labour availability was less of a constraint and the production of staple food was relatively high. Purchase of staple food did therefore not exceed 13 % of all expenditures. Livestock contributed 30 % to all income. Because of household size, income and expenditure per capita were lower than for households from any of the other categories. The cash flow balance was negative.

For small sedentary Mossi households, cash was rare and the cash flow balance was small and negative. Cereals comprised 23 % of all expenditures and livestock was responsible for 21 % of all revenues. At the end of the budget study none of these households showed characteristics of wealth or investment. Their livestock assets at the end of the study were also very small (Table 5.4.7).

Table 5.4.7 Livestock assets per household in Tagalla in September 1997 and August 1998.

Household		September 1997		August 1998	
Number	Characteristic	Cattle	Small Ruminants	Cattle	Small Ruminants
1	Fulani	31	26	27	9
2	Fulani	52	94	42	70
3	Mossi, small	n.a.[1]	3	n.a	3
4	Mossi, small	n.a.	17	n.a.	5
5	Mossi, big	n.a.	5	n.a.	0
6	Mossi, big, trader	n.a.	32	n.a	20
7	Mossi, big, trader	n.a.	15	n.a	12
8[2]	Mossi, rich	n.a.	10	n.a.	5
9	Mossi, rich, trader	n.a.	30	n.a	20

Source: Budget-study (Tapsoba, 1998)

[1] n.a. = not available

[2] household 8 also sold a donkey, a horse and three pigs

For so-called rich households, 25 % of all expenditures was on purchase of cereals, whereas 28 % of all revenues came from livestock sales. Although these households were classified as rich, their cash flow balances for the year were negative. As these households are also influential socially, many flows are in kind and are difficult to express in money. One of the households, for instance, showed a high annual cash income and expenditure associated with sales of fuel wood, preparation and sale of local beer and receipt of many cash donations. In terms of wealth, these households were comparable to the large households, owning means of transport, radio, cart, plough, improved houses and some small ruminants and donkeys.

For Fulani, semi-nomadic livestock owners, 73 % of all revenues came from sales of animals, whereas 30 % of all expenditures went to purchase of cereals. The cash balance was about zero, i.e. household revenues were about equal to expenditures. Households were of medium size and their food needs were satisfied. Wealth indicators, such as means of transport, agricultural equipment and improved housing were absent. Livestock was sold to buy cereals. Livestock asset position decreased with 4 and 10 cattle and 17 and 24 small ruminants for households 1 and 2, respectively (Table 5.4.7). At the end of the budget study, these households still owned considerable numbers of both cattle and small ruminants.

For Mossi households, net expenditures on staple food were not matched by net revenues from livestock sales. These households therefore had to generate income from other sources to satisfy their food needs and they were not in a position to improve their liquidity position. For Fulani, sales of livestock generated more income than needed for expenditures on staple food. The generated surplus could have been used to improve their liquidity position through assets other than livestock, but in reality all income was spent on consumables.

Conclusions and discussion

Two approaches to explication and quantification of the role of livestock in mixed farming households in Burkina Faso are presented. The first one compares financing through livestock to financing through loans from co-operatives (banks), using a balance equation; the second estimates the contribution of livestock to cash flows and assets at household level. Mixed farmers in Burkina Faso appear to prefer livestock as means for financing to various alternatives. The balances show that sales of livestock for financing has a negative effect on total farm production in terms of money, especially for female animals or draught bullocks. However, only when substantial cash needs occur at short notice, farmers consider such sales. Normally, farmers sell young male animals and only loose the value of potential weight gain. This sales strategy shows that farmers realise the differences in costs to the total farm, when selling different categories of animals. Farmers also take into account the burden of administrative procedures when they apply for a loan. Most farmers have little choice but to use livestock for financing, because they cannot avail of the 150 % pledge, necessary for a loan at a co-operative. Saving at a co-operative is also not attractive, because it does not generate interest, whereas livestock increases both in weight and in numbers. Hence, although the balances are not favourable for livestock as a means of financing, farmers have not much choice.

The current analysis refers to mixed farming systems, therefore transactions of livestock are considered in relation to cropping. As cropping generates revenues only once a year, farmers tend to manage their farm on an annual basis. The impact of livestock sales is therefore also analysed on an annual basis.

Bosman and Moll (1995) quantify the role of goats on the basis of primary and secondary benefits, the latter including financing and insurance. Their analysis is based on goat herd and its annual dynamics, excluding interactions with other farm activities. In their approach all benefits of goat keeping are added, and costs (loss of manure) for the cropping component of the household when a goat is sold, are ignored. In adding the values of meat, manure, insurance and financing to calculate benefits of livestock keeping, Bosman and Moll (1995), but also Ifar (1996) seem to forget that " you can not sell the cow and drink the milk." In addition, those authors implicitly assume that animals are only sold when it is economically interesting from both, a herd management and market price perspective. When animals must be sold because of emergency expenditures, the herd management perspective can not always be taken into account. Sales of young female animals may be necessary, implying costs in terms of loss of offspring and loss of potential liveweight gain. Sales may also be required in a period with low market prices for livestock. All these costs should be taken into account in the analysis.

The examples of cash flows and livestock assets for Mossi and Fulani households in Sanmatenga province show that the importance of livestock in households strongly varies. For Fulani households, sales of livestock are necessary to buy food grains and for survival. For Mossi traders, a large part of the cash flow originates from commercial activities. Consequently, the liquidity position and survival of these Mossi households does not depend on livestock.

For most Mossi households, net expenditures on staple food could not be matched by the revenues from livestock sales. This is understandable, as 1997 was a year with very low precipitation, about similar to the drought of 1984, hence very low cereal yields. Many farmers had to sell livestock to buy cereals. The high demand for cereals increased cereal prices, whereas the large supply of animals on the market decreased livestock prices. Low cereal yields and deteriorating exchange rates between livestock and cereals negatively affected the average liquidity position of these households.

In this paper, some approaches towards quantification of short term financing capacities of livestock and their role in household cash flows have been illustrated. Some other approaches are under development, but need additional and very specific research. A major problem is to establish real cereal and livestock stocks at the beginning of a year and to track them during an entire year. Many transactions take place, and both, cereal stocks and livestock may be entrusted to family members or even strangers (remunerated herdsmen for instance) living elsewhere. Another problem is to assess the risk of crop failure, harvest and storage losses, and the risk of theft of animals. The first could be based on stochastic yield distributions. Moreover, the identified types of costs are not independent and some costs, such as inflation costs and opportunity costs of labour have not been taken into account though they play a role. Timing costs were defined for constant market prices, but prices may fluctuate, for instance because of local crop failures. Market prices may also be influenced by externally funded food aid in times of local scarcity or by the supply of cheap European meat on coastal markets, undermining the export position of Sahel countries. Farmers have no influence on these types of macro-economic events, nor can they be anticipated, so that adaptation is all but impossible.

6 Exploring the potential of animal traction in the North Sudan zone of Burkina Faso

Abstract

In Burkina Faso, animal traction is recommended to increase cereal production to feed the rapidly growing population. For Zoundwéogo province and Kaïbo village, the potential of animal traction is assessed. Farm households, using animal traction are larger in terms of family size, total cultivated area, and area of cash crops, compared to unequipped households. In Kaïbo, the number of draught animals was predicted to be sufficient to work all arable land and replacement animals could be provided by the village herd. In Zoundwéogo province, 48% of the provincial herd was estimated to be needed to plough all arable land and 87 % of the herd to provide bullocks for each family. Ploughing soils in Kaïbo required draught forces of 480-825 N, whereas estimated draught power potential was about 304 N per bullock. Animals therefore work at the peak of their potential, reflected in short working days of 2-3 hours. This resulted in low daily output in area and moderate daily estimated energy expenditures. Daily output could be increased by doubling the number of animals or by increasing their liveweight. Both options need additional feeding. Farmers use animal traction mainly on cash crops. Animal power enables farmers to grow additional cereals such as maize, and obtain cash from sales of cotton which can be used to buy cereals. In this way animal traction contributes to feed supply of the population.

Keywords: animal feed, Burkina Faso, cereals, draught force, herd size, energy requirements

Introduction

Burkina Faso is situated in the semi-arid zone of West Africa where low and erratic rainfall is a major constraint to agricultural production. In the country, the demand for cereals is increasing due to an annual population growth of 2.6 % (EIU, 1996). To satisfy this demand, either the cropping area must expand or the yield per hectare must increase. Animal traction can contribute to both options, through increasing labour availability at the start of the rainy season, facilitating land preparation and timely planting, allowing a larger cropping area and reducing the risk of crop failure (Fall *et al.*, 1997; Starkey and Faye, 1990). Animal traction facilitates incorporation of manure and fertiliser, particularly important for cotton and maize (Savadogo *et al.*, 1998). In a review of animal traction experiments in Burkina Faso and Senegal over the 1969-1986 period, Nicou and Le Moigne (1991) reported that use of animal traction increased yields of millet, sorghum and maize by on average 18, 27 and 54 %, respectively, compared to cultivation without animal traction. The use of animal traction by traditional arable farmers thus seems an attractive option, which is supported by the Burkinabé government (MRA, 1997) and development agencies.

In the past, research on animal traction in Burkina Faso was concentrated mainly in the Western part of the country, with a rainfall of 950 to 1200 mm, where cotton dominates the agricultural production system (DSAP, 1998) and the introduction of tractors is currently an important issue (Tersiguel, 1995). Other research concentrated on the impact of animal traction on crop yield (Nicou and Le Moigne, 1991), on the development of animal-drawn implements (Slingerland, 1989), and on socio-economic aspects (Savadogo *et al.*, 1998; Dijkman, 1991) of animal traction.

Quantitative data on animal traction potential for the drier, North-Sudanian part of Burkina Faso, where population density and growth are highest (DSAP, 1998), are not available. Climatic and soil conditions enable moderate cereal yields and the zone experiences annual deficits in cereals (DSAP, 1996). To explore animal traction potential for this zone, some studies were conducted in Zoundwéogo province and in particular in the village Kaïbo Sud V5. One objective was to measure draught requirements for ploughing and weeding, and animal draught force potentials to evaluate whether the available animals were suitable. An additional objective was to estimate current and future demands for draught animals and relate these to herd sizes needed for their production and replacement, to examine whether current stocking rates would be sufficient for animal traction development. Finally, animal feed requirements and availability related to the length of working days were evaluated.

Materials and methods

Interviews and surveys

A form used by a governmental service in other provinces, was adapted for use in Zoundwéogo in 1995. Thirty villages were randomly selected to participate in the survey. In each village, the village chief, the extension officer, a village group and four individual Mossi farmers, two with and two without animal traction, were interviewed. Questions, related to household composition, farm area, food crop area, cash crop area and animal ownership were analysed with the students T-test (Snedecor and Cochran, 1967).

Additional to the interviews, the number of cattle belonging to Mossi and Fulani inhabitants of Kaïbo Sud V5 was established in a rapid survey in December 1998. A distinction was made between draught animals, milking cows and other cattle. The particular use of draught animals by both ethnic groups was investigated.

Measurements of animal power and energy requirements

Field research was carried out on two farms (farm 1 and 2) where ploughing and weeding were performed with the farmer's pair of draught bullocks of 250 kg liveweight (LW) each (Van Waveren, 1996). All parameters used in the animal traction model of Van der Lee *et al.* (1993) were measured on the farmers' fields.

The animals worked four plots per farm, 1A-D and 2A-D, each planted with several crops. For direct measurements, three furrows per plot were selected per working day, with ten sticks placed along each at equal distances. Working width (WW), working depth (WD) and non-cultivated area between furrows (SBF) were measured adjacent to each stick (n= 30 per working day). Each plot was characterised by a specific soil structure, depending on soil type and soil surface conditions. Soil compaction, but also low moisture content or high clay content generally increase the forces needed to plough or weed. Soil resistance (SSR) was calculated using the Resistance to Ploughing Model (Canarache, 1993) based on clay percentage, soil humidity and bulk density. To determine soil moisture content, four soil samples per furrow (n = 12) were taken each working day, weighed immediately, and again after drying at 100 ^{O}C till constant weight. After mixing the samples, particle size distribution was determined using the standard hydrometer method (Ulmer *et al.*, 1994) and classified in clay, silt and sand (Smith and Mullins, 1991). Bulk density was derived from earlier studies (Wijnhoud and Otto, 1994).

The angle of pull (θ) was measured and the Width-Depth Fraction (WDF) was set to 0.60 for ploughing and 0.17 for weeding (Van der Lee *et al.*, 1993). Average draught force requirements (F_{req}) were calculated (Van der Lee *et al.*, 1993; Lawrence and Stibbards, 1990; Perdok and Van der Werken, 1980):

$$F_{req} = (WW * WD * WDF * SSR)/\cos\theta \qquad (N) \qquad [1]$$

Length of an average furrow was 45 m with a turnaround (TO) distance of one meter at each end, hence TO equalled 2 m. The distance walked for ploughing or weeding an entire plot (DP), with PA as plot area, equals:

$$DP = (45 + TO) * PA /[45 * (WW+SBF)] \qquad (m) \qquad [2]$$

Work requirements (in Nm or Joules) depend on force requirements (N) and the distance covered in meters:

$$W_{req} = F_{req} * DP \qquad (Nm) \qquad [3]$$

Energy requirements were divided in fractions for walking, lifting, the horizontal component and the vertical component according to the factorial approach of Lawrence (1985). For each component, the work (W) requirements and the associated requirements in terms of Metabolic Energy (ME) were calculated. ME costs for the different components were derived from Lawrence and Stibbards (1990) and Mathers *et al.* (1985): ME cost of walking was 2.0 J kg^{-1} m^{-1}, of lifting 28 J kg^{-1} m^{-1}, of pulling (horizontal component) 33 J kg^{-1} m^{-1} and of carrying loads and LW (vertical component) 2.6 J kg^{-1} m^{-1}.

$$W_{walk} = LW * DP \qquad (kgm) \qquad [4]$$

$$ME_{walk} = W_{walk} * 2.0 \qquad (J = Nm) \qquad [5]$$

$$W_{lift} = [(LW * 9.8) + (F_{req} * \sin\theta)] * SL/100 * DP/2 \qquad (J = Nm) \qquad [6]$$

$$ME_{lift} = W_{lift} * 28/9.8 \qquad (J = Nm) \qquad [7]$$

$$ME_{hor} = W_{req} * \cos\theta * 33/9.8 \qquad (J = Nm) \qquad [8]$$

$$ME_{ver} = W_{req} * \sin\theta * 2.6/9.8 \qquad (J = Nm) \qquad [9]$$

The factor 9.8 converts from kilogram to Newton; SL is slope in %; ME requirements for work are converted to NE for work through multiplying by 0.3 (Blaxter, 1989, quoted by Van der Lee *et al.*, 1993). ME requirements for maintenance are converted to NE requirements for maintenance through multiplying by 0.55. NE for maintenance was set to 0.28 MJ $kg^{-0.75}d^{-1}$, as used for cattle by Van der Lee *et al* (1993).

Estimation of draught animal potential

Potential draught force of the available draught animals depends on animal liveweight, body condition and team efficiency. Condition score (CS) is expressed as a function of actual liveweight and optimal weight (OW); Team efficiency (TE) depends on team size (TS) (Van der Lee *et al.*, 1993).

$$CS = 5 * (LW/OW) - 0.4 \qquad [10]$$

$$TE = 1 - [(TS-1) * 0.075] \qquad [11]$$

Liveweight percentage (LWP) is used as a correction factor to account for loss of efficiency due to poor animal condition or inefficient harnessing. Harnessing Score (HS) is a measure of the efficiency of transfer of draught force from animal to implement and is expressed as a subjective classification between 1(inefficient) via 2 (moderately efficient) to 3 (efficient) (Van der Lee *et al.*, 1993).

$$LWP = 8 + CS + HS \qquad [12]$$

Potential draught force equals now:

$$F_{pot} = LW * LWP/100 * TE * 9.8 \qquad [13]$$

Estimation of herd sizes needed for animal traction

The consequences of animal traction development at provincial and village level were assessed by calculating required herd sizes for current and potential animal traction use. For Kaïbo Sud V5, the required number of animals was calculated for four situations:

- to replace current draught animals (1)
- to provide draught power to work all crop land (2)
- to provide draught power for all Mossi families (3)
- to provide draught power for all families housed in the village area (4)

At the level of Zoundwéogo province, the required number of animals was calculated for the situations 1, 2 and 4.

For the Central region, where Zoundwéogo province and Kaïbo Sud V5 are situated, Meyer (1989) established the following production parameters (% per year) for cattle: Mortality rate of calves 10.7; Mortality rate of steers, heifers, adult cows 6.5; Calving percentage 56. Boudet and Dumas (1975) recommended annual replacement rates of 20 % for draught bullocks (including mortality) in the Kaïbo area, assuming buying for replacement at the age of three year.

Results

Household characteristics

Due to missing data, only 40 households per category could be analysed. Households owning animal traction equipment were significantly larger than unequipped ones: a higher number of family members, a larger area of land and higher numbers of livestock (Table 6.1).

Table 6.1 Household characteristics for an average Mossi household with and without animal traction equipment in Zoundwéogo province, 1995.

Characteristic	Without equipment	With equipment
Number of persons[a]	5.2	9.2
Number of ploughs	0	1
Number of draught bullocks	0	2
Farm area (ha)[b]	4.1	6.9
Cultivated area (ha)[b]	3.6	5.5
Cash crop area (ha)[b]	0.2	0.7
Food crop area (ha)[a]	3.2	4.6
Number of sheep[b]	1.3	5.2
Number of goats[b]	2.6	5.0
Number of cattle[b]	2	6.8

[a] significantly different at $p < 0.10$
[b] significantly different at $p < 0.05$

Soil analysis

Texture of the plots was either clay loam (1A, 2A, 2B, 2C) or sandy clay loam (1B, 1C, 1D, 2D) and humidity varied between 4.3 and 14.8 ($g\ g^{-1}$). Bulk density equalled 1.70 g cm^{-3} (Wijnhoud and Otto, 1994).

Measurements and required draught forces

Working width, working depth, non-cultivated area between furrows and angle of pull were averaged per activity and per farm, because these characteristics appeared mainly dependent on farmers' implements and their operation (Table 6.2).

Table 6.2 Average working width (WW), working depth (WD), fraction actually moved (WDF), non-cultivated area between furrows (SBF) and angle of pull (θ) for ploughing and weeding for two farms in Kaïbo Sud V5, 1995.

Farm	Activity	WW (m)	WD (m)	WDF ($m^2\ m^{-2}$)	SBF (m)	θ (degrees)
1	ploughing	0.260	0.054	0.60	0.104	24.5
1	weeding	0.504	0,027	0.17	0.371	17.8
2	ploughing	0.205	0.052	0.60	0.114	28.3
2	weeding	0.414	0.028	0.17	0.392	20.3

Plots differed in size and in soil resistance, therefore, force (F), work (W) and metabolic energy (ME) requirements were calculated per activity, per plot per farm (Table 6.3).

Table 6.3 Plot area (PA), distance covered per plot (DP), soil resistance (SSR), force requirements per team (F_{req}), slope, and ME requirements for work (ME_{tot}), all per plot, per farm, and per activity in Kaïbo Sud V5, 1995.

Farm	Plot	Activity	PA (ha)	DP (hm)	SSR (kN m^{-2})	F_{req} (N)	Slope (%)	ME_{tot} (MJ)
1	A	ploughing	0.74	211.5	89	824	2.90	70.4
1	A	weeding	0.74	87.9	89	217	1.52	11.6
1	B	ploughing	2.36	677.3	69	639	0.13	172.0
1	B	weeding	2.36	281.5	69	168	1.39	32.3
1	C	ploughing	1.62	464.8	65	602	0.92	115.2
1	C	weeding	1.62	193.2	65	158	0.72	20.7
1	D	ploughing	1.15	329.9	68	629	0.71	24.8
1	D	weeding	1.15	136.8	68	166	1.32	15.7
TOTAL FARM 1			5.87					463
2	A	ploughing	0.80	262.3	106	770	0.87	77.2
2	A	weeding	0.80	103.9	106	222	0.87	13.4
2	B	ploughing	0.86	281.5	80	581	0.55	65.9
2	B	weeding	0.86	111.4	80	168	0.55	12.2
2	C	ploughing	2.90	948.9	102	741	0.90	271.0
2	C	weeding	2.90	375.5	102	214	0.90	47.2
2	D	ploughing	1.03	337.5	66	479	0.48	68.1
2	D	weeding	1.03	133.5	66	138	0.48	13.0
TOTAL FARM 2			5.59					568

For each plot, the number of days needed per activity was calculated by dividing total plot area (Table 6.3) with average output (ha) per activity per day. On farm 1, average outputs of 0.24 ha d^{-1} for ploughing and 0.33 ha d^{-1} for weeding were realised, on farm 2, 0.17 ha d^{-1} for ploughing and 0.51 ha d^{-1} for weeding. Total working time per draught animal team was therefore 42 days for farm 1 and 44 days for farm 2, with corresponding ME requirements of 463 MJ for farm 1 and 568 MJ for farm 2 (Table 6.3).

Potential draught force

Actual weight of each of the four draught animals was 250 kg, and as optimal weight (OW) was estimated at 325 kg per adult animal, CS was 3.4 (Eqn. 10). Farmers worked with a team of two animals, hence TE was 0.925 (Eqn. 11). Harnessing was average (HS = 2), thus LWP was 13.4 (Eqn. 12). That yields for F_{pot} 304 N per animal or 608 N per team (Eqn. 13).

For all plots, except 1C, 2B and 2D, force requirements for ploughing (Table 6.3) exceeded the calculated team potential. The work appeared to be done in several short working periods of 2 to 3 hours per day, hence farmer 1 needed 12 hours and farmer 2 almost 18 hours for ploughing one hectare. For weeding, the potential force of the available animal traction team was sufficient.

Herd size

Using the production parameters of Meyer (1989) and a replacement rate of 20 %, the required herd size was calculated for four situations in Kaïbo Sud V5, a village comprising 52 Mossi and 11 Fulani households :

(1) The actual number of 145 draught animals (survey 1998) must be maintained;
(2) The cultivated area was 204 hectares in 1993 (Leenaars, 1998) and equipped households cultivated on average 5.5 hectares with one team of two bullocks (Table 6.1), hence a total of 74 draught bullocks would be needed;
(3) To equip all 52 Mossi households, 104 animals would be needed;
(4) To equip all Mossi and Fulani households 126 bullocks would be needed

For the entire Zoundwéogo province three situations have been analysed:

(1) According to the national census on agriculture and animal production (DSAP, 1998), 69,570 hectares were cultivated by 23,022 households, using10,798 draught bullocks in 1993;
(2) For 69,570 hectares 12,649 teams, i.e. 25,298 bullocks are needed;
(3) 46,044 bullocks are needed to equip every household with one team.

To extend the use of animal traction to all crop land, 2.3 times as many animals would be needed than for maintaining current draught animal numbers. To equip all families 4.2 times as many animals would be needed.

Draught animal feeding

Feeding draught animals is particularly a problem on working days. Other days the animals have ample grazing time, especially when night grazing is allowed (Ayantunde, 1998), to meet maintenance requirements, whereas additional intake of nutrients in the rainy season may be transformed into body mass (growth). On working days, grazing time is limited. Moreover, the farmers are occupied with agricultural tasks and will not be available to guide the animals to distant favourable grazing spots on the village territory. The animals are generally tied to a tree or bush on recent fallow near crop fields, or they are fed crop residues at home. Only in the dry season draught animals are entrusted to Fulani herdsmen who let them graze day and night. It has been shown (Fall *et al.*, 1997) that draught animals can neither increase feed intake, nor use feed more efficiently to compensate for the extra energy used for work.

At the onset of the working season, draught bullocks are mainly fed low quality crop residues while they have to perform maximally in terms of draught power. When, for instance, only millet stover with an energy content of 8 MJ ME per kg DM is available, in theory the requirements for draught in the Kaïbo situation can still be met. Draught required 11 and 13 MJ (ME) per day for farm 1 and 2, respectively, while daily maintenance required on average 64 MJ (ME) for the two draught bullocks. For animals of 250 kg liveweight maximum daily intake of stover is estimated at 6.25 kg providing 50 MJ per animal. Two animals can thus expend 100 MJ daily by consuming millet stover, while average ME requirements for a team are 76 MJ per working day (of 2 to 3 hours). On a ration of millet stover, these animals can thus, in theory, even grow during the working period. The animals used in the experiments increased 17 to 20 kg in body weight between the beginning of May and the end of August (Van Waveren, 1996). If daily working time would be doubled, the associated requirements of 88 MJ a day would be difficult to cover under limited feeding time.

Discussion and conclusion

Average household size and cultivated area in this study were similar to those of Dijkman (1991), and these observations agree with the general observation that equipped farmers have larger families and larger areas of crop land than non-equipped farmers (Le Thiec, 1996; Tersiguel, 1995; Starkey and Faye, 1990). As land preparation and sowing using animal traction take less time, the cultivated area can be expanded, while cultivation of cash crops is necessary to cover the additional expenses on animal feed, maintenance of implements and repayment of loans (Le Thiec, 1996; Tersiguel, 1995). On the other hand, larger and richer families, based for instance on livestock numbers as a wealth indicator, can more easily afford to invest in animal traction. Large families and larger cultivated areas seem to stimulate adoption of animal traction (Starkey and Faye, 1990). For Burkina Faso, only the correlation between farm size, number of animals, and animal traction use and not the causality has been established.

Draught force requirements of 479 to 824 N (Table 6.3) for ploughing in Kaïbo, with working depths of 5-6 cm, were comparable to the 450 to 800 N, measured on sandy soils at the ICRISAT research station in Sadoré, Niger (Slingerland, 1989). Fall *et al.* (1997) reported an average draught force of 825 N for ploughing sandy soils in Mali. For weeding, requirements were 500-700 N at Sadoré, i.e. much higher than at Kaïbo due to the fact that working depth at Sadoré was about 11 cm against scratching the surface, at 3 cm depth at Kaïbo.

Comparison of required (F_{req}) and potential (F_{pot}) draught forces show that animals worked at the peak of their capacity when ploughing. The tasks could only be completed, because for a short time span animals can perform above the calculated potential (Le Thiec, 1996). Working periods for ploughing were therefore short, 2 to 3 hours a day, at maximum. Both, weeding and ploughing required much force considering the shallowness of the work (Table 6.2). During the trial, the soils in the area were very dry and compact which made them difficult to work. Distances between furrows (SBF) appeared wide (Table 6.2), which is also characteristic for difficult working conditions.

Fall *et al.* (1997) quote Lawrence (1985), showing that realistic total energy expenditure (NE_{tot}) of draught animals equalled 1.3 to 1.8 times maintenance (NE_m) requirements. Our findings, of NE_{tot} being 1.1 times NE_m , are much lower, mainly because animals worked only very short periods of 2 to 3 hours a day. Tripling daily working time, would increase NE_{tot} to 1.3 times NE_m. However, that would be unrealistic for the available draught animals, considering the required draught forces in relation to their liveweight.

In Kaïbo, 204 ha of land was cultivated in 1993 (Leenaars, 1998). When all families would be equipped with draught animals, 347 ha of crop land could be worked. As all Mossi families own 10 ha of land, 520 ha of arable land is available in the village area. In principle, families can expand their cultivated area by using animal traction.

The current number of draught animals, 145, is already higher than the number theoretically required to cultivate all crop land. Several Mossi households own more than one pair of bullocks, while none of the Fulani households own draught animals (survey in 1998). Mossi households owning two pairs of bullocks generally have a young pair, performing small tasks and an old pair becoming weaker, but still active (survey in 1998). Generally, Fulani prefer renting animal traction units from Mossi instead of owning them (survey in 1998). Fulani own the main cattle herds (including females and young stock) and are hence responsible for breeding bullocks, while Mossi mainly own the draught bullocks during their working life. In the village territory, 773 head of cattle were present of which 502 were owned by Fulani households (survey in 1998). In theory, these numbers are sufficient to produce draught bullocks for replacement and even some additional ones. Some Mossi households also accumulated capital in the form of cattle. In December 1998, Mossi households in Kaïbo owned 46 cows all together. They may produce some bullocks in the future.

Estimates for total cattle herd size in Zoundwéogo province in 1994 varied between 110,600 (PDI/Z, 1993) and 116,687 (Antenne Provincial du Plan, 1997). To maintain current draught animal numbers, on average 20 % of the entire provincial herd would be necessary. To provide draught power to work all crop land, this percentage would increase to 48 %. To provide draught power to all families in the province, it would be 87 %, but this option is unrealistic, as the number in the former situation is already sufficient to cultivate all crop land with animal draught power. Additional crop land is scarce, thus additional draught animals to equip all families would be idle, part of their working life, although they could be used to reduce the number of days needed to work one hectare, thus allowing timely seeding and weeding. To use large parts of the herds for the production of draught animals is no problem, as milk and meat are produced concomitantly, while secondary benefits like manure production become increasingly important.

Both, at village and provincial level, enough animals are available to maintain or increase the number of draught animals. Calculations show however, that their working potential is rather weak compared to the required forces, especially for ploughing. Ploughing could continue for only a few hours each day which leads to delayed seeding. An option could be to double the number of draught animals, so that tired animals could be replaced after 2 or 3 hours and the entire day could be used for ploughing. All these animals would have to be fed, however, both for maintenance and for work. As potential draught force is mainly related to animal weight and not to body condition (Fall *et al.*, 1997), it is recommended to aim at higher animal weights, either by improved feeding regimes, or by using older animals or by crossbreeding with races with genetically higher adult weight.

On the other hand, animals can work on their body reserves for a short period, because liveweight can be regained rapidly after the working period (Fall *et al.*, 1997). By the time weeding operations are completed, natural pastures of good quality are abundantly available and therefore can support compensatory growth (Fall *et al.*, 1997). As farmers have little cash available for animal feed (DSAP, 1998), supplementary feeding is only recommended in the working (rainy) season when animals must work for more than 6 weeks, or are scheduled to be sold for meat after the working season (Fall *et al.*, 1997). Supplementing during the dry season is not profitable in this situation, as it does not lead to significant increases in work output (Fall *et al.*, 1997). Animals that have not received supplementation in the dry season, show compensatory growth during the rainy season, which leads to comparable gain at the end of the rainy season for supplemented and non-supplemented animals (Schlecht, 1995). Reducing weight losses in the dry season by increasing feed intake through day and night grazing (Ayantunde, 1998), may however be a low cost option. In both seasons, intake of roughages such as millet stover can be improved by offering animals excessive quantities, allowing selection of the most digestible parts so that liveweight can be maintained (Savadogo, 2000).

Smallholder arable farmers show very low levels of market incorporation and almost no investment capacity (DSAP, 1996), therefore introduction and maintenance of animal traction does not only need a sound technical basis, but also the availability of credit systems with favourable conditions.

Savadogo *et al.* (1998) found that traditional farmers, thought to be tied to safety-first subsistence strategies, applied improved techniques to cash crops, such as cotton and maize, and not to subsistence crops. It is therefore questionable whether the use of animal traction will improve availability of food in terms of sorghum and millet for the growing population of

Burkina Faso. The cash crop maize is also mainly consumed within Burkina Faso. An increase in its cropping area and yield, associated with the use of animal traction, will provide additional, though alternative, food. The sale of cotton provides farmers with cash to buy cereals. In both ways, animal traction may contribute to satisfying the growing demand for cereals, and hence to increased food security.

CHAPTER 7 Village territory land use for grazing and fuel wood

7.1 Feeding behaviour on natural pasture, a complex of man-livestock-environment interactions **171**

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7.2 Influences of herding system and season on grazing patterns and cattle diet composition in a patchy environment **179**

M.A. Slingerland[4] and H. Hiemstra[5]

7.3 Cutting and resprouting of *Detarium microcarpum* and herbaceous forage availability in a semi-arid environment **191**

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7.4 Herbivore-vegetation interactions: theory and research results **20[illegible]**

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7.1 Feeding behaviour on natural pasture, a complex of man-livestock-environment interactions

Abstract

World-wide, livestock is accused of degrading soils and vegetation. Generally, the concept of carrying capacity is used to support this accusation. This concept neglects plant species characteristics and also animal species particularities such as energy and protein needs and selection behaviour. Therefore it is not very adequate for the estimation of livestock production potentials of village territories. In Burkina Faso, the increase in animal numbers and the increase in the occupation of grazing land for cereal production lead to the hypothesis that overgrazing will become a serious problem in the near future. From March 1994 to February 1995, research has been conducted on the use of a village territory in the Zoundwéogo province by sheep and goat within Mossi and Fulani livestock systems. Animal species ($p < 0.0001$), livestock systems ($p < 0.05$) and season ($p < 0.0001$) significantly influenced animal diet composition and also animal behaviour on the village territory. Vegetation quality and availability, depending on vegetation species and season, determined its contribution to the animals' diets. The animals showed high selection capacities, which made joint exploitation by animal species possible and left considerable parts of edible biomass untouched. Sheep preferred crop residues to natural vegetation. A decrease in natural vegetation was compensated by an increase in crop residue availability. The contribution of Sahelian species to the vegetation, which is a sign of degradation, was almost insignificant (4 %). In summary, the results of the study gave no cause for alarm. Complementary studies on cattle, interaction between animal species and plant species, but also on regeneration of trees on the territory, are currently executed to examine how the territory can maintain more tropical livestock units than its calculated carrying capacity would dictate, without degrading. This information is necessary for the formulation of realistic recommendations based on potential danger of livestock for existing vegetation, either now or in future.

Introduction

In Burkina Faso, most farming systems comprise a livestock component which mainly depends on grazing of natural resources. Due to population growth, land is increasingly needed for food production, thus grazing land decreases with 3.3 % annually for the central plateau (Zoundi, 1997), while livestock numbers increase by 2 to 3 % annually for cattle and small ruminants, respectively (ENEC, 1990). Combination of these processes leads to the hypothesis that natural rangelands will, in due course, degrade as a result of overgrazing. This hypothesis is based on the concept of carrying capacity, which compares livestock numbers to available biomass. The interactions among animal numbers, livestock species, livestock systems and vegetation are treated as a black box. Most studies focus on cattle, because this species contributes most to stocking density expressed in Tropical Livestock Unit (Breman and De Ridder, 1991). The grazing behaviour of sheep, and particularly of goats, however, differs considerably from that of cattle. Recently, two studies based on the carrying capacity concept have been conducted (Sanon *et al.*, 1997; Kagoné *et al.* 1997) in Zoundwéogo province. In the same province, a study that attempts to open this black box through examining the grazing behaviour of goats and sheep within Mossi and Fulani livestock systems on a village territory has been executed between March 1994 and February 1995. Results of that study will be presented here.

Study area

Zoundwéogo province is located in the Sudanian climate zone with an annual rainfall between 750 and 1000 mm and a dry season of 6-7 months. Next to the rainy season from May to October, a cold dry season from November to February and a hot dry season from March to May can be distinguished. The landscape is dominated by parklands, characterised by *Butyrospermum paradoxum* subsp. *parkii* (Karité), *Parkia biglobosa* (Néré), *Lannea microcarpa* and savannas which are mostly old fallows, characterised by the same tree species, but dominated by bushes such as *Combretum glutinosum, Piliostigma* spp. and some *Acacia* spp. The herbaceous layer is dominated by annual species: *Andropogon pseudapricus, Brachiaria* spp. and *Pennisetum pedicellatum* (Guinko, 1984). On degraded soils, Sahelian species occur such as *Schoenefeldia gracilis, Cassia tora* and *Cymbopogon schoenanthus,* a perennial grass (Guinko, 1984). The older the fallow, the larger the contribution of perennial grasses: first *Andropogon gayanus*, normally followed by *Andropogon ascinodis* (Zoungrana, 1992).

The population of Zoundwéogo province consists of sedentary Mossi and Bissa farmers mainly involved in crop production, but also practising some animal husbandry, and Fulani, traditionally semi-nomadic livestock keepers. In Kaïbo Sud V5, the village that has been studied, Mossi live concentrated in the central village and Fulani live in family units in temporary settlements scattered around the village territory.

Materials and methods

Two animal production systems, Fulani and Mossi, were distinguished (ENEC, 1990; De Graaff, 1995) and representative herd sizes per system and species were determined: 12 animals for Mossi sheep and goats, 80 for Fulani sheep and 50 for Fulani goats. Six sheep and four goat herds were selected equally distributed over the two systems. Only male animals were selected for the surveys, because the grazing behaviour of female animals may be influenced by physiological status, such as pregnancy or lactation. Animal breeds were Djalonké sheep and West African dwarf goats.

Within a herd one animal was selected and its movements and activities were followed during a full day. Each 5 min, the following information was recorded: (i) landscape unit in which the animal was present; (ii) the activity of the animal and (iii) if eating, the species and plant part it ingested. Each month, at least one herd of each combination of animal species and system was monitored. For each survey, another animal was selected to avoid individual preferences to interfere with the overall picture.

The different landscape units in which animals grazed were marked during the survey, and an inventory of these units was made using the step-point method (Kessler *et al.*, 1998), which is based on the geometric units of points, lines and quadrants (Floyd and Anderson, 1987; De Vries, 1979). An error of 5 % was allowed. Each survey resulted in (i) length of time spent per unit, expressed as a percentage of total survey time and (ii) frequencies of species in diets, expressed as percentages of the daily diets. For each plant species (i) the specific alimentary contribution (SACi) was calculated. The inventories of the units also resulted in frequencies of species, as a percentage of all species present. For each species (i) the specific contribution (SCi) can be calculated (Poissonet *et al.*, 1992). The selection behaviour of animals was expressed in the Selection Index SIi defined as SACi/SCi. When SI is less than or greater than 1, respectively, the animal ignores or selects (prefer) the species. When SI equals 1, the species is eaten proportionally to its presence in the unit (no selection).

Results

Effects of species, system and season on grazing behaviour

ANOVA analysis was performed for the factors animal species, system and season. The contribution of each factor to differences in diets, in units frequented and frequencies of activities has been established. For the sake of the analysis, the many different vegetation species have been grouped in four categories: perennial herbs, annual herbs, woody species and crop residues. In the analyses, data for the same month have been averaged, thus season must be interpreted as month. Results are presented in Table 7.1.1.

Goats and sheep have significantly different diet compositions, goats preferring woody and sheep preferring annual herbs (Table 7.1.1). In the Fulani system the percentage annual herbs is significantly lower and the percentage crop residues in the animals' diets significantly higher. The data on interaction show that the species effect is strong for woody species and annual herbs, while the system effect is weak. However, Fulani sheep eat more residues than Mossi sheep and the latter more than Mossi goats. Fulani goats eat less annual herbs than any of the other system-species combinations. The grazing units showed no significant differences between animal species or systems. However, Fulani goats spent significantly more time on fallow and Mossi goats on bush.

Table 7.1.1 Differences between animal species, management systems and their interactions for diet components (%) and time spent (%) on landscape units.

	SPECIES		SYSTEM		Interactions SPECIES x SYSTEM			
	Goat	Sheep	Fulani	Mossi	GoatFu	GoatMo	SheepFu	SheepMo
DIET (%)								
annual herbs	20.08^{b}	62.07^{a}	43.29^{d}	46.66^{b}	18.23^{bd}	21.11^{b}	55.16^{a}	67.37^{a}
woody	70.44^{b}	20.08^{a}	37.45	42.81	67.81^{b}	71.91^{b}	23.07^{a}	16.93^{a}
residues	5.12	9.60	11.85^{c}	4.45^{b}	7.36	3.86^{c}	13.97^{b}	4.98^{d}
UNIT (%)								
field	28.12	36.80	37.24	30.06	28.43	27.95	41.41	31.93
fallow	39.25	28.68	36.57	29.95	59.64^{d}	27.77^{b}	25.64	31.89
bush	22.14	22.71	16.31	27.56	3.07^{d}	32.87^{b}	22.58	22.84

a-b $P < 0.0001$ b-c $P < 0.01$ b-d $P < 0.05$

Analysis of the three factors (animal species, system, season) shows that the contributions of diet components differed significantly due to both season ($P < 0.0001$) and animal species ($P < 0.0001$), while time spent on landscape units differed only significantly due to season ($P < 0.0001$). For none of the variables, a significant difference between systems or an interaction effect was found.

Differences between animal species

It seems that goats consume significantly more woody species and therefore less herbs and crop residues than sheep in all seasons (Table 7.1.1). This impression is supported by the data provided in Table 7.1.2.

Table 7.1.2 Contribution of woody species (SACi) to goat and sheep diets from March 1994 till February 1995 (%).

Month	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Goat	100	100	94	*	83	90	65	73	23	37	80	93
Sheep	77	63	7	8	9	6	15	8	6	4	27	45

* observations for goat missing in June

Of the woody species, some tree species such as *Combretum glutinosum* and *Piliostigma* spp., were almost only consumed by goats, that seem less affected by their high tannin contents. On the other hand, *Balanites aegyptiaca* and *Acacia* spp. were present in 30 and 40 diets, respectively, equally distributed between sheep and goats. *Balanites*, which is a semi-evergreen, is appreciated throughout the year due to its high protein content both in fruit and leaves, while the average digestibility of leaves (59 %) is also high.

Selection within woody vegetation generally was governed by the quality of the available vegetation. The selected woody plant foliage was characterised by higher mean digestibility, higher N concentrations and lower tannin concentrations (< 60 g kg^{-1}) than moderately palatable species (Breman and Kessler, 1995).

Following the beginning of the rains (May 1994), annual grasses were abundantly present, but goats hardly altered their diet. In fact, they only consumed less woody species when high-quality crop residues were available in November and December. In December, legume haulms and scattered groundnuts in the field contributed up to 30 % of their diet and other crop residues up to 20 %. Sheep, on the contrary, switched to annual herbs as soon as they were available. On the 18th of May, they accounted for 90 % of the diet. Up to the beginning of November, their contribution remained at that high level. Subsequently, when all fields were harvested, crop residues accounted for about 30 % of the sheep diet up to early March.

Differences between systems

From December to March, crop residues are much more important in diets of Fulani herds than in those of Mossi herds. Although all herds spent, on average, 39 % of their time on harvested fields, crop residues contributed significantly ($P < 0.05$) more to Fulani diets (19 %) than to Mossi diets (8 %). This difference is related to time and space. Fulani need very little time to harvest their few small fields, so that labour is available to guide their herds to the bush fields of Mossi. The crop residues of these fields are mostly not or only partially transported to the Mossi farm, because of the long distance. Fulani herds avoid home fields of Mossi until all fields have been harvested. In the same period, small ruminants of Mossi are roaming freely on fields around the houses. The residues of these fields are the first to be collected and stored on the farms, hence, little is left. Mossi farmers have no labour available to guide the animals to bush fields, as they are still harvesting and transporting grains and residues to their farms.

Consumption of karité flowers and fruits also differs between systems. Fulani goats were deliberately herded far away from the fields from March until the end of the rainy season. Therefore, they almost had no access to the products of karité trees. Herdsmen guided Fulani sheep, Mossi sheep and Mossi goats deliberately to spots where karité was abundant. These herds were easily controlled near cultivated fields, as they were small in numbers and sheep are generally easier to control than goats. Differences between systems are entirely due to behaviour of the (herds)men.

Differences between seasons

Seasonal differences are mainly due to the distinct rainy period and the related cropping activities. In 1994, the rains started in May, resulting in an increase in availability of highly palatable and nutritious annual herbs in the following months. Sheep particularly benefited as they changed their diet accordingly. The onset of the cropping season also interferes indirectly with feeding patterns as the animals have to be kept away from the fields or tied to bushes or poles to avoid damage to the crops. Animals will feed on bush and old fallow mainly. Another important seasonal event is the time just after harvest, November, characterised by high availability of crop residues of medium quality. In the hot dry season, March-May, water is the main constraint, forcing Fulani to guide their large goat herds towards the river and its surroundings. Mossi can water their small herds at village wells, thus allowing their animals to roam freely in the immediate surroundings of their houses.

The phenological status of the vegetation determines its seasonal attractiveness as animal feed. Fruits from *Acacia seyal* and *Acacia senegal,* containing between 25 and 30 g N kg^{-1} and no tannins are consumed eagerly, while their leaves, containing much more tannins are rejected (Breman and De Ridder, 1991). Goats and sheep also consume flowers of *Butyrospermum paradoxum* (karité) in the hot dry season, March-May, and its fruits in June-August. Outside that period, the species is not consumed. *Ficus gnaphalocarpa* and *Lannea acida* substantially contribute to the animals' diets in April and May. Only fruits are eaten; other parts are rejected. These examples illustrate the need to consider plant parts rather than plant species in analysing animal diets. No differences were found between animal species.

In fact, the differences between species, systems and seasons are closely related. Water availability for animals and plants appears an important factor influencing feeding behaviour, either directly (availability of annual herbs, fruits) or indirectly (choice of unit by the herdsmen).

Discussion and conclusion

The question to be answered is: is Zoundwéogo province, or more particularly the Kaïbo area, subject to overgrazing, reflected in degradation of its grazing area, now or in future?

Clearing of bushland for cultivation reduced the area of grazing land in Zoundwéogo, but did not necessarily reduce the fodder availability for livestock. Kagoné *et al.* (1997) found, in the South-West of Zoundwéogo, biomass production values between 667 and 2737 kg dry matter ha^{-1}. Sanon *et al.* (1997) found, in North Zoundwéogo, biomass values between 1520 and 4400 kg dry matter ha^{-1}. For sorghum, yields of 600 to 1400 kg grains ha^{-1} were recorded between 1984 and 1994 (MARA, 1995), associated with 1200 to 4200 kg crop residues ha^{-1}. Thus, 1 ha of crop land yielded as much biomass as 1 ha of natural vegetation.

The Kaïbo study showed that crop residues contributed substantially to sheep's diets.
from beans and groundnuts and even cereal straw had significantly higher quality than the natural vegetation that was present in the same period, but not selected. The increase in crop land can, therefore, be considered positive from a sheep feeding point of view.

One of the symptoms often considered indicative for degradation of pasture is the disappearance of perennial grasses (Breman and De Ridder, 1991). Perennial grasses, present on the Kaïbo territory (on all 16 units from September to December), hardly contributed to the diets of goats or sheep. The dominant species are *Andropogon gayanus* and *Cymbopogon schoenathus*, the latter being mostly ignored (SI < 1) by the animals, due to its odour. As perennial grasses were not important to the animals' diet in Kaïbo, it is questionable whether they will eventually disappear in this area due to overgrazing. And even when they do disappear, one could doubt whether that will be dramatic for the prevailing livestock systems.

Goats are often blamed for destroying woody vegetation. In Kaïbo, herdsmen cut branches of *Acacia* spp., *Anogeissus leiocarpus, Sterculia setigera* and *Balanites aegyptiaca* to facilitate browsing by goats. Cutting of trees for firewood and poles and clearing bush for arable farming reduces tree cover as well. Frequent cutting of fodder species elsewhere has been found to be very damaging for trees (Cissé, 1984). Cutting of woody species can even be considered detrimental to the nutritional ecology of goats. In the Kaïbo area, at the grazing sites close to the Mossi village, 70 % of the trees on fallow and fields and 60 % of the trees on bush units showed signs of cutting. These figures reflect man's influence on his direct environment. Further from the houses, only 20-30 % of the trees in the bush units in Kaïbo-territory showed signs of cutting. Clearly, it is not the browsing goat that is a danger to the woody vegetation, but man. In fact, goats stimulate establishment of certain tree species, such as *B. aegyptiaca* and certain *Acacia* species by breaking seed dormancy.

A sign of degradation may also be the appearance of Sahelian species (Guinko, 1984). The contribution of *Cassia tora* varied between 0 and 1.4 % of the vegetation, and the contribution of *C. schoenanthus* between 0 and 4 %. Neither figure is very alarming. The specific contribution of *S. gracilis* varied between 0-36 %, showing serious invasion of certain units by this Sahelian species. Hiernaux (1996) stated, however, that changes in species composition in response to drought are often similar to those in response to grazing pressure. Moreover, many of these changes are reversible within a relevant time scale (Behnke and Abel, 1996). Spatial scales must also be considered as local run-off may favour Sahelian species while local run-on may favour Sudanian species. In Kaïbo, local run-on and run-off patches are clearly present (Rietkerk *et al.*, 1998).

Sheep and goats clearly are complementary feeders, the former being grazers and the latter browsers. Both animal species select considerably within the vegetation, leaving much of it untouched, proving that the resources are not so scarce that animals are forced to eat whatever is available. To summarise, the territory of Kaïbo does not show serious signs of degradation due to overgrazing. So far, man only can be considered directly responsible for the few signs of degradation (cutting of trees).

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7.2 Influences of herding system and season on grazing patterns and cattle diet composition in a patchy environment

Abstract

To study the influence of herding system and season on grazing patterns and animal diet composition for cattle in a patchy environment in Burkina Faso, 100 surveys of individual animals were conducted from October 1996 through September 1997. Fulani herds spent more time on bush (26.3 % versus 9.6 %; $p < 0.05$) and Mossi herds more on fallow (46.4 % versus 27.3 %; $p < 0.05$) and at home (9.8 % versus 1.7 %; $p < 0.05$). Season influenced the time herds spent on fallow (0 %-81 %; $p < 0.05$) and on crop fields (0 %-64.5 %; $p < 0.005$). It also influenced the contribution of crop residues (0 %-79 %; $p < 0.0005$) and forbs (0 % - 36.5 %; $p < 0.05$) to the diets. Crop residues were available from November through January and were preferred by cattle because their digestibility was higher than that of the available annuals (54 % versus 41 % in November). Forbs only contributed to the diets from June through September when they were highly digestible (74 to 58 %) and had high N contents (2.6 to 3.7 %). Fulani herds spent more time walking (25.3 % versus 16.6 %; $p < 0.005$) and less time resting (16.7 % versus 26.2 %; $p < 0.05$) than Mossi herds. Season influenced time spent eating (30 %- 75 %; $p < 0.0005$). In the dry season eating time is reduced, because vegetation becomes scarce and animals lose time searching and rest more to reduce heat stress. Herd size, control of water points and of crop residues were found to govern grazing patterns, constraining free movement of livestock in a patchy environment. Herded cattle selected vegetation with the highest quality, and can therefore be assumed to be "energy maximisers". Differences between diets of Mossi and Fulani cattle may have been masked by grouping vegetation species in broad categories. Moreover, the year under study was dry resulting in low biomass availability, restricting selective behaviour. Mossi control access to crop residues left for grazing in the fields and increasingly collect them for home-feeding in the dry season. They thereby withdraw the residues from the feed resources for Fulani herds. Because of population growth, fallow disappears and Mossi herds have to change their grazing pattern, starting to compete with Fulani cattle on bush areas during the rainy season. These changes reduce both, quantity and quality of feed for Fulani cattle with the risk of lower production of these herds.

Key-words: crop residues, foraging strategy, herd size, vegetation patches

Introduction

Burkina Faso is a Sahelian country, characterised by a distinct short rainy season followed by a dry season lasting at least seven months. In such a climate livestock production is one of the few means of life. Traditionally, semi-nomadic Fulani herdsmen own large herds of cattle but, more recently, sedentary Mossi farmers also own some cattle. Livestock production is based on grazing of natural resources, including crop residues left in farmers' fields. Crop residues are very important as animal feed and are therefore increasingly stored at the homestead by Mossi farmers for use as supplementary feed for their cattle and small ruminants during the hot dry season. Fulani and Mossi herd their cattle year-round.

In a free grazing system, cattle are free to select at different levels. They can choose where to graze, how long to graze and what to ingest. In a herding situation, herdsmen determine where cattle are grazed and how long they are on pasture (Ayantunde, 1998). Herdsmen consider total travel time and total feed intake per day per herd important with respect to grazing patterns, whereas place and time for watering or milking constrain daily movement patterns (Ayantunde, 1998; De Boer and Prins, 1989; Coppock *et al.*, 1988). Cattle can choose among the activities grazing, walking and resting while herded. Around the hottest time of the day, both herdsmen and livestock prefer to rest to restrict heat stress (Belovsky and Slade, 1986).

Herded cattle can choose between grazing units, vegetation patches, plant species, individual plants and plant parts (Heitkönig *et al.*, 1998; Diarra *et al.*, 1995; Guerin *et al.*, 1988). Following optimal foraging theory, animals can behave according to the time-minimising or the energy-maximising foraging strategy (Belovsky, 1986; Schoener, 1971). The first strategy implies that animals try to minimise travel time between vegetation patches within a grazing unit, and will move to another grazing unit when searching time between patches within the unit exceeds the average searching time for the entire area (De Boer and Prins, 1989). The latter strategy imples that animals select those food items (or preys) that contain the highest energy content, even though that may increase searching time. Maximisation of the ratio of protein to fibre seems more appropriate for cattle than maximisation of energy content (Krebs and McCleery, 1984). Strongly selective behaviour has been reported for cattle grazing Sahelian rangeland (Ayantunde, 1998; Diarra *et al.*, 1995; Dicko and Sangaré, 1986). In support of the time-minimising strategy, it has been reported that the contribution of a plant species in a ruminant's diet, in a free grazing situation, depends more on the probability to encounter the species than on its nutritive value (Genin, 1991). In support of the energy-maximising strategy, has been shown that ruminants tend to select the most nutritious parts of plants when excess feed is available, for instance in situations with low grazing pressure (Guerin *et al.*, 1988; Belovsky, 1986) or when crop residues are offered ad libitum (Savadogo, 2000; Zemmelink 1980). Quality of livestock diets was shown superior in digestibility and protein content to the average quality of pasture it grazed (Guerin *et al.*, 1988; Squires, 1982).

Several studies conducted in Zoundwéogo province, and in particular on the village territory of Kaïbo Sud V5, have shown that patchiness is present at different scales and that it provides livestock with the opportunity to select its diet (Rietkerk *et al.*, 1998; Rering, 1997;

Smeets, 1997; Mulders, 1996; Van den Berg, 1994). In the present study the units field, fallow, bush and riverside are distinguished (Smeets, 1997; Van den Berg, 1994). Road and compound will also be recorded when animals stay there for more than 10 minutes.

The objective of the present study is to investigate whether herding system (Mossi versus Fulani) and time of the year (Season), influence grazing patterns and cattle diets. Furthermore, the study should allow prediction of the impact of rapid population growth and changing crop residue management on grazing patterns and associated production potential of cattle herds.

Material and methods

In Kaïbo Sud V5, a village in Zoundwéogo province, Burkina Faso, Mossi and Fulani livestock owners jointly use the village territory. Fields and recent fallow are interspersed near the houses, while older fallow, bush fields and natural lands, such as riversides and bush, are further away from the houses. Herdsmen can decide roughly the location of their herds but, due to the fragmented land use, animals can still choose between harvested fields and recent fallow, when close to the houses or between bush and old fallow at larger distance. Within these units livestock can select for patches consisting of preferred plant species.

Households living in the village were asked to participate in the study. Most Mossi households did not own cattle or paid Fulani to herd them in the dry season. Only five Mossi households, owning and herding cattle, were included. Fulani households are generally very mobile. Only three Fulani households lived on the Kaïbo territory during the entire period. Their herds were also included.

Within each herd one adult animal was selected at random per survey, and its movements and activities were recorded during an entire day. Every two minutes, three types of data were monitored: (1) the landscape (grazing) unit in which the animal was present (2) the activity of the animal and (3) if eating, the plant species ingested. Over a period of 12 months 100 animal surveys were conducted. As Mossi herds consisted of only six to nine animals, some animals were monitored more than once. When an individual animal was monitored it was assumed to have a foraging behaviour that was representative for the herd, and hence for the management system. We were only interested in differences between systems and not between individual animals. A second survey for the same animal was therefore considered to be a repetition for the herd or system but not a repetition for the animal. Fulani herds were much larger, therefore animals were monitored only once. When more than one animal of a herd was monitored at the same time, the observations on their behaviour were combined to give one average result. The number of independant surveys was hence reduced to 77.

The selected animals were observed in the period October 1996 through September 1997. Although Fulani practise night grazing, their animals were monitored only during the day for practical reasons. Ayantunde (1998) has shown that, in Niger, the diet selected during day or night grazing did not differ. Neglecting night grazing presumably has no consequences for the results.

Each month, the five most dominant vegetation plant species were sampled. Dominant species were identified as those contributing most to the animals' diet in that month. Most species were therefore only sampled a few times a year as they were not every month amongst the dominating species. Samples were dried at air temperature at the study site before being transported to the capital where they were oven dried at 70 ^{0}C and ground to pass a 1 mm seeve, before being sent to a laboratory in Wageningen. For each sample of each species, nitrogen (N) content and in vitro organic matter digestibility were determined (Van Soest, 1977; Van Soest, Wine and Moore, 1966). For in vitro analysis, rumen fluid had to be used from Dutch cows, that are used to diets that differ considerably from diets of cattle in Burkina Faso. This can introduce a modification of the digestibility values. As we are only interested in comparing digestibilities among plant species and not in absolute values, this problem is further ignored. Analysis were carried out in the laboratory of the Department of Agronomy of Wageningen University.

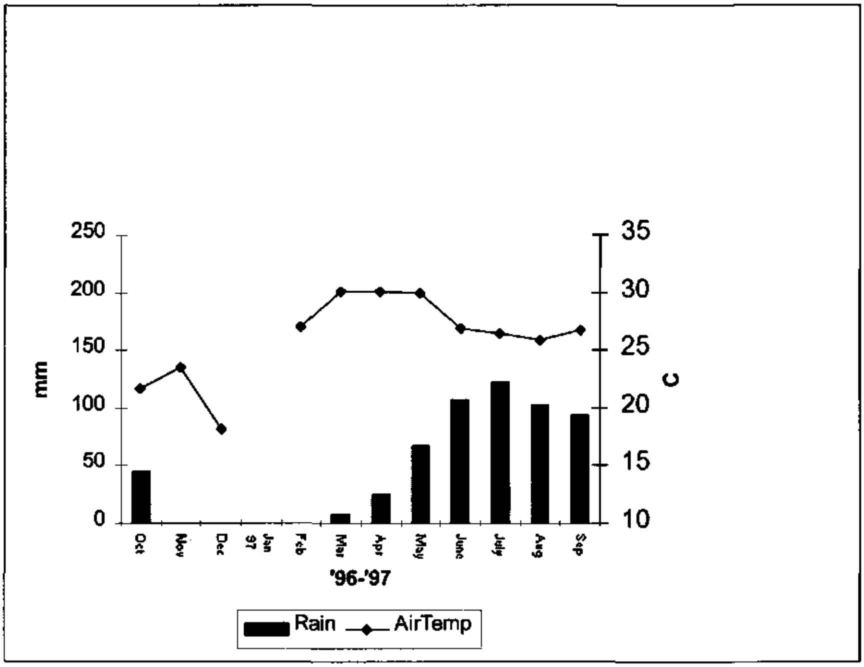

Figure 7.2.1 Average monthly precipitation (mm) and air temperature (^{o} C) from October 1996 through September 1997, Kaïbo Sud V6.

Results and discussion

Grouping of data

The different vegetation species are grouped in six categories: annual grasses, perennial grasses, woody species, crop residues, forbs and others. Vegetation development is governed by rainfall, therefore vegetation availability for livestock depends on time of the year. Daily rainfall data, measured in Kaïbo, are expressed in mm per month for 1996 and 1997 (Fig. 7.2.1). Season may influence the availability of fodder, therefore, monthly averages have been calculated (Table 7.2.1). Herding system may influence the choice of grazing units, therefore, averages per herding system have been calculated (Table 7.2.1).

Table 7.2.1 Effects of grazing system and season on time (% of total) spent on different grazing units, on animal activities, and on diet components (% of total diet) in Kaïbo Sud V5, October 1996 through September 1997.

	SYSTEM	(df = 1)	SEASON (df = 11)
	Mossi	Fulani	Lowest - highest monthly average
GRAZING UNIT			
Bush	9.6[a]	26.3[b]	5.5 - 38.5
Fallow	46.4[a]	27.3[b]	7.0[a] - 81.0[b]
Field	20.9	22.3	0.0[a] - 64.5[c]
Valley	13.3	22.4	3.5 - 48.0
Other (home, road)	9.8[a]	1.7[b]	0.0 - 20.0
ACTIVITY			
Eating	56.0	56.0	30.5[a] - 75.0[d]
Walking	16.6[a]	25.3[c]	15.0 - 31.5
Resting	26.2[a]	16.7[b]	4.5 - 37.0
DIET			
Annual grasses	53.7	48.4	11.0 - 80.5
Perennial grasses	1.8	6.3	0.0 - 16.0
Woody	4.3	6.7	0.0 - 24.0
Forbs	18.4[a]	8.8[b]	0.0[a] -36.5[b]
Crop residues	18.8	20.3	0.0[a] - 79.0[d]
Other	2.8[a]	9.5[b]	0.0 - 20.5

a-d significant for $p < 0.0005$

a-c significant for $p < 0.005$

a-b significant for $p < 0.05$

ANOVA is used to investigate whether herding system or month influence diet composition or time spent by animals on grazing units or on distinct activities. Twenty four data sets of averages (2 systems x 12 months) have been analysed (Table 7.2.1).

Table 7.2.1 shows that Fulani herds spent more time on bush and Mossi herds on fallow and at home. Season influenced the time herds spent on fallow and on fields, time spent eating, and the contribution of crop residues and forbs to the diets. Fulani herds spent more time walking and less resting than Mossi herds. Fulani and Mossi cattle did not differ in diet composition although they grazed on different units. Figs. 7.2.2, 7.2.3 and 7.2.4 give more details on specific time expenditure throughout the year.

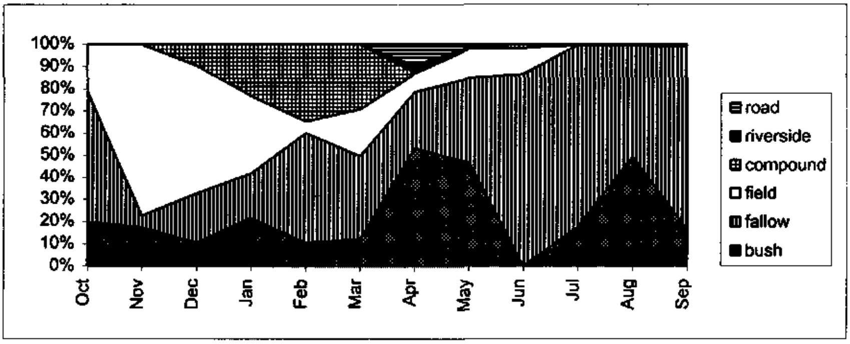

Figure 7.2.2a Average monthly grazing time per unit (%) for Mossi cattle, October 1996-September 1997, Kaïbo area

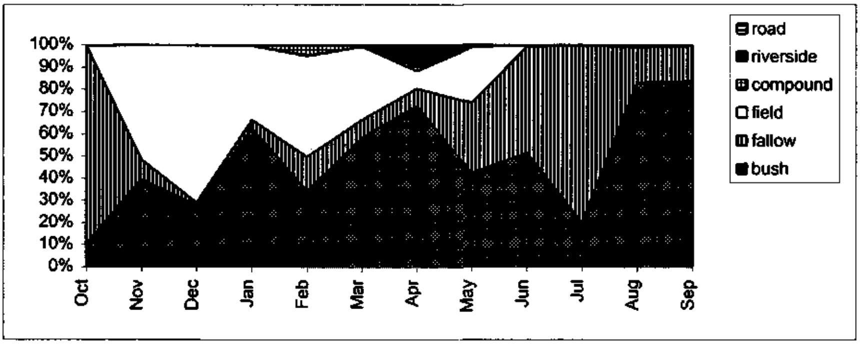

Figure 7.2.2b Average monthly grazing time (%) per unit for Fulani cattle, October 1996-September 1997, Kaïbo area

Grazing units

Fulani herds spent significantly more time on bush and Mossi herds on fallow (Table 7.2.1). Figs. 7.2.2a and b give more insight in the occupation of the grazing units over the year. In rainy season (June-October), Fulani cattle are herded far from the fields, in bush area, because it is difficult to prevent these large herds from damaging crops. The small Mossi herds can be herded on fallow between the fields without risk. Most crops belong to Mossi and damage by a fellow-Mossi is taken as a lesser offence than by Fulani, which explains the more risk-avoiding behaviour of Fulani.

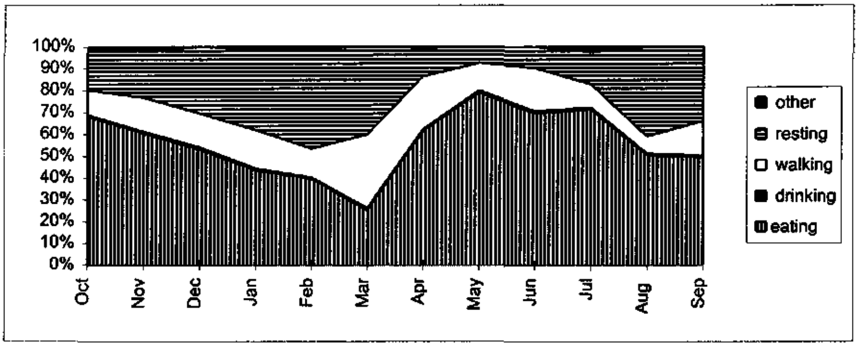

Figure 7.2.3a Average monthly time spent per activity for Mossi cattle, October 1996-September 1997, Kaïbo area

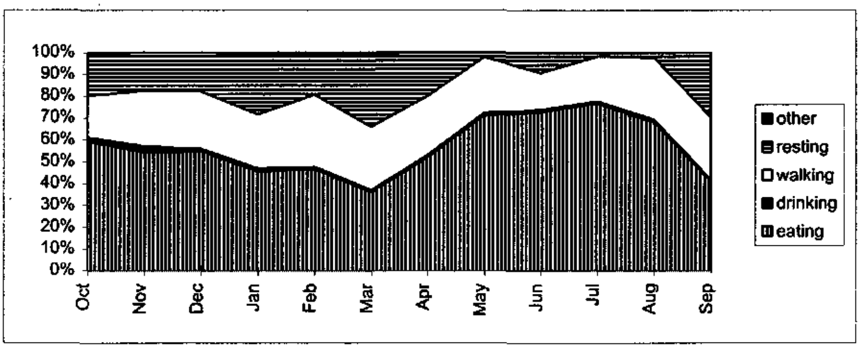

Figure 7.2.3b Average monthly time spent per activity (%) for Fulani cattle, October 1996-September 1997, Kaïbo area

From November through April Mossi return home at noon to water their animals at a well. Watering a small number of animals requires not much labour. The animals stay some time at home before going out again. Table 7.2.1 confirms that Mossi cattle spent more time on other units (home), mainly resting. Fulani water their
animals at the riverside, far away from the village and easily combined with bush grazing. As they have large herds, watering at the well is no option because of high labour requirements. Moreover, the well does not belong to Fulani, hence their access is restricted. In the rainy season, water is available at several places and passing along fields to go to the well is risky, because of crop damage. In this period, only draught bullocks after working the land, are watered at the well.

Animal activity

Figs. 7.2.3a and b show that Fulani herds spent generally more time walking than Mossi herds, partly because Fulani can not stay on recent fallow land in the rainy season and partly because they have to water their animals at the river in the dry season. As a consequence Mossi herds rest more (Table 7.2.1). In both systems, animals spent the longest time eating when fresh annual herbs are available in large quantities (May-July). In the dry season, eating time is reduced because vegetation becomes scarce and animals lose time searching and they rest more to restrict heat stress.

Animal diets

Figs. 7.2.4a and b show the contribution of the various plant categories to animal diets over the year. Crop residues were only available after crop harvest which starts at the end of September. In November and December 1996 they contributed on average 68 and 79 % to the animal diets, decreasing to only 37 % in January 1997. From April to September no residues were ingested, because they were not available.

Annual grasses started growing after the onset of the rainy season as early as March in 1997 and contributed up to 81 and 74 % to animal diets in, for instance May and July. Large quantities remained available as standing hay in the dry season, and were ingested in that period, as no other forage was available, which explains the absence of a season effect. They still contributed 65 % to diets in February. Annual grasses were, however, hardly consumed in the period November to January due to the very high availability of crop residues.

In this period, the quality of crop residues was generally higher than of annual grasses (Table 7.2.2), hence their preferential consumption. The average digestibility for sorghum residues declined rapidly and was similar to the quality of annual grasses in January, but the digestibility of maize stover remained high. Average nitrogen (N) contents of annual grasses and crop residues were about equal. Cattle selected, however, within crop residues, and ingested only the leaves, with much higher N-contents than stems as is shown for sorghum residues in January (Table 7.2.2). Other crop residues, such as millet stover, also showed differences, although moderate, between plant parts: In January, N-contents were 0.47 % for stems and 0.52 % for leaves. Millet residues were ingested in very small quantities by cattle, because not only their N-content is low, but also their digestibility, varying from 42 % for leaves to 34.4 % for stems in January.

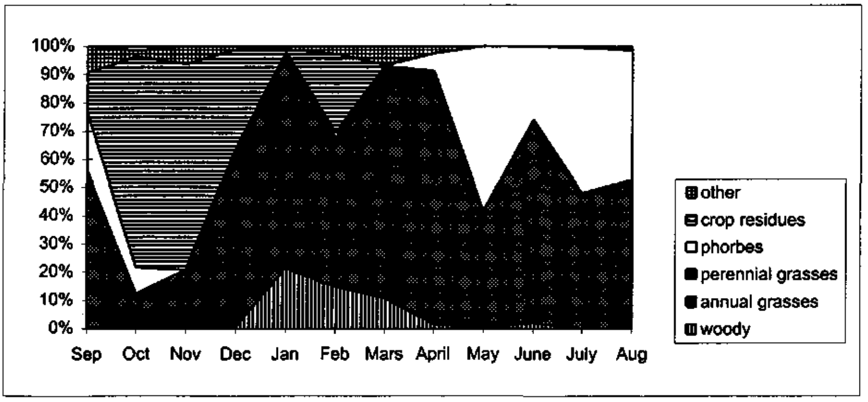

Figure 7.2.4a Average monthly diet composition for Mossi cattle, September 1996-August 1997, Kaïbo area

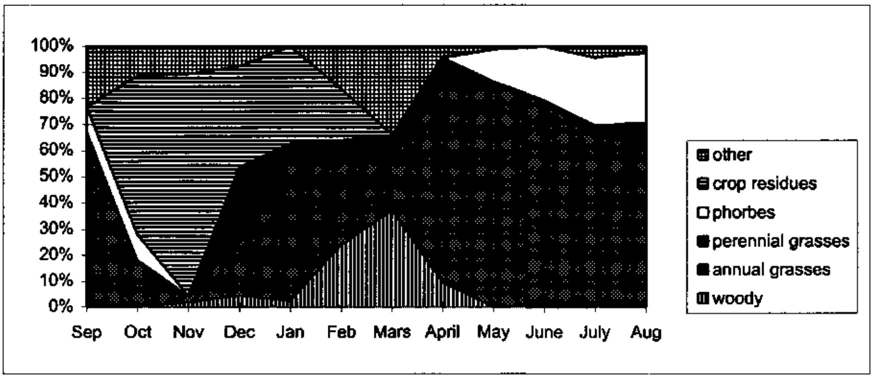

Figure 7.2.4b Average monthly diet composition for Fulani cattle, September 1996-August 1997, Kaïbo area

The contribution of forbs to the diet differed between Mossi and Fulani herds and was influenced by season. Figs. 7.2.2a and b show that Mossi herds spent much more time on fallow in the period June-October than Fulani herds.The main forbe species were *Tephrosia* spp., growing mainly on fallow, and showing seasonally high digestibility and N-contents. Digestibility was highest in June at 74.3 % and dropped to 51.7 % in October, while N-contents dropped concurrently from 3.72 to 1.96 % . In June, August and September *Tephrosia* spp. contributed 57, 52 and 45 % to diets of Mossi cattle, and only 12, 26 and 25 % to diets of Fulani cattle. In other months the species was not found in the diets.

Table 7.2.2 In vitro digestibility and N contents of crop residues and annual grasses found to dominate cattle diets in November and December 1996 and January 1997 (laboratory results).

	Digestibility (%)			N-contents (%)		
Month	Nov	Dec	Jan	Nov	Dec	Jan
Crop residues						
Sorghum bicolor[1]	53.0	44.2	41.1	0.53	0.31	3.01[2]
Zea Mais[1]	55.7	56.8	51.0	0.45	0.49	0.39
Annual grasses						
Schoenfeldia gracilis[1]	40.1	41.5	41.9	0.54	0.49	0.35
Andropogon pseudapricus[1]	*ND	37.5	36.0	ND	0.35	0.23[3]
Pennisetum pedicellatum[1]	41.4	ND	38.0	0.61	ND	0.42

[1] average for total aerial biomass of plant

[2] leaves only (stems: % N = 0.29)

[3] heads only (stems: % N = 0.18)

* ND = No Data available

Conclusions and prospects

Herds of Mossi and Fulani use different parts of the territory. The observed differences are mainly associated with access to water points and herd size that force Fulani herds to graze further away from the houses and the crop fields. These differences are reflected in animal activities, such as longer walking and shorter resting times for Fulani herds. These results confirm the findings of De Boer and Prins (1989) and Coppock *et al.* (1988) that herdsmen have to adapt grazing patterns to constraints, such as water availability or milking opportunities. The optimal foraging theory, assuming that animals minimise travel time between patches, does not hold in Kaïbo, because of these constraints. The same constraints prevent Fulani herdsmen from minimising total daily travel time, when compared to Mossi herdsmen.

Herding system has a significant influence on choice of grazing unit, but not on diet composition. One possibility is that the grazing units do not differ much in species composition, presenting animals with the same room for selection. Van den Berg (1994) and Smeets (1997) have shown, however, that grazing units on Kaïbo village territory did differ considerably in species composition. Alternatively, selection among plant species may be masked by grouping forages in large categories (Squires, 1982). That could indeed be the case here. A specific case of masking is associated with annual grasses because they can not easily be identified before flowering. They are just recognised as annual grasses and classified as such in all units. Yet, another possibility is that scarcity of feed prevents animals from selecting so that they become generalisers (Schoener, 1971). That could also be the case, because the 1997 rainy season (with 570 mm in Kaïbo) was the driest since the drought of 1984, leading to very low biomass production.

Season influences the choice of grazing units. Fields and young fallow can, for instance, only be grazed after harvest, which is the time that crop residues become available and contribute to animal diets. Season also influences eating time. During the rainy season eating time increases, because of abundant availability of acceptable forage that minimises searching time.

When population growth in Burkina Faso continues at an annual rate of 2.6 % (EIU, 1996), more land will be used for cropping and fallow will become scarce in the future. Between 1984 and 1994 the cropped area increased from 2,064.,610 hectares to 3,654,380 hectares for the entire country (MARA, 1995). In the rainy season, Mossi cattle will then have to graze outside the cropping area on bush land. Hence, the competition for grazing land in the rainy season will increase.

The importance of crop residues is shown for both Mossi and Fulani herds. As Mossi increasingly collect these residues for home-feeding, they are withdrawn from the feed resources for Fulani herds. Figures 4a and b show that crop residues represent a considerable proportion of animal diets, even when annual herbs are still available. In the period November through January, the quality of crop residues is higher than of annual grasses. Hence, in the future, Fulani herds will suffer from a decrease in both fodder quantity and quality, which may reduce animal production from this system.

Acknowledgements

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7.3 Cutting and resprouting of *Detarium microcarpum* and herbaceous forage availability in a semi-arid environment

Abstract

The tree-shrub savanna "*Forêt Classée de Nazinon*" (Burkina Faso) is submitted to a management of grazing and rotational cutting of *Detarium microcarpum*. This species resprouts after cutting. In order to investigate whether this silvopastoral land use system is sustainable, aboveground herbaceous biomass was measured on subplots under uncut trees ("uncut"), next to the stubs of cut trees ("cut") and on subplots not influenced by the (former) crowns of trees ("open grassland") in four lots. These lots were cut 1, 3, 6 and 7 years before the study. Vegetation composition of the lots and the composition of the diet of cattle were also determined. Comparisons were made between treatments and lots. Herbaceous biomass was lower in the open grassland subplots than in uncut or cut subplots. We speculate that soil enrichment and more efficient precipitation input in (former) tree crown zones could have resulted in this pattern. Cutting and subsequent resprouting of trees did not lead to significant differences in herbaceous biomass between cut and uncut subplots. The most simple explanation for this is that the trees could extend their roots beyond the location of their neighbouring trees. Biomass and coverage of perennial grasses, mainly *Andropogon ascinodis* and *Andropogon gayanus*, did not change in lots cut 1, 3 or 6 years before the study, but decreased dramatically in lots that were cut 7 years before the study. When foraging, cattle spent more than 90 % of their time feeding on these species. This indicates that, as a consequence of tree cutting, forage availability may be reduced to the point where local herdsmen are forced to take their cattle to another region.

Key words: bush encroachment, grazing, silvopastoralism, tropical savanna, vegetation dynamics.

Introduction

Trees and shrubs in tropical savannas have often been found to improve their understorey environment (Belsky *et al.*, 1989; Kellman, 1979). This common finding is important for the field of silvopastoralism, a land management system in which trees and shrubs are retained in or introduced into pastoral land (Le Houérou, 1987). But the effect of trees and shrubs on their understorey environment depends on factors such as rainfall, type and intensity of use of the different components of the silvopastoral system, and the density of the trees. As an example, Belsky *et al.* (1993) found that the beneficial effect of widely spaced trees on the biomass of the herbaceous layer diminishes with increased livestock utilisation.

The herbaceous-woody plant ratio of savannas seems to be mainly governed by rainfall, which is low to moderate (500-1300 mm) and extremely variable (Whittaker, 1975). This suggests that soil water availability is a major factor limiting the growth of savanna vegetation. Fire and herbivory may also have a profound effect on this ratio (Dublin, 1995; Werger, 1983; Kelly and Walker, 1976). The general model for the competition between the woody and herbaceous vegetation component is that of a two layered soil-water system in which each vegetation component is the superior competitor in a different layer (Walker *et al.*, 1981). Herbs are more efficient in extracting water from the upper soil layer (topsoil, 0-30 cm) whereas woody plants have better access to water that percolates through the topsoil and infiltrates into the subsoil (30-150 cm). Field evidence to support this hypothesis was obtained in dry savannas (Brown and Archer, 1990; Sala *et al.*, 1989; Knoop and Walker, 1985).

Recent work by Le Roux *et al.* (1995), however, shows that in more humid environments (>1300 mm rainfall per year) both woody and herbaceous plants obtain their water from the same soil layer. Competition between these two vegetation components for available soil water may thus be stronger than in arid areas, provided that soil water availability is still a major factor limiting plant growth. The same was found by Belsky (1994), who demonstrated that trees competed with herbaceous species for soil water and reduced their productivity at wetter sites (>750 mm per year). Vegetation at drier sites (450 mm per year) showed less intense competition between the woody and herbaceous component, as trees at these sites extended their roots over a larger area than trees at wetter sites. In all cases herbaceous productivity was higher in the tree crown zone than in the open grassland zone. The reason for this seems to be that trees add nutrients to the understory environment in the crown zone in the form of litter and droppings of reposing animals and reduce soil and plant temperatures and evapotranspiration by the shade they cast (Belsky, 1994; Belsky *et al.*, 1993).

Thus, in a semi-arid ecosystem plants in an understory environment may benefit from tree presence by the increased nutrient input and decreased temperature in the below-crown microhabitat, but they may also suffer from the increased competition for available soil water and nutrients. Cutting of a tree eliminates these immediate effects on the herbaceous layer. The accumulated amount of nutrients in the former crown zone, which is a long term effect of tree presence, is now exclusively available to the herbaceous component of the vegetation. As the benefit of increased levels of available nutrients is expected to outweigh the possible disadvantage of increased radiation, it seems plausible to expect an increase in herbaceous biomass in the former tree crown zone after cutting (Breman and Kessler, 1995). A higher biomass yield for grasses in areas recently cleared of woody vegetation has been found by Ben-Shahar (1992). He argues that for this reason bush clearance may be of some benefit to herbivores.

The aims of this study were to determine the effects of cutting and resprouting of *Detarium microcarpum* on herbaceous biomass over several years, including the subsequent implications for biomass availability for grazing cattle.

Material and Methods

Study site and plot choice

The fieldwork of this study was performed in the rainy season of 1996 in the "*Forêt Classée de Nazinon*", with an area of 23.699 ha, situated in the province of Ziro, district of Sapouy, Burkina Faso (11°30'-11°51' N, 1°27'-1°50' W). Around the woodland 24 villages are situated, with a total population of 15.511 in 1985 (estimated yearly increase of 4.9 %). The main ethnic groups are Mossi, Gourounsi and Fulani (Peulh). The vegetation in this woodland can be characterised as a tree-shrub savanna. Dominant woody species (low trees and shrubs) are *Detarium microcarpum*, *Burkea africana* and *Strychnos spinosa*, with a highly variable total aerial coverage of 3-75 %. Precipitation is 850 mm per year (1961-1990) which classifies the region as North Sudanian ecoclimatic zone; the rainy season lasts from May - September. Physiographically the area can be classified as a slightly undulating plateau. Soils were classified as Haplic Luvisols (Lvh) and Haplic Alisols (Alh) (FAO, 1988). Both natural and man-induced fires occur with an estimated frequency of one fire per year. The woodland is divided into 140 lots, of which seven are selected every year for harvesting part of the woody vegetation (about 50 % of the trees in a 20-year rotation) for fuel wood. The woodland is grazed mainly by cattle with an estimated density of 0.5-1.0 tropical livestock unit (TLU) per ha. (Ouédraogo, 1997; Diarra and Selmi, 1994; Coulibaly, 1993).

In order to determine the effect of cutting and resprouting of *Detarium microcarpum* over several years, four neighbouring lots were selected, from which part of the woody vegetation was cut in 1989, 1990, 1993 and 1995 respectively (7, 6, 3 and 1 years before this study). The area of each of these lots is 100-140 ha. Within these lots, subplots of 1 m^2 were selected through stratified random sampling under uncut trees ("uncut"), next to the stubs of cut trees ("cut") and on subplots not influenced by the (former) crowns of trees ("open grassland"). The three types of subplots are refered to as "treatments" and there were five replications per treatment. All 60 subplots were selected in areas with similar tree densities. Large irregularities in the terrain (rocks, eroded areas, local depressions, etc.) other than local soil differences were avoided. In view of the large areas of the lots, we assumed that all relevant soil variation was included within each lot representing a certain year of cutting. Therefore, biomass differences could not be atrributed to local soil differences, which were not measured. It was further assumed that the lots had a similar vegetation before cutting. All selected trees were of the species *Detarium microcarpum* (Caesalpiniaceae), which is abundant in the woodland and is used as firewood. This species resprouts after cutting. The density of this species in this area is 2-4 trees per 100 m^2, crown diameter is 3.69 ± 0.12 m (mean ± SE) (Ouédraogo, 1997).

Herbaceous biomass

Herbaceous biomass, excluding litter, and including tree seedlings and small shrubs with a stem diameter of less than 0.5 cm, was harvested from the subplots by hand-clipping. Biomass was sorted into functional groups (annual grasses, perennial grasses, and forbs) and fresh weight was determined per functional group using a spring balance (Weighmaster).

Vegetation composition

In order to determine any long term effect of cutting on vegetation composition, five transects were laid out according to the point-quadrat method in each of the four lots studied. Along two lines of 10 m, which crossed each other in the middle at a right angle, each plant species and functional group (trees, shrubs, annual and perennial grasses, annual and perennial forbs) touching an imaginary vertical line was noted at 20 cm intervals. Resprouting *Detarium microcarpum* were noted as trees. Thus for each transect information was collected at 100 points in an area of 50 m^2 (a square area from which the lines are the diagonals) rendering a species-specific coverage as a percentage of surface area.

Herbivory

In order to determine the effect of cutting of the woody vegetation component on forage availability for grazers, the dependence of these grazers on the different species of gramineous herbs occurring in the area was determined. To this purpose herds of cattle were followed when foraging in the woodland, and the forage-species eaten by a randomly picked animal was noted every minute. Thus the amount of time spent foraging on any species was obtained as a percentage of total foraging time. The term foraging here includes the action of biting only, as further ingestion and digestion of food is not directly related to forage availability.

Data analysis

Two-way ANOVA tests were used to determine the main and interaction effects of treatments and year of cutting. If effects were found one-way ANOVA tests and Student-Newman-Keuls tests were used to determine significant differences ($P< 0.05$) between means. Before testing, biomass and percentual data were log and arcsine transformed respectively.

Results

Herbaceous biomass

Total herbaceous biomass and forb biomass was lower in the open grassland subplots than in uncut and cut subplots, no significant differences were found between cut and uncut subplots and no interaction effects with year of cutting were found (Figure 7.3.1 and Table 7.3.1).

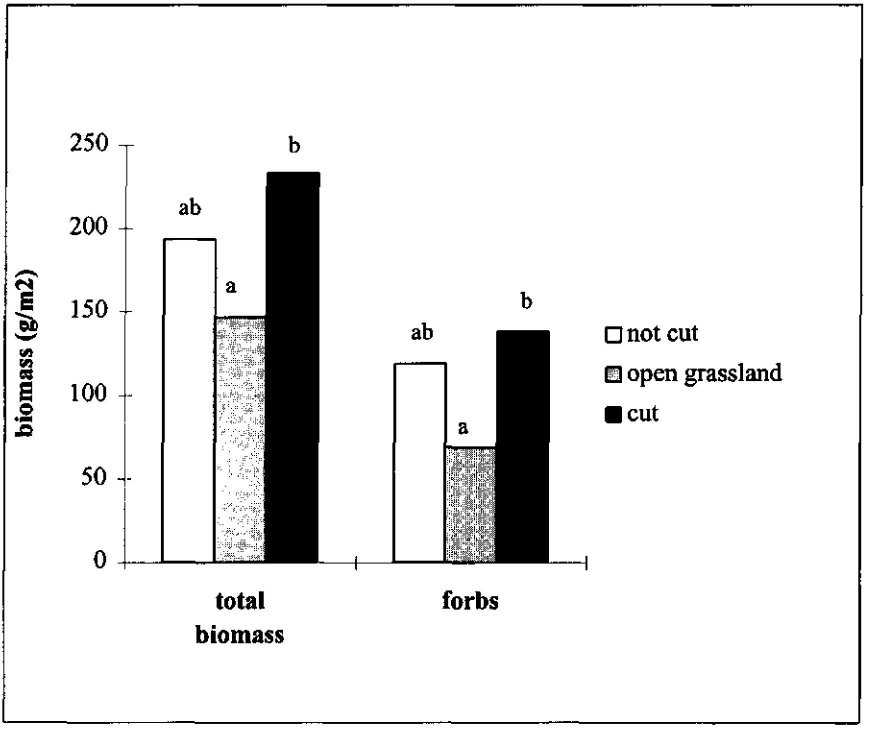

Fig. 7.3.1 Biomass of different functional groups in relation to treatment at Sapouy, Ziro, Burkina Faso. Different letters indicate significant differences between means ($P<0.05$) of each selected dataset

Total herbaceous biomass and biomass of all of the functional groups showed significant differences for the time passed after cutting (Table 7.3.1 and Fig. 7.3.2). In general, biomass changed little in recently cut lots (1-3 years before the study), but decreased significantly in lots that were cut longer ago (6 and 7 years before the study), except for annual grasses. The herbaceous layer in the four lots was characterised by an almost complete absence of annuals.

Table 7.3.1 Biomass (mean ± s.d) per treatment (treat), per year of cutting (year) at Sapouy, Ziro, Burkina Faso, and ANOVA test results.

Year	Treat	Total biomass (g/m^2)	Forbs (g/m^2)	Grass (g/m^2)	Annual grass (g/m^2)	Perennial grass (g/m^2)
(1)	u	230.0	152.0	78.0	3.0	75.0
1995		(± 131.6)	(± 149.8)	(± 28.3)	(± 3.3)	(± 27.2)
	o	232.0	117.0	115.0	0.5	114.5
		(± 102.3)	(± 101.3)	(± 23.7)	(± 1.1)	(± 24.0)
	c	300.5	161.0	139.5	9.5	130.0
		(± 60.6)	(± 113.3)	(± 60.0)	(± 13.5)	(± 54.2)
(3)	u	225.0	164.0	61.0	2.5	58.5
1993		(± 237.7)	(± 239.6)	(± 24.1)	(± 1.8)	(± 23.4)
	o	217.0	154.0	63.0	3.0	60.0
		(± 253.5)	(± 275.8)	(± 40.5)	(± 2.7)	(± 42.4)
	c	342.0	246.0	96.0	2.5	93.5
		(± 303.6)	(± 276.2)	(± 62.3)	(± 0.0)	(± 62.3)
(6)	u	125.0	14.0	111.0	4.0	107.0
1990		(± 20.5)	(± 11.9)	(± 20.9)	(± 2.1)	(± 22.0)
	o	99.5	2.0	97.5	2.5	95.0
		(± 64.7)	(± 2.1)	(± 64.9)	(± 1.8)	(± 65.2)
	c	214.0	118.5	95.5	2.0	93.5
		(± 187.5)	(± 220.7)	(± 51.0)	(± 2.1)	(± 50.7)
(7)	u	194.5	146.0	48.5	6.5	42.0
1989		(± 155.0)	(± 156.3)	(± 22.1)	(± 3.4)	(± 19.6)
	o	38.0	3.0	35.0	10.0	25.0
		(± 26.8)	(± 2.1)	(± 25.0)	(± 5.0)	(± 27.2)
	c	77.0	28.0	49.0	6.0	43.0
		(± 35.0)	(± 44.0)	(± 23.1)	(± 2.9)	(± 24.6)

Year indicates the year of cutting. Treat indicates treatment, where u = uncut; o = open grassland; c = cut. Values in parenthesis indicate s.d.

ANOVA	Total biomass	Forbs	Grass	Annual grass	Perennial grass
year	F= 8.132	F= 8.462	F= 8.991	F= 6.305	F= 9.656
n=60; df=3	P= 0.000	P= 0.000	P= 0.000	P= 0.001**	P= 0.000
treat	F= 4.683	F= 5.674	F= 0.913	F= 0.399	F= 1.863
n=60; df=2	P= 0.014*	P= 0.006**	P= 0.408	P= 0.673	P= 0.166
year * treat	F= 1.652	F= 1.416	F= 0.750	F= 1.680	F= 1.372
n=60; df=6	P= 0.154	P= 0.228	P= 0.612	P= 0.146	P= 0.245

* $P < 0.05$; ** $P < 0.01$; $P = 0.000$ means $P < 0.001$

Table 7.3.2 Coverage (mean ± s.d.) of different functional groups and species in lots cut in different years at Sapouy, Ziro, Burkina Faso, and ANOVA test results. Different letters in bold type indicate significant differences (P<0.05) between means when comparing different years of cutting for trees, perennial forbs, perennial grasses and *Andropogon spp.*, respectively.

Coverage (%)	1 (1995)	3 (1993)	6 (1990)	7 (1989)	ANOVA n=20; df=3
Total	52.60	56.80	61.20	63.00	F= 0.4600
	(± 18.98)	(± 12.52)	(± 14.87)	(± 11.90)	P= 0.7141
Trees	15.60 **a**	27.60 **ab**	36.80 **ab**	50.80 **b**	F= 3.3062
	(± 13.18)	(± 16.83)	(± 24.43)	(± 13.54)	P= 0.0472*
Shrubs	8.80	2.80	0.80	5.60	F= 1.3865
	(± 11.92)	(± 2.77)	(± 0.84)	(± 4.88)	P= 0.2830
Annual forbs	0.20	0	0	0	F= 1.0000
	(± 0.45)	(± 0)	(± 0)	(± 0)	P= 0.4182
Perennial forbs	11.20 **b**	8.00 **ab**	4.80 **ab**	1.60 **a**	F= 5.2392
	(± 5.36)	(± 3.81)	(± 3.96)	(± 2.19)	P= 0.0104**
Annual grasses	0.60	2.00	0.40	9.60	F= 2.5924
	(± 0.89)	(± 2.83)	(± 0.55)	(± 11.67)	P= 0.0887
Perennial grasses	28.20 **b**	29.60 **b**	38.00 **b**	8.80 **a**	F= 10.1989
	(± 10.69)	(± 3.85)	(± 11.68)	(± 4.71)	P= 0.0005***
Detarium	5.20	20.20	15.60	24.40	F= 1.6617
microcarpum	(± 4.32)	(± 19.75)	(± 10.50)	(± 16.88)	P= 0.2151
Andropogon spp.	27.80 **b**	29.40 **b**	38.00 **b**	8.20 **a**	F= 11.1103
	(± 10.26)	(± 3.78)	(± 11.68)	(± 4.21)	P= 0.0003***

* P<0.05; ** P<0.01; *** P<0.001

Vegetation composition

The woody component was dominated by *Detarium microcarpum* and the herbaceous layer consisted mainly of *Andropogon spp.* Tree coverage became higher with increasing time passed after cutting (Table 7.3.2). The coverage of *Andropogon spp.* did not change significantly in lots cut 1, 3 or 6 years before the study, but decreased dramatically in lots that were cut 7 years before the study. Coverage of perennial forbs decreased continuously with increasing time after cutting. Mean coverage of annual grasses was higher in the lot that was cut 7 years earlier, as compared to the other lots.

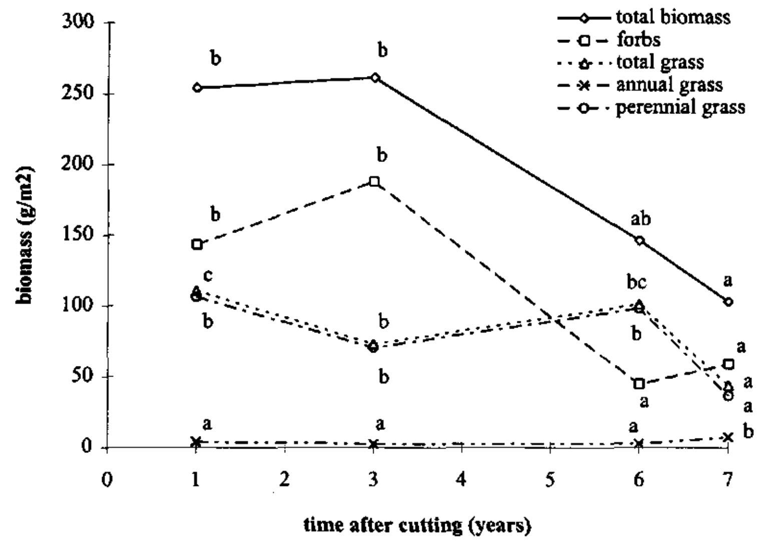

Fig. 7.3.2 Biomass of different functional groups in relation to time passed after cutting at Sapouy, Ziro, Burkina Faso. Different letters indicate significant differences between means ($P<0.05$) of each selected dataset.

Herbivory

Cattle spent more than 90 % of their grazing time on *Andropogon ascinodis* and *Andropogon gayanus* (Table 7.3.3). The percentage of foraging time spent by the herbivore feeding on a certain species is not correlated with the coverage of forage species (Spearman correlation coefficients not shown, $P > 0.05$). Further, the animals followed were not observed to switch to other forage species in areas where *Andropogon spp.* did not occur at all.

Discussion and Conclusion

In all the lots investigated, herbaceous biomass was lower in the open grassland plots than in the uncut or cut subplots (Table 7.3.1 and Fig. 7.3.1). This could be attributed to the commonly found long term effect that soils under tree crowns are generally enriched and have more efficient precipitation input as compared to neighbouring grassland (Belsky, 1994; Belsky *et al.*, 1993; Kellman, 1979). More surprising is that cutting and subsequent resprouting of *Detarium microcarpum* did not lead to differences in herbaceous biomass between cut and uncut subplots. If only tree cutting was considered, an explanation could be that the possible disadvantage of increased radiation for the herbaceous layer is balanced by increased levels of available nutrients (Breman and Kessler, 1995). The subsequent resprouting of the trees and the fact that no differences were found between cut and uncut subplots, independent of year of cutting, points to the possibility that there could be a continuous balance between decreased radiation and decreased nutrient availability for the herbaceous layer. However, this would only be a satisfactory explanation if, additional to the absence of interaction, no differences in herbaceous biomass were found between years of cutting. The fact that these differences were found (Table 7.3.1 and Fig. 7.3.2) points to a different and more simple explanation: in this system trees may extend their roots over a distance larger than crown diameter and intracrown distance. It has been documented that *Detarium microcarpum* often forms lateral roots within the root zone of the herbaceous layer (Thies, 1995). A density of 2-4 trees per 100 m^2 also indicates that these trees can not be seen as isolated. Crown size of *Detarium microcarpum* is relatively small when compared to the size of trees used in other studies (e.g. *Acacia tortilis* in Belsky, 1994; *Adansonia digitata* and *Acacia tortilis* in Belsky *et al.*, 1993).

Table 7.3.3 Foraging time of cattle in different lots as a percentage of following time, and foraging time on *Andropogon spp.* as a percentage of total foraging time in relation to their coverage in the Nazinon woodland at Sapouy, Ziro, Burkina Faso.

	(1) 1995	(3) 1993	(6) 1990	(7) 1989
Foraging time				
(% following time)	68,52	57,89	51,85	47,83
Andropogon gayanus				
(% foraging time)	54,05	81,82	64,29	54,55
(% coverage)	4.4	6.6	2.0	1.8
Andropogon ascinodis				
(% foraging time)	40,54	18,18	35,71	40,91
(% coverage)	23.4	22.8	36.0	6.4

Generally, herbaceous biomass changed little in recently cut lots (1-3 years before the study), but decreased dramatically in lots that were cut longer ago (6 and 7 years before the study), except for annual grasses (Table 7.3.1 and Fig. 7.3.2). These results are corroborated by the results on vegetation composition, which indicate that the occurrence of the dominant perennial herbaceous species (*Andropogon spp.*) decreases dramatically as tree coverage surpasses about 40 % in the lot cut 7 years ago (Table 7.3.2). These results could be explained by the following hypothetical scenario. As transpiration and the uptake of soil nutrients is initially arrested after cutting, the situation may resemble that of non-resprouting trees. It could then be expected that the competition for soil resources between trees and herbaceous biomass may decrease and herbaceous biomass may increase, as put forward by Breman and

Kessler (1995). In our study, however, herbaceous biomass did not increase significantly, probably because neighbouring trees continued to compete with the herbaceous vegetation near the stubs of the cut trees. Subsequently, the cut trees resprouted from stored nutrients in root reserves. Gradually, transpiration and the uptake of soil nutrients by the resprouting trees could have increased according to the amount of newly produced foliage, and root reserves may have become restored. As a consequence, competition for soil resources between trees and herbaceous biomass could have become stronger for all subplots, as the roots from the resprouting tree may cover a distance larger than crown diameter and intracrown distance. Continued grazing may have accelerated the process of encroaching tree coverage by causing a decline in herbaceous biomass and thus reducing soil resource competition in favour of the woody vegetation component. Increase in size and density of woody plants or less palatable herbaceous plants may have further intensified the grazing pressure on remaining palatable herbaceous plants. This positive feedback could have driven the system into a state mainly dominated by trees making a return to the original vegetation unlikely, even when livestock are removed (Archer, 1996). This hypothetical scenario will be tested in future research in this area.

Competition for light was not considered as a major factor diminishing plant growth in understorey layers. Earlier investigations (e.g. Belsky, 1994) showed that improved environmental conditions in understorey layers provided by savanna trees outweighed the negative aspects of competition, which is confirmed by our study.

Domestic herbivores in "*Forêt Classée de Nazinon*" showed a strong dependence on perennial grasses, especially *Andropogon spp*. It is especially this species which is reduced drastically as a consequence of cutting and subsequent resprouting of *Detarium microcarpum*. If these results concerning the dynamics of the forage species in this woodland indicate a general pattern, grazing possibilities for cattle could be limited to uncut or recently cut areas, whereas forage availability could decrease with increasing time after cutting. Ultimately forage availability may be reduced to the point where local herdsmen are forced to take their cattle to another region.

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7.4 Herbivore-vegetation interactions: theory and research results

For evaluation of the impact of changes in grazing systems, interactions among different components of a vegetation and between the vegetation and (wild) herbivores must be understood. Theories on competition/facilitation processes, predator-prey relations, optimal foraging, succession of vegetation, carrying capacity, ecosystem resilience, non-equilibrium/equilibrium environments to mention the most important ones, have been developed in an ecological setting, considering wildlife in a natural environment. In our study area, livestock systems are all based on free grazing herbivores. Therefore those theories should be applicable to these herbivore-vegetation systems. In many cases, however, the impact of man must be included because he can use various strategies to feed his livestock and thus affect animal-vegetation interactions.

Interactions among vegetation components

The relative variation in contribution of annual and perennial species to a plant community can be explained by processes of **facilitation** and **competition** between these species (Belsky, 1994). These processes depend on soil and weather conditions because water and nutrients are the main determinants of plant growth (Rietkerk and Van de Koppel, 1997; Penning de Vries and Djitèye, 1982). Examples of both facilitation and competition have been shown in the Nazinon experiment (Section 7.3). Herbaceous biomass was higher in the plots where trees were present or recently cut than in open grassland, because soils under tree crowns are generally enriched and have more efficient precipitation input as compared to neighbouring grassland (Belsky *et al.*, 1993; Kellman, 1979). The potentially negative effects of competition for light in understorey layers due to the presence of savanna trees, were outweighed by improved environmental conditions, such as increase in soil fertility (Belsky, 1994). Cutting and subsequent re-sprouting of trees in Nazinon did not lead to significant differences in herbaceous biomass between cut and uncut subplots, because presumably neighbouring trees, extending their lateral roots in the root zone of the herbaceous layer, continued to compete with the herbaceous vegetation near the stubs of the cut trees. The cut trees re-sprouted from stored nutrients in root reserves. Gradually, transpiration and the uptake of soil nutrients by the re-sprouting trees may have increased in proportion to the amount of newly produced foliage, and root reserves may have become restored. As a consequence, competition for soil resources between trees and herbaceous biomass could have become stronger for all subplots, as the roots from the re-sprouting tree may cover a distance larger than crown diameter and intra-crown distance. Herbaceous biomass decreased therefore dramatically in plots that were cut longer ago. Continued grazing may have accelerated the process of encroaching tree cover by causing a decline in herbaceous biomass and thus shifting the competitive power for soil resources in favour of the woody vegetation component. Increase in size and density of the woody vegetation may have further intensified the grazing pressure on remaining palatable herbaceous plants. This positive feedback could have driven the system into a state mainly dominated by trees making a return to the original vegetation unlikely, even when livestock are removed (Archer, 1996). Several other examples of bush encroachment have been reported due to heavy grazing in Niger (Hiernaux and Fernãndez-Rivera, 1995) and due to the absence of browsers in Southern Africa (Jordaan and Le Roux, 1996; Skarpe, 1990; Aucamp, 1976).

Regulation of herbivore numbers

Predator-prey models have been developed to explain fluctuations in herbivore numbers due to activities of carnivore species. In Serengeti, populations of small ungulates appeared to be regulated by predators (Sinclair, 1985). Availability and quality of natural vegetation also influence herbivore numbers and performances. In the same Serengeti, numbers of large herbivores, such as buffalo and elephant, appeared to be regulated by variation in food availability rather than by predators (Sinclair, 1985). Caswell (1978) applied the predator-prey model to herbivore-plant relations, considering herbivore as predator and vegetation as prey. He showed a decline in species diversity (prey) with increasing grazing intensity (predator pressure) on short grass steppe. Noy-Meir (1975) also applying the predator-prey model to plant-herbivore systems showed that simple grazing systems may be characterised by discontinuous stability.

Interaction between herbivore and vegetation

The **optimal foraging theory** (Belovsky, 1984; Pyke *et al.*, 1977; Schoener, 1971) provides an explanation for the selection of food items (or prey) by animals (predators), and for the strategy of animals to move within and between patches. For herbivores, this theory can explain why and how they select within available vegetation, in such a way that they reach higher production and reproduction than would be expected from average vegetation quality. According to Schoener (1971), herbivores can be considered as energy maximisers, although energy can better be substituted by the ratio of protein to fibre (Krebs and Davies, 1984). In this respect, animals cover a range from species accepting long searching times to select only those feed items with the highest possible feeding value (specialists) to species minimising searching time and accepting feed items of lower average quality (generalists). Large herbivores, such as cattle and elephants, have to be generalists because their absolute daily feed requirements are high. An increase in energy requirements generally decreases selectivity (Schoener, 1971). Searching time can be within and between vegetation patches. A predator (or herbivore) should leave a patch when the rate of feed (energy, nutrient) intake in that patch drops to the average for the habitat (Charnov *et al.*, 1976). During grazing, the resource (patch) is being depleted which implies that it must recover before it is worthwhile to be visited again. Grazing pressure must allow for this recovery time, otherwise animals have to accept lower quality feed items resulting in lower animal production (Charnov *et al.*, 1976). When feed becomes scarce, individuals respond by widening their choice of feeds and thus decreasing selectivity. In such circumstances, diets of specialists and generalists tend to converge and competition between species will increase even to the point that one species may displace another (Pyke *et al.*, 1977).

Competition or complementarity of herbivore species

Cohabitation of different herbivores can also be considered in terms of **competition** and **facilitation**. In 1960, Vesey-Fitzgerald introduced the idea of migration related to a grazing succession, in which some herbivores generate a feeding niche for others. In Tanzania it was shown that wildebeest increased (facilitated) food supply for Thompson's gazelle (McNaughton, 1979) but also that domesticated herbivores (Zebu-cattle) and wild herbivores (zebra) compete for the same feed resources (Voeten, 1999).

Milne (1994) reported that body size and mouth dimensions influence diet selection, foraging strategy and digestive capacity. These attributes lead to the commonly accepted classification of ruminants in grazers, such as cattle and sheep, browsers, such as goats, and mixed feeders, such as deer. Within the category of grazers, cattle appear to be less selective than sheep. The higher the variability of plants in the vegetation, the larger the difference in diet between sheep and cattle (Guerin *et al.,* 1988). At very low availabilities of green herbage, where competition between species would be most severe, the difference in diet composition between sheep and goats was smallest (Gurung *et al.*, 1994). When vegetation composition changes, the main target for sheep is to maintain dietary nutrient concentration, but for cattle to maintain rate of intake, accepting lower quality species (Milne, 1994).

Squires (1982), studying diet overlap in sheep, goats and cattle, found that sheep achieved the highest diet quality in terms of digestibility and protein content. Sheep showed the widest diet overlap with cattle, also being grazers, and the narrowest with goats, being browsers. In general, overlap was largest in the rainy season when all livestock species consumed a considerable amount of grasses. The larger the overlap, the higher the risk of overgrazing. Mixed herds of goats and sheep were shown to be less detrimental to the vegetation in enclosures than pure sheep or goat herds at the same animal densities, because diet overlap for mixed herds was smaller than for monospecies herds (Hiernaux and Fernãndez-Rivera, 1995) .

In Kaïbo, complementarity between goats and sheep was shown, allowing for cohabitation of the species (Section 7.1). Vegetation quality and availability, depending on vegetation species and season, but also the selection capacity of the animal species determined its contribution to the animal diets. In the rainy season, goats preferred browse to grasses, whereas sheep switched to grass as soon as the rains started. In the dry season, goats still preferred browse, whereas sheep preferred crop residues to natural vegetation (Section 7.1). On the other hand, cattle appeared to compete with sheep: in the rainy season both species preferred grasses and in the dry season both depended on crop residues (Section 7.1 & 7.2). The advantage of mixed herbivore communities, characterised by complementary use of various vegetation components, were recognised long ago by traditional pastoralists (Lamprey, 1983; Dahl, 1981). It must, however, be recognised that competition can be stronger than complementarity. In the rainy season, and particularly in the short grass vegetation of the "mopane" habitat in Zimbabwe, cattle with their broad muzzles, were more efficient at utilising the grazing resources than the small and more selective Impala. The latter had to adapt their foraging behaviour by moving to another habitat or modifying their diet (Fritz, 1996). Goats are very selective feeders, similar to Impala. In similarity to the situation in Zimbabwe, free movement of goats and cattle on a restricted grazing area, especially in the wet season, might in Kaïbo also lead to such a strong competition for feed resources, that goats either have to leave or modify their diet.

Influence of herbivory on vegetation

Herbivores influence vegetation composition and growth (Hiernaux 1992a; Poissonnet *et al.*, 1992; McNaughton *et al.*, 1988; Sousa, 1984). Management of grazing lands has primarily been based on changes in species composition and individual species have been used as indicators of range condition (Milchunas and Lauenroth, 1993). In the Sahel, overstocking in the rainy season and repetitive overgrazing of preferred species, such as *Andropogon gayanus*, has been reported to have a strong detrimental effect on range composition, quality and productivity (Breman and De Ridder, 1991; Breman and Cissé, 1977). It leads to replacement of palatable perennials by less palatable annual grasses such as *Elionorus elegans* and favours legumes with a short growth cycle and low productivity, such as *Zornia glochidiata* (Hiernaux, 1992b; LeHouérou, 1980; Breman and Cissé, 1977). Hiernaux and Fernãndez-Rivera (1995) studying mixed herds in enclosures observed that sheep-dominated herds particularly overgrazed grasses and favour unpalatable dicotyledons, whereas goat-dominated herds particularly reduced *Andropogon gayanus* stands. On Kaïbo territory, perennial grasses were present, but hardly contributed to the diets of goats or sheep. Other signs of degradation, due to overgrazing, may be the appearance of Sahelian species (Guinko, 1984; Breman and Cissé, 1977) in Sudanian ecological zones. In Kaïbo the contribution of two Sahelian species, *Cassia tora* and *Cymbopogon schoenanthus*, in the vegetation was less than 4 % which is not alarming (Section 7.1). The contribution of *Schoenefeldia gracilis*, another Sahelian species, varied between 0-36 %, indicating a serious occupation of certain units. Based on observations in Mali, Hiernaux (1992b) states that changes in species composition in response to grazing pressure are often similar to those in response to drought. Many of these changes are reversible within a relevant time frame (Behnke and Abel, 1996). Spatial scales must also be considered: local run-off may favour Sahelian species while local run-on may favour Sudanian species. A heterogeneous distribution of scarce or limiting resources (water, nutrients) across the landscape and within soils results in patchy vegetation distribution (Tongway and Ludwig, 1990; Noy-Meir, 1981). In Kaïbo, local run-on and run-off based patches were clearly discernible (Rietkerk *et al.*, 1998).

Lubchenko (1978) combined the optimal foraging theory with the impact of grazing on plant species composition. He showed that plant community structure can be affected quite differently by generalist herbivores and specialist herbivores, depending on whether the specialist consumes competitively dominant or competitively weak species.

Herbivore-vegetation feed-back mechanisms: palatability & succession

Milchunas *et al.* (1988) showed that feed-back mechanisms between large generalist herbivores and plants are not similar in all environments, but depend on environmental moisture availability and history of grazing. In sub-humid grasslands with long histories of grazing, such as the Serengeti, continuous adaptation to grazing and responses to moisture availability have led to a community consisting of a mixture of short, intermediate-height and tall grasses. These species differ in grazing tolerance, hence the composition of the community is very susceptible to changes in grazing pressure. In semi-arid grasslands with long histories of grazing, such as the North American Great Plains steppe, adaptation to both drought and grazing favoured short grasses, that currently dominate the community. All these grass species respond very rapidly and most adequately to changes in grazing pressure, keeping the composition of the community reasonably constant. Feed-back mechanisms are less developed in grasslands with short evolutionary histories of grazing.

Westoby (1974) refers to **palatability** as a concept that has been widely used by range and wildlife managers as an attribute of individual plant species. The abundance of palatable species is subsequently used to evaluate the range condition. Different indices used in this process, such as relative preference index (Van Dyne and Heady, 1965), electivity (Ivlev, 1961) and frequencies of consumption and availability (Poissonnet *et al.*, 1992; Guerin *et al.*, 1988), all show that palatability is a relative concept. It is not constant for a particular plant and herbivore, but depends on what other plants, in what abundance, are associated with the one being considered (Westoby, 1974) and on moment of measurement because plant quality changes with the season. The preference indices developed by Poissonnet *et al.* (1992) have been used to illustrate the relative preference of goats for woody species (Section 7.1) in the Kaïbo village area. The value of these preference indices was only relative, as can be concluded from the fact that they differed for the same plant species per grazing unit and per season (Section 7.1).

The palatability concept and the optimisation (optimal foraging) concept, predict different reactions to a change in availability of feed items. The first assumes a continuous response to availability, with consumption/availability remaining constant. Optimal foraging, on the other hand, assumes an increase in grazing pressure when the availability of a feed item decreases, to keep the contribution of the feed item to the diet constant. In the palatability concept, the probability that a feed item will be selected remains constant for each encounter, depending only on its abundance in the vegetation community. Optimal foraging assumes that this probability changes and will be different at each encounter, because the probability for selection depends on animal requirements, and therefore on the diet that the animal has consumed prior to the encounter.

Another theory used in range management, and strongly rooted in ecological feedback systems, is the **successional theory** of vegetation development. According to this theory one plant community replaces another, until ultimately a persistent and characteristic 'climax vegetation' is reached, determined by climate and soil conditions (Stoddart *et al.*, 1975). If this climax vegetation is disturbed, it gradually changes towards lower successional stages, a trend that can be reversed. Whether grazing must be seen as a disturbance in communities that have co-evolved with grazing or whether protection from grazing must be considered a disturbance in such communities is debatable (Milchunas *et al.*, 1988). In either case, one of the methods to influence gradual changes between successional stages is to vary livestock densities.

Herbivory-vegetation feed-back mechanisms: carrying capacity

The concept of **carrying capacity** (CC) has been developed as a measure for the (in)balance between animal densities and vegetation. It assumes an **equilibrium** environment and is based on a direct negative feedback between animal numbers and vegetation (Behnke and Scoones, 1993). Buttersworth and De Ridder (1984) refer to the definition that was agreed upon in 1964 by the American Society of Range Management: the maximum stocking rate possible, without inducing damage to vegetation or a related resource. Although this definition was particularly developed for ranching systems in America, it has also been used to estimate sustainable stocking rates on Sahelian rangelands (Boudet, 1984; LeHouérou, 1980).

A distinction must be made between ecological carrying capacity, i.e. the population size characterised by an equilibrium between food demand and supply without external interference, and economic carrying capacity, i.e. an equilibrium sustained through human intervention (Behnke and Abel, 1996; Caughley, 1979 in: Bartels *et al.*, 1993). Scoones (1993) found that cattle populations in South Zimbabwe approached a ceiling, set by ecological carrying capacity without ever reaching it. In a series of good rainfall years the CC approach could be applied and the vegetation could be assumed to be in equilibrium with the livestock population, but random interspersion of stress years resulted in temporary **non-equilibrium** situations in which the CC concept could not be applied. The economic carrying capacity is applicable to ranching systems that aim at maximum sustainable yields, the ecological one is applied to nature reserves, but might also be applicable to pastoral systems in Africa (Behnke and Abel, 1996).

Buttersworth and De Ridder (1984) pointed out that once a safe (conservative) stocking rate is set, continuous monitoring of vegetation and range condition related to secondary production is necessary. They highlighted that not only forage attributes determine carrying capacity, but also factors such as accessibility, availability of water, topography, climatic factors, etc. Estimates of dry matter production by the natural vegetation are so far based on rainfall and on average soil fertility, while run-on and run-off processes are accounted for (Breman and De Ridder, 1991).

The CC concept is generally simplified to matching annual dry matter production of herbaceous vegetation with annual dry matter requirements for an average livestock unit. Such a unit is a tropical livestock unit (TLU), representing one head of cattle weighing 250 kg and fed at maintenance. To guarantee sustainable primary production, various estimates have been made of the fraction of the aerial biomass that can safely be consumed without hampering next year's biomass production. Boudet (1984) concluded this fraction to be one third of the total aerial biomass for year-round grazing. Breman and De Ridder (1991) postulate that 50% of aerial biomass can be consumed without danger of degradation, when consumption takes place in the rainy season only (Chapter 2).

The simplification of the CC concept, as presented above, is wrought with at least three problems with respect to the vegetation. Firstly, it neglects the contribution of woody species, although their importance as browse species particularly for goats, but also for cattle in the dry season, has been well-documented (LeHouérou, 1980b). Secondly, it neglects the variability within the herbaceous vegetation. Species composition is important, because many species are not selected by animals due to low nutritional quality (low nitrogen content, high water content), low palatability (hairy, toxins), low digestibility (anti-nutritional factors, lignification) or difficult accessibility (erect species versus running species, understorey species). Breman and De Ridder (1991) partly improve the concept in providing an estimate of N-content variability. Plant species and parts that are rejected or ignored by the animals form the major part of the aerial biomass that remains after grazing and prevent degradation of the grazing area. Finally, it assumes a linear, negative impact of grazing, proportional to increases in stocking rate. The simplified CC concept, moreover, is wrought with at least three problems with respect to the animal. Firstly, it assumes that requirements of 10 goats or sheep of 25 kg live weight each are equivalent to the requirements of one head of cattle of 250 kg live weight. Secondly, it assumes that feed requirements only depend on body weight and not on physiological status of the animal (pregnant, lactating). Thirdly, it neglects the fact that animal species can be complementary feeders, e.g. goats (browser) and sheep (grazer), and that vegetation of rangelands is less susceptible to high stocking densities of mixed flocks than of mono-species flocks. Finally, the

CC concept neglects forage losses due to trampling, dunging, urinating and to external influences such as fire, cutting of grasses by man, etc.

Most of these problems have been recognised. The relation between stocking rate and production objectives of the livestock managers received more attention (De Leeuw and Tothill, 1993; Breman and De Ridder, 1991; Boudet 1984). The need to consider energy, protein and mineral content of the fodder and not only the produced biomass has been acknowledged (Breman and De Ridder, 1991). Theoretical concepts and practical tools have been developed to allow inclusion of browse in the estimation of CC (Breman and De Ridder, 1991). Although the CC concept has thus been fine-tuned, it has not led to a real operational tool for evaluation of semi-arid rangelands as a basis for formulation of management recommendations and policy options.

Feeding strategies in a heterogeneous environment

To cope with temporal and spatial low availability of vegetation, various strategies, such as herd mobility, dry season supplementation and/or temporary de-stocking (Toulmin, 1995) can be applied. Incidental disasters, such as severe droughts or grasshopper invasions can lead to temporarily high stocking rates, because the strategy of **tracking** includes a time lag and becomes almost impossible when the disaster is not limited to a small area (Toulmin, 1995). High overall livestock mortality due to infectious animal diseases may on the other hand lead to temporary understocking. Range productivity appears a function of climate (a density-independent factor) rather than of stocking rate (Milchunas and Lauenroth, 1993; Westoby *et al.*, 1989; Ellis and Swift, 1988) and the climatic and stocking rate effects interact and exert periodic rather than continuous impacts (Bartels *et al.*, 1993). In environments experiencing massive and unpredictable fluctuations in rainfall, **non-equilibrium, event-driven** grazing systems are the rule rather than the exception (Scoones, 1993; Ellis and Swift, 1988)

The response of species composition to grazing densities exceeding the estimated CC value for a specific site, depends more on its long-term grazing history and moisture regime (Milchunas and Lauenroth, 1993; Milchunas *et al.,* 1988) than on recent-time grazing variables such as intensity and duration of grazing. CC change also in space and over time (De Leeuw and Tothill, 1993). Hence, whenever the CC concept is used it should include a time frame, include information on grazing history, be specific for moisture regime, be specific for site (soil, topography) and consider a specific livestock system.

For North America the CC concept could be applied with some success, because livestock were kept within fixed areas of land with recognisable boundaries and with one person owning both livestock and land. In Africa, such a situation might occur on farms owned by rich former colonial settlers in Southern Africa. Elsewhere in Africa, mobility of animal, communal land tenure and fluid rights of access to grazing and water creates a very complex situation. This complexity increases when herds of different animal species belonging to different owners are involved. The conclusion here must be that the CC concept, in its current state of development, is unsuitable as a management tool for Sahelian rangelands (Kessler, 1994; Bartels *et al.*, 1993) and the more so because these rangelands comprise vegetation communities in non-equilibrium environments (Ellis and Swift, 1988). It is extremely difficult already to estimate a CC value for a certain area and to monitor primary and secondary production for this area, but it is even more complex to design management systems aiming at respecting that value.

In the 90s the use of the carrying capacity principle has been extended to the area of population growth and the debate on trade-offs between its economic and ecological implications. Economists and ecologists have agreed that injudicious use of the environmental resource base may irreversibly reduce the capacity of generating material production in the future (Ludwig, 1996; Arrow *et al.*, 1995). Economic growth requires stable, resilient ecosystems that will continue to provide life-support services. But economic development will impose stress on ecosystems, resulting in cumulative depletion of resources, land use changes with implications for water quality and biodiversity, and rates of exploitation that exceed rates of regeneration (O'Neill *et al.*, 1996).

Ecosystem resilience can be understood in the framework of ecosystem dynamics in a situation with multiple locally stable equilibria. Resistance is a measure of the persistence of a system and its ability to absorb disturbances/changes before it flips from one equilibrium to another, whereas resilience refers to the ability of the system to return to an initial state after disturbance (Holling, 1973). When the system flips to another equilibrium a sudden loss of biological productivity may be experienced with the consequence of an immediate reduction in the capacity to support human life. In addition, it may imply an irreversible change in the set of options available to both present and future generations (depletion of groundwater reserves, desertification, loss of biodiversity, soil erosion, etc.). Finally, new equilibria may increase the uncertainties associated with the environmental effects of economic activities (Arrow *et al.*, 1995).

This ecosystem resilience theory seems applicable to semi-arid systems. The retreat of the Sahara desert after some good rainfall years (Tucker *et al.*, 1991), suggests for instance a high level of resilience. The observed high variability in herbaceous fodder production in the Southern Sahel, due to erratic rainfall and small-scale variation in soil fertility, suggests on the other hand low resistance (Breman and De Ridder, 1991). Ecosystem dynamics could be described by a set of relatively stable states and linking transitions, the **state-and-transition** concept (Friedel, 1991; Laycock, 1991; Westoby *et al.*, 1989). **Thresholds** mark transitions, such as those due to over-exploitation and these transitions can have an irreversible character. At certain sites in the Sahel zone, a vegetation dominated by perennial grasses completely collapsed, leading to increased exposure of bare soil and increased soil erosion by run-off and wind (Rietkerk, 1998). To reverse such changes in vegetation composition or to restore a low vegetation cover, a reduction in the exploitation intensity appeared to be insufficient for rapid spontaneous regeneration (Rietkerk *et al.*, 1996; Breman and De Ridder, 1991; Westoby *et al.*, 1989). The succession theory (Stoddart *et al.*, 1975) cannot cope with such situations of

8 GENERAL DISCUSSION

Perspectives of the crop-livestock integration concept and mixed farming model

In the introduction to this thesis the importance of the crop-livestock integration concept or mixed farming model for agricultural development in Francophone West Africa till today has been shown. The history of the model, starting under colonial rule, was described and appeared to be strongly associated with the introduction of cash crops, particularly cotton (Massa and Madièga, 1995; Landais and Lhoste, 1990). Biases against nomadic pastoralism (Bernus, 1990) were identified as strong drives towards mixed sedentary farming. The transition from shifting cultivation to more permanent cropping created the need for soil fertility maintenance through the use of manure for livestock owners, and techniques, such as rotation with leguminous crops, application of green manure, compost, for all farmers, including those without livestock.

In East Africa, British colonial administration characterised the prevailing farming system between 1920 and 1960, by severe food shortages, deterioration of the environment, and a low level of civil and cultural development (Sumberg, 1998). Farming methods such as shifting cultivation leading to extensive deforestation, and nomadic pastoralism with under-utilisation of large livestock numbers leading to overgrazing, were held responsible for these characteristics (Lugard, 1965; Hall, 1936). Crop and livestock producers were considered ignorant and to behave irrationally. A mixed farming model was proposed, rooted in a UK context where arable land was relatively scarce, where systems of crop-rotation with widespread use of manure, legumes and fodder crops proved to be successful, and with a class of self-sufficient land-owning peasant farmers (Hall, 1936). The British focused especially on the abolishment of shifting cultivation and added two arguments in favour of mixed farming that were not found in literature on French West Africa: (1) the need to change the observed widespread plot fragmentation into a one-unit farm, with all the fields around the compound, because that would be easier for planning, farm management, and research and extension (2) the need to create a class of peasant farmers, based on private land rights (Rounce, 1937).

After independence, national governments in both East and West Africa needed to increase agricultural production to feed a fast growing population. They were also confronted with degradation of natural resources associated with severe droughts. For both reasons they continued to focus on mixed farming. At the same time new insights were generated with respect to the complexity and variability of farming systems. Mixed farming as a means to create a class of peasant farmers no longer figured in the debate. Shifting cultivation was scientifically rehabilitated and acknowledged as an efficient and sustainable way of crop production, when sufficient land is available (Allan, 1965). Ecological understanding of pastoral systems continues to develop, disputing their contribution to resource degradation (Behnke *et al.*, 1993).

The world-wide sustainability debate has renewed the interest in low external input (LEIA) mixed farming in Africa. Soil fertility maintenance has always been one of the leading principles underlying mixed farming. Recently, nutrient cycling has become a major issue again (Powell *et al.*, 1996), because research highlighted the importance of nutrients in limiting crop production (Breman and Sissoko, 1998; Penning de Vries and Djitèye, 1982) and the prevalence of negative soil nutrient budgets (Turner, 1995; Van der Pol, 1992). In some of these studies it was also emphasised that these nutrient deficiencies also negatively affected the quality of the vegetative material as source of animal feed. Schematically, the debate is now between high external input agriculture (HEIA) based on the use of inorganic fertiliser and concentrates for animal feed or LEIA based on efficient nutrient cycling. A synergy between the two approaches seems most promising and is currently promoted by the International Fertiliser Development Centre (IFDC). That includes optimal management of organic matter to improve recovery of nutrients from inorganic fertiliser, in plants (Breman on behalf of IFDC, personal communication).

Structural adjustment programmes and their negative impact on availability of external inputs to farmers, favour the LEIA vision, self-sufficiency and essentially closed smallholder farming systems (Sumberg, 1998). Rainfall variability makes the use of inorganic fertiliser a risky proposition anyway (Shapiro and Sanders, 1998). Cheap inorganic fertiliser is not necessarily a blessing because it may have social disadvantages such as disrupting relations between herdsmen and arable farmers (Bayer and Waters-Bayer, 1991; Delgado, 1989).

LEIA nutrient management is neither without problems. Only the use of large quantities of (vegetative) bedding material in stables guarantees capture of urine nitrogen, representing 40-60 % of all nitrogen excreted by animals (Powell and Williams, 1995). This material is often not available due to alternative uses. Moreover, it is labour demanding, for collection and transport. Hence, large amounts of nitrogen are lost in LEIA systems. Mixed farming, based on on-farm production of animal feed does not exist yet. Livestock grazes natural resources and manure (not urine) is collected in variable quantities, depending on the system (night paddock, stall fed, penning on field). The calculated grazing land-crop land ratio required for soil fertility maintenance of the crop land varies between 10 and 45, hence a maximum of 9 % of all land can be cropped in a sustainable way, without the use of inorganic fertiliser or animal feed supplements (Turner, 1995; Van Keulen and Breman, 1990; Swift *et al.*, 1989; Breman *et al.*, 1986; Quilfen and Milleville, 1981).

Despite limited adoption of mixed farming as an integrated system, outright failure of certain technologies, such as production of fodder crops, and very limited scope for sustainability on the basis of even optimal nutrient cycling (Savadogo, 2000; Sumberg, 1998; Landais and Lhoste, 1990), the mixed farming model has been shown to persist. One explanation might be that is ahead of its time (Pingali and Binswanger, quoted in Van Keulen and Breman, 1990) but that socio-economic conditions are not (yet) conducive for its success. Efforts to promote it will finally be rewarded as and when key conditions, such as population growth, environmental degradation, increasing fertiliser prices, etc. further develop. Another way to look at it is to appreciate the partial adoption of the model. Several components, such as animal traction, use of manure, use of crop residues to feed livestock on-farm, have flexibly been adopted by farmers to respond to changing environmental, market, economic and social conditions. This analysis has shown that research should distinguish between underlying principles on one hand and a comprehensive, ideal model on the other. A focus on unitary models with general applicability may hamper agricultural research in the development of technical options directed to farmer-specific or site-specific needs.

Results of research in the framework of this thesis

In **Chapter 1** the following question was asked:

"Is crop-livestock integration or mixed farming a suitable model for farming systems development, leading to guaranteed food security and socio-economic survival for all social entities of the rapidly increasing population in Sahelian countries, without endangering their resource basis?".

In the same chapter, three flaws in the crop-livestock integration model were identified:

- interactions between a farm household and its socio-economic and ecological environment is neglected
- economic complementarity is neglected
- competition for labour and land is neglected

In addition, it was observed, that crop-livestock integration was ideally presented in the form of a unique mixed farming system, presumed to be suitable and attractive for both former extensive crop producers and former extensive livestock owners. During colonial times and before, both producer groups were very mobile: crop producers practised shifting cultivation and animal producers moved with their herds over longer and shorter distances in response to rainfall. The mixed farming model requires sedentarisation.

To answer the central question, Zoundwéogo province and its village Kaïbo Sud V5, in Burkina Faso, an area with a rapidly increasing population, were selected as study areas. The three identified flaws were addressed and the existence and development of alternative farming systems were explored. The impact of various forms of crop-livestock integration on the use of natural resources was examined.

In **Chapter 2,** the heterogeneity of natural resources in Zoundwéogo province and in the village territory of Kaïbo Sud V5 were presented and its consequence for production potentials. Model studies at village (Van Rheenen, Antenne Sahélienne, 1999, personal communication) and farm level (Savadogo, 2000) have shown that low external input agriculture (LEIA) can not provide sufficient food grains to feed the village population in an average rainfall year, and food shortages will be more serious during dry years. Since rainfall is highly variable in the study area, surpluses must be transferred from good rainfall years to unfavourable years. LEIA mixed farming, aiming at food sufficiency or at maximising Gross Margin was shown to lead to soil depletion for the main nutrients N and P and for organic matter. High external input (HEIA) systems appeared to be more sustainable in terms of soil quality than LEIA, because external inputs replaced the nutrients withdrawn from the production system. Another important conclusion was that the availability of a cart was essential for crop-livestock integration for transport of crop residues from the fields to the farm for stall feeding, and of manure or compost from the stable at the farm to the fields for fertilisation (Savadogo, 2000).

In **Chapter 3,** the agricultural knowledge system, comprising research, extension and user subsystems, has been analysed. Research and extension in Burkina Faso appeared to act according to the transfer of technology model (Chambers and Ghildyal, 1985), combined with the progressive farmers approach. Technologies are developed by research and transferred to farmers by extension. Farmers were not part of technology development. Policy makers aim at the design of one unique mixed farming system for both formerly extensive crop producers and formerly mobile animal producers. They propose technical packages that are suited to sedentary wealthy farmers that have the means to purchase external inputs and to take some risks. The consequence was that resource-poor farmers, by far the largest group of farmers in West African savanna, had no influence on research and extension. These farmers were not organised and lack political influence because of the absence of a social network.

Mobile livestock producers neither played a role in research and extension, because they do not belong to administrative units, such as villages, and do not form a constituency for policy makers. Ever since colonial times, biases (Bernus, 1990; Lugard, 1965) against their lifestyle put them under strong pressure towards sedentarisation. Research and extension on animal production focused on sedentary mixed farming systems in which livestock have to provide draught power and manure, and in which crop producers are the main actors. Research on high input-high output systems, such as peri-urban intensive meat and milk production becomes increasingly important. In this segment of the animal production sector, urban investors such as merchants and politicians are the main actors. Research to improve sustainability and output of mobile livestock herds has no priority.

This chapter clearly shows the need for differentiation in farming systems, because of the range in societal demands.

Cereal production, to feed the growing population requires at least two farming systems:

- LEIA crop producers that produce their own food on-farm. This production system is relatively low-cost for the farmer and the government, because it requires neither infrastructure nor imported external inputs. LEIA crop producers can only produce surpluses to feed the urban population in good rainfall years.

- HEIA crop producers are needed to produce grain surpluses to feed the growing urban population, civil servants, but also those mobile animal producers that generally do not produce sufficient grains to feed their families. HEIA needs infrastructure and external inputs, and is therefore costly for farmers and governments.

Urbanisation leads to an increase in the demand for quality food, produced close to urban centres. Hence, again two farming systems are required:

- HEIA crop production to supply cereals with special taste and cooking qualities, rice instead of millet, and/or a variety of exotic vegetables to increase variation in the diet of urban consumers. These production systems need high external inputs, such as improved and exotic seeds, inorganic fertiliser, pesticides and irrigation infrastructure.
- HEIA animal production such as fattening of cattle and pigs, commercial egg production with exotic laying hens, chicken production with exotic broilers, intensive milk production to provide fresh milk year-round. These production systems need high external inputs, such as concentrates and veterinary drugs, and exotic animal breeds.

Governments requiring foreign exchange demand export products in large quantities. These can be supplied by two major farming systems:

- HEIA cotton production, based on on-farm delivery of cotton seed, fertiliser, pesticides and extension messages. In addition, on-farm collection and payment of the produce is organised. Research, extension and other services, including credit facilities are provided by para-statal cotton companies, such as SOFITEX (Burkina Faso) and CMDT (Mali).
- LEIA mobile livestock production, because of its low production and transport costs. This production system is the only way to exploit (add value to) the areas in the North of the Sahelian countries, that are too marginal for crop production. This production system needs no external inputs, hence no scarce foreign currencies. Transport of animals is often organised by the producer, sending some herdsmen with the animals on foot either from the North to the capital and from there to coastal countries or directly to neighbouring countries. Transport by railway and road becomes, however, increasingly popular.

In **Chapter 4,** farming systems development, is analysed. Schematically, six levels of integration between crop and livestock have been distinguished:

- LEIA, specialised crop or livestock producers (1)
- agro-pastoralists (2)

- LEIA, integrated crop or livestock producers (3)
- LEIA, mixed farmers (4)
- HEIA, mixed farmers (5)
- HEIA, specialised crop or livestock producers (6).

Criteria used for classification, differentiating among levels and among discrete farming systems within each level appeared to be: agro-climate (North/South), ethnography (Fulani/Mossi), production goal (manure/milk/meat/traction/saving), ratio of cattle to small ruminants, use of bullocks for traction, and use of external inputs (LEIA/HEIA). The discrete farming systems have been presented in a framework (Figure 4.3) to elucidate the dynamics, i.e. the transitions from one system to another.

The framework accounts for important concepts related to change and illustrates the drives behind transitions. Concepts used in the development debate, such as intensification and integration, but also social concepts such as identity and gender are shown to play a role in farming systems development. Ethnic identity and gender are intertwined with production goals and labour distribution, and hence with motives towards intensification of crop or livestock production or mixed farming (Van Veen, 1996; Van Dongen, 1995). Drives behind transition to agro-pastoralism appear to be related to ethnic group. For Mossi crop farmers, wealth accumulation, based on remittances from migration or cash from cotton, is a drive towards acquisition of cattle and associated crop-livestock integration. For Fulani livestock producers, poverty due to externalities such as droughts and animal diseases, that lead to high animal mortality, appears the main drive towards cropping and hence crop-livestock integration. In the reality of Burkina Faso, households recognisably corresponded to the described farming systems and development pathways. Mace (1993), applying a dynamic optimalisation model of herding and farming as long-term survival strategies, predicted that a shift to pastoralism would be principally associated with increasing wealth and quotes examples from history in support. The drive of wealth in farming systems development, as found for Burkina Faso, can hence be generalised for Sub-Saharan Africa.

The transition from one farming system to another can strongly be influenced by policy measures (Chapter 1) and the research-extension-users system (Chapter 3). Since colonial times (Massa and Madièga, 1995; Landais and Lhoste, 1990) policy makers have stimulated mixed farming, hence research and extension, working according the transfer of technology model (Chambers and Ghildyal, 1985) offering advice and technical packages aiming at the transition of any farming system to this unique mixed farming system. Mixed farming is also stimulated by the recent sustainability debate, because it is supposed to minimise nutrient losses through adequate management of crop residues and manure (Sumberg, 1998; Powell *et al.*, 1996).

Lack of purchasing power at the level of the actual farm population (resource-poor farmers) prevents HEIA farming from taking off. The support of cotton production by specialised organisations, such as SOFITEX, may, however, lead to HEIA production techniques. The sale of cotton may provide cash to purchase external inputs needed for successful HEIA farming, in addition to extension services, credit facilities, infrastructure such as roads and markets, but also a distribution network of inputs. Subsidies on inputs or guaranteed prices for outputs can easily stimulate the development of these farming systems and affect their choice of products. When households are hardly incorporated in markets, their farming system depends less on policy and is mainly shaped by farmers' decisions. Policy measures introducing private land ownership may have impact on all farming systems, but the reality in, for instance, (AVV) settlement zones shows that customary land tenure procedures are adhered to and that legal land rights are submitted to customary laws and regulations. Social structures are much more important than claims, based on formal law (Breusers, 1998).

Although the framework does not explicitly describe development in the reverse direction, this option must not be ignored because several examples were found in the context of Burkina Faso alone. The framework does not include time, because it is not deterministic: developments can take place in any period and at any rate. The framework was only constructed to increase understanding of farming systems development. It successfully represents the criteria that shape discrete farming systems and the concepts and drives behind the transitions.

One important factor shaping farming systems development, omitted in this discussion so far, is land scarcity due to population growth and periods of droughts. This aspect will be treated at the end of this discussion.

In **Chapter 5,** different roles of animals and animal production are discussed, but the main objective is to analyse the role of animals as a means for financing. Examples from Zoundwéogo province have been used to assess this financing role for agro-pastoral of mixed farming systems. Most examples refer to small ruminants, that are present in large numbers and increase annually by 3 % in the province, and seem to play a more important role in financing than cattle.

Animal production has always been evaluated in terms of meat and milk. The animal is object of research. The leading concept for livestock studies are input/output ratios in physiological terms such as quantity of feed needed per quantity of meat & milk produced, or in economic terms of costs and benefits. It is also possible to consider animals as components of farming systems. The crop-livestock integration concept considers animals as focal point of the complementarity between the two components, that centres around nutrient cycles, comprising crop residues fed to livestock and manure restored to the crop fields. Nutrient management to safeguard the soil as production factor is then the object of livestock studies. However, farm households seem to emphasise an economic complementarity between crop and livestock production. Particularly in the Sahel, where households are confronted with unpredictable and erratic rainfall and hence the risk of crop failure, temporary crop surpluses and shortages have to be dealt with. Livestock serves as a buffer against calamities such as crop failure, or unforeseen expenditures for disease or death of family members. Household survival then becomes the object of livestock studies. The three types of livestock studies do not necessarily lead to the same results, whereas the two identified complementarities are not necessarily cumulative.

Research has and will continue to be focused on input/output ratios with respect to specific animal products. The last twenty years much research has also been done on aspects of nutrient cycling, especially in developing countries (Powell *et al.*, 1996), and more recently also in Europe. The financing function of livestock has received far less attention. In this study various aspects of this function were investigated, such as their interaction with optimal animal production and with the complementarity based on nutrient cycling.

Small ruminant markets were studied to investigate whether financing is an important motive for livestock sales and whether it has consequences for total animal (meat) production (Section 5.1). Mossi farmers and Fulani herdsmen consider small ruminants as assets that are easily convertible into cash. Both, Mossi and Fulani sell small ruminants in the rainy season to buy cereals. In this period, the supply of animals on the market is high and the demand is low, i.e. prices are low. Mossi exploit their small ruminants more intensively than Fulani and sheep appear to be more intensively exploited than goats.

If only meat production is considered, timing to sell an animal is not optimal, because animals are sold before reaching adult live weight (1), and before generating the maximum number of offspring (2) for young females. On small ruminants markets, 56 % of ewes and 63 % of does, sold, were at live weights below that at first conception, and 95 % of all animals were sold below adult live weight. Moreover, sales of animals are strongly seasonal (3) and especially high at times when prices are low. These three factors result in considerable financial losses for the livestock sector.

Apparently, small ruminants are so important for financing that optima in terms of animal production are not reached. Revenues from small ruminants might be greatly improved when farmers could concentrate on animal production and alternatives for financing would be available. Revenues could increase even more when seasonality in prices would be exploited by seasonal fattening and selling. Fattening of sheep, especially Bali Bali breeds, should for instance be planned in conjunction with Muslim feasts such as Tabaski, when prices are higher than in any other period of the year. Fattening for export might also be an option.

Formal and informal financial markets were studied to investigate whether farmers have alternatives for financing and what makes financing through livestock attractive (Section 5.2). Rural banking services do not function properly in Burkina Faso (Bosch, 1994; Lelart, 1992). A rural financing, multiple criteria matrix has been developed, to evaluate and compare the following alternatives: saving in stored cereals, taking loans from family or friends, using local co-operatives for saving and credits. On the basis of the used criteria, livestock breeding appeared the most interesting alternative, because of its accessibility, security, liquidity and profitability.

The formal financial market in rural areas might become more attractive for smallholders when the number of co-operatives in the province would increase and when both their savings and credit services would be available more frequently, thus improving accessibility and liquidity. However, they are only viable when the saving volume increases, hence more savers should be attracted through better information and by offering interest on deposits, thus improving profitability. Another incentive might be the realisation that credits are offered related to the value of the savings account. The value of grain stocks as savings asset could be increased by better storage conditions and better information about markets and prices. When infrastructure would be created for transporting grain quickly at low costs to areas where prices are high due to temporary deficits, general interest in grain stocks might increase further.

A comprehensive assessment was performed of the function of livestock in financing and insurance (Section 5.3), by looking at foregone costs of external sources of financing and insurance, taking into account the costs incurred when livestock is used for financing and insurance. These costs are compared to the costs of those external sources or - a more common situation - the costs incurred when farm households use other assets. An approach has been proposed to quantify the costs and benefits of individual financing and insurance operations and the contribution of livestock to the farm household's financial strength is qualitatively evaluated through indicators derived from the financial analysis of enterprises. In addition, a framework has been designed to assess the overall capacity of farm households for financing and insurance and the contribution of livestock to this capacity. The two approaches allow a more explicit analysis of the way in which farm households are dealing with their resources, and with livestock in particular.

Part of the framework presented in Section 5.3 was operationalised and quantified (Section 5.4) to highlight the interaction between economic and nutrient complementarity at farm household level. Keeping in mind the crop-livestock integration concept, transactions of livestock are considered in relation to cropping. As cropping generates revenues only once a year, farmers tend to manage their farm on an annual basis and so are analysis of the effect of livestock sales.

Firstly, financing with livestock is compared to financing through loans from financial institutions, using a balance equation on the basis of the concepts of liquidity and timing costs. The balances show that the sale of livestock for financing has a negative effect on total farm production in financial terms, especially for female animals or draught bullocks. Losses in offspring, but also in crop yields, due to lack of manure and animal traction, are accounted for. Farmers realise the differences in costs incurred to the total farm when selling different categories of animals, which is reflected in their selling strategy (Section 5.1). Although the balances are not in favour of livestock as a means of financing, farmers do not have much choice, as they do not have a 150 % pledge, necessary for a loan at a co-operative (Section 5.2).

Our approach differs from the one developed by Bosman and Moll (1995). They considered financing and insurance functions of goats, as secondary benefits to be added to the primary benefits, such as milk and meat. Their analysis is based on the flock and its annual flows, excluding any interaction with other farm activities. They add all benefits of goat keeping and ignore costs (loss of manure) to the cropping component of the household when a goat is sold. In following this procedure, Bosman and Moll (1995), and Ifar (1996), seem to forget that " you can not sell the cow and drink the milk." In addition, these authors implicitly assume that animals are only sold when economically attractive from both, a herd management and market price perspective. When animals must be sold for emergency expenditures, the herd management perspective can, however, not always be respected. Sales of young female animals may be necessary, leading to costs in terms of loss of offspring and loss of live weight gain. Sales may also have to take place at times when market prices are low. All these costs should be subtracted from the benefits.

A totally different approach for quantification of the role of livestock considers their contribution to cash flows and assets of various household types. The relative importance of livestock varies between Fulani and Mossi households but also for different types of Mossi households. For Fulani households, sale of livestock is necessary to buy subsistence food grains. For Mossi traders, commercial activities generate a large part of the cash flow. Consequently, the liquidity position and survival of these Mossi households does not depend on livestock. For most Mossi households, net expenditures on staple food could not be compensated by net revenues from livestock sales in the study year, because 1997 was a year with very low precipitation, about similar to the drought of 1984, and consequently very low cereal yields. Many farmers had to sell livestock to buy cereals. The high demand for cereals increased cereal prices, whereas the large supply of animals on the market resulted in low livestock prices. Low cereal yields and deteriorating terms of exchange between livestock and cereals, negatively affected the average liquidity position of these households.

Short term financing capacities of livestock and their role in household cash flows have been quantified according to some approaches. For some other approaches additional and very specific research is required. A major problem is to establish real cereal and livestock stocks at the beginning of a year and to keep track in the course of an entire year. Many transactions take place and both cereal stocks and livestock may be entrusted to family members or even strangers (remunerated herdsmen for instance) living elsewhere. Another problem is to assess the risk of crop failure, crop spoilage, and the risk of theft of animals. Risk for crop failure could be estimated on the basis of stochastic yield distributions. Furthermore, the types of costs distinguished are not independent and some costs not taken into account, such as inflation costs and opportunity costs of labour, may also play a role.

Delgado (1979), in his study of crop-livestock interactions in the Tenkodogo area of Burkina Faso, identified seasonal labour constraints as reason for the division between cropping activities by Mossi and livestock activities by Fulani. Opportunity costs for herding were very high in the cropping season, therefore Mossi preferred to entrust their cattle to Fulani. Opportunity costs for weeding were high for Fulani who preferred to herd and water their animals, and buy cereals. Opportunity costs thus, may play an important role. Small ruminants, however, can be herded by children, hence opportunity costs are very low.

Timing costs were defined at constant market prices, but prices may fluctuate, for instance because of local crop failures. Market prices may also be influenced by externally funded food aid in times of local scarcity or by the supply of cheap European meat on coastal markets, negatively influencing the export position of Sahel countries (Williams *et al.*, 1995; Rolland, 1994; Ruben *et al.*, 1994; Klugkist, 1993). Farmers have no influence on such macro-economic events and cannot anticipate (Chapter 1). They can but adapt to the new situation. While our results suggest that taking a loan at a bank is preferable to using livestock for financing, farmers will often use the latter for various reasons.

These results show that the financing function of livestock interferes with nutrient cycling (Section 5.4) and with maximisation of animal production (Section 5.1). In the crop-livestock integration concept, the economic complementarity of crop and livestock production should therefore receive much more attention.

Chapter 6 explores the role of draught power for the study area, because animal power for ploughing has always been presented as the core of crop-livestock integration (Massa and Madièga, 1995; Landais and Lhoste, 1990). In Zoundwéogo province, farms that owned animal traction equipment appeared to be larger in family size, total cultivated area, and area of cash crops, than unequipped farms. In Kaïbo Sud V5 and Zoundwéogo province cattle herds were sufficiently large to provide draught animals for all farm households and to plough all actually cultivated area. Draught animals only worked 2-3 hours a day because ploughing required much power relative to animal live weights. Daily output could be increased by doubling the number of animals or increasing animal live weight. Both options need additional feeding. The quality of crop residues, such as millet straw is sufficient for maintenance, but animal growth requires concentrate supplements. Availability of crop residues should be no problem as straw yield per unit area of crop land is similar to that of natural vegetation.

For resource-poor farmers supplementary feeding of draught bullocks is only attractive when immediate benefits can be expected. Supplementary feeding in the rainy season is only advised when animals have to work for more than 6 weeks or are scheduled to be sold for meat after the working season, otherwise, animals can work on their body reserves (Fall *et al.*, 1997). Animals not receiving supplementation in the dry season generally show compensatory growth during the rainy season which leads to comparable weight gain at the end of the rainy season (Schlecht, 1995).

The option to cultivate fodder crops to feed draught animals, as proposed in the mixed farming model, was not widely adopted, because: (i) improved feeding of draught animals has only limited impact on crop production in the current system (Fall *et al.*, 1997); (ii) cultivation of fodder in the rainy season will compete for labour with cereal crops; (iii) inputs such as seeds and pesticides are generally not available at farm level and technical packages are not fully developed. Finally, resource-poor farmers will be reluctant to spend their scarce capital on inputs to improve animal feeding.

Two low-cost options to improve feeding of draught animals could be: (i) night grazing added to day grazing, to increase feed intake with longer access to feed resources

(Ayantunde, 1998). Labour availability for night herding may, however, be a problem in the rainy season; (ii) large quantities of crop residues or other low quality feed can be offered to the animals to increase feed intake through selective consumption (Savadogo, 2000). Crop residues are, however, generally not available in the rainy season. Both options seem more suitable to maintain animal weight during the dry season than to increase animal performance in the rainy and hence working season.

The observed relation between animal traction equipment and area of cash crops shows that cash earnings are needed to maintain and value an animal traction unit. The fact that farms owning animal traction equipment had significantly more animals, confirms that either only wealthier farmers can invest in animal traction (Chapter 2) or the inverse, that animal traction and cash crop production lead to wealthier farmers.

In **Chapter 7,** the impact of crop-livestock integration through adapted crop residue management, and the impact of a growing population through a decrease in grazing area, on animal production and on the vegetation of the grazing lands was assessed. Actual grazing systems applied by Mossi and Fulani livestock owners for sheep, goats and cattle on Kaïbo village territory serve as case study.

In Sahel countries such as Burkina Faso, population growth leads to an increase in crop land and associated decrease in grazing area, especially in the rainy season. The spatial distribution of crop lands leads to enclosure and hence inaccessibility of recent fallow lands to grazing livestock, accentuating the decrease in grazing area in this season.

In Zoundwéogo province and Kaïbo village the same processes take place. Moreover, in Zoundwéogo, the demand for grazing land has increased because of immigration of Fulani in the years of extreme droughts. The crop-livestock integration concept stimulates "settlement" of Fulani and allows only restricted mobility of their herds. The concept also stimulates the use of draught animals, and the use of crop residues to feed them, leading to increased cattle numbers in Mossi arable farming households. In Kaïbo, many Mossi families already own draught animals (Chapter 6). Due to the increased density of crop lands close to the compounds, in the rainy season, these animals have to graze outside the cropping area on bush land, the traditional domain of Fulani cattle. Hence, the competition for grazing land in the rainy season increases (Section 7.2). In the dry season, Mossi feed crop residues (cereal straw and legume hay) to their livestock and Fulani herds can just graze the cereal stubble, which is the plant part with lowest nutrient contents.

The three-pole model has presented itself as a useful framework for analysing grazing systems on village territories (Landais, 1992a). In Kaïbo (Sections 7.1 and 7.2) the activities of man to large extent determine the use of the environment by grazing livestock. Mossi occupy the best quality soils (water and nutrients) for crop production and hence these soils (and their potential natural vegetation) are withdrawn from the grazing areas in the rainy season. In line with the crop-livestock integration concept, Mossi collect crop residues for storage on their compounds. Savadogo (2000) has shown that ownership of a donkey cart is then essential. They can also make hay from natural grasses for stall feeding. **Control** over natural resources by Mossi is increasing as exemplified by the transfer of natural resources such as crop residues and hay from the wet season to the dry season. Another aspect of this control is **privatisation** of these formerly common resources. Mossi already had privileged (private) access to good soils for crop lands. Finally, Mossi control water points and can prevent their use by others, forcing Fulani to graze their herds near permanent water sources with free access, such as rivers or lakes (Section 7.2).

Fulani do not have formal access to land (land rights), hardly cultivate any crops (hardly any crop residues), have large herds which makes haymaking futile, and can only graze on the poorest (water, nutrients) soils. The traditionally mobile system of Fulani is not based on control but on **tracking** (Toulmin, 1995; Behnke and Kerven, 1994): following rainfall and subsequent vegetation growth, so that access to very high quality fodder at the start of the rainy season is guaranteed. For the remainder of the rainy season, Fulani herds graze vegetation of non-cropped land. In the dry season, Fulani can graze their animals on the stubble of croplands or on natural pastures. Due to activities of Mossi, the rainy season grazing lands for Fulani herds are restricted to the poorest soils, the dry season crop lands are bare and the quantity of dry season natural vegetation is small. Mossi livestock generally have access to sufficient and high quality fodder. Fulani have progressively less access to fodder and have to cope with decreasing quantity and quality of fodder (Sections 7.1 and 7.2).

Although the area of grazing land has decreased, overall fodder availability did not decrease (Section 7.1) thanks to increased availability of crop residues, that contributed substantially to sheep diets. Haulms from beans and groundnuts and even cereal straws had significantly higher quality than the natural vegetation, present in the same period, but not selected. The increase in crop land can, therefore, be judged positively for sheep feeding (Section 7.1). Savadogo (2000) has shown that excess feeding of these crop residues to sheep allows animal growth due to selective consumption.

The increase in area of crop land in the rainy season and the increased value of crop residues under the crop-livestock integration concept force Mossi farmers and Fulani herdsmen to herd their animals in the rainy and post-harvest seasons, instead of letting them roam freely. Herd size, control of water points and of crop residues determined grazing patterns of cattle (Section 7.2) and small ruminants (Section 7.1), throughout the year, constraining free movement of livestock in a patchy environment. Herds of Mossi and Fulani therefore occupy different parts of the Kaïbo territory (Section 7.2). Fulani cattle were more present on bush, Mossi cattle on fallow and at home (Section 7.2). Grazing units on Kaïbo village territory varied considerably in species composition, so a difference between diets of Mossi and Fulani cattle was expected. No such difference was found, probably because it was masked (Squires 1982) by grouping of vegetation species in broad categories and because of low rainfall (570 mm), in the year under study (1997), resulting in low biomass availability, hampering selectivity of cattle, which thus became generalisers (Schoener, 1971). For small ruminants, diets of Fulani and Mossi systems did differ in the year of study (1994): Annual grasses contributed significantly less and crop residues significantly more to diets of Fulani small ruminant herds (Section 7.1). Fulani herdsmen faced no labour constraint at harvesting time and could therefore guide their animals to (illegally) graze on crop residues on newly harvested fields. In the same period, Mossi were fully occupied with cereal harvests and transporting crop residues to their compounds. Hence, they confine their animals to poles on recent fallow or small children take them out of the cropping area. After the harvest, both herds were free to graze stubble and recent fallow, while the major part of the residues was already stored in Mossi compounds.

Herdsmen, in Kaïbo, deliberately guide livestock to places where specific vegetation (karité fruits, pods from *Faidherbia albida*) for grazing was available (Chapter 7.1). They also cut branches of *Acacia* spp., *Anogeissus leiocarpus, Sterculia setigera* and *Balanites aegyptiaca* for browsing by goats (Section 7.2). Both actions of herdsmen interfere with the optimal foraging theory or any theory on selective behaviour of livestock. Foliage and fruits were made accessible and hence the probability that livestock encounter these highly nutritious feed stuffs is artificially increased. Herded cattle and small ruminants were found to be nutrient maximisers, selecting vegetation with the highest quality such as forbs in June-September, crop residues from November to January (Section 7.2), and high quality browse and fruits in all seasons, especially by sheep and goats (Section 7.1). Constrained herding patterns can have negative implications for this selective behaviour, because livestock can not freely choose where to graze, but activities from the herdsmen support livestock in finding highly nutritious feed stuffs within the grazing areas.

Studies on grazing behaviour of cattle and goats have shown that cattle are generalists and goats specialists (Schoener, 1971). The optimal foraging theory indicates that composition of diets of generalists and specialists will converge when feed availability decreases (Pyke *et al.*, 1977). The current and continued reduction in grazing area in the rainy season leads to concentration of livestock in a restricted area and consequently scarcity of food. Animals will respond by widening their choice of food and limiting selectivity. The diets of cattle and goats will become similar, mainly because goats (specialists) have to change their diets (Fritz, 1996; Gurung *et al.*, 1994; Pyke *et al.*, 1977). Overlap of diets increases the risk of overgrazing (Hiernaux and Fernãndez-Rivera, 1995; Squires, 1982). High grazing pressure, preventing depleted patches to recover, also leads to overgrazing (Charnov *et al.*, 1976). So far, no signs of degradation such as reduced *Andropogon gayanus* cover or increased *Zornia glochidiata* cover, have been observed on Kaïbo territory (Section 7.1). In line with the palatability concept, preference indices (Poissonnet *et al.*, 1992) were used to express the preference of goats, sheep and cattle for specific plant species in specific seasons and to show overlaps in diets between the species. Keeping in mind that preference indices have generally only relative value (Westoby, 1974), they can nevertheless draw attention to important fodder species that can be used as indicator species in long term studies on the evolution of the value of rangelands.

Causes for changes in grazing areas can also be external to the village. In Burkina

Faso, the urban population increased between 1975 and 1985 from 6.4 % 12.7 % of the population (INSD, 1985). **Urbanisation** leads to an increase in the demand for wood from cities and this demand has to be satisfied from village territories or formerly protected forest areas, which may have negative impacts on grazing possibilities in these areas. In Nazinon forest, cutting trees for fuel, to be sold in Ouagadougou, has been shown to negatively affect feed resources for grazing animals (Section 7.3). *Detarium microcarpum* trees progressively occupied the area, leaving less space for herbaceous vegetation, hence increasing grazing pressure on all, but mainly the preferred perennial grass species that subsequently tend to disappear. Cutting of fuelwood thus induced a decrease in both fodder quantity and quality which may in the future may force livestock to graze elsewhere.

Cutting of trees for firewood and poles, and clearing bush for new crop fields reduced tree cover in the Kaïbo area. The number of trees showing signs of cutting was especially high at the grazing sites close to the Mossi houses, reflecting man's influence on his direct environment. Decreasing tree cover may also decrease herbaceous production in the long run, because trees facilitate herbaceous growth by enriching the soil under their crowns (Belsky, 1994). In Mali, frequent cutting of fodder species, such as *Acacia* spp. and *Pterocarpus* spp., appeared to be very damaging to trees (Cissé, 1984) and can be considered detrimental to the goats' main feed resources. Livestock, and particularly goats, have always been accused of destroying (woody) vegetation (Bernus, 1990; Lugard, 1965), but extreme high stocking rates did not impede the regeneration through seeding in lowland *Acacia* stands in Mali (Hiernaux, 1992). Long-term research by ILCA (1992) in the Sahel zone of Mali showed that annual biomass production closely followed annual rainfall, even after extended drought and heavy grazing pressure. Also, an extensive literature study by Dodd (1991) concluded that no solid evidence exists of irreversible effects from livestock on vegetation other than around water points and permanent settlements. De Leeuw and Reid (1995) add, that in tropical Africa, bush fires and fuel wood extraction remove much more herbaceous and woody biomass than livestock. Goats, on the contrary, facilitate establishment of certain tree species, such as *Balanites aegyptiaca* and some *Acacia* species in Mali (Hiernaux, 1992) and in the Kaïbo area. When seeds of these species pass the digestive tract of goats, dormancy is broken. Although goats are often blamed for destroying woody vegetation, evidently, both in Kaïbo and in Nazinon forest, man is the real danger to the woody vegetation and indirectly the herbaceous vegetation as well.

Population growth and crop-livestock integration or mixed farming

Population growth is inevitable, especially in developing countries. Even when family planning will be more widely adopted, the present age structure of the population, will lead to more people. In Africa, population growth is high, for instance 2.6 % for Burkina Faso between 1985 and 1995 (EIU, 1996; INSD, 1985) and more than 3 % for several other countries (Brown *et al.*, 1998). Apart from disasters such as AIDS and hunger periods due to grasshopper invasions, or events such as prolonged droughts or flooding, Africa's population will continue to grow very fast because most of its population is young. In Burkina Faso, 54 % of the population was under 19 years of age in 1985 (INSD, 1985). Conflicting views exist on the social, economic and ecological impact of these high population growth rates.

Malthus (1798) observed that populations had the tendency to grow exponentially, while food supply grew arithmetically, hence he saw a world in which human numbers would continually collide with available food supplies. Natural resources were considered finite, thus more people would imply smaller shares for each. This also holds for government services such as education and health care. In Burkina Faso, building more schools has not reduced the high illiteracy rate of 87 % in 1985 (INSD, 1985). The number of children of schoolage increased much faster than the schooling capacity (Brown *et al.*, 1998). Malthus also held the view of diminishing returns to the same input when technology is held constant. In situations of low rainfall in North Burkina Faso, for instance, increased fertiliser use is of no use under current production techniques, because outputs will not increase unless irrigation is provided. Malthus was not optimistic with respect to technological development. Differences in cultivation systems were explained in terms of climatic conditions, type of soil and other natural factors, believed to remain uninfluenced by changes in the size of population. When a population grows nevertheless, it leads to a labour surplus on the land leading to migration to other rural areas or urban centres. A change in farming system as a result of development or application of new technologies is not accounted for in Malthusian theory.

Boserup (1965) presents an alternative view in which farming systems development is explained on the basis of differences in population density. As long as the population in a given area is sparse, food can be produced with little input of labour per unit of output and with virtually no capital investment, since very long fallow periods help to preserve soil fertility. As population density increases, soil fertility can no longer be maintained through fallow and new systems have to be introduced that require a much larger agricultural labour force. Two effects can be expected:

(1) More intensive land use leads to increased total agricultural output, and can therefore support much higher population densities without lack of food, or lack of employment opportunities in agriculture. An increase in population therefore contributes to the generation of new technologies (induced innovation). Increased population density leads to restriction of available land relative to labour. Labour then becomes relatively cheap and labour-intensive technologies become economically attractive as a means to increase production per unit area. This is an economic view on development that supports the notion that mixed LEIA farming, with its associated labour-intensive technologies, would come to the fore under increasing population densities.

(2) Labour costs per unit of output tend to increase, when going from cropping, based on long fallow periods, towards permanent cropping. Farmers may look for alternative, more remunerative and less arduous work in non-agricultural sectors. leading to large-scale

migrations of unskilled labour to urban centres, aggravating competition on urban labour markets and creating labour shortages for food production in rural areas. The urban population must now carry the double burden of lacking labour opportunities, and higher food prices. These high food prices can become an incentive for agricultural intensification or for imports of food to avoid social and political trouble in urban centres. They are, however, still very low compared to prices of industrial goods and thus do not serve as incentives to use external inputs such as mechanisation and inorganic fertilisers, to increase food production. The modest increases in output per man-hour, resulting from the use of industrial products or scientific methods may not be sufficient to pay for the required scarce resources of skilled labour and foreign exchange. An agricultural revolution through modern industrial and scientific methods can not be expected in countries that have not reached the stage of urban industrialisation (Binswanger and Pingali quoted in Van Keulen and Breman, 1990). High food prices then only serve as an incentive for labour-intensive food production, such as LEIA mixed farming.

Boserup (1965) argued that incentives for change are important. Farmers search for change to achieve greater food security or higher income to pay for schooling, clothing, etc. New technologies may come from own experimentation, but many come from outside through trade, research and extension services, non-governmental organisations, religious institutes, etc. The more open an economy, with respect to freedom of trade, freedom of speech, and freedom of access to information, the more innovative it is likely to be (Tiffen *et al.*, 1994). As population density increases, the cost of infrastructure and services per user, decreases. This applies to roads and sources of information, but also to traders' overheads, enabling them to offer higher farm gate prices.

In most Sahelian countries, with their scattered populations over large areas, infrastructure is indeed poorly developed because of the high cost per capita. Boserup added to her analyses based on labour, that high population densities lead to cheaper transport, easier marketing and more specialisation. This would lead to the growth of local towns, and more profitable agriculture, provided absence of cheap imports of food. Under these circumstances, HEIA specialised farming systems may finally develop.

Breusers (1998) warned that opportunity costs of labour outside the direct farm area (or region) must be taken into account. In colonial times, the high labour demand in coastal areas (Ivory Coast, Gold Coast) and its associated high remuneration drained all labour from agricultural production in Upper Volta (Burkina Faso), resulting in very low annual population growth of 0.9 % for the 1921-1960 period, compared to 2.5 % for Gold Coast (Ghana) in the same period (Goarnisson, 1984). More recently, Breusers (1998) showed for North Burkina Faso high remittances from migration of large numbers of the active population to Ivory Coast for shorter or longer periods. Despite the high population growth of 2.6 % (EIU, 1996), labour shortages, specially in the cropping season, may partly be responsible for the limited adoption of LEIA mixed farming in Burkina Faso. The findings of Breusers support Boserup's view that national population growth must not be confused with local population density, because of migrations, Boserup stressing migration to cities and Breusers to rural areas inside and outside the country.

McIntire *et al.* (1992) discuss the impact of population growth and climatology on type of crop-livestock integration on the basis of literature and rapid field visits to 33 sites. Their model of crop-livestock interaction shows separate and partially integrated herding and cultivation enterprises to be economically advantageous at low population densities, with integration becoming increasingly advantageous at higher densities as agriculture intensifies. With increasing population density, farming intensity and market infrastructure, the costs of combining the two enterprises decrease and benefits increase, therefore crop-livestock interactions increase. At very high population densities, specialised livestock or crop enterprises may become attractive again. This study supports the Boserup (1965) hypothesis that population growth increases the scarcity value of land, leading to factor and input substitutions, and a process of crop-livestock integration in many areas. McIntire *et al.* (1992) also found that stocking rates initially increased with population density, because crop residues can supplement scarce dry season feed resources, but levelled off when wet season grazing became a problem. Stocking rates tend to vary in relation to agro-climatic conditions.

Population growth intensifies the competition between crops and livestock for both land and labour, as it leads to expansion of cropping and reduces grazing land. Land scarcity implies increased labour requirements to produce a given amount of manure or fodder. Crop residues make a net positive contribution to fodder supply, but can also be used to improve soil fertility. When wet season grazing becomes constraining, animal numbers can not grow without the use of external inputs.

McIntire *et al.* (1992) conclude their study by formulating policy measures to promote mixed farming in five different agro-climatic environments. They focus on policies with respect to relative prices, land management and credit and determine key inputs per agro-climatic zone. When relative prices of non-tradable inputs such as manure, crop residues, pastures, and animal traction remain low, compared to prices of tradable inputs such as inorganic fertiliser, pesticides, concentrate feeds and fossil fuels for tractors, then animals generally have a place in cropping systems. In humid and sub-humid regions, animal diseases prohibit permanent livestock keeping, but introduction of disease-tolerant animal breeds might be an option. Although they are generally too small to be used for draught purposes, they may provide meat and can be fed leguminous crops that improve soil fertility at the same time. Key inputs are veterinary drugs. Soil fertility can best be managed with mulching and nitrogen fixation with legumes, because it will be risky and hence costly to have high animal stock. In sub-humid zones with lower disease pressure and in semi-arid regions where crop production is possible, interactions are through animal traction, manure and crop residue management. Policy must encourage availability of key inputs such as cheap by-products for animal feed, fertilisers for crop production, and animal traction equipment. Manure is a key element but availability is inherently limited by the availability of fodder. On-farm animal fattening, should be promoted through credit facilities in sub-humid zones with low animal disease pressure, and generally substantial consumer concentrations. It could also be encouraged in semi-arid regions, but price incentives and infrastructure should come along. Fattening of small ruminants will be easiest. In (un)mechanised highlands, credit for dairying and fattening could be provided when consumer concentration and hence purchasing power, is nearby. Interactions will be through manure and crop residues. Fodder quantity and quality is a key input.

McIntire *et al.* (1992) observed that research and extension only played a minor role in the development towards mixed farming. Only expansion of cash crops appeared to be a strong drive towards animal traction. Introduction of draught animals was assumed to lead to improved animal feeding through cultivation of fodder crops and feeding of crop residues, thus creating the ideal mixed farm. This appeared to be a myth. Manure use was widespread and mixed farming does not provide added value. Farmers understood its value already. Research and extension recommend excessively high manure levels on crop fields, regardless of the associated labour requirements and forage requirements for the livestock that has to produce the manure. Inorganic fertilisers are expensive and hardly available, otherwise farmers might prefer them, because of their much lower labour demand. Fodder crops are competing with other crops for labour and land, and they had very little impact on draught animals performance. The use of agro-industrial by-products was more spontaneous, because they only need small cash investments and yield direct results, especially in milk production and fattening. Animal fattening has become widespread, using available feed stuffs optimally. To further stimulate that practice, external inputs will be needed or feed must be specially produced. The major research problem is not to show the value of animal traction, manure, fodder crops, or fattening, but to present to farmers in all agro-climatic regions all alternative uses of crop residues, and alternative land and labour allocations with their respective outputs. Farmers could then select the techniques most suitable for their specific conditions.

Mortimer and Turner (1993) developed a typology of farming systems, based on degree of intensification and crop-livestock integration. They identified 22 cases for which population density, cultivation intensity and crop-livestock integration could be (subjectively) ranked. Population density was strongly positively correlated to cultivation intensity. Livestock densities were positively associated with both population density and cultivation intensity. Degree of crop-livestock integration did only weakly associate with either population density or cultivation intensity. Hence, livestock and crop production were not necessarily integrated in mixed farming systems, although livestock density and crop intensity both increased under increasing population density.

Their typology can not be used as a basis for assessing the consequences for degradation or conservation: types cannot be distinguished on the basis of sustainability. They add that sustainability depends not only on endogenous factors, such as cropping systems, agronomic technologies, grazing management, etc., but also on exogenous factors, such as tenurial security, prices and governance. Whether development follows a sustainable or degradational pathway, depends among other things on decisions about labour allocation.

Under conditions of labour bottlenecks, labour-intensive systems cannot evolve, unless population is high or increasing (Boserup, 1965).

A recently described and widely quoted example of population pressure and its impact on farming systems development and environment in Africa is that of Machakos district in Kenya (Tiffen *et al.*, 1993, 1994a and 1994b). The heart of the matter is the change in and variety of livestock feeding methods. In the past, competition between crops and livestock for crop residues was neglected and the contribution of livestock to the household was never fully quantified. Production data for Zebu cattle and for goats were absent, home consumption of milk, family labour inputs, crop residues used as animal feed, were not valued and impact of rainfall variability on livestock output was generally ignored. Milk yields, reproductive performance and survival in relation to feeding methods, health care and other management factors, and varying according to the degree of intensification of the farming system, were not known.

The Machakos study supports McIntire *et al.* (1992) by showing that livestock becomes at first more integrated in the cropping enterprise when population density increases. It brings out, however, additional issues, not discussed by McIntire *et al.* (1992), such as land tenure, multiple pasture use, impact of management and ownership of pasture on the degree of erosion and fertility loss and costs of infrastructure.

Private ownership tends to develop, as land scarcity increases and investments in land improvement and protection become necessary (Tiffen *et al.*, 1994a;b). Breusers (1998) and Benoit (1982) indicate different territorial concepts for Fulani pastoralists and Mossi crop producers, and suggest that multiple and overlapping claims on land, hamper establishment of private ownership in Burkina Faso. In the AVV settlement zone in Burkina Faso where ten hectares of land were allotted to each individual farm family, customary rights appeared to continue to dominate use of this land. In Machakos, however, individual title to land, operationalised in demarcation and enclosure of grazing areas, was a necessary condition for intensification of the feeding systems on small holdings. During the transition from extensive to more intensive systems, remaining areas of open access land may become degraded, but Machakos farmers proved that after improvement of the arable part of their farms, they were also capable of improving these grazing lands. As soon as individual ownership was attributed, some farmers recovered and developed these grazing areas to provide grazing, timber and fuel (Tiffen *et al.*, 1993).

Livestock is often accused of degrading soils and vegetation in grazing areas, mainly due to high stocking rates (Bernus, 1990; Boudet, 1973). In Machakos, stocking rates were judged to be too high by standards of a ranching system in which meat production per head should be maximised. Mixed farmers in Machakos have multipurpose animals, do not aim at fast maturity and accept seasonal weight losses of their livestock, but aim nevertheless at high production on an area basis. The observed stocking rates were in line with this way of production. High stocking rates could be maintained through the use of crop residues (Tiffen *et al.*, 1993).

The Machakos experience suggests an S-shaped curve in the relation between population density and output, rather than a bell shape. Output per person and per hectare may initially fall as population density approaches a level not compatible with extensive methods, as farmers struggle to find remedies to land degradation. When further increases in population density improve access to markets and information, and stimulate investments, output per person and per hectare may rise fast. In this process, the share of higher value crops increases, and they replace livestock and food crops as sources of cash. In Machakos, increasing population led to a reduced area of grazing land, a change in the role of cattle, and the replacement of livestock by specialised crops as the main source of cash (Tiffen *et al.*, 1993). Population growth itself spontaneously responded to changed economic conditions between 1979 and 1989. Extreme shortages of land in parts of the district, combined with a national economic recession and very high costs of education and other expenses for raising children led to voluntary family limitation.

Evolution of the livestock component differed between drier and wetter areas of Machakos district, confirming the results of McIntire *et al.* (1992), and depended on farm size. In the semi-arid region, animal draught power was important in various water conservation techniques, reducing risks of crop failure. On smaller farms, farmers combine wet-season grazing with dry season use of crop residues, while larger farms rely more on grazing. In the sub-humid region, where high population density leads to very small farms, draught power becomes obsolete and cattle are valued more for manure and milk. Land being scarce, fodder production is combined with soil conservation and stall feeding or tethering (Tiffen *et al.*, 1993). Land scarcity has to be very extreme for planted fodder, and cut and carry methods of feeding, to become more attractive than grazing. Other methods of range improvement such as hedging, fencing, bush and indigenous tree management, scratch ploughing, become attractive at an earlier stage, because they need much labour but hardly any cash (Tiffen *et al.*, 1994b).

In Machakos, increased population led via higher demand (mouths to feed), more labour (hands), more brains (increased knowledge), and a reduction in the per capita cost of physical and social infrastructure, to an autonomous development towards higher agricultural production per unit area and per capita. The requirements for change were the means and incentives to invest money and work in farm improvement, and secondly, knowledge of new and appropriate technologies.

Means for investment must come from profits in farming. When agriculture is unprofitable, farmers tend to migrate out. Policies must aim at higher farm-gate prices to provide incentives for conservation of land and intensification of agriculture. Free markets allow farmers to select crops in response to markets and weather conditions. In Machakos, new technologies came from various sources, such as traders, merchants, research and extension, religious groups, educated relatives, experimenting fellow farmers. This confirms Boserup's (1965) idea of an open economy with free trade and free access to information. Literacy, numeracy and general knowledge were increasingly useful to find non-agricultural work, to make most of a farming enterprise, and to participate in the various social and commercial networks. Sufficient and adequate schooling facilities appeared to be needed to enhance farmers' capabilities to select, evaluate, and use technologies, judge market opportunities, value trade-offs among different alternatives in the search for risk minimisation, profit maximisation, fertility maintenance, etc. (Tiffen *et al.*, 1994b).

In Machakos, development was assisted by government interventions and policies with respect to pricing, investments and education (Tiffen *et al.*, 1994b). Government also provided community development services and changed research and extension from a top-down approach to one involving farmers in development of technology. It supported small towns in creating jobs and infrastructure and becoming centres of trade and services for the rural area. Governments carry heavy responsibilities at macro-economic level and in maintenance of peace, law and order to provide a stable environment for agricultural development. In Kenya, peace was maintained and major macro-economic problems did not occur, both being in favour of development in Machakos. On the other hand, regional demands for infrastructure, such as roads, were neglected for a long time impeding marketing of agricultural products to Nairobi.

The Machakos case illustrates that farmers must be offered a variety of techniques from which they can select for managing pasture and other systems of animal feeding. The differentiation is necessary not merely because agro-climatic conditions vary, but also because, within any agro-climatic zone, different combinations of grazing and stall feeding may be economic for small farmers and large farmers. To be able to offer suitable alternatives, a thorough understanding is necessary of farmers' objectives, both in keeping livestock and in the output they require from their grazing land. Economic aspects of farming systems analysis must be developed, so that they reflect these objectives and take into account annual variation in output.

In conclusion, Malthus (1798) associated population growth with competition among social groups, economic decline because of dilution/sharing of resources and benefits, and deterioration of the resources. Boserup (1965) saw population growth as an opportunity to develop new technologies that become attractive, because of changed land to labour price ratios, and that can increase the carrying capacity of the resources. She anticipated big socio-economic problems, such as high urban unemployment rates and food prices, and labour shortages and low food production in rural areas, when governments do not provide incentives to stimulate agricultural production. McIntire *et al.* (1992) were not very explicit on the impact of population growth. They supported the necessity for more crop-livestock interaction under higher population density, but doubted that the proposed mixed farming model were an autonomous and ultimate response to population pressure. Mortimer and Turner (1993) saw high cropping intensity, but not necessarily crop-livestock integration, as a logical effect of increased population pressure. They distinguished two development pathways, one degradational and one sustainable, each depending on endogenous and exogenous factors. In Machakos high population growth resulted in socio-economically highly diverse farming systems, using, in general, sustainable farming methods. Tiffen *et al.*, (1994b) stressed the facilitating role of the government in this process.

Our experiences show that Burkina Faso is in an intermediate stage of population growth. At the moment, the increase in population increases the demands for services, such as schooling, health care, markets and roads, and dilutes their per capita effect. On the other hand, population increase is not yet sufficiently high to reduce per capita costs for the construction of infrastructure. In combination with current high migration of farm population to neighbouring countries (Breusers, 1998) this follows Malthus' (1798) scenario. Performance of current farming systems seems to be entirely dependent on intrinsic soil properties (Malthus, 1798) and farming strategies are mainly based on tracking weather patterns through adaptations in cropping pattern in arable farming and mobile grazing systems in livestock production (Toulmin, 1995; Behnke *et al.*, 1993).

Many farm households have changed from low external input specialised crop and livestock farming systems to agro-pastoralist farming systems, but a transition to LEIA mixed farming is all but absent. Although many Mossi farmers own cattle nowadays, they often entrust them to Fulani instead of keeping them on-farm (Breusers, 1998). Integrated farming is more common than mixed farming. In the meantime fallow periods shorten and increased efforts are expended in labour- intensive techniques such as soil and water conservation through the construction of stone rows, and soil fertility management through the use of manure and mulching. This is in line with Boserup (1965) and with the first phase of the S-curve between population growth and agricultural output (Tiffen *et al.*, 1994a;b). The use of crop residues for feeding livestock is also common for those farmers having the means of transportation, such as a cart (Savadogo, 2000). This is in line with McIntire *et al.* (1992) and the Machakos case (Tiffen *et al.*, 1994b), i.e. under increasing population density, carrying capacities for livestock will increase through the use of crop residues.

The case study in Kaïbo, Zoundwéogo province, has shown that wet season grazing becomes a serious problem. Increased competition for resources hampers selective consumption, leading to lower animal production in the wet season. Mossi crop farmers monopolise crop residues and water sources, and cut hay from common grazing lands to increase control over their livestock feeding (Chapter 7). They own cattle for animal traction and to support cotton production, they use manure from their own stock and purchase additional external inputs such as inorganic fertiliser and cottonseed cake (Chapter 6). They withdraw these feed stuffs from resources for Fulani livestock and force the Fulani to graze their livestock near public water sources in the dry season, reducing their mobility, thus negatively affecting their feed quantity and quality (Chapter 7). So far, increased population density has led to integrated farming and wealth for Mossi crop producers and increased poverty for Fulani livestock keepers (Chapter 4).

The current urbanisation rate in Burkina Faso, shows that following the reasoning of Boserup (1965), national policy has not been able to provide incentives such as high farm-gate prices to stimulate agricultural (food) production in rural areas. Although the Machakos case

(Tiffen *et al.*, 1994a;b) learned that governments can not really easily promote agricultural development through research and extension, comparison with agricultural development and policy in Tanzania (Tiffen *et al.*, 1994b) showed, that governments can certainly impede development by macro-economic policy measures.

Boserup (1965) also stresses that an open economy, providing free trade and free access to knowledge is important. The point in case seems to have been made in Machakos, where education successfully improved farmers skills and knowledge to use and evaluate new technologies (Tiffen *et al.*, 1994b). In Burkina Faso, many farmers live in relative isolation. They hardly ever leave their village, have no access to newspapers nor to international or even national television, and only few own a radio. On the other hand, family members of many farmers have migrated, at least for part of their life, they could provide access to alternative technologies. New technologies are now mostly offered by national research and extension, or by donor-funded development projects.

The role of research and extension in encouraging mixed farming has been shown to be very limited (McIntire *et al.*, 1992; Tiffen *et al.*, 1993 and 1994a;b), but policy may have some influence (McIntire *et al.*, 1992; Tiffen *et al.*, 1993; Boserup, 1965). It appeared very important that the population had influence on the agenda of the government with respect to the distribution of resources, for construction of roads for instance (Tiffen *et al.*, 1994b). Our study in Burkina Faso indicated that research and extension worked top-down and addressed mainly resource-rich farmers. The majority of resource-poor farmers and mobile livestock producers had no influence on research or policy (Chapter 3).

Mortimer and Turner (1993) found a strong correlation between population density and cropping intensity but only a weak correlation with crop-livestock integration. It remains therefore doubtful whether high population density in Burkina Faso will ever autonomously lead to mixed farming for all rural households. Mixed farming mainly seems a goal for policy makers, research and extension, aiming at control over mobile livestock producers by settling them, aiming at cheap food production and sustainable agriculture through nutrient cycling on farms of crop producers (Chapters 3 and 4). Research and extension might have more results when they involve themselves in strategic, on-farm, research to develop, in co-operation with farmers, a large number of alternative technologies. These alternatives present farmers with the choice to adopt only those technologies that are suitable for their particular situation.

Environmental dimensions of crop-livestock integration under high population growth

High population growth inevitably leads to a certain degree of urbanisation. Diets of urban populations contain on average much more meat and milk than those of rural populations (IFPRI, 1995). Urbanisation leads thus to a high local demand for livestock products, preferably produced close to urban centres to minimise time and costs of transportation of products towards the consumers, to guarantee fresh products at any time.

Concentration of animals around cities creates a high demand for animal feed. This feed can not be transported from rural areas because it is very costly and logistically complicated. Specialised animal production systems based on external inputs (HEIA) will develop, because the urban market and scarcity of land around cities, makes high production per hectare and per animal profitable. Mixed farming does not develop, because livestock producers around cities are investors and not necessarily farmers. They have no waste from cereal production to feed to their livestock and they do not need the manure for cropping. They buy animal feed and sell their manure to peri-urban vegetable growers.

Cattle are most suitable for milk production, but poultry and pigs are more suitable for intensive meat production, because their conversion efficiency of cereals in meat is higher than for ruminants. World-wide, pork and poultry production use each 35 % of all concentrate feeds, intensive milk production and fattening in cattle another 25 % and small ruminants only 5 % (Hendy *et al.*, 1995). Large scale industrial poultry or pig production is based on western (Europe, USA) breeds, that are kept in confinement and fed concentrate feeds. These feeds consist for a large part of cereals and these activities compete therefore directly with human consumption. When these cereals have to be produced in the rural areas, intensive peri-urban animal production puts additional pressure on arable land. When cereals are imported, arable land in other countries is occupied. Figures of 1990 to 1992 show that about one third of global cereal production was consumed by livestock and produced on about 20 % of the total arable land (Hendy *et al.*, 1995). For HEIA livestock production, cereal prices determine the price of the products. Politicians therefore, aiming at keeping their urban constituency satisfied, will aim at low cereal prices to keep meat and milk prices also low. Specialised HEIA livestock production will not be an incentive for higher cereal production in rural areas.

At global scale, 55 % of the concentrate feeds are used in mixed systems and only 5 % in grazing systems, industrial systems consuming the remaining 40 % (Hendy *et al.*, 1995). Concentrate feeds for grazing livestock disrupt the feedback between vegetation (quantity and quality) and animal numbers. Hence, serious overgrazing may occur, especially after a drought period in which concentrates are used for animal survival. Permanent availability of concentrate feeds in urban centres or around harbours can lead to overgrazing of their surroundings. Subsidies on concentrate feeds, for the purpose of increasing animal production, can have the same effect. Urban consumers are mostly not directly dependent on natural resources and are therefore reluctant to pay for their conservation. In many countries, the city environments area degraded due to overgrazing and over-exploitation for fuelwood. Rural producers faced with low prices for their cereals, are generally to poor to invest in conservation of natural resources, especially soil fertility.

The direct impact of population growth on rural environments is through expansion of crop land, increase in intensity of fuelwood exploitation, and contraction of the grazing area. When cropping area increases, cropping becomes more permanent. Soil fertility can no longer be maintained by fallow periods, but depends on fertilisation with animal manure, inorganic fertiliser, green manure or a combination. Mixed farming thus seems a solution. When the ratio grazing land/crop land decreases, animal numbers will finally be constrained by availability of fodder, although the demand for manure is still increasing. Soil fertility of the entire system will decrease and the pressure for higher animal numbers can lead to overgrazing of rangelands. The value of crop residues as animal feed can not be ignored, but plant breeders have always aimed at increased grain yield often at the expense of straw yields, through development of so-called High Yielding Varieties (Steinfeld *et al.*, 1997). Abundant availability of crop residues is therefore not to be expected, restricting the prospects for mixed farming.

Urbanisation has also an effect on crop production and environment. Urban consumers want cheap cereals and a diverse food package. LEIA cereal production under rainfed conditions is relatively cheap, because the main input is labour. Land of LEIA farmers runs the risk of being rapidly exhausted, as cereals are exported to the cities and the exported nutrients are not replaced by external inputs. Reliance on small surpluses from many farmers makes feeding of the urban population strongly dependent on logistics. HEIA farming facilitates supply of cereals at urban level but is more expensive due to the use of external inputs. Rice and vegetables, produced under irrigation, are important components of the diet of urban populations. Their production requires high levels of input per unit area to value infrastructure (irrigation) or land (vegetables) that can be very scarce and expensive around cities. The high nutrient requirements preclude complete cover through animal manure only. Their production requires infrastructure, concentrating water from other parts of the land, and inputs, such as pesticides, that might pollute the environment, when used injudiciously. Intensive systems can easily form a threat to natural resources, especially fauna. Pesticide use in irrigated rice in the "*Office du Niger*" in Mali and cotton in South Mali and South East Burkina, is blamed for decreasing populations of wild birds. Irrigation schemes are blamed for limiting water resources for drinking water, especially in low rainfall years. The debate was very lively in 1998 when Burkina Faso, Benin and Ghana suffered from shortages in drinking water.

Policies aiming at an increase in grazing area by creating water points or by eradicating animal or human diseases in more humid zones, mostly overlook that use of the new land must be regulated (Steinfeld *et al.*, 1997). Under scarcity of grazing lands, water points in traditional wet season grazing areas may transform these areas into open access and permanent grazing lands, leading to rapid destruction of the vegetation that is not suitable for such a grazing regime. Sometimes, water points are used for vegetable gardening in the dry season, excluding livestock from its surroundings. Under high population pressure and its associated land scarcity, fertile land in more humid zones, formerly 'protected' by prevalence of diseases, will rapidly be transformed in crop land after their eradication. Improvement of pasture by planting or sowing fodder species in existing pastures, will lead to degradation, unless open access is avoided by parallel introduction of adequate management. Models of timely (rotational) grazing as proposed in holistic pasture management (Savory, 1988) should be tested, as they seem to suggest possibilities to reconcile the advantages of mobility with the restriction in grazing area. Policy makers should involve pastoral communities when proposing measures with respect to water, fodder or animal diseases, because they may interfere with traditional grazing rights.

Policy makers should also pay attention to the balance between users degrading resources, and those suffering from their degradation (Steinfeld *et al.,* 1997). They should tax enterprises that pollute the environment ('The polluter pays'). They should also aim at higher food prices in urban centres, providing incentives for rural producers for conservation and/or improvement of production factors such as land and labour. High producer prices may discourage migration to cities and encourage investment in soil conservation through use of external inputs. This should be accompanied by prevention of imports of cheap food, and creation of facilities for transport of food from rural areas to cities and of inputs to rural areas, by good roads, information about market prices, etc. The same infrastructure can be used to transport animal products to the urban centres and so discourage high concentrations of animals and its associated problems around cities. Markets and slaughterhouses in rural areas and cold chains could also stimulate de-concentration of animal production.

Concentrations of animals close to population centres can produce wastes that are dangerous to human health. Waste from slaughterhouses, entering the environment without proper processing, is dangerous in case of diseases that can transfer from livestock to humans. Wastes from leather manufacturing, mainly chemical products (metals et tannins), can enter the environment and lead to intoxication of humans and animals, especially when it pollutes scarce resources, such as drinking water. Around Ouagadougou in Burkina Faso, waste from leather processing has entered the environment, leading to casualties in sheep, drinking polluted water. These types of waste cannot be recycled by adding a crop component to the farming system. Mixed farming thus offers no solution. Decentralised farming and processing might reduce local pressure of pollution, but on the other hand, concentration of the problem might make a technical solution feasible, because of economy of scale and low transportation costs.

Social dimensions of crop-livestock integration under high population growth

Resource-poor farmers and pastoralists have been shown to be hardly involved in planning of their future. Their objectives and aspirations do not reach policy makers or do not interest them (Chapter 3). Mixed farming seems an interesting option for crop farmers that are wealthier and can buy livestock. Resource-poor farmers have no means to maintain soil fertility, except through contracts with mobile livestock producers, and/or application of labour-intensive measures for soil and water conservation.

Specialised HEIA animal production might be attractive for investors around cities, but not for pastoralists with large herds, with no recognised claim on land, and therefore no secure place to graze their herds or to produce animal fodder. Living in rural areas, they lack infrastructure such as roads, slaughterhouses, veterinary services to provide disease prevention and artificial insemination with exotic breeds, agro-industrial by-products at fair prices, cold chains to guarantee quick and safe transport of products to urban centres. Because of lack of collateral they have no access to loans from formal financial institutions (Chapter 5). They might consider crop production to meet part of the households food requirements and part of the animal feed requirements through crop residues (Chapter 4). By settling permanently on a village territory they might even maintain or acquire some grazing rights.

Delgado (1979) suggested policies encouraging **interaction** (trade) between crop producers and livestock producers, instead of promoting mixed systems. When cropping provides high returns on labour, it will economically be more attractive for specialised crop producers to entrust their animals to Fulani than to become mixed farmers. Keeping animals in enclosures and feeding crop residues, for the sole purpose of producing manure for cropping, is very time-consuming. On the other hand, mobile Fulani, fully occupied by herding, should not be constrained by labour bottlenecks on their small crop field, but be in a position to buy cereals from crop producers. For the system to work, cereals should be cheap for Fulani. Remuneration of cattle in terms of meat and milk should be encouraging to Fulani to accept animals of crop producers in their herds. Because of the soil fertility bottleneck, clear agreements should be made about ownership of the manure of all (and certainly the entrusted) livestock. The value of crop residues as animal feed makes it important to include them in agreements between crop producer and herdsman. Do Fulani have the right to graze their herds on crop residues of farmers that have entrusted their animals to them? In Tenkodogo, Fulani preferred to sell manure from their paddocks to vegetable producers instead of giving it "for free" to crop producers who's cattle they herded (Delgado, 1979). The trade of manure against money has partly replaced the exchange for crop residues and weakens relations between crop producers and animal producers. When crop farmers can replace manure by cheap inorganic fertiliser the relations become even weaker (Bayer and Waters-Bayer, 1991). National price policy for fertiliser thus plays an important role.

National governments profit from livestock exports. For most West African countries, large parts of their territory are situated in low rainfall areas, where crop production is very risky, but is suitable for livestock part of the year. To value these areas, mobile animal production is the only way. Policy makers should realise that and facilitate mobile animal production by reserving grazing areas in more Southern parts of the country that tend to become increasingly dominated by crop production. They should also provide adequate infrastructure to facilitate take-off of animal products and implement a fair tax policy. They should discourage livestock production by absentee owners by taxing them higher than pastoralists, because they tend to destroy the environment, rather than manage it.

The disequilibrium (cusp) state and transition theory has been applied to herbivore-vegetation relations under erratic and highly variable rainfall regimes. The theory suggests, that in addition from gradual change, sudden shifts from one state to an extreme other state can occur, skipping a number of intermediate states. It would be interesting to apply the same theory to the transition between farming systems (Schiere, Animal Production Systems Group, Wageningen University, pers. comm.). An example is the development of specialised HEIA livestock production systems around urban centres, totally independent of the pathway through agro-pastoral, integrated and mixed farming systems illustrated in Chapter 4. A consequence of the applicability of this theory on farming systems would be that one should accept that certain farming systems may disappear due to a(n) (in)visible threshold that can be crossed. Such thresholds may be the price of fertiliser, or the price of cotton, both favouring HEIA production systems. Another threshold may be the concentration of people in urban centres with associated purchasing power, increasing demands for certain products. For mobile systems, available grazing area in the wet season in the savanna zone may be critical for their survival.

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9 CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The crop-livestock integration concept and the mixed farming model, have been shown to be rooted in colonial times, for both East and West Africa (Sumberg, 1998; Massa and Madièga, 1995). Ever since it has been the leading model for agricultural development in these areas. Despite its apparent failures (Sumberg, 1998; Landais and Lhoste, 1990), and shortcomings (Chapter 1), it has kept this position till today. The challenge is to examine whether the model retains its value for the future. Therefore, our investigation attempted to answer the following question:

" *Is crop-livestock integration or mixed farming a suitable model for farming systems development, leading to guaranteed food security and socio-economic survival for all social entities of the rapidly increasing population in Sahelian countries, without endangering their resource basis?* "

For Zoundwéogo province and Kaïbo village, it was shown that optimising the use of natural resources needs HEIA farming to feed the population and to prevent soil degradation. LEIA farming does not generate sufficient food, even in average rainfall years, and production is associated with soil depletion of nutrients (N, P) and organic matter. Simple equipment appeared to have a major impact on farming methods: A cart was a prerequisite for mixed farming based on intensive management of crop residues and manure. (Chapter 2)

In Burkina Faso, policy makers to a large extent determine which technical options are developed by research and hence proposed to farmers through extension. Implicitly, only progressive (wealthier) farmers that have access to a large variety of resources are addressed. The majority of resource-poor farmers and mobile herdsmen are not reached, because the proposed techniques are not adequate for their situation. In turn they have no influence on research or extension, because they are not organised around common objectives, do not form a constituency for politicians, and do not participate in local administration, either because of illiteracy or mobility. (Chapter 3)

Influence from policy increases, from traditionally research and extension, to internal price policies (subsidies, guaranteed prices), provision of infrastructures (roads, water points, markets), and response to donor demands as conditions for investments in development projects (sustainability in terms of nutrients, gender). (Chapter 4)

Societal demands for food production both in quantity and quality, and for export products, require specific farming systems. LEIA farming systems are appropriate for self-sufficiency in food for the rural population and for cheap production of livestock for export. To feed the urban population and to produce cotton for export, specialised HEIA crop and livestock production appear more appropriate, but also more expensive in terms of infrastructure. (Chapter 4)

In Kaïbo, Zoundwéogo, Burkina Faso, schematically six levels of crop-livestock integration can be distinguished: specialised, agro-pastoralist, integrated and mixed LEIA systems, and mixed and specialised HEIA systems. These farming systems are representative for the whole of the West African savanna (CORAF, 1993). Each of the farming systems contributes to a certain extent to societal demands and there seems no need to change them all to HEIA mixed farming systems. (Chapter 4)

Ethnic identity and gender appear to be intertwined with production goals and labour distribution, and thus with motives towards intensification of crop or livestock production or mixed farming. Fulani livestock keepers only engage in crop production when they are forced by external conditions, such as droughts or animal diseases leading to loss of (part of) their herds. Mossi crop producers can only acquire cattle when they have resources to accumulate wealth, such as remittances from migration or cash from cotton. The main drive towards agro-pastoralism for Fulani is poverty, opposite to that for Mossi, for whom it is wealth. (Chapter 4)

In situations with high variability in rainfall between years and between locations within years, rainfed crop production strongly fluctuates (Chapter 2). This requires a mechanism to transfer surpluses to years with deficiencies. Livestock plays an important role in this transfer and has a function of financing of foreseen and emergency cash needs. This financing function of livestock is generally ignored in the crop-livestock integration model, but appears particularly important for resource-poor farmers in situations where formal financial infrastructures are absent. Compared to livestock, alternative forms of financing have disadvantages in terms of accessibility, liquidity and security (Section 5.2).

The financing function of livestock has, however, also disadvantages. For small ruminants, it interferes with maximum animal production, because of foregone offspring and foregone animal live weight. It also interferes with the important role of cattle as source of manure and draught power for crop production in mixed farming. Selling strategies show that farmers and herdsmen are aware of these disadvantages: small ruminants were sold before cattle, males were sold before reproductive females in all cases, except for cattle in crop-based systems where draught bullocks have the highest value for crop production (Section 5.1).

A theoretical model was developed to compare financing through livestock with alternatives. In the study area, financing through saving and credit co-operations appears cheapest. As a collateral is needed for a credit from these formal institutions, resource-poor farmers resort to livestock because of its accessibility. The contribution of livestock to household budgets, hence its current role in financing, appears to be farming system-specific (Section 5.4). The nutrient and economic complementarity postulated in the mixed farming model is limited by the financing role of livestock.

Animal traction is supposed to be a key-element in mixed farming. Most farmers entrust their draught animals to Fulani, instead of stall feeding them with fodder crops.

Cereals, cash crops (cotton) and fodder crops compete for labour and land, therefore most farmers can not produce fodder on-farm. Complementarity, presented as the advantage of mixed farming, appears to be limited because of competition for these production factors.

Average bullocks are weak compared to the draught requirements, hence working days are short and timeliness in sowing and weeding is not guaranteed. Improved feeding, improved animal breeds, or more draught animals are needed. In Zoundwéogo province and in Kaïbo village, sufficient cattle are available to work all fields with animal traction, but many animals should be trained. So far, most cattle are owned by Fulani, hence to increase animal traction capacity, ownership of cattle should be transferred from Fulani to Mossi, or an alternative system in which Mossi for instance hire bullocks from Fulani should be set up. Animal traction is mainly applied on cash crops, such as cotton and maize. Although cash from sales of these crops increases purchasing power and hence access to food, direct impact of animal traction on food production is limited. Animal traction appears to be positively correlated with farm size and area of cash crops, hence mainly used by wealthier farmers. The role of the animal traction component in mixed farming is thus limited to cash crop production by wealthier farmers and its contribution to feeding a growing population is therefore small. (Chapter 6)

Fulani and Mossi herds both use village territories. Mossi tend to occupy progressively larger areas for cropping, reducing the grazing area. Increased crop-livestock interaction within Mossi farms is associated with the need for livestock feed on-farm, to supplement draught animals and small ruminants, that are partly kept near the house to facilitate collection of manure. Hay is made from grasses of communal grazing areas and in addition to crop residues, these feed resources are collected at the Mossi homestead. These feeds are therefore not available for free grazing or herded Fulani livestock. Mossi also control the village wells and can force Fulani to water their herds outside the village territory, again limiting their access to village territory feed resources. Fulani herds are confronted with lower quantity and quality of feed resources, as the quality of most dry season grasses is lower than that of the crop residues they used to feed their animals. (Chapter 7)

The risk of degradation of the village territory increases when mixed farming is introduced under high population growth, because:

(1) crop land increases and grazing land decreases, while
(2) animal numbers increase, especially in the hands of Mossi (draught bullocks), and
(3) diets of specialist (goats) and generalist (cattle) ruminants, being complementary in situations of food abundance, tend to overlap in situations of food scarcity, which may lead to overgrazing of certain plant species.

Population growth and increased urbanisation increase demands for fuel wood from village territories, enhancing degradation risks. (Chapter 7)

In situations of high population growth, policy makers tend to focus on increased cereal production, and so far, mainly through the application of the mixed farming model. As this model is not suitable for resource-poor farmers and mobile herdsmen, their position is at risk, and they tend to be replaced by wealthier farmers that can more easily transform to HEIA farming systems. Therefore, policies aiming at expansion of mixed farming have social drawbacks. Mixed farming is presented as a closed system, based on efficient nutrient cycling. When mixed farming has to produce cereal surpluses to feed the growing population, nutrients are exported from the farm and must be restored either through inorganic fertiliser or manure. Hence, LEIA farmers have to use their environment to graze their animals that provide manure and to collect biomass for soil and water conservation measures. Moreover, because of unavoidable losses during recycling, more intensive flows lead inevitably to higher absolute losses. Wealthier HEIA farmers can purchase inorganic fertiliser, but recovery of fertiliser nutrients in crops can only be high when organic matter content of the soil is maintained, therefore they also have to exploit their environment. In addition, HEIA farming can lead to pollution of the environment and the food chain and negatively affect farmers' health, because external inputs, such as pesticides and veterinary products need very skilful and judicious application.

Focusing on mixed farming appears socio-economically and ecologically undesirable. A mixture of different farming systems can better respond to the variety of societal demands under high population growth. These demands include accessible food for all people, cash from export, and fresh products such as milk and vegetables and attractive diets for the population in cities. Farming systems depend to a variable degree on natural resources, allowing complementarity in use that can avoid their degradation. Dry areas can only be valued through animal production and wetter areas are more suitable for crop production. Research should address the specific needs of each of these farming systems to guarantee that they can also meet societal demands in future.

Recommendations

Policy makers should be transparent and explicit about their objectives and provide the socio-economic environment to achieve them. They can focus explicitly on the development of farming systems supporting their policies, but they have also to consider farmers needs and the quality of the natural resources. We have schematically distinguished discrete farming systems (Chapter 3 and 4), allowing policy makers, research and extension to more explicitly discuss and respond to their specific requirements. It is recommended that research and extension co-operate with each of these farming systems to develop suitable technical solutions and to identify and evaluate socio-economic constraints per farming system.

So far, all attention has been focused on the development of technologies relevant for LEIA or HEIA mixed farming systems. Technologies suiting mobile herdsmen and resource-poor farmers were particularly neglected. Therefore, it is recommended to encourage participation of these groups in technology development, so that they can influence the research agenda and be co-responsible for technical solutions addressing their needs. Research and extension should be trained in participatory technology development, and in taking farmers' needs as basis for their work instead of curiosity or top-down policy priorities.

Resource-poor farmers and mobile herdsmen appear to have very little political influence, and policy makers, therefore pay hardly attention to their interests. Efforts should therefore be made to stimulate their organisation around common objectives, and to increase their participation in political decision making. A certain level of literacy and education at farmers' level must be provided to stimulate the processes. Explicit training on negotiation with administration and policy makers, but also with researchers and extension agents, or with international development agencies, may also be useful.

Not only training is needed, but policy measures should provide farmers with certain means (credit, carts, ploughs) allowing adoption of technologies. We found, for instance, that LEIA farming alone cannot feed the population nor successfully prevent soil degradation. External inputs, such as inorganic fertiliser or concentrates for animal feed are needed. In terms of agricultural equipment, a cart contributes probably more to development of mixed farming than a plough. Purchasing external inputs requires cash. Subsidies and presents are possibilities but they are by nature incidental, create dependency of their beneficiaries, distort economic relations, and can not be sustained in the long-term. The current trend is against subsidies, because World Bank and other international organisations, make free trade and liberal economies without much public influence, conditional for loans and other support. We therefore recommend to focus on ways to increase the purchasing power of crop producers:

- increased farm-gate (food) prices, through for instance higher prices for food grains in cities, improved transport and storage facilities, transparent markets;

- incentives towards saving and adequate credit provision by improving accessibility, liquidity, security and profitability of savings and credit co-operations;

- increased farmers' influence on the entire production-consumption chain, through for instance contract production ("*haricot vert*" for export), storage of cereals to avoid speculation by merchants and increase profits for crop producers ("*banques de cereales*"), serving niche-markets such as production of tasty rice that can be sold for higher prices to urban consumers ("*Office de Niger*" for the Bamako market) or special onion production and harvesting leading to high quality and onions with longer shelf-life leading to higher prices ("*Office du Niger*" for Bamako and export market);

- introduction of remunerative crops such as cotton, sesame, onions, "*haricot vert*", flowers.

With Delgado (1979) we recommend that policy makers emphasise the complementarity of crop production and animal production, instead of mixed farming. Policy measures focusing on improving the economic situation of animal producers include:

- increasing benefits of cattle keeping through increased milk production for range-fed animals, and increased possibilities for sales of milk, which will encourage Fulani to accept entrusted animals. Discouraging of cheap import of milk powder and meat;

- optimal use of cattle dung by explicit ownership regulations (herdsman versus cattle owner), fair prices (it can be purchased for gardening) and by improved means of transportation from corral to field;

- reduction of crop damage conflicts by:
(1) restraining (by law) Mossi in clearing fields in wet season grazing areas and gardening in dry season grazing areas,
(2) clear delineation of corridors in village cropping areas, where cattle may pass even in the rainy season,
(3) charging Mossi cattle owners for part of the crop damage done by their cattle when herded by Fulani;

- improving access of Fulani to food grains (low prices, high availability on markets) to reduce their need for cropping. To provide both, low cereal prices for Fulani and high prices for urban consumers, a market differentiation is needed;

- improving access of Fulani to agro-industrial by-products that are useful in animal production (such as cotton seed cake, salt, groundnut cake, molasses), but also to veterinary care, vaccines and drugs;

- improving benefits from marketing of livestock, through increase in transport facilities, transparent tax systems and protection against "*taxe sauvage*", cold chains for perishable meat and milk products, and promotion of associated small industries, providing added value to meat, milk, and hides and addressing niche-markets with attractive prices.

Policy makers and development projects should consider all these possibilities and be aware of the need to increase accessibility of external inputs, not only through increases in purchasing power, but also through transparent distribution channels for scarce inputs such as cotton seed cake and rock phosphate.

Policy makers should stimulate adequate formal financing infrastructures in rural areas to prevent premature sales of livestock for financing. Livestock production may increase through reduced losses of offspring and foregone weight gain, associated with sales for financing. The number of co-operatives must increase, saving must become more attractive, hence interest on savings should be provided and additional advantages, such as loans proportional to savings should be given. The obligation of a pledge should be reconsidered. When farmers can make use of formal financing infrastructure, they have the opportunity to plan animal production in accordance with known fluctuations in market prices, that are mainly related to season, religious festivities, and world trade agreements. In this way farmers' income from livestock can increase.

Policy makers may influence world trade by organising lobbies against dumping of meat on markets of coastal areas of Africa for instance. They may also negotiate cotton prices.

Policy makers should also take measures to increase the profitability of grain storage. Information and transportation infrastructure must be created, facilitating farmers to sell and transport their surpluses at adequate times for attractive prices. The influence of merchants, speculating on the grain market will then automatically be limited. The effect will be higher farmers' income, lower cereal prices for urban consumers (no speculation) and lower costs for buffer stocks at the level of the government, because internal redistribution between surplus and deficiency zones of the country is facilitated.

Animal traction has led so far to an increase in cropping area, instead of intensification on existing fields. Population growth leads to relative land scarcity, and hence to relatively cheap labour. Although intensification per unit area should be the next step, it will especially be through introduction of labour-intensive techniques. Animal power does not alleviate labour constraints in activities such as soil and water conservation, compost making, transport, etc. The demand for donkey carts will therefore be higher than for ploughs. Low purchasing power of the average farmer may be a bottleneck. It is therefore recommended to stimulate animal traction only when associated with (HEIA) cash crop production, such as cotton. Stimulation of donkey carts can be recommended for LEIA farming systems, because transport of crop residues and manure is crucial in nutrient management, and because soil and water conservation measures, such as mulching and construction of stone lines are also highly dependent on transport facilities.

Mixed farming seems to lead to expulsion of Fulani from village territories, either on purpose (limitation of watering rights at wells) or because of increased competition for feed resources, such as crop residues and grazing land. It is recommended to designate grazing areas for Fulani herds in the savanna zone, because those herds that value the Northern, Sahelian, part of the country, can only be maintained when they have access to grazing areas in the Southern part, for part of the year. To avoid damage to crops, corridors in which cropping is prohibited must be secured, allowing passing of Fulani herds to the grazing reserves or to livestock markets within and outside the country.

Soil fertility maintenance through manure requires large numbers of animals. It remains therefore to be demonstrated that average crop producers can function sustainably without large Fulani herds providing this manure. Inorganic fertilisers are expensive and therefore not accessible for resource-poor farmers. Recovery of nutrients from these fertilisers is low on soils with low organic matter content, hence green manure or animal manure is required. Resource-poor farmers will not be capable to acquire and sustain sufficient animals to maintain soil fertility. They need transactions with mobile animal producers, in which crop residue grazing can be exchanged for manure for fertilising of fields. On the other hand, mobile livestock keepers will not succeed in producing sufficient cereals to satisfy their food needs. Therefore crop-livestock interaction between crop producers and livestock owners is more appropriate for these groups than mixed farming.

Societal demands dictate the need for a variety of farming types. It is thus recommended to abandon the rather rigid mixed farming model and to focus on the consequences of the principles underlying crop-livestock integration. A distinction between these principles on one hand, and comprehensive ideal models on the other, should be made in policy, research and extension to facilitate development and diffusion of a variety of techniques from which farmers can choose. Imposing or proposing a complete and integrated package only suits those few farmers that have the means and the motivation to develop towards the "ideal" unique farming model.

The mixed farming model has failed (has been rejected) but many of the concepts underlying crop-livestock integration form the basis for farmers' behaviour.

REFERENCES

Adamou, L., 1991. Functions and possibilities of developing livestock farming in the Sahel, *Animal Research and Development* 34:100-113

Allan, W., 1965. *The African husbandman,* Oliver and Boyd, Edinburgh

Amir, P., and H.C. Knipscheer, 1989. *Conducting on-farm animal research: procedures and economic analysis,* Morrilton, Winrock International Institute for Agricultural Development, 244 p.

Antenne Provincial du Plan, 1997. *Atlas du Zoundwéogo,* Tome 1, Première Edition, Ministère de l'Economie et des Finances, Burkina Faso

Archer, S., 1996. Assessing and interpreting grass-woody plant dynamics. In: Hodgson, J., and A.W. Illius (eds), *The Ecology and Management of Grazing Systems,* CAB International, Oxon, UK, p. 101-134

Arrow, K., *et al.*, 1995. Economic growth, carrying capacity, and the environment, *Science* 268:520-521

Atlas du Burkina Faso, 1993, Les Atlas Jeune Afrique, Les éditions Jeune Afrique, Paris, France

Aucamp, A.J., 1976. The role of the browser in the bushveld of the Eastern Cape, *Proceedings of Grassland Society of South Africa* 11:135-138

Ayantunde, A.A., 1998. *Influence of grazing regimes on cattle nutrition and performance and vegetation dynamics in Sahelian rangelands,* PhD thesis, Wageningen Agricultural University, The Netherlands

Badini, O., 1991. *Identification et caractérisation des systèmes d'élevage et étude des ecosystèmes pâturés dans les villages, sites RSP (Kayao, Kawara, Dimolo, Yasso),* Rapport RSP Zone-Ouest, INERA, Burkina Faso

Ban, A.W. van den, and H.S. Hawkins, 1988. *Agricultural extension,* Burnt Mill/Harlow: Longman, 328 p.

Barning, N.M., and J.B. Dambré, 1994. *Les styles d'exploitation. Une classification des exploitations dans la province du Sanmatenga, Burkina Faso,* étude dans le cadre du projet PEDI, Kaya, 33 p.

Barral, H., 1970. *Etude socio-géographique pour un programme d'aménagement pastoral dans le Nord-Est de l'Oudalan,* ORSTOM, Ouagadougou, 92 p.

Barral, H., 1976. *Nature et genre de vie au Sahel. L'année 1973 dans le Nord de la Haute Volta,* Rapport multigrav., ORSTOM, Ouagadougou, 163 p.

Bartels, G.B., Norton, B.E., and G.K. Perrier, 1993. An examination of the carrying capacity concept, in: Behnke, R.H., Scoones, I., and C. Kerven (eds), *Range Ecology at Disequilibrium,* Overseas Development Institute, London, p. 89-103

Baxter, P.T.W., 1977. Some consequences of sedentarization for social relationships, in: Monod, T. (ed), *Pastoralism in Tropical Africa,* Oxford University Press for the International African Institute, p. 206-228

Bayer, W., and A. Waters-Bayer, 1991. Relations between cropping and livestock husbandry in traditional landuse systems in tropical Africa, *Animal Research and Development* 34:57-69

Behnke, R. H., Scoones, I., and C. Kerven (eds), 1993. *Range ecology at disequilibrium: New models of natural variability and pastoral adaptation in Afrcan savannas*, ODI, London

Behnke, R., and C. Kerven, 1994. *Redesigning for risk: tracking and buffering environmental variability in Africa's rangelands*, Natural Resource Perspectives No. 1, Overseas Development Institute, London, 4 p.

Behnke, R., and N. Abel, 1996. Revisited: the overstocking controversy in semi-arid Africa, 3. Sustainability and stocking rate on African rangelands, *World Animal Review* 87:17-25

Behnke, R.H., and I. Scoones, 1993. Rethinking Range Ecology: Implications for Rangeland Management in Africa, in: Behnke, R.H., Scoones, I., and C. Kerven (eds), *Range Ecology at Disequilibrium*, Overseas Development Institute, London, p. 1-30

Belem, C., 1985. *Coton et systèmes de production dans l'Ouest du Burkina Faso*, Thèse de doctorat de 3e cycle en géographie de l'aménagement, Université de Montpellier III

Belovsky, G.E., 1984. Herbivore optimal foraging: a comparative test of three models, *The American Naturalist* 124(1):97-115

Belovsky, G.E., 1986. Optimal foraging and community structure: implications for a guild of generalist grassland herbivores, *Oecologia* (Berlin) 70: 35-52.

Belovsky, G.E., and J.B. Slade, 1986. Time budget of grassland herbivores: body size similarities, *Oecologia* (Berlin) 70:53-62.

Belsky, A.J., 1994. Influences of trees on savanna productivity: tests of shade, nutrients, and tree-grass competition, *Ecology* 75(4):922-932

Belsky, A.J., Amundson, R.G., Duxbury, J.M., Riha, S.J., Ali, A.R., and S.M. Mwonga, 1989. The effects of trees on their physical, chemical and biological environments in a semi-arid savanna in Kenya, *Journal of Applied Ecology* 26:1005-1024

Belsky, A.J., Mwonga, S.M, and J.M. Duxbury, 1993. Effects of widely spaced trees and livestock grazing on understorey environments in tropical savannas, *Agroforestry Systems* 24:1-20

Benoit, M., 1980. *Réflexions sur le forage christine et de la pastorale dans le Nord-Ouest de la Haute-Volta*, Rapport multigrav., ORSTOM, Ouagadougou, 163 p.

Benoit, M., 1982. *Nature peule du Yatenga: Remarques sur le pastoralisme en pays Mossi,* Collection Travaux et Documents de l'ORSTOM, Paris, No. 143, 171 p.

Ben-Shahar, R., 1992. The effects of bush clearance on African ungulates in a semi-arid nature reserve, *Ecological Applications* 2(1):95-101

Berg, S. van den, 1994. *Etude de l'utilisation de l'espace sylvo-pastoral par les petits ruminants*, MSc thesis, Wageningen Agricultural University

Bernus, E., 1990. En guise de conclusion: les pasteurs nomades africains, du myth éternel aux réalités présentes, in: Bernus, E., et F. Pouillon (eds.), *Sociétés pastorales et développement*, Cahiers des Sciences Humains 26 (1-2):267-280

Boer, F. de, and J.J. Kessler, 1994. *Le système d'élevage Peulh dans le sud du Burkina Faso, une étude agro-écologique du département de Tô (Province de la Sissili),* Tropical Resources Management Papers 4, 106 p.

Boer, W.F. de, and H.H.T. Prins, 1989. Decisions of cattle herdsmen in Burkina Faso and Optimal Foraging Models, *Human Ecology* 17(4):445-463

Bonfiglioli, A.M., 1990. Pastoralisme, agro-pastoralisme et retour: Itérinaires sahéliens, in: Bernus, E., et F. Pouillon (eds.) *Sociétés pastorales et développement*, Cahiers des Sciences Humaines 26 (1-2):255-266

Bosch, E., Zoundi, S., Somda, D.A. and X. Bakyono, 1994. *Mission d'étude, Institutions de financement du développement rural, au Burkina Faso*, Ambassade Royale des Pays-Bas

Boserup, E., 1965. *The conditions of agricultural growth: The economics of agrarian change under population pressure*, Unwin University Books, George Allen and Unwin Ltd, London

Bosma, R.H., Meurs, C.B.H., Bengaly, K., and W.M.L. Berckmoes, 1992. *La productivité des ruminants dans les exploitations agricoles de la zone de Tomian*, Rapport partiel du programme de recherche Suivi Troupeau, Département de Recherche sur les Systèmes de Production Rurale (DRSPR), Sikasso

Bosman, H.G., 1995. *Productivity assessments in small ruminant improvement programs. A case study of West African dwarf goat*, PhD thesis, Wageningen Agricultural University

Bosman, H.G., and H.A.J. Moll, 1995. Benefits of livestock and missing markets: The case of goat keeping in South-Western Nigeria, in: Bosman, H.G., *Productivity assessments in small ruminant improvement programmes. A case study of the West African dwarf goat.* PhD thesis, Agricultural University Wageningen

Bosman, H.G., Moll, H.A.J., and H.M.J. Udo, 1997. Measuring and interpreting the benefits of goat keeping in tropical farm systems, *Agricultural Systems* 53:349-372.

Boudet, G., 1973. *Etude agrostologique préalable à l'implantation d'un ranch d'embouche dans la région de Kassou (cercle de Leo)*, Rapport de tournée en Haute Volta, Maisons-Alfort IEMVT

Boudet, G., 1984. L'exploitation des parcours et de la conduite des troupeaux dans les systèmes d'élevage, *Les Cahiers de la Recherche-Developpement* (3-4):97-101

Boudet, G., and R. Dumas, 1975. *Intégration de la production animale dans l'exploitation agricole dans le cadre de l'aménagement des Voltas*, FAC/IEMVT, Ministère de la Coopération, La République Francaise

Bourzat, D., 1979. *Projet petits ruminants, Rapport semestriel 1979*, Ministère du Développement Rural, Ouagadougou

Breman, H., and A.M. Cissé, 1977. Dynamics of Sahelian Pastures in relation to Drought and Grazing, *Oecologia (Berl.)* 28:301-315

Breman, H., and JJ. Kessler, 1995. *Woody Plants in Agro-Ecosystems of Semi-Arid Regions*, Advanced Series in Agricultural Sciences no. 23. Springer Verlag, Berlin, Germany, 340 p.

Breman, H., and K. Sissoko (eds), 1998. *L' intensification agricole au Sahel*, IER/AB-DLO/DAN-WAU, Karthala, Paris

Breman, H., and N. de Ridder, 1991. *Manuel sur les pâturages des pays sahéliens*, éditions ACCT-CTA-KARTHALA, CABO-DLO, Wageningen

Breman, H., and N. Traore (eds), 1985. *Analyse des conditions de l'élevage et propositions de politiques et de programmes, Burkina Faso*, Etude préparée pour le Club du Sahel et le CILLS, CABO, Wageningen

Breusers, M., 1996. *Conflict and friendship: Changing relations between Moose farmers and Fulbe herdsmen in a context of growing land scarcity*, Paper presented at the Social

Science and History Conference 9-11 May, 1996, Noordwijkerhout
Breusers, M., 1998. *On the move: Mobility, land use and livelihood practices on the central plateau in Burkina Faso*, PhD thesis, Wageningen Agricultural University
Brody, S., 1937. Relativity of physiologic time and physiologic weight, *Growth* 1:60-67
Brody, S., 1945. *Bioenergetics and growth*, Reinhold Publishing Corporation, New York
Brouwer, B.O., and F.A. Steenstra, 1994. *PCHERD livestock production simulation model.* Department of Tropical Animal Production, Agricultural University Wageningen
Brown, J.R., and S. Archer, 1990. Water relations of a perennial grass and seedling vs. adult woody plants in a subtropical savanna, Texas, *Oikos* 57:366-374
Brown, L.R., Gardner, G., and B. Halweil, 1998. *Beyond Malthus: sixteen dimensions of the population problem,* World Watch Paper 143, World Watch Institute, Washington
Buttersworth, M., and N. de Ridder, 1984. Concepts and methods determining carrying capacity, in: Siderius, W. (ed), *Proceedings of the workshop on Land Evaluation for Extensive Grazing (LEEG),* October 31 - november 4 1983, ILRI, Addis Ababa, Ethiopia, p. 325-326
Byerlee, D., *et al.*, 1980. *Planning technologies appropriate to farmers, concepts and procedures*, CIMMYT, Mexico (ICRA)
Canarache, A., 1993. A preliminary model estimating soil specific resistance to ploughing, *Soil and Tillage Research* 27:355-363
Carles, A.B., 1985. Factors affecting the growth of sheep and goats in Africa, in: Wilson, R.T., and D. Bourzat (eds), *Small ruminants in African agriculture*, ILCA, Addis Ababa, p. 34-44
Cashdan, E., 1985. Coping with risk: reciprocity among Basarwa of northern Botswana, *Man N. S.* 20:454 – 474
Caswell, H., 1978. Predator-mediated coexistence: a non-equilibrium model, *The American Naturalist* 112:127-154.
CEBV, 1995. *Impact de la devaluation du franc CFA dans le secteur de l'Elevage*, Communauté Economique du Bétail et de la Viande (CEBV), Ouagadougou
Cellule statistiques animales, 1993. *Bulletin annuel statistique de l'élevage, année 1992,* Cabinet du Ministère Délégué Chargé des Ressources Animales, Ministère de l'Agriculture et des Ressources Animales, Burkina Faso
Chambers, R., and B.P. Ghildyal, 1985. Agricultural research for resource-poor-farmers: the farmer-first-and-last model, *Agricultural Administration and Extension* 20: 1-30
Chambers, R., and J. Jiggings, 1987. Agricultural Research for Resource-poor farmers. Part I: Transfer-of-technology and farming systems research, *Agricultural Administration and Extension* 27:35-52
Chambers, R., and M. Leach, 1987. *Trees to meet contingencies: saving and security for the rural poor*, Institute of Development Studies, Discussion paper 228, University of Sussex, England
Charnov, E.L., Orians, G.H., and K. Hyatt, 1976. Ecological implications of resource depression, *The American Naturalist* 110:247-259
Cissé, M.I., 1984. *Synthèse des essais d'ébranchage pratiqués sur quelques arbres fourragèrs sahliens de 1978 à 1983*, Programme des zones aride et semi-aride, ILCA/CIPEA, Bamako, Doc. Prog. AZ103

Cissé, S., 1980. Sedentarisation of nomadic pastoralists and "pastoralisation" of cultivators in Mali, in: IDRC (ed), *The future of pastoral peoples*, Proceedings of a conference held in Nairobi Kenya, 4-8 August, p. 318 – 324

CNRST, 1995. *Strategic Plan for Scientific Research*, General synthesis, Ministry of Secondary and Higher Education and of Scientific Research, p. 34 – 38

Coppock, D.L., Ellis, J.E., and D.M. Swift, 1988. Seasonal patterns of activity, travel and water intake for livestock in South Turkana, Kenya, *Journal of Arid Environments* 14:319-331

CORAF, 1993. *Transformation des Relations Agriculture Elevage au Sahel*, Rapport Technique, Reseau R^3S, Projet TS2 CT91 – 0329

Coulibaly, A., 1993. Mission d'appui á l'aménagement pastoral de la forêt classée du Nazinon, Document FAO: FO:GCP/RAF/276/ITA, Ouagadougou,Burkina Faso, 33 p.

Dahl, G., 1981. Production in pastoral systems, in: Galatay, J.G., Aronson, D., Salzman, P.C., and A. Chouinard (eds), *The future of pastoral people*, International Development Research Centre, Ottawa, p. 200-209

Dahl, G., and A. Hjort, 1976. *Having Herds, Pastoral Herd Growth and Household Economy*, Stockholm Studies in Social Anthropology, University of Stockholm

Damiba, D., 1989. *Essaie d'amélioration de l'élevage traditionnel ovin dans les actions de développement intégré au Kouritenga: cas de la zone d'encadrement de l'élevage (ZEE) de Pouytenga*, Mémoire de fin d'étude, Université de Ouagadougou

Debrah, S., and K. Sissoko, 1990. *Sources and transfers of cash income in the rural economy: The case of smallholder mixed farmers in the semi-arid zone of Mali*, African Livestock Policy Analysis Network (ALPAN), Network Paper No. 25, International Livestock Centre for Africa (ILCA), Addis Ababa

Delgado, C., 1978. *Livestock Versus Foodgrain Production in Southeast Upper Volta: a Resource Allocation Analysis*, Ann Arbor, Michigan, Center for Research on Economic Development, University of Michigan

Delgado, C.L., 1979. *Livestock versus foodgrain production in South Upper Volta: A resource allocation analysis, Monographe I. Livestock Production and Marketing in the Entente States of West Africa*, Center for Research on Economic Development, University of Michigan,

Delgado, C.L., 1979. *The southern Fulani farming system in Upper Volta: a model for the integration of crop and livestock production in West African savannah*, African Rural Economy Paper 20, Michigan State University, East Lansing, Michigan

Delgado, C.L., 1982. *Les systèmes d'exploitation agricoles des peuls du Sud de la Haute-Volta: une nouvelle forme d'un ancien modèle d'intégration de l'agriculture et de l'élevage dans la savane de l'Afrique Occidentale*, Michigan State University, 205 p.

Delgado, C.L., 1989. The changing economic context of mixed farming in savanna west Africa: A conceptual framework applied to Burkina Faso, *Quarterly Journal of International Agriculture* 28 (suppl. 3):106-109

Dianda, N.P., 1981. *Contribution à l'étude des paramètres zootechniques de l'élevage ovin dans le bloc pastoral de Sondré-Est*, Mémoire de fin d'étude, Université de Ouagadougou

Diarra, A., and M.T. Selmi, 1994. *Aménagement des forêts naturelles pour la sauvegarde de l'environnement et la production de bois*, Document FAO:FO: BKF/89/011.

Ouagadougou, Burkina Faso, 140 p.

Diarra, L., Hiernaux, P., and P.N. de Leeuw, 1995. Foraging behaviour of cattle grazing semi-arid rangelands in the Sahel of Mali, Powell, J.L., S. Fernandez-Rivera, S., Williams, T.O., and C. Renard (eds), *Livestock and sustainable nutrient cycling in mixed farming systems of sub-saharan Africa, Vol. II: Technical Papers* pp. 313-319. International Livestock Centre for Africa, Addis Ababa, Ethiopia.

Dicko, M.S., and M. Sangaré, 1986. Feeding behaviour of domestic ruminants in Sahelian zone. in: P.J. Loss, P. Lynch and O.B. Williams (eds), *Rangelands: a resource under siege*, pp. 389-390. Australian Academy of Science, Canberra, Australia.

Dijkman, J.M., 1991. *Culture attelée au Burkina Faso. Evaluation de son impact sur la position économique des femmes: une revue critique de la littérature*, Ouagadougou, Burkina Faso

Dillon, J.L, and J.B. Hardaker, 1980. *Farm Management Research for Small Farmer Development*, FAO Agricultural Services Bulletin 41, Rome

Direction des Etudes et de la Planification (DEP), 1990. *Enquête Nationale sur les Effectifs du Cheptel (ENEC), Volume I, Resultats et analyse*, Ministère de l'Agriculture et de l'Elevage (MAE), Burkina Faso, 77 p.

Direction des Etudes et de la Planification (DEP), 1990. *Paramètres zootechniques des petits ruminants*, Projet Statistiques Animales, Ministère de l'Agriculture et de l'Elevage, Burkina Faso

Direction des Statistiques Agro-Pastorales (DSAP), 1995. *Bulletin annuel statistique de l'élevage, année 1994*, Ministere de l'Agriculture et des Ressources Animales (MARA), Burkina Faso

Direction des Statistiques Agro-Pastorales (DSAP), 1996. *Bulletin annuel statistique de l'élevage, année 1995*, Ministere de l'Agriculture et des Ressources Animales (MARA), Burkina Faso

Direction des Statistiques Agro-Pastorales (DSAP), 1996. *Enquête Nationale de Statistiques Agricoles (ENSA) 1993, Rapport d'Analyse*, Ministère de l'Agriculture et des Ressources Animales, Ouagadougou, Burkina Faso

Direction des Statistiques Agro-Pastorales (DSAP), 1998. *Enquête Nationale de Statistiques Agricoles (ENSA) 1993, Rapport Général*, Ministère de l'Agriculture et des Ressources Animales, Ouagadougou, Burkina Faso

Dodd, J.L., 1991. *Animal agriculture and desertification/degradation in Sub-Saharan Africa*, University of Wyoming: Laramie, USA

Dollé, V., 1984. Les outils et méthodes du diagnostic sur les systemes d'élevage, *Les Cahiers de la Recherche-Developpement* 3-4:89-96

Dongen, S. van, 1995. *Identiteit- en Intergroepsrelatie Onderzoek onder Mossi en Peulh in een meer en een minder Gedegradeerde regio van Burkina Faso*, Afstudeerscriptie voor cross-culturele psychologie, Katholieke Universiteit Brabant, Rapport d'étudiant No. 33, Antenne Sahélienne, Wageningen Agricultural University, 52 p.

Doran, M.W., Low, A.R.C., and R.L. Kemp, 1979. Cattle as a store of wealth in Swaziland: implications for livestock development and overgrazing in Eastern and Southern Africa, *American Journal of Agricultural Economics* 61:41-47

Douma, P., Diop, M., and L. de Haan, 1994. *Les associations pastorales et la gestion de la* *ressources naturelles*, Rapport final, Commission des Communautées Européennes, Direction Générale du Développement, Université d'Amsterdam, Groupe de Recherche "Genre de Vie et Environnement", Amsterdam

DSAP, 1996a. *Enquête Nationale de Statistiques Agricoles, 1993, Rapport Général*, Ministère de l'Agriculture et des Ressources Animales, Ouagadougou

DSAP, 1996b. *Enquête Nationale de Statistiques Agricoles, 1993, Rapport d'Analyse*, Ministère de l' Agriculture et des Ressources Animales, Ouagadougou

Dublin, H.T., 1995. Vegetation dynamics in the Serengeti-Mara ecosystem: the role of elephants, fire and other factors, in: Sinclair, A.R.E. and P. Arcese (eds), *Serengeti II, Dynamics, Management and Conservation of an Ecosystem*, University of Chicago Press, Chicago, USA, p. 71-90

Dugué, P., 1989. *Possibilités et limites de l'intensification des systèmes de cultures vivrières en zone Soudano-Sahélienne; le cas du Yatenga (Burkina Faso)*, Documents agraires, No. 9, INERA Burkina Faso and CIRAD France

Dumas, R., and H. Raymond, 1975. *L'élevage des petits ruminants dans les circonscriptions de Kaya, Ouahigouya et du Sahel*, Paris, SEDES

Duperray, A.M., 1984. *Histoire de la colonisation en AOF: la Haute-Volta*, Ouagadougou, 72 p.

Dupont de Dinéchin, B., Malcoiffe, C., and J. D'Arondel de Hayes, 1969. Données actuelles sur l'association de l'agriculture et de l'élevage en Haute-Volta, in: *Colloque sur l'Elevage*, IEMVT, Paris, p. 226-286

Dyne, G.M. van, and H.F. Heady, 1965. Botanical composition of sheep and cattle diets on a mature annual range, *Hilgardia* 36:465-492

Economic Intelligence Unit (EIU), 1996. *Country profile Niger Burkina Faso, 1996-1997*, Manley A. (ed), The Economic Intelligence Unit Limited, London, 58 p.

Efdé, S.L., 1996. *Quantified and integrated crop and livestock production analysis at the farm level: Exploring options for land use and limestone soils south of Malang, East Java, Indonesia*, PhD thesis Wageningen Agricultural University

Ellis, J.E., and D.M. Swift, 1988. Stability of pastoral ecosystems: alternate paradigms and implications for development, *Journal of Range Management* 41:450-459

Elskamp, F., 1995. *Les petits ruminants dans trois systèmes d'élevage dans la région de Manga, Burkina Faso*, SPS students thesis report No. 40, Wageningen Agricultural University

ENEC, 1990. *Enquête Nationale sur les Effectifs du Cheptel (ENEC), Volume I, Resultats et Analyse*, Ouagadougou, Burkina Faso

Fafchamps, M., and S. Gavian, 1997. The determinants of livestock prices in Niger, *Journal of African Economics*, 6 (2):255-95

Fall, A., Pearson, R.A., Lawrence, P.R., and S. Fernandez-Rivera, 1997. *Feeding and Working Strategies for Oxen used for Draft Purposes in Semi-arid West Africa*, ILRI, Nairobi, Kenya.

FAO, 1977. *Les systèmes pastoraux Sahéliens*, Etude FAO: Production végétale et protection des plantes 5, FAO, Rome

FAO, 1988. FAO-Unesco soil map of the world: revised legend, World soil resources report 60, FAO, Rome, Italy, 109 p.

Farrington, J., and A. Martin, 1987. *Farmer Participation in Agricultural Research: A review of* *concepts and practices,* Agricultural Administration Unit, Occasional Paper 9, Overseas Development Institute, London, 88 p.

Fauré, A., and E. Le Roy, 1990. Experts et Développeurs face aux Enjeux de la Question Foncière en Afrique Francophone, *Les Cahiers de la Recherche Développement* 25:5-17

Fauré, G., 1994. Mécanisation et pratiques paysannes en région cotonnière au Burkina Faso, *Agriculture et Développement* 2:3-14

Felix, V.C., 1985. *Contribution à la connaissance des systèmes agropastoraux au Yatenga. La conduite de l'élevage à Bidi, Burkina Faso,* Mémoire fin d'étude IDR, Université Ouagadougou

Floyd, D.A., and J.E. Anderson, 1987. A comparison of three methods for estimating plant cover, *Journal of Ecology* 75:221-228

Fresco, L., 1984. *Comparing anglophone and francophone approaches to farming systems research and extension,* The 4th annual conference on farming systems research at Kansas State University, Manhattan, Kansas

Fricke, W., 1979. *Cattle husbandry in Nigeria: a study of its ecological conditions and socio-geographical differentiations,* Heidelberger Geographische Arbeiten, University of Heidelberg

Friedel, M.H., 1991. Range condition assessment and the concept of thresholds: a viewpoint, *Journal of Range Management* 44(5):422-427

Fritz, H., Garine-Wichatitsky, M. de, and G. Letessier, 1996. Habitat use by sympatric wild and domestic herbivores in an African savanna woodland: the influence of cattle spatial behaviour, *Journal of Applied Ecology* 33:589-598

Genin, D., 1991. *MIAMH: un modèle prévisionel des choix alimentaires des ruminants sur parcours,* CNRS-CEPE, Montpelier.

Gervais, R., 1990. *Population et Politiques Agricoles coloniales dans le Mosi, 1919-1940,* Thèse de Doctorat, Université de Paris 7 Jussieu, Paris

Gnoumou, B., 1992. *Systèmes d'élevage et espaces pâturés dans les villages de Thiougou et Donsin, Identification et caractérisation,* Rapport de synthèse, RSP-Equipe Centre-INERA, Burkina Faso

Goarnisson, L., 1984. *Ghana,* in: Groupe de Démographie Africaine, L'évolution des effectifs de la population des pays africains, Tome II, IDP-INED-INSEE-MINCOOP-ORSTOM

Graaff, J. de , Mijl, J.P. van der, and J.W. Nibbering, 1999. Farm survey design in the Sahel: experiences from Burkina Faso, *Quarterly Journal of International Agriculture* 38(1):35-52

Graaff, J. de, 1995. *La situation agro-économique et les mesures anti-érosives dans les six villages sur le Plateau Central: Quelques données des enquêtes agro-économiques 1992-1994,* Document de projet 28, Antenne Sahélienne, Ouagadougou

Graaff, J. de, Nikiema, R., Tapsoba, G., and S. Nederlof, Socio-economic land use analysis in Sahelian villages, in: Rheenen, T. van, and L. Stroosnijder (eds), *Agro-sylvo-pastoral land use in Sahelian villages* (in prep.)

Grainger, A., 1992. Characterization and assessment of desertification processes, In: Chapman, G.P. (ed), *Desertified grasslands: their biology and management,* Linnean Society Symposium Series No. 13, University of London, p. 17-33

Guerin, H., Friot, D., Mbaye, Nd., Richard, D., and A. Dieng, 1988. Régime alimentaire de ruminants domestiques exploitant des parcours naturels sahéliens et soudano-sahéliens, II Essai de description du régime par l'étude de comportement alimentaire, Facteurs de variation des choix alimentaires et conséquences nutritionnelles, *Revue d'Elevage et de Médecin Vétérinaire des Pays Tropicaux* 41(4):427-440

Guinko, S., 1984. *Végétation de la Haute-Volta, Tome I,* Thèse présentée à l'Université de Bordeaux III, U.E.R. Aménagement et ressources naturelles, Département l'homme et son environnement, France

Gurung, N.K., Jallow, O.A., McGregor, B.A., Watson, M.J., McIlroy, B.K.M.H., and J.H.G. Holmes, 1994. Compementary selection and intake of annual pastures by sheep and goats, *Small Ruminant Research* 14:185-192

Hall, A.D., 1936. *The improvement of native agriculture in relation to population and public health,* Oxford University Press, London

Havelock, R.G., 1969. *Planning for Innovation: A comparative study of the literature on the dissemination and utilization of scientific knowledge,* Ann Arbor, University of Michigan, Institute for Social Research/Center for Research on Utilization of Scientific Knowledge (ISR/CRUSK), 533 p.

Hazell, P.B.R., and R.D. Norton, 1986. *Mathematical Programming for Economic Analysis in Agriculture,* MacMillan, New York

Heitkönig, I.M.A., Kaasschieter, G.A., Ballo, A., Van Nierop, B., Lycklema à Nijeholt, R., Van de Pol, H.M., and Y. Coulibaly, 1998. Supplémentation et comportement du bétail sur les parcours: les bovins et les caprins, Breman, H., and K. Sissoko (eds), *L'intensification agricole au Sahel,* pp. 429-453. Editions Karthala, IER, AB-DLO-DAN-UAW.

Hendy, C.R.C., Kleih, U., Crawshaw, R., and M. Phillips, 1995. *Interactions between livestock production systems and the environment, Impact domain: concentrated feed demand,* Working document livestock and environment, finding a balance, FAO/World Bank/USAID, Rome

Hengsdijk, H., Quak, W., Bakker, E.J., and J.J.M.H. Ketelaars, 1996. *A technical coefficient Generator for land use activities in the Koutiala region of South Mali,* DLV Report No. 5, Wageningen

Hesseling, G., and B.M. Ba, 1994. *Land Tenure and Natural Resource Management in the Sahel,* Praia

Hiernaux, P., 1992. *The crisis of Sahelian pastoralism: ecological or economic?* Article based on a paper presented at the conference on "Ecology-economy interactions in the Sahel", held at the University of Oslo, March 1992, Norway, ILCA, Addis Ababa

Hiernaux, P., 1992a. *The crisis of Sahelian pastoralism: ecological or economic?* Article based on a paper presented at the conference on "Ecology-economy interactions in the Sahel", held at the University of Oslo, March 1992, Norway, ILCA, Addis Ababa

Hiernaux, P., 1992b. *Sustainability of sahelian pastoralism: a quantification of the impact of livestock production on the renewal of sahelian range resources,* CIPEA/ILCA, Bamako, Mali

Hiernaux, P., 1995. *Grazing effects of goat-sheep mixes on vegetative structure and productivity of old fallow in the Sahel,* Presented at the Fifth International Rangeland

Congress, July 23-28, Salt Lake City, Utah

Hiernaux, P., 1996. *The Crisis of Sahelian Pastoralism: Ecological or Economic?* Pastoral Development Network, Network Paper 39a, Overseas Development Institute, London

Hiernaux, P., and S. Fernãndez-Rivera, 1995. *Grazing effects of goat-sheep mixes on vegetation structure and productivity of old fallow in the Sahel*, Fifth International Rangeland Congress from July 23 to 28, Salt Lake City, Utah

Höfs, S., Hinterberger, J., Engelhardt, T., Dürr, G., and U. Hoesle, 1995. On the integration of animal husbandry in farming and household systems in Africa south of the Sahara, *Animal Research and Development* 41:7-22

Holling, C., 1973. Resilience and stability of ecological systems, *Annual Review of Ecology and Systematics* 4:1-24

Hoogmoed, W., Stroosnijder, L., and P. Yanogo, Water resources in sahelian villages, in: Rheenen, T. van, and L. Stroosnijder (eds), *Agro-sylvo-pastoral land use in Sahelian villages* (in prep.)

Hoogmoed, W.B., 1999. *Tillage for soil and water conservation in semi-arid tropics*, Tropical Resources Management Papers No. 24, Wageningen University, 184 p.

Hopkin, J.A., Barry, P.J., and C.B. Baker, 1973. *Financial Management in Agriculture*, The Interstate Printers and Publishers, Inc. Danville

IEMVT, 1991. in: Gonneville, G. de, and P. Lhoste (eds), *Etude prospective du sous-secteur élevage au Burkina Faso*, Tome I et II. Rapport de Synthèse. Ministère de l'Agriculture et de l'Elevage, Sécretariat d'Etat à l'Elevage, Burkina Faso, IEMVT-CIRAD et SFC CEDES-CEGOS

Ifar, S., 1996. *Relevance of Ruminants in Upland Mixed Farming Systems in East Java, Indonesia*, PhD thesis, Wageningen Agricultural University

IFPRI, 1995. *A 2020 vision for food, agriculture and environment*, International Food Policy Research Institute (IFPRI), Washington D.C.

ILCA, 1975. *Evaluation and mapping of tropical African rangelands*, Seminar in Bamako-Mali, 3-8 March 1975, ILCA, Addis Ababa, 399 p.

ILCA, 1992. *Annual report and programm highlights, 1991*, Addis Ababa, Ethiopia

Imbs, F., 1987. *Kumtaaba, Une collectivité rurale Mossi et son rapport à l'Espace* (Burkina Faso), Collection Atlas des Structures Agraires au Sud du Sahara No. 21, ORSTOM, Paris

INERA, 1993. *Transformation des relations agriculture-élevage sous l'action de la sécheresse au Burkina;* Synthèse bibliographique et propositions d'intervention dans le cadre du projet R^{3}S-Système, Rapport RSP/Yatenga, 44 p.

INERA, 1994. *Synthèse des recherches sur la production animale au Burkina Faso*, Programme Production Animale, MESSR/CNRST/ INERA, 176 p.

INERA, 1995. Projet Optimisation de l'Elevage au Burkina Faso, Etat d'avancement du projet, Période:2ème semestre 1995, CNRST/INERA/PPA, 39 p.

INSD, 1985 et 1989. *Recensement général de la population; analyse des résultats définitifs*, Institut National de la Statistique et de la Démographie, Ouagadougou.

Ivlev, V.S., 1961. *Experimental ecology of the feeding of fishes*, Yale University Press, New Haven, 302 p.

Jahnke, H.E., 1982. *Livestock Production Systems and Livestock Development in Tropical*

Africa, Kieler Wissenschaftsverlag VAUK, Kiel, Germany

Jong, R. de, 1996. *Dairy stock development and milk production with smallholders*, PhD thesis, Wageningen Agricultural University, 308 p.

Jordaan, J.J., and A. le Roux, 1996. The short-term effect of fire, boer goats and cattle on the woody component of the Sourish Mixed Bushveld, in: Jordaan, J.J. (ed), *Boerbokke in die bosvelddele van die noordelijke provinsie*, Towoomba Landbou Ontwikkelingscentrum, Warmbad, South Africa, p. 116-120

Josserand, H.P., 1993. Impact of world frozen meat imports on west african trade in livestock products, in: Bruner, L., Kroch, L., and M. Meyer (eds), Proceedings of the 5th Sahel Workshop: *Natural Resources and Social conflicts in the Sahel*, 4-6 january 1993, Aarhus University Press, Denmark, p. 75-86

Jouve, P., and M.R. Mercoiret, 1987. La Recherche-Développement: Une démarche pour mettre les recherches sur les systèmes de production au service du développement rural, *Les Cahiers de la Recherche-Développement* 16:8-13

Kaboré, N., 1994. Banque agricole classique et SFD: Situation et perspectives au Burkina Faso, *Techniques Financières & Développement* 33:29-32

Kaboré, O., Zoungrana, T.P., and T.S. Kaboré, 1996. *Analyse de la filière élevage au Burkina Faso*, version provisoire, Centre d'Etudes de Documentation, de Recherches Economiques et Sociale (CEDRES), Université de Ouagadougou, Faculté des Sciences Economiques et de Gestion (FASEG), 44 p.

Kaboré, P.D., Kaboré, T.S., Maatman, A., Ouédraogo, A.A., Ruijs, A., Sawadogo, H., and C. Schweigman, 1995. Analyses des stratégies paysannes dans les régions centre et nord-ouest du Burkina Faso: Approche et quelques résultats, Réseau SADAOC, Université de Groningen, Université de Ouagadougou, INERA

Kagoné, H., Kissou, D., et S. Ouaro, 1997. *Etude Agrostologique de la Zone Sud-Ouest de la Province du Zoundwéogo*, Projet de Développement Intégré du Zoundwéogo (PDI/Z), Burkina Faso

Kambou-Ferrand, J.M., 1993. *Peuples voltaïques et conquête coloniale: 1885-1914*, ACCT/L'Harmattan, Paris, 478 p.

Kellman, M., 1979. Soil enrichment by neotropical savanna trees, *Journal of Ecology* 67:565-577

Kelly, R.D., and B.H. Walker, 1976. The effects of different forms of land use on the ecology of a semi-arid region in south-eastern Rhodesia, *Journal of Ecology* 64:553-576

Kessler, J.J., 1994. Usefulness of the human carrying capacity concept in assessing ecological sustainability of land-use in semi-arid tropics, *Agriculture, Ecosystems and Environment* 48:273-284

Kessler, J.J., et C. Geerling, 1994. *Profil environnemental du Burkina Faso*, Département de l'Aménagement de la Nature, Université Agronomique de Wageningen, les Pays-Bas

Kessler, J.J., Slingerland, M.A., and M. Savadogo, 1998. Regeneration of sylvopastoral lands in the Sahel zone under village management conditions, *Land Degradation and Development* 9:95-106

Keulen, H. van, and H. Breman, 1990. Agricultural development in the west African sahelian region: a cure against land hunger? *Agriculture, Ecosystems and Environment* 32:177-197

Kiema, S., 1992. *Utilisation pastorale des jachères dans la région de Bondoukuy, Zone soudanienne, Burkina Faso.* Mémoire Université Paris XII, Val de Marne

Kintz, D., 1992. *Les éleveurs de la province de la Sissili*, SNV-Burkina Faso, 24 p.

Kirk, M., 1991. Technological and institutional changes: livestock-keeping systems in the Sahel, *Animal Research and Development* 34:17-35

Klaver, J.M.C., 1982. Het natuurlijk milieu in de Sahel, in Boom, P.H.J. van de, and M.P. van Dijk (eds), De Sahel na de grote droogte, Landendocumentatie nr. 2/3, KIT, Amsterdam

Klugkist, J., 1993. *De gesubsidieerde export van EG rundvlees naar West-Afrika, Hoe de Europese vleesberg de veehouderij in de Sahel ondermijnt*, Novib, Den Haag, 40 p.

Knoop, W.T., and B.H. Walker, 1985. Interactions of woody and herbaceous vegetation in a Southern African savanna, *Journal of Ecology* 73:235-253

Kohler, J-M., 1971. *Activités agricoles et changements sociaux dans l'Ouest-Mossi*, ORSTOM, Paris

Kotler, P., 1975. *Marketing for non-profit organisations*, Englewood Cliffs N.J.:Prentice Hall, in: Röling, 1985b:277-279

Krebs, J.R., and N.B. Davies, 1984. *Behavioural Ecology, An Evolutionary Approach*, second edition, Blackwell Scientific Publications, Oxford

Krebs, J.R., and R.H. McCleery, 1984. Optimization in Behavioural Ecology, in: Krebs, J.R., and N.B. Davies (eds), *Behavioural Ecology*, 2nd edition, pp. 91-121. Blackwell Scientific Publications, Oxford.

Kunze, D., 1994. *Typologie des systèmes d'exploitation dans la province de Bam/Burkina Faso, Kongoussi*, PATECORE, Universitat Goettingen/Institut fur Agraroekonomie, 72 p.

La documentation française, 1960. *La République de Haute-Volta, Notes et études documentaires No 2 693*, 19 août 1960, Paris

Lalba, A., and B. Gnoumou, 1992. *Diagnostique sur le troupeau bovin. Identification et caractérisation globale des systèmes d'élevage dans des villages de Yasso et Kawara*, RSP Zone Ouest, Rapport INERA, Burkina Faso

Lallemand, S., 1977. *Une famille Mossi*, Recherches Voltaiques 17, Ouagadougou, Burkina Faso

Lambert, S., and A. Sindzingre, 1995. Droits de propriété et modes d'accès à la terre en Afrique: Une revue critique, *Cahiers d'Economie et Sociologie Rurales* 36:95-128

Lamprey, H.F., 1983. Pastoralism yesterday and today: the overgrazing problem, in: Bourlière, F. (ed), *Tropical Savannas*, Elsevier, Amsterdam, p. 643-666

Landais, E., 1992a. Les Trois Poles des Systemes d'Elevage, *Les Cahiers de la Recherche-Développement* 32(2):3-5

Landais, E., 1992b. Principes de Modélisation des Systèmes d'Elevage, Approches grafiques, *Les Cahiers de la Recherche-Développement* 32(2):82 - 95

Landais, E., and P. Lhoste, 1990. L' association agriculture-élevage en Afrique intertropicale: un mythe techniciste confronté aux réalités du terrain, in: Bernus, E., et F. Pouillon (eds.), *Sociétés pastorales et développement*, Cahiers des Sciences Humaines 26(1-2): 217-235.

Lawrence, P.R. and R.J. Stibbards, 1990. The energy costs of walking, carrying and pulling loads on flat surfaces by Brahman cattle and swamp buffalo, *Animal Production* 50:29-39

Lawrence, P.R., 1985. A review of the nutrient requirements of draught oxen, in: Copland, J.W. (ed), *Draught animal power for production*, ACIAR proceedings 10, James Cook University, Townsville, p. 59-63

Laycock, W.A., 1991. Stable states and thresholds of range condition on North american rangelands: a viewpoint, *Journal of Range Management* 44(5):427-433

Le Houérou, H.N., 1987. Indigenous shrubs and trees in the silvopastoral systems of Africa, in: Steppler, H.A., and P.K.R. Nair (eds), *Agroforestry: A Decade of Development*, International Council for Research in Agroforestry, Nairobi, Kenya, p. 141-156

Le Roux, X., Bariac, T., and A. Mariotti, 1995. Spatial partitioning of the soil water resource between grass and shrub components in a West African humid savanna, *Oecologia* 104:147-155

Le Thiec, G., 1996. *Agriculture africaine et traction animale*, CIRAD, France, L'édition ORSTOM, Collection Atlas des structures agraires au sud du Sahara No. 21, Paris

Lee, J. van der, Udo, H.J.M., and B.O. Brouwer, 1993. Design and validation of an animal traction module for a smallholder simulation model, *Agricultural Systems* 43: 199-277

Leenaars, J.G.B., 1998a. *Soil mapping at local scale in Burkina Faso*, LEECON documents No. 18, Internal Paper, Antenne Sahélienne, Ouagadougou, Wageningen Agricultural University

Leenaars, J.G.B., 1998b. *L'interprétation géographique de l'utilisation des terres villageois au Burkina Faso,* LEECON, Université Agronomique Wageningen.

Leeuw, N. de, and J.C. Tothill, 1993, The concept of rangeland carrying capacity in Sub-Saharan Africa, Myth or Reality, in: Behnke, R.H., Scoones, I., and C. Kerven (eds), *Range Ecology at Disequilibrium*, Overseas Development Institute, London, p. 77-88

Leeuw, P.N. de, and R. Reid, 1995. Impact of human activities and livestock on the African environment: an attempt to partition the pressure, in: Wilson, R.T., Ehui, S., and S. Mack (eds), *Livestock Development Strategies for Low Income Countries*, Proceedings of the joint FAO/ILRI roundtable held from 27 February to 2 March 1995, in Addis Ababa, Ethiopia, p. 29-39

Leeuwis, C., Long, N., and M. Villarreal, 1990. Equivocations on knowledge systems theory: An actor-oriented critique, Knowledge in Society: *International Journal of Knowledge Transfer* 3 (3):19-27

LeHouérou, H.N. (ed), 1980b. *Browse in Africa, the current state of knowledge,* Papers presented at the International Symposium on Browse in Africa, April8-12, and other submissions, ILCA, Addis Ababa

LeHouérou, H.N., 1980. The rangelands of the Sahel, *Journal of Range Management* 33(1):41-45

Lelart, M., 1992. Mobilisation de l'épargne, *Techniques Financières & Développement,* 28/29:20-43

Lhoste, P., 1984. Le diagnostic sur le système d'élevage, *Les Cahiers de la Recherche-Développement* 3-4:84-88

Lhoste, P., and D. Richard, 1993. Contribution de l'élevage à la gestion de la fertilité à l'échelle du terroir, in: *Réseau Erosion*, Bulletin no. 14, les communications à la 10èmes Journées du réseau érosion, Montpellier, 15-18 septembre 1993, p. 463-489

Lhoste, P., Dolle, V., Rousseau, J., and D. Solner (eds.), 1993. *Zootechie des Régions Chaudes:*

les Systèmes d'Elevage, Collection Manuels et Press d'Elevage, Paris, Ministère de la Coopération, CIRAD

Lubchenco, J., 1978. Plant species diversity in a marine intertidal community: importance of herbivore food preference and algal competitive abilities, *The American Naturalist* 112:23-39

Ludwig, D., 1996. The end of the beginning, *Ecological Applications* 6(1):16-17

Lugard, L., 1965. *The dual mandate in British tropical Africa*, 5th edition, Frank Cass and Co., London

Maatman, A., Schweigman, C., Thiombiano, T., and J. van Andel, 1992. Food security and sustainable agriculture on the Central Plateau in Burkina Faso: Observations on a research agenda. *Tijdschrift voor sociaal-wetenschappelijk onderzoek van de landbouw* 7 (2):157-182

Mace, R., 1993. Transitions between cultivation and pastoralism in Sub-Saharan Africa, Current Anthropology 34(4):363-372

Malthus, T.R., 1798. *An essay on the principle of population*, in: Wrighley E.A. and D. Souden (eds), 1986.The works of Thomas Robert Malthus, volume four, Essays on population, William Pickering, London

Mando, A., 1997. *The role of termites and mulch in the rehabilitation of crusted Sahelian soils*, Tropical Resources Management Papers 16, Wageningen University, 101 p.

MARA, 1995. *Performances de l'Agriculture 1984-1994*, Projet Amélioration des instruments du diagnostic permanent pour la securite alimentaire regionale, Phase III" (DIAPER III), CILLS-CE, Département des statistiques agro-pastorales, Ministère de l'Agriculture et des Ressources Animales (MARA), Ouagadougou

Marchal, J.Y.,1983. *Yatenga, Nord Haute Volta, la dynamique de l'espace rural Soudano-Sahélien*, ORSTOM, Paris

Massa, G., 1995. Introduction, in: Massa, G., and Y. G. Madièga (eds), *La Haute-Volta coloniale: Témoignage, recherches, regards*, Collection Hommes et Sociétés, Edition Karthala, Paris, p. 9-33

Massa, G., and Y.G. Madièga, 1995. *La Haute-Volta coloniale: Témoignages, recherches, regards*, Collection Hommes et Sociétés, Edition Karthala, Paris

Mathers, J.C., Pearson, R.A., Sneddon, J.C., Matthewman, R.W., and A.J. Smith, 1985. The use of draught cows in agricultural systems with particular reference to their nutritional needs, in: Smith, A.J. (ed.), *Milk Production in Developping Countries*, Centre for Veterinary Medicine, Edinburgh, p. 476-496

McIntire, J., Bourzat, D., and P. Pingali, 1992. *Crop-Livestock interactions in Sub-Saharan Africa*, The World Bank, Washington D.C., USA, 246 p.

McNaughton, S.J., 1979. Grassland-herbivore dynamics, in: Sinclair, A.R.E and M. Norton-Griffiths (eds), *Serengeti: Dynamics of an ecosystem*, University of Chicago Press, Chicago, p. 46-81

McNaughton, S.J., Ruess, R.W., and S.W. Seagle, 1988. Large mammals and process dynamics in African ecosystems, *BioScience* 38:794-800

Merrill-Sands, D., 1986. Farming systems research: Clarification of terms and concepts. *Experimental Agriculture* 22:87-104

Mettrick, H., 1993. *Development oriented research in agriculture*, an ICRA textbook.

International Centre for development oriented Research in Agriculture (ICRA), Wageningen, the Netherlands

Meuldijk, R., 1997. *Animal production practices in the Kaibo region, Burkina Faso*, MSc thesis, Wageningen Agricultural University

Meyer, J.F., 1989. *Le Troupeau Bovin du Burkina Faso, Résultats d'enquêtes*, Service des Statistiques Agricoles, Direction des Etudes et de la Planification, Ministère de l'Agriculture et de l'Elevage, Ouagadougou, Burkina Faso

Milchunas, D.G., and K. Lauenroth, 1993. Quantitative effects of grazing on vegetation and soils over a global range of environments, *Ecological Monographs* 63(4):327-366

Milchunas, D.G., Sala, O.E., and W.K. Lauenroth, 1988. A generalized model of effects of grazing by large herbivores on grassland community structure, *The American Naturalist* 132(1):87-106

Milne, J.A., 1994. Comparative abilities of different herbivorous species to graze in upland areas: consequences for productivity and vegetation, *Ann Zootech* 43:3-9

Ministère des Ressources Animales (MRA), 1997. *Synthèse de la note d'orientation du plan d'action de la politique de développement du secteur élevage au Burkina Faso,* Version Officielle, Ouagadougou, Burkina Faso

Mohammed-Saleem, M.M., 1995. Mixed farming systems in Sub-Saharan Africa, in: Wilson, R.T., Ehui, S., and S. Mack (eds.), *Proceedings of the Joint FAO/ILRI Roundtable on Livestock Development Strategies for Low Income Countries*, ILRI, Addis Adaba, Ethiopia, 27 February 2 March 1995, FAO/ILRI, Nairobi, Kenya, p. 93-100

Monicat, F., Borne, P.M., and P. Maron, 1992. Zonage et typologie des exploitations possédant des pétits ruminants dans les systèmes de production traditionnels du Zimbabwe, *Les Cahiers de la Recherche-Développement* 32(2):38-56

Monod, T., 1975. Introduction, in: Monod T. (ed), *Pastoralism in Tropical Africa*, Oxford University Press, London, p. 99 - 183.

Mortimer, M., and B. Turner, 1993. *Crop-livestock farming systems in the semi-arid zone of sub-saharan Africa, Ordening diversity and understanding change,* Agricultural administration (research and extension) network, Network Paper 46, Overseas Development Institute, London, 33 p.

Moulin, C.H., and E. Tillard, 1993. *Le troupeau: un système biotechnique complexe;* Les enseignements d'une recherche pluridisciplinaire menée au Sénégal, ENSA/INRA France, CIRAD-EMVT, Laboratoire National de l'Elevage et des Recherches vétérinaires, Dakar, Sénégal, 16 p.

Mulders, M.A., 1996. *Soil and land use of the Kaibo area at medium scale*, Project Document No. 39, Antenne Sahélienne, Wageningen Agricultural University, Wageningen.

Murphy, J., and L.H. Sprey, 1980. *The Volta Valley Authority: Socio-economic evaluation of a resettlement project in Upper Volta*, Purdue University, Department of Economics, West Lafayette, Indiana, USA

Murray, W.G., and A.G. Nelson, 1961. *Agricultural Finance*, The Iowa State University Press, Ames

Nagel, U.J., 1980. Institutionalisation of knowledge flows: An analysis of the extension role of two agricultural universities, *India Quarterly Journal of International Agriculture*, Special Series Issue, no 30, Frankfurt Main, DLG Verlag

Niamir, M., 1990. *Herders' decision-making in natural resources management in arid and semi-arid Africa*, Community Forestry Note 4, FAO, Rome, 126 p.

Nianogo, A., 1990. *Bilan de quelques années d'études de la race ovine mossi à Gampéla,* Rapport de recherche,Université de Ouagadougou

Nibbering, J.W., 1992. *The security function of livestock. Asystem-analytical approach*, INRES working paper, Universitas Brawijaya, Malang, 22 p.

Nicou, R., and M. Le Moigne, 1991. Efficacité agronomique de la mécanisation des opérations culturales, in: Pieri C. (ed), *Savanes d'Afrique, terres fertiles? Comment produire plus de façon durable en zone de savanes au sud du Sahara*, Actes des rencontres internationales, Montpellier 10-14 décembre 1990, Ministère de la Coopération et du Développement, Centre de coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), p. 475-506

Noy-Meir, I., 1975. Stability of grazing systems: an application of predator-prey graphs, *Journal of Ecology* 63:459-481

Noy-Meir, I., 1981. Spatial effects in modelling of arid ecosystems, in: Goodall, D., and R. Perry (eds), *Arid Land Ecosystems*, Cambridge University Press, p. 411-432

O'Neill, R.V. *et al.*, 1996. Economic growth and sustainability,: a new challenge, *Ecological Applications*, 6(1):23-24

Ouédraogo, A., 1997. L'effet de la coupe de *Detarium microcarpum* Guill. & Perr. sur la régénération de la végétation dans la forêt classée de Nazinon, Msc thesis. University of Ouagadougou, Ouagadougou, Burkina Faso, 73 p.

Ouédraogo, D., 1985. *Les causes de la suppression de la colonie de la Haute-Volta en 1932,* Mémoire de Maîtrise, Histoire, Université Paris 7, 120 p.

Ouédraogo, T., 1991. *Etude sur les systèmes de production dans le Sahel Burkinabè*, Rapport Final, INERA, PSB/UNSO. Ouagadougou, Burkina Faso

Payne, W.J.A., 1963. Relations of animal husbandry to human nutritional needs in east Africa, *E.A.Agr. and For J.*

PDI/Z, 1993. *Projet de développement intégré du Zoundwéogo, Troisième phase,1994-1998*, Ministère de l'Agriculture et des Ressources Animales, Burkina Faso, et Ministère des Affaires Etrangères, Direction Générale de la Coopération Internationale, le Royaume des Pays-Bas

PDI/Z, 1997. *Atlas du Zoundwéogo*, Tome 1, première édition, Ministère de l' Economie et des Finances, Burkina Faso

Penning de Vries, F.W.T., and M.A. Djitèye (eds), 1982. *La productivité des pâturages sahéliens: une étude des sols, des végétations et de l'exploitation de cette ressource naturelle*, Centre for Agricultural Publishing and Documentation (Pudoc), Wageningen

Penson, J.B., and D.A. Lins, 1980. *Agricultural Finance, an Introduction to Micro and Macro Concepts*, Prentice Hall, Englewood Cliffs

Perdok, U.D., and G. van der Werken,1980. Grondbewerking, Relatie grondsoort vermogens- en arbeidsbehoefte (1), *Landbouwmechanisatie* 31(6):66-71

Pieri, C., 1989. *Fertilité des terres de savanes*, Ministère de la coopération et CIRAD-IRAT, Paris, 444 p.

Pitroipa, D., 1983. *Paramètres zootechniques des ovins. Essai de supplémentation des ovins* *avec des sous-produits agro-industriels: mélasse, urée, graines de coton,* Mémoire de fin d'étude, Université de Ouagadougou

Pitschke, J.D. von, Vogel, R.C., Flath, P., and M.C. Mould, 1988. Measurement of loan repayment performance. Course note Economic Development Institute of the World Bank, 23 p.

Poissonnet, J., Chambris, F., and I. Touré, 1992. Equilibre et déséquilibre des phytocénoses herbacées sahéliennes, In: Le Floch, E., Grouzis, M., Cornet, A., and J.-C. Bille (eds), *L'aridité: une contrainte au développement,* Collection Didactiques, Editions de l'ORSTOM, Paris, p. 283-296

Pol, F. van der, 1992. *Soil mining, an unseen contributer to farm income in Southern Mali,* Bulletin 325, Royal Tropical Institute, Amsterdam, 47 p.

Powell, J.M., 1986. *Manure for cropping: a case study from central Nigeria,* Experimental Agriculture 22:15-24

Powell, J.M., and T.O. Williams, 1995. An overview of mixed farming systems in sub-saharan Africa, in: Powell, J.M., Fernandez-Rivera, S., Williams, T.O., and C. Renard (eds), *Livestock and sustainable nutrient cycling in mixed farming systems of sub-saharan Africa,* Volume II: Technical Papers, Addis Ababa, Ethiopia, p. 21-36

Powell, J.M., Fernandez-Rivera, S., Hiernaux, P., and M.D. Turner, 1996. Nutrient cycling in integrated rangeland/cropland systems of the sahel, *Agricultural Systems* 52 (suppl. 2/3):143-170

Prins, G.J., 1995. *Feasibility of formal financial intermediation in Burkina Faso,* SPS students report No. 68, Wageningen Agricultural University

Provost, A. (ed), 1980. *Synthèse des connaissances sur l'élevage des petits ruminants dans les pays tropicaux d'Afrique centrale et d'Afrique de l'ouest,* IEMVT-FAC, France

Prudencio, M.Y., 1983. *A village study of soil fertility management and food crop production in Upper Volta; technical and economic analysis,* PhD thesis, Department of Economics, University of Arizona, USA

Pyke, G.H., Pulliam, H.R., and E.L. Charnov, 1977. Optimal foraging: a selective review of theory and tests, *Quarterly Review of Biology* 55:137-154

Quarles van Ufford, P., 1994. *De franc CFA gedevalueerd, een studie naar de gevolgen van de devaluatie van de franc CFA voor de veehandel in de "couloir central" van West-Afrika,* Vakgroep sociale wetenschappen, Universiteit van Amsterdam, 29 p.

Quilfen, J.P., and P. Milleville, 1981. Résidue de culture fumure animale: un aspect des relations agriculture-élevage dans le nord de la Haute-Volta, *Agronomie Tropicale* 38:206-212

Raay, J.G.T. van, 1975. *Rural Planning in a Savanna Region,* Rotterdam University Press

Rabbinge, R., and M.K. van Ittersum, 1994. Tension between aggregation levels, in: Fresco, L., Stroosnijder, L., Bouma, J., and H. van Keulen (eds), *Future of the land, mobilising and integrating knowledge for land use options,* Wiley and Sons, England, p.31-41

Rabot, C., 1990. Transfert de fertilité et gestion de terroirs. Quelques points de vue. *Les Cahiers de la Recherche-Développement* 25:19-32

Raijmakers, F., 1993. *Rapport final,* PDI/Z, Manga, Burkina Faso

Remy, G., 1973. *Les Migrations de Travail et les Mouvements de Colonisation Mossi, Recueil Bibliographique,* Travaux et Documents de l'ORSTOM No. 20, ORSTOM, Paris

Republique de la Haute Volta, *Plan Interimaire 1963-1964*, Ouagadougou

Rering, G., 1997. *Evaluation of the integrated transect method as a tool for land use characterization in West Africa*, MSc thesis, Student Report No. 82, Antenne Sahélienne, Wageningen Agricultural University, Wageningen.

Rheenen, T. van, and L. Stroosnijder (eds), *Agro-sylvo-pastoral land use in Sahelian villages* (in prep.)

Ridder, N. de, and H. Breman, 1993. A new approach to evaluating rangeland productivity in Sahelian countries, in: Behnke, R.H., Scoones, I., and C. Kerven (eds), *Range Ecology at Disequilibrium*, Overseas Development Institute, London, p. 104-117

Rietkerk, M., 1998. *Catastrophic vegetation dynamics and soil degradation in semi-arid grazing systems*, PhD thesis, Wageningen Agricultural University, 155 p.

Rietkerk, M., Blijdorp, R. and M. Slingerland, 1998. Cutting and resprouting of *Detarium microcarpum* and herbaceous forage availability in a semi-arid environment, *Agroforestry Systems* 41: 201-211

Rietkerk, M., and J. van de Koppel, 1997. Alternate states and threshold effects in semi-arid grazing systems, *Oikos* 79(1):69-76

Rietkerk, M., Ketner, P., Burger, J., Hoorens, B., and H. Olff, 1998. Multiscale soil and vegetation patchiness along a gradient of herbivore impact in a semi-arid grazing system, Chapter 6 in: Rietkerk, M., *Catastrophic vegetation dynamics and soil degradation in semi-arid grazing systems*, Tropical Resource Management Papers No. 20, Wageningen Agricultural University

Rietkerk, M., Ketner, P., Strroosnijder, L., and H.H.T Prins, 1996. Sahelian rangeland development; a catastrophe?, *Journal of Range Management* 49(6):512-519

Robson, D.S. (eds), *Sampling Biological Populations. Vol. 5. Statistical Ecology*, International Co-operative Publishing House, Fairland, MD, p.1-70

Roeleveld, A.C.W., 1996. The diagnostic phase in research on livestock systems, in: Roeleveld, A.C.W., and A. van den Broek (eds), *Focusing Livestock Systems Research*, Royal Tropical Institute, Amsterdam

Rogers, E.M., 1983 (reprint from 1962 and 1971). *Diffusion of Innovations*, New York, The Free Press/Collier McMillan (third edition), 447 p.

Röling, N., 1985a. Extension science:increasingly preoccupied with knowledge systems, *Sociologia Ruralis* 25 (3/4):269-290

Röling, N., 1985b. *Extension and agricultural knowledge systems, An advanced text for professionals in Agricultural Extension, Rural Development, and, by implication, others who live by inducing voluntary change*, Department of Extension Education, Agricultural University Wageningen, The Netherlands (not published)

Röling, N., 1992. The emergence of knowledge systems thinking: A changing perception of relationships among innovation, knowledge process and configuration, Knowledge and Policy: *The International Journal of Knowledge Transfer and Utilization* 5(1):42-64

Röling, N., 1994. Platforms for decision-making about ecosystems, in: Fresco, L., Stroosnijder, L., Bouma, J., and H. van Keulen (eds), *Future of the land, mobilising and integrating knowledge for land use options*, Wiley and Sons, England, p. 385-395

Röling, N.G., 1989. *The agricultural research-technology transfer interface: A knowledge systems perspective*, Linkages Theme Paper No. 6, ISNAR, The Hague

Röling, N.G., Kuiper, D., en R. Janmaat, 1994. *Basisboek voorlichtingskunde*, Vakgroep Voorlichtingskunde van de Landbouwuniversiteit Wageningen, Amsterdam en Meppel: Boom

Rolland, J.P, 1994. *Impact de l'accord du GATT et de la réforme de la PAC. Le cas du marché euro-africain de la viande bovine*, Le Réseau Stratégies Alimentaires, Collection SOLAGRAL, Montpellier, 182 p.

Rondo, P., 1986. *Evolution des systèmes de production agricole au Sahel Burkinabè*, Thèse Université Montpellier I. France

Rounce, N.V., 1937. Individual native small holdings, *The East African Agricultural Journal*, September: p. 133-137

Ruben, R., Attema, J., and H. Breman, 1994. Export van Europees rundvlees naar West-Afrika, *Internationale spectator* 4812:599-600

Ruiter, A. de, 1995. *Le rôle du bétail dans le financement d'un ménage rural*, SPS students report No. 57, Wageningen Agricultural University

Ruiz, A., 1982. Sistemas de doble propósito para pequeños productores, in: Pearson de Vacaro, L. (ed), *Sistemas de Producción con Bovinos en el Trópico Americano*, Universidad Central de Venezuela, Maracay, p. 137-158.

Ruthenberg, H., 1980. *Farming systems in the tropics* (3rd edition). Oxford Clarendon Press

Sala, O.E., Golluscio, R.A., Lauenroth, W.K., and A. Soriano, 1989. Resource partitioning between shrubs and grasses in the Patagonian steppe, *Oecologia* 81:501-505

Sanogo, Z.J.L., Joeldersma, R., and B. Fomba, 1991. *Choix de villages de recherche. L'expérience du DRSPR/SIKASSO*, IER, DRSPR/Fonsebougou

Sanon, Y., Koudougou, Z., and N. Sidibé, 1997. *Etude Agrostologique de la Zone de Luili-Nobéré*, Projet de Développement Intégré du Zoundwéogo, Burkina Faso, 80 p.

Savadogo, K., Reardon, T., and K. Pietola, 1998. Adoption of Improved Land Use Technologies to Increase Food Security in Burkina Faso: Relating Animal Traction, Productivity, and Non-Farm Income, *Agricultural Systems* 58(3):441-464

Savadogo, M., 2000. *Crop residue management in relation to sustainable land use*, A case study in Burkina Faso, PhD Thesis, Wageningen University

Savory, A., 1988. Holistic Resource management, Island Press, Washington D.C., 599 p.

Sawadogo, S., 1986. *Situation de l'élevage ovin dans la zone de Tenkodogo. Perspectives d'amélioration*, Mémoire fin d'étude IDR, Université Ouagadougou, Burkina Faso

Schlecht, E., 1995. *The influence of different levels of supplementation on feed intake and nutrient retention of grazing Zebu cattle in Sahelian agro-pastoral systems*. Berichte aus der Agrarwissenschaft, Hohenheim Universität Dissertation 1994, Aachen, Verlag Shaker

Schoener, T.W., 1971. Theory of feeding strategies, *Annual Review of Ecology and Systematics* 2:369-405

Schwartz, A., 1995. La politique coloniale de mise en valeur agricole de la Haute-Volta (1919-1960), in: Massa, G., and Y.G. Madièga (eds), *La Haute-Volta coloniale: Témoignages, recherches, regards*, Collection Hommes et Sociétés, Edition Karthala, Paris, p. 263-291

Schweigman, C., Snijders, T.A.B., Van Andel, J., and M. van Noordwijk, 1988. *Observations quantitatives sur les risques dans l'approvisionnement alimentaire sur le plateau Mossi*, projet CEDRES/AGRISK, Université de Ouagadougou et Université de Groningen

Scoones, I., 1993. Why are there so many animals? Cattle population dynamics in the Communal areas of Zimbabwe, in: Behnke R.H., Scoones, I., and C. Kerven (eds), *Range Ecology at Disequilibrium*, Overseas Development institute, London, p. 62-76

Sedogo, M., 1981. *Contribution à la valorisation des résidus culturaux en sol ferrugineux et sous climat aride.* Thèse de docteur-ingénieure Science du Sol, Ecole Nationale Supérieure d'Agronomie et des Industries Alimentaires, Nancy

Shaner, W.W., Philipp, P.F., and W.R. Schmehl, 1982. *Farming systems research and development: Guidelines for developing countries*, Westview Press, Boulder, Colorado, 414 p.

Shapiro, B.I., and J.H. Sanders, 1998. Fertilizer use in semi-arid west Africa: profitability and supporting policy, *Agricultural Systems* 56 (suppl. 4):467-482

Sharma, K., Saini, A.L., Singh, N., and J.L. Ogra, 1998. Seasonal variations in grazing behaviour and forage nutrient utlization by goats on a semi-arid reconstituted silvipasture, *Small Ruminant Research* 27:47-54

Shipton, P., and M. Goheen, 1992. Introduction, understanding African land-holding : power, wealth, and meaning, *Africa* 62(3):307-325

Sinclair, A.R.E., 1985. Does interspecific competition or predation shape the African ungulate community?, *Journal of Animal Ecology* 54:899-918

Sissoko, K., 1998. *Et demain l' Agriculture?* Options techniques et mesures politiques pour un développement durable en Afrique subsaharienne. Cas du cercle de Koutiala en zone sud du Mali, PhD Thesis, Wageningen University

Skarpe, C., 1990. Shrub layer dynamics under different herbivore densities in an arid savanna, Botswana, *Journal of Applied Ecology* 27:873-885

Slangen, A., 1986. in: Masini, M. (ed), *Burkina Faso, Rural Finance Profiles in African Countries*, Volume 2, The credit markets of africa series, FAO, Finafrica working group, Finafrica-Cariplo-Milan

Slingerland, M.A., 1989. Selection of animals for work in Sub-Saharan Africa: research at the ICRISAT Sahelian Centre, in: Hoffman, D., Nari, J., and R.J. Petheran (eds), *Draught Animals in Rural Development*, ACIAR Proceedings Series No. 27, ACIAR, Canberra, p. 203-210

Slingerland, M.A., Rheenen, T. van, and J.W. Nibbering, 1998. Animal production and rural financing: The case of Zoundwéogo province, Burkina Faso, *Quarterly Journal of International Agriculture*, 37(3):180-200

Smeets, K., 1997. *La conduite des bovins dans la region de Manga, Burkina Faso*, MSc thesis, Student Report No. 134, Antenne Sahélienne, Wageningen Agricultural University, Wageningen.

Smith, K.A., and C.E. Mullins (eds), 1991. *Soil Analysis, Physical Methods*, Marcel Dekker Inc., New York, USA

Snedecor, G.W., and W.G. Cochran, 1967. *Statistical methodes*, sixth edition, The Iowa State University Press, Ames, Iowa, USA

Soest, P.J. van, 1977. *Modified procedure for determining plant cell wall by the neutral detergent procedure*. Paper presented at the 69th Annual Meeting American Society of Animal Science, Madison, Winconsin.

Soest, P.J. van, Wine, R.H., and L.A. Moore, 1966. Estimation of the true digestibility of forage by the in vitro digestion of cell walls, in Hill, A.G.G. (ed), *Proceedings X. International Grassland Congress*, pp. 438-441, Helsinki, Finland.

Solichin Abdul Wahab, 1996. *Case Studies of Decision-making in Six Farm Households in the South of Malang, East Java*, PhD thesis, Wageningen Agricultural University

Soulama, S., and J.B. Zett, 1994. *Economie des organisations coopératives et de type coopératif*, RUG/UO/FASEG, Burkina Faso

Sousa, W.P., 1984. The role of disturbance in natural communities, *Annual Review of Ecology and Systematics* 15:353-391

Squires, V.R., 1982. Dietary overlap between sheep, cattle, and goats when grazing in common, *Journal of Range Management* 35(1): 116-119

Starkey, P., and A. Faye (eds), 1990. *Animal Traction for Agricultural Development*, Proceedings of the Third Workshop of the West Africa Animal Traction Network held 7-12 July 1988 in Saly in Senegal, Technical Centre for Agricultural and Rural Cooperation (CTA), The Netherlands

Steinfeld, H., and J. Mäki-Hokkonen, 1995. A classification of livestock production systems. *World Animal Review* 84/85:83-94

Steinfeld, H., Haan, C. de, and H. Blackburn, 1997. *Interactions entre l'élevage et l'environnement, Problématique et propositions*, Secretariat d' Etat à la Cooperation, Direction du Developpement, Bureau Gestion des ressources naturelles et environnement, CIRAD, France

Stoddart, L.A., Smith, A.D., and D.T.W. Box, 1975. *Range management*, 3rd edition, McGraw-Hill, New York, 156 p.

Sumberg, J., 1998. Mixed farming in Africa: The search for order, the search for sustainability, *Land Use Policy* 15(4):293-317

Suurmond, J., 1994. *Rôle de l'élevage dans la zone traditionnelle de la province du Zoundwéogo*, MSc thesis, Wageningen Agricultural University

Swift, M.J., Frost, P.G.H., Campbell, B.M., Hatton, J.C., and K.B. Wilson, 1989. Nitrogen cycling in farming systems derived from savanna: perspectives and challenges, in: Clarholm, M., and L. Bergström (eds), *Ecology of Arid Lands*, Kluwer Academic Publishers, Dordrecht, the Netherlands

Tapsoba, G., 1998. *Dépenses ménagères et intrants agricoles en milieu rural: cas de villages de Sidogo et Tagalla dans le province de Sanmatenga*, SPS students report No. 131, Université Polytechnique, Bobo-Dioulasso, Burkina Faso

Tendler, J., 1982. *Rural projects through urban eyes: An interpretation of the World Bank's new style rural development projects*, Washington, The World Bank, Staff Working Paper 532

Tersiguel, P., 1995. *Le pari du tracteur. La modernisation de l'agriculture cotonnière au Burkina Faso*, La collection "à travers du Champs", ORSTOM, Paris

Thies, E., 1995. *Principaux ligneux (agro-) forestiers de la Guinée*; Zone de transition Guinée-Bissau, Guinée, Côte d'Ivoire, Chana, Togo, Bénin, Nigeria, Cameroun, TZ Verlagsgesellschaft, Rossdorf, Germany

Tiffen, M., Mortimer, M., and A.C. Ackello-Ogutu, 1993. *From agropastoralism to mixed farming: the evolution of farming systems in Machakos, Kenya, 1930-1990*, Agricultural administration (research and extension) network, Network Paper 45, Overseas Development Institute, London, 35 p.

Tiffen, M., Mortimer, M., and F. Gichuki, 1994a. *More people, less erosion, environmental recovery in Kenya*, Overseas Development Institute, John Wiley & Sons, England, 311

Tiffen, M., Mortimer, M., and F. Gichuki, 1994b. *Population growth and environmental recovery: policy lessons from Kenya*, Gatekeeper series 45, International Institute for Environment and Development, London, 26 p.

Tongway, D.J., and J.A. Ludwig, 1990. Vegetation and soil patterning in semi-arid mulga lands of Eastern Australia, *Australian Journal of Ecology* 15:23-34

Toulmin, C., 1993. Population and social conflicts-household strategies for dealing with risk and ensuring survival in the Sahel, in: Brimer, L., Krogh, K., and M. Meyer (eds), *Natural Resources and Social conflicts in the Sahel*, Proceedings of the 5th Sahel Workshop 4-6 January 1993, Aarhus University Press, Denmark, p. 174 - 179

Toulmin, C., 1995. Tracking through drought: options for destocking and restocking, in: Scoones, I. (ed), *Living with uncertainty*, New directions in pastoral development in Africa, Intermediate Technology Publications, London, p. 95-115

Touré, S.M. *et al.*, 1985. *L'élevage au Burkina Faso.* Etude générale, Ouagadougou, FAO

Tourte, R., 1984. *Synthèse introductive*, Systèmes agraires, CIRAD-GERDAT, p. 445-457

Tucker, C.J., and S.E. Nicholson, 1998. Large scale Saharan-Sahelian vegetation variations from 1980 to 1996 derived from ground precipitation and NOAA satellite data, in: Squires, V.R., and A.E. Sidahmed (eds), *Drylands: sustainable use of rangelands into the 21th century*, p. 237-247

Tucker, C.J., Dregne, H.E., and W.W. Newcomb, 1991. Expansion and contraction of the Sahara desert from 1980-1990, *Science* 253:299-301

Turner, M., 1995. The sustainability of rangeland to cropland nutrient transfer in semi-arid west Africa: ecological and social dimensions neglected in the debate, in: Powell, J.M., Fernandez-Rivera, S., Williams, T.O., and C. Renard (eds), *Livestock and sustainable nutrient cycling in mixed farming systems of sub-saharan Africa*, Volume II: Technical Papers, Addis Ababa, Ethiopia, p. 435-452

Tyc, J., Nianogo, A.J., and G. Mahoux, 1997. Aide-memoire de la mission de recentrage du projet Optimisation de l'Elevage au Burkina Faso, CNRST/INERA/PPA, 27 p.

Ulmer, M.G., Knuteson, J.A., and D.D. Paterson, 1994. *Particle size analysis by a hydrometer: a routine method for determining clay fraction*, USDA-SCS, Bismarck, USA

Upton, M., 1996. *The Economics of Tropical Farming Systems*, Cambridge University Press

Vale, W.G., Tourrand, J.F., Bastos da Veiga, J., Simo-Neto, J., Ferreira, L.A., Ludovino, R.R., and A.P.O. Mares Guia, 1996. Animal husbandry on the agricultural frontier of Brazilian Amazon, sustainable agricultural systems or ecological disaster?, *Animal Research and Development* 43/44:80-98

Vall, E., 1992. Une Enquête sur la Traction Animale dans le Nord Cameroun. *Les Cahiers de la Recherche-Développement* 32(2):67-81

Veen, M. van, 1996. *De invloed van economische en psychologische variabelen op investeringsbereidheid in Burkina Faso*, Afstudeerscriptie cross-culturele Psychologie aan de Katholieke Universiteit Brabant, Rapport d'étudiant No. 55, Antenne Sahélienne, Wageningen Agricultural University, 74 p.

Vesey-Fitzgerald, D., 1960. Grazing succession among East African game animals, *Journal of Mammalogy* 41:161-72

Voeten, M.M., 1999. Living with the wildlife: coexistence of wildlife and livestock in an East African Savanna system, PhD thesis, Wageningen University

Vries, P.G. de, 1979. Line intercept sampling -statistical theory, applications and suggestions for extended use in ecological inventory, in: Cormack, R.M., Patil, G.P., and Robson, D.S. (eds), *Sampling Biological Populations. Vol. 5. Statistical Ecology*, International Co-operative Publishing House, Fairland, MD, p. 1-70

Walker, B.H., Ludwig, D., Holling, C.S., and R.M. Peterman, 1981. Stability of semi-arid savanna grazing systems, *Journal of Ecology* 69:473-498

Waters-Bayer, A., and E. Taylor-Powell, 1986. Settlement and landuse by Fulani pastoralists in case study areas, in: Von Kaufmann, R., Chater, S., and R. Blench (eds), *Livestock Systems Research in Nigeria's Subhumid Zone*, Addis Ababa, ILCA, p. 213-226

Waveren, W. van, 1996. *Animal traction in Zoundwéogo province (Burkina Faso) and its role in the intensification of the farming system*, Msc thesis, SPS student report No. 78, Wageningen Agricultural University

Werger, M.J.A., 1983. Tropical grasslands, savannas, woodlands: natural and manmade, in: Holzner, W., Werger, M.J.A., and I. Ikusima (eds), *Man's Impact on Vegetation*, Dr. W. Junk publishers, The Hague, The Netherlands, p. 107-137

Westoby, M., 1974. An analysis of diet selection by large generalist herbivores, *The American Naturalist* 108:290-304

Westoby, M., Walker, B., and I. Noy-Meir, 1989. Opportunistic management for rangelands not at equilibrium, *Journal of Range Management* 42:266-274

Whittaker, R.H., 1975. *Communities and Ecosystems*. 2nd edition, Macmillan, New York, USA, 385 p.

Wijnhoud, J.D., and A.J. Otto, 1994. *Physical properties of soils in the Kaya area, Burkina Faso*, MSc thesis, Rapport des Etudiants no. 30, Antenne Sahélienne, Université Agronomique Wageningen, Les Pays-Bas

Williams, T.O., DeRose, D.A., and O. Badiane, 1995. Macroeconomic international trade and sectorial policies in livestock development, in: Wilson, R.T., Ehui, S., and S. Mack (eds), *Livestock Development Strategies for Low Income Countries*, Proceedings of the joint FAO/ILRI roundtable, 27 February-2 March 1995, Addis Ababa, Ethiopia, FAO/Rome and ILRI/Nairobi, p. 47-68

Williams, T.O., Powell, J.M., and S. Fernandez-Rivera, 1995. Manure utilisation, drought cycles and herd dynamics in the Sahel: Implications for cropland productivity. in: Powell, J.M., Fernandez-Rivera, S., Williams, T.O., and C. Renard (eds), *Livestock and sustainable nutrient cycling in mixed farming systems of sub-Saharan Africa*, volume II: Technical papers, ILCA, Ethiopia, p. 393-410

Wilson, R.T., 1983. Production animale. Troisième partie. Le système agro-pastoral, in: Wilson, R.T., Leeuw, P.N. de, and C. de Haan (eds), *Recherches sur les systèmes des zones arides du Mali: Résultats préliminaires*. Rapport de recherche No. 5, Centre International Pour l'Elevage en Afrique (CIPEA), Addis Ababa

Wilson, R.T., 1986. *Livestock production in central Mali: Long-term studies on cattle and small ruminants in the agropastoral system*, Research Report No. 14, International Livestock

Centre for Africa (ILCA), Addis Ababa

Wilson, R.T., Leeuw, P.N. de, and C. de Haan (eds.), 1983. *Recherches sur les systèmes des zones arides du Mali: Resultats préliminaires*, ILCA Research Report 5. Addis Ababa

Wooning, A., 1992. *Le prix du bétail, de la viande, des produits laitiers et des engrais dans les pays sahéliens*, Rapport PSS No. 1, Wageningen

World Bank, 1996. *The World Bank Atlas 1996*, Washington D.C.

Yonli, E., 1987. Commercialisation, prix et système de stockage du sorgho et mil au plateau Mossi. In: Stanneveld, A., *et al.* (ed). *Le secteur agricole du plateau Mossi au Burkina Faso.* Projet CEDRES/AGRISK, Université de Ouagadougou et Université de Groningen

Zandstra, H.G., Price, E.C., Litsinger, J.A., and R.A. Morris, 1981. *A methodology for on-farm cropping systems research*, IRRI, Los Banos, The Philippines, 147 p.

Zemmelink, G., 1980. *Effect of selective consumption on voluntary feed intake and digestibility of tropical forages*, PhD thesis, Agricultural Research Reports 896. PUDOC, Wageningen.

Zemmelink, G., and B.O. Brouwer, 1991. *JAVA: Simulation of Animal Production as a Function of Quality and Utilization of Feeds*, Department of Tropical Animal Production, Wageningen Agricultural University

Zerbo, L., Mulders, M., and L. Thiombiano, 1998. *Etude morpho-pédologique de la province du Zoundwéogo*, Echelle 1/100.000, CNRST-INERA, AUW, Antenne Sahélienne, Ouagadougou

Zoundi, J.S., 1997. Interaction agriculture-élevage et développement agricole en zone semi-aride d'Afrique sub-Saharienne, in: Abiolo, F.A. et Laporte, J.P. (eds), *Actes du Seminaire sur l'Etude des Contraintes au Developpement des Productions Animales en Afrique Sub-Saharienne*, Abidjan, les Cahiers de l'EISMV No. 3, Dakar, p. 185-198

Zoungrana, I., 1992. Diversité, stabilité et évolution des communautés végétales, Cas des jachères Nord-Soudaniennes du Burkina Faso, *Annales de l'Université de Ouagadougou*, Série B, p. 115-125.

SUMMARY

Since colonial times the crop livestock integration concept has been a leading development model in francophone West Africa. So far, it has failed in certain aspects, such as cultivation of fodder crops, intensification of cereal production through animal traction, and sedentarisation of mobile livestock keepers. Three major flaws in the concept have been identified, that are partly responsible for the reported failure: neglect of the farm (household) context, neglect of the financing role of livestock, neglect of competition for land and labour. Whether crop livestock integration can remain the leading development model in a situation of high population growth, has been explored through the following research question:

"Is crop livestock integration or mixed farming a suitable model for farming systems development, leading to guaranteed food security and socio-economic survival for all social entities of the rapidly increasing population in Sahelian countries, without endangering their resource basis?"

The context

Physical context

In the study area, the village Kaïbo Sud V5, Province Zoundwéogo, Burkina Faso, resources and their use appeared to be heterogeneous. Scenario studies with SHARES, a model at the level of Kaïbo Sud V5, and HOREB, a model at the level of an average farm in Zoundwéogo province, indicated that self-sufficiency in grain can not be achieved under currently applied crop and animal production technology in average rainfall years. External inputs in the form of inorganic fertiliser and/or concentrate feed for livestock are needed to compensate unavoidable nutrient losses, and a cart is needed to allow intensive management of crop residues and manure.

Agricultural knowledge system

In Burkina Faso, policy makers, research and extension appear to follow the transfer of technology model, a top-down approach leading to development of technologies that are not necessarily addressing farmers' needs. Research is either curiosity-driven or guided by objectives of policy makers. Extension only reaches a limited number of farmers, hence the progressive farmers approach dominates their relations. Farmers generally adopt proposed technologies, either because they have the means to introduce the innovations or because the proposed innovation suits them best. Only farmers that adopted technologies were contacted subsequently, and in turn, those farmers actively asked research and extension for solutions to their problems. Only when they were recognised as a constituency of the policy makers, they could influence the research agenda. Resource-poor farmers and mobile livestock keepers are neither recognised as a constituency nor possessed the means to innovate, hence they hardly benefit from research and extension.

Farming systems development

A framework situating discrete farming systems in the development perspective of mixed farming, has been designed. The framework ranges from separate specialised low external input (LEIA) systems, through integrated and mixed farming systems without or with external inputs, to specialised high external inputs (HEIA) farming systems. Observed farming systems in Burkina Faso could be classified within the proposed framework. Policy makers, driven by the objective to settle and control mobile herdsmen and to constrain crop producers to permanent fields, aimed at mixed farming systems for everyone. The recent sustainability debate appears to support their promotion of mixed (LEIA) farming systems because they are assumed to reduce nutrient losses. Mobile Fulani herdsmen engage in crop production only, when forced by circumstances, such as drought or animal diseases, leading to severe losses in livestock, making continuation of their former way of life impossible. Mixed farming is a poverty-induced option for them and therefore not attractive. For Mossi crop producers, on the contrary, wealth is the drive towards mixed farming, cattle being needed to support the associated technologies, such as animal traction and use of manure. Resource-poor farmers going into mixed farming have to apply labour-intensive techniques (their only resource) and, because of their low purchasing power, they cannot afford external inputs and have no option but to (over) exploit the environment. High external input (HEIA) farming should avoid pollution of the environment. Ecologically, both HEIA and LEIA can have negative effects on natural resource quality. Socio-economically, high agricultural production per unit area, based on the use of external inputs will lead to larger scale production and lower prices. Resource-poor farmers cannot follow this development and run the risk of being expelled from farming. Economically, HEIA farming is only sustainable when cash crops are cultivated or when high prices can be guaranteed. Around cities, capital intensive production systems can exist, because of the high purchasing power of the urban population and because of the short producer-consumer lines. In rural areas, farming systems that do not rely on high-quality infrastructure and use labour-intensive techniques, achieving moderate production levels are most suitable, guaranteeing local self-sufficiency in food. Production for export should be based on industrially organised systems using high levels of external inputs and capital. To aim at a variety of farming systems, each addressing specific societal needs, seems a more suitable strategy than to aim at the mixed farming system proposed in the model.

Financing role of livestock

In the mixed farming model, the role of livestock was limited to the supply of manure and animal power for crop production, and to value crop residues. For farmers in Burkina Faso and elsewhere in West Africa, livestock plays an important role as capital asset, to cover (emergency) cash needs. In farming systems where crop production depends on erratic rainfall, as in West Africa, livestock can be used to transfer surpluses from years with abundant rainfall to years with deficiencies. Livestock production was negatively affected by this buffer function, because emergency (premature) sales are associated with losses due to foregone offspring and foregone live weight. Emergency sales further restricted revenues, when livestock had to be sold in periods with low market prices. Sales of livestock for financing purposes also negatively affected performance of the farming system as a whole, in terms of foregone manure and animal traction, limiting crop production.

For financing, farmers preferred livestock to other means, even though taking a loan with a savings and credit co-operative was cheaper. Accessibility, security, liquidity and profitability were all more favourable for livestock than for any of the alternatives examined. The fact that a pledge of 150 % of the credit is needed for a loan from a co-operative, was a major constraint for resource-poor farmers. Financing through livestock was therefore more attractive than taking a loan with a co-operative or any other source.

Animal traction

Animal traction has been presented as a key element of crop livestock integration. It appears to be associated with larger farm sizes, larger areas of cash crop and higher livestock numbers, hence with wealthier farmers. In Zoundwéogo province and Kaïbo village, animal traction could develop as there were sufficient animals to serve all households and to cultivate total current crop area. Additional efforts should be made to increase training of bullocks and transfer of bullocks from Fulani livestock keepers to Mossi crop producers is needed. Bullocks appeared too weak for the tasks asked from them, resulting in short working days of 2-3 hours. Output per animal might be increased through introduction of heavier animal breeds or additional animal feeding. Timeliness of seeding and weeding might also be improved by using additional bullocks. The scope for improvement is limited as any solution depends on purchasing power of the farmer and availability of inputs.

Natural resource basis

Mossi and Fulani herds appeared to use the village territory in different ways, dictated by animal species, production objectives and season. Current high population growth leads to an expanded area under crops, for food production, and consequently reduced grazing area in the rainy season. Crop residue management, as proposed in the crop livestock integration model, leads to increased control over this feed resource by Mossi crop producers. As a result, room for the traditional feeding strategy, applied by Fulani and consisting of mobility and tracking changes in vegetation, becomes limited. The quantity (area) of animal feed becomes limiting, especially in the rainy season. In the post-harvest, dry season, both quantity and quality of animal feed becomes limiting because crop residues are no longer available and their animals thus have to rely on low quality grasses from the natural vegetation. Options for Fulani herds were further restricted by excluding them from the use of village wells in the dry season. Fulani have either to leave the village territory more often and for longer periods, or to accept lower animal production. When Mossi specialised crop producers become mixed farmers, the number of animals in their system increases. When Fulani become mixed farmers, their livestock will reside more permanently on the village territory. Larger livestock numbers and smaller grazing area increase risks of degradation, especially because specialist feeders such as goats and sheep will be forced to accept a more general diet, resulting in diet overlap between formerly complementary feeders. Population growth and subsequent **urbanisation** has been shown to lead to increased demands for firewood that has to be provided from village territories. Degradation of the natural resources in village territories and a decrease in feed resources for browsers can be the result.

Conclusion

The crop livestock integration model, and especially the mixed farming model, has only limited applicability as goal for farming systems development. In Burkina Faso, the majority of the farming population consists of resource-poor farmers, incapable to adopt technologies associated with mixed farming, because they lack the purchasing power to acquire ploughs, draught bullocks, inorganic fertilisers, etc. Mixed farming as a comprehensive development model therefore fails, although several of its components are (at least partially) adopted by a variety of farmers. The concept of restricted nutrient losses through intensive management of manure and crop residues appeared, for instance, valid, but, because of unavoidable losses during (re-)cycling, external inputs are needed to guarantee sufficient food production for the rapidly growing population. Moreover, exchange of crop residues and manure between specialised farming systems, has the same potential for nutrient cycling as mixed farming, but may be preferred because of advantages associated with labour distribution. Constraints for farming system development, especially for crop farmers, can be alleviated by creation of an optimal farm environment, such as a sound financial infrastructure, an agricultural knowledge system addressing farmers needs, a professional infrastructure to provide inputs and to guarantee marketing of outputs, fair farm-gate prices for agricultural products, etc. Attractive prices for meat and milk, infrastructure for veterinary care, grazing rights protected by law and limiting crop production in designated grazing areas and corridors, etc. are needed to facilitate mobile animal production. Technology development should already take its impact on the environment into account. Research and extension should stimulate participation of resource-poor farmers and mobile livestock keepers in technology development and support development of a range of farming systems, in terms of inputs and outputs, because together they can address the variety of societal needs.

Samenvatting

In franstalig West Afrika is, sinds de koloniale tijd, integratie van akkerbouw en veehouderij in de vorm van een gemengd bedrijf het heersende ontwikkelingsmodel geweest. Dit model heeft gefaald in de teelt van voedergewassen, intensivering van voedselproductie door middel van dierlijke trekkracht en in het vestigen van rondtrekkende veehouders. Drie onvolkomenheden van het model liggen, voor een deel, ten grondslag aan dit falen: het buiten beschouwing laten van de omgeving van het boerenbedrijf, het verwaarlozen van de financieringsfunctie van vee en het verwaarlozen van de schaarste aan land en arbeid. Het belang van het model in een situatie van snelle bevolkingsgroei is onderzocht middels de volgende onderzoeksvraag:

"Is de integratie van akkerbouw en veehouderij oftewel het gemengd bedrijf een geschikt model voor ontwikkeling van bedrijfssystemen, leidend tot voedselveiligheid en biedt het een mogelijkheid tot overleven aan alle sociale groepen waaruit de snel groeiende bevolking van Sahellanden bestaat, zonder hun natuurlijke hulpbronnen in gevaar te brengen?"

De omgeving

Fysieke omgeving

In het onderzoeksgebied, het dorp Kaïbo Sud V5, in de provincie Zoundwéogo, Burkina Faso, bleken de natuurlijke hulpbronnen en hun gebruik zeer heterogeen. Scenariostudies zijn uitgevoerd met behulp van SHARES, een dorpsmodel, toegepast op Kaïbo Sud V5, en HOREB, een bedrijfsmodel, toegepast op een gemiddeld boerenbedrijf in Zoundwéogo. Uit beide modellen bleek dat, in een gemiddeld regenvaljaar, zelfvoorziening in graan onmogelijk was gebruik makend van de huidige productietechnieken. Externe inputs zoals kunstmest en krachtvoer zijn nodig om onvermijdbare verliezen van nutriënten tijdens recirculatie te compenseren en het bezit van een kar was onontbeerlijk voor intensief management van gewasresten en dierlijke mest.

Landbouwkundige kennissystemen

Beleid, onderzoek en voorlichting werken in Burkina Faso volgens het "technologie overdrachtsmodel" (Transfer of Technology), een top-down benadering, leidend tot ontwikkeling van technologieën die niet noodzakelijkerwijs aansluiten bij wat boeren nodig hebben. Onderzoek wordt gedreven door nieuwsgierigheid of aangestuurd door doelstellingen van beleidsmakers. In de voorlichting domineert de "vooruitstrevende-boeren aanpak". Boeren passen nieuwe technologieën toe, omdat ze de daarvoor benodigde middelen bezitten of omdat de technologie precies één van hun problemen oplost en goed past binnen hun bedrijfsvoering. In het vervolg worden alleen die boeren aangesproken die positief reageren op voorgestelde technologieën en omgekeerd zullen juist die boeren actief een beroep doen op ondersteuning door onderzoek en voorlichting. Wanneer zij deel uitmaken van de achterban of

het electoraat van beleidsmakers, kunnen ze de onderzoeksagenda beïnvloeden. Armere boeren en rondtrekkende veehouders zijn als achterban oninteressant en bezitten niet de middelen om te vernieuwen, terwijl veel voorgestelde technieken niet bij hun bedrijfsvoering aansluiten. Daardoor profiteren zij nauwelijks van onderzoek en voorlichting.

Ontwikkeling van bedrijfssystemen

Er is een raamwerk ontwikkeld waarin bedrijfstypen gerangschikt zijn volgens het heersende ontwikkelingsmodel richting gemengd bedrijf. Onderscheiden zijn gespecialiseerde lage input akkerbouw en veehouderij, geïntegreerde bedrijven, gemengde bedrijven met een hoog en laag niveau van externe inputs en gespecialiseerde bedrijven met een hoog input niveau. In het onderzoeksgebied in Burkina Faso bleken deze bedrijfssystemen inderdaad voor te komen en in dit raamwerk in te passen. Beleidsmakers, die streven naar vestiging van, en controle over voormalige rondtrekkende veehouders en permanente teelt van gewassen door akkerbouwers, propageren het gemengde bedrijf voor iedereen. Het recente debat over duurzaamheid sterkt ze in hun streven, omdat in gemengde bedrijfssystemen de kans op nutriëntenverliezen kleiner zouden zijn. Rondtrekkende Fulani veehouders bleken echter slechts op akkerbouw over te gaan wanneer hun kuddes door calamiteiten zoals extreme droogte of besmettelijke dierziektes gedecimeerd waren, en ze niet in hun levensonderhoud konden voorzien op basis van de overgebleven dieren. Het gemengd bedrijf is voor hen een optie voortvloeiend uit armoede en daarom niet aantrekkelijk. Mossi akkerbouwers daarentegen kunnen pas overgaan op een gemengd bedrijf, wanneer ze voldoende rijkdom vergaard hebben om rundvee te kunnen kopen dat nodig is voor dierlijke trekkracht en mest. Armere boeren die op een gemengd bedrijf overgaan, zijn gedwongen arbeidsintensive technieken te gebruiken en hun omgeving te exploiteren, omdat ze nauwelijks koopkracht hebben om externe inputs te kopen. Boeren die een hoog niveau aan externe inputs gebruiken, moeten daarentegen oppassen voor vervuiling van hun omgeving. Ecologisch gezien, kunnen zowel bedrijven gebaseerd op lage als op hoge externe inputs, leiden tot schade aan natuurlijke hulpbronnen. Sociaal gezien, zal een hoge landbouwkundige productie per eenheid van oppervlak, gebaseerd op gebruik van externe inputs leiden tot schaalvergroting en lagere prijzen. Kleinere, armere boeren die niet kunnen aansluiten zullen uit de landbouw uitgestoten worden. Economisch gezien, kunnen externe inputs slechts toegepast worden wanneer handelsgewassen verbouwd worden of er een voldoende hoge prijs gegarandeerd is. Rond grotere steden kunnen kapitaalsintensieve bedrijven bestaan vanwege aanwezigheid van een koopkrachtige vraag en korte lijnen van producent naar consument. Op het platteland kunnen van infrastructuur onafhankelijke, arbeidsintensieve bedrijven met een betrekkelijk laag opbrengstniveau per eenheid oppervlak bestaan die met name zelfvoorziening in voedsel nastreven. Voor exportproducten kunnen bedrijven bestaan die industrieel produceren met hoge niveaus van externe inputs en kapitaal. Het streven naar variatie in bedrijfssystemen, elk gericht op het voldoen aan een vraag vanuit de samenleving, lijkt daarom effectiever dan het streven naar een standaard gemengd bedrijf.

Financieringsrol van vee

In het model van het gemengde bedrijf is de rol van vee beperkt tot het leveren van mest en trekkracht voor de akkerbouw en het benutten van gewasresten. Voor boeren in Burkina Faso en elders in West Afrika echter is vee belangrijk als middel om in verwachte en onverwachte uitgaven te kunnen voldoen. Wanneer akkerbouw plaats vindt onder omstandigheden van onregelmatige regenval, zoals in West Afrika, dan kunnen via vee de overschotten van een goed regenvaljaar overgedragen worden naar een jaar met tekorten. Deze bufferfunctie van vee kan echter negatieve effecten hebben op de productie van de veeteeltsector, omdat door noodverkoop de potentiële opbrengst van toekomstige nakomelingen en toekomstig lichaamsgewicht van het op jonge leeftijd verkochte dier wordt gemist. Daarnaast kan gedwongen verkoop in tijden van lage prijzen leiden tot lage opbrengsten. Noodgedwongen verkoop van vee uit een gemengd bedrijf heeft ook negatieve effecten op de bedrijfsvoering als geheel omdat de mest en de trekkracht van het verkochte dier wegvallen, hetgeen kan leiden tot een lagere akkerbouwproductie. Uit een aantal alternatieven kozen boeren vrijwel steeds voor vee als financieringsbron, hoewel bijvoorbeeld in Zoundwéogo, lenen bij een cooperatie, in geld uitgedrukt, voordeliger bleek te zijn. Vee is voor iedereen toegankelijk, draagt een laag risico, is gemakkelijk te gelde te maken en levert een hoog rendement. Als voorwaarde voor een lening bij een cooperatie moest bijvoorbeeld een borg met een waarde van 150 % van de lening overlegd worden en armere boeren hebben zo'n borg niet. Om die redenen was financiering via vee aantrekkelijker dan sparen en lenen bij een cooperatie en dan elk andere onderzochte alternatieve financieringsbron.

Dierlijke trekkracht

Dierlijke trekkracht wordt gepresenteerd als belangrijke bindende factor in de integratie van akkerbouw en veehouderij. Bezit van dierlijke tractie bleek samen te gaan met grotere bedrijven, een groter areaal aan handelsgewassen en hogere veebezetting, dus met rijkere boeren. In de provincie Zoundwéogo en in het dorp Kaïbo Sud V5 bleken voldoende dieren aanwezig te zijn om dierlijke trekkracht zodanig te ontwikkelen dat elk huishouden de beschikking zou kunnen krijgen over trekdieren en dat het totale akkerbouwareaal met behulp daarvan bewerkt zou kunnen worden. Om dit te bereiken zullen echter veel dieren getraind moeten worden en zal er overdracht van rundvee moeten plaatsvinden van Fulani veehouders naar Mossi akkerbouwers. De gebruikte ossen bleken relatief te zwak voor hun taken, hetgeen resulteerde in zeer korte werkdagen van 2 tot 3 uur. Werkdagen zouden verlengd kunnen worden door gebruik van zwaardere dieren, hetzij van andere rassen, hetzij beter gevoerd. Tijdigheid van zaaien en wieden kan ook bevorderd worden door meer ossen per span of meer spannen na elkaar te gebruiken. Verbetering zal echter moeilijk zijn, want elke mogelijkheid tot investering wordt beperkt door de koopkracht van de boeren en de beschikbaarheid van inputs.

Natuurlijke hulpbronnen

Het vee van Mossi en dat van Fulani bleek het dorpsgebied van Kaïbo Sud V5 op verschillende manieren te gebruiken, afhankelijk van diersoort, productiedoel en seizoen. De huidige snelle bevolkingsgroei leidt tot toename van het graan areaal en daarmee tot minder ruimte voor beweiding, met name in het regenseizoen. Het gebruik van gewasresten voor stalvoedering, zoals voorgesteld in het gemengd bedrijfsmodel, zal leiden tot monopolisering van deze bron van veevoer door Mossi boeren. Fulani herders hebben daardoor minder mogelijkheden om hun voederstrategie, gebaseerd op mobiliteit en het volgen van veranderingen in vegetatie, uit te voeren. De hoeveelheid beschikbaar voer in de regentijd neemt af, terwijl in de droge tijd, na de oogst, zowel kwaliteit als kwantiteit afnemen doordat hoogwaardige gewasresten onttrokken worden en het vee terug moet vallen op lagere kwaliteit grassen in de natuurlijke vegetatie. Daarnaast worden Fulani in de keuze van hun graasgebieden beperkt, omdat hun vee geen toegang krijgt tot waterputten op het dorpsgebied. Fulani moeten om al deze redenen vaker en langer van het dorpsgebied wegtrekken met hun vee of anders productieverlies accepteren. In het gemengde bedrijf, zoals voorgesteld in het model, hebben Mossi meer vee, dan wanneer ze gespecialiseerde akkerbouwers zouden zijn. Wanneer Fulani veehouders overgaan op productie in de vorm van een gemengd bedrijf, dan zal hun vee meer permanent in het dorpsgebied verblijven. De overgang naar gemengde bedrijven zal de veebezetting verhogen en voor beweiding beschikbaar areaal verkleinen, hetgeen een risico tot overbeweiding met zich meebrengt, met name omdat in situaties van voedselschaarste, veesoorten die normalerwijze een zeer gespecialiseerd dieet hebben, verplicht zijn meer plantensoorten in hun dieet op te nemen en daarmee in dieet meer gaan overlappen met andere grazers. Bevolkingsgroei en de daarmee gepaard gaande verstedelijking, zal leiden tot een toename in de vraag naar brandhout, waarin dan met name voorzien moet worden vanuit de dorpsgebieden. Degradatie van natuurlijke hulpbronnen van dorpsgebieden en afname van de voedselbron voor "browsers" kunnen hiervan het gevolg zijn.

Conclusies

De rol van het gemengde bedrijf, gebaseerd op integratie van akkerbouw en veehouderij, als model en uiteindelijke doel van bedrijfsontwikkeling bleek beperkingen te hebben. De boerenbevolking in Burkina Faso bleek met name te bestaan uit boeren met zeer beperkte middelen, niet in staat om de technologieën waarop het gemengde bedrijf gebaeerd is in te voeren, met name omdat ze onvoldoende koopkracht hebben om ploegen, trekdieren, kunstmest, etc. aan te schaffen. Het gemengde bedrijf als ontwikkelingsmodel faalt daarom, hoewel diverse onderliggende concepten, in ieder geval gedeeltelijk, door boeren gebruikt worden. Het principe dat nutriëntenverliezen beperkt worden door intensief management van gewasresten en dierlijke mest klopt, maar externe inputs zijn nodig om de onvermijdbare verliezen te compenseren en zodoende de nutriëntenbeschikbaarheid op peil te houden nodig om voldoende voedsel te produceren voor de snel groeiende bevolking. Ook tussen gespecialiseerde bedrijven kan ruil van gewasresten tegen dierlijke mest plaatsvinden om verlies van nutriënten te beperken. Uit het oogpunt van arbeidsverdeling kan deze optie zelfs aantrekkelijker zijn dan de uitwisseling op een gemengd bedrijf. Veranderingen in de omgeving waarin bedrijfssystemen geacht worden zich te ontwikkelen, kunnen beperkingen voor bedrijfsontwikkeling voor akkerbouwers opheffen. Daarbij kan met name gedacht worden aan een gezonde financiële infrastructuur, een landbouwkundig kennissysteem dat zich richt op de behoeften van de boerenbevolking, een professionele inputvoorziening en vermarktingsstructuur, hogere en gegarandeerde prijzen voor landbouwproducten voor de boeren, enz. Aantrekkelijke prijzen voor vlees en melk, infrastructuur voor diergeneeskundige zorg, beschermde beweidingsrechten en beperking van akkerbouw productie in graasgebieden en op veeroutes zijn onder andere nodig om dierlijke productie te stimuleren. Technologieontwikkeling moet rekening houden met effecten op de natuurlijke hulpbronnen. Onderzoek en voorlichting zouden arme boeren en rondtrekkende veehouders moeten betrekken bij technologieontwikkeling en differentiatie in bedrijfssystemen moeten ondersteunen, zodat deze samen kunnen voldoen aan de totaliteit aan maatschappelijke vragen.

Résumé

Depuis le temps colonial, le concept qui a guidé le développement agricole de l'Afrique de l'Ouest est le concept de l'intégration entre production végétale et animale. Ce concept a échoué par rapport aux sujets comme les cultures fourragères, l'intensification de la production céréalière à travers la traction animale, et la sédentarisation des pastoralistes. Le concept connaît trois insuffisances qui sont en partie responsables de son échec: la négligence de l'environnement de la ferme, celle des fonctions du bétail dans le financement des besoins de la famille, et enfin celle de la compétition des facteurs de production notamment de la terre et de la main- d'oeuvre.

Nous avons exploré l'importance du concept dans une situation de croissance de la population. La question a répondre était:

Est-ce que le concept de l'intégration entre production animale et végétale convient comme ligne directrice pour le développement des systèmes de production, assurant la sécurité alimentaire et la survie de tous les groupes socio-économiques de la population croissante des pays Sahéliens, sans dégradation de leurs bases en ressources naturelles.

Le contexte

Contexte physique

Dans la zone d'étude, le village Kaïbo Sud V5, dans la province Zoundwéogo, au Burkina Faso, les ressources naturelles et leur utilisation sont très hétérogènes. Les études de scénario, basées sur les modèles de l'échelle village et l'échelle ferme moyenne, ont montré que l'autosuffisance alimentaire ne peut pas être achevée avec les techniques culturales actuelles dans une année de pluviométrie moyenne. Des ressources externes comme l'engrais et le concentré pour le bétail sont nécessaires pour remplacer les pertes de nutriments, et les moyens de transport comme la charrette sont nécessaires pour une gestion de résidus de récoltes et de fumier.

Structure de connaissance agricole

L'Etat, la recherche et la vulgarisation, suivent un modèle de transfert de technologie, responsable du développement des technologies qui ne répondent pas nécessairement aux besoins des paysans. La recherche est dirigée par la curiosité du chercheur ou les objectifs des politiciens. La vulgarisation ne pouvant pas s'adresser à chaque paysan, se limite aux paysans progressifs, qui répondent bien aux techniques proposées parce qu'ils ont les moyens d'innover ou parce que la technique est parfaitement adaptée à leurs conditions de production. Ces mêmes paysans s'adressent à la recherche et à la vulgarisation pour d'autres solutions techniques. Quand ils forment la base électorale des politiciens ils peuvent influencer l'agenda de la recherche. Les paysans à faibles ressources et les pastoralistes ne forment pas une base électorale et n'ont pas les moyens d'innovation, donc ils ne bénéficient pas de la recherche ni de la vulgarisation.

Evolution des systèmes de production

Un cadre a été développé dans lequel des systèmes de production différents ont été placés dans une séquence d'évolution. Les systèmes distingués sont:

- système spécialisé en production animale ou en production végétale, chacun à faible utilisation des intrants,
- système intégré,
- système mixte avec ou sans utilisation des intrants,
- système specialisé basé sur l'utilisation des intrants.

Au Burkina Faso, les systèmes de production correspondaient aux systèmes décrits. Les politiciens, motivés par l'objectif de sédentariser et d'accroître le contrôle des pastoralistes et de fixer les cultivateurs sur des champs permanents, visent au système de l'intégration complète entre agriculture et élevage, c.a.d. le système mixte, comme solution pour chaque producteur. La discussion récente sur la durabilité, appuie la promotion de ce système mixte parce qu'il est supposé réduire les pertes de nutriments. Les pastoralistes n'acceptent pas la production de cultures sauf quand ils sont forcés de chercher des alternatives pour la production animale parce qu'ils ont été soumis à une perte importante de leurs animaux suite à une période de sécheresse ou à une maladie contagieuse. L'intégration agriculture-élevage est une option de pauvreté pour eux. Pour le Mossi c'est le cas inverse. Les producteurs Mossi doivent avoir des moyens pour associer l'élevage à leurs systèmes de production. Le bétail est nécessaire pour la traction et pour le fumier. Les paysans à faibles ressources doivent se baser sur les systèmes de production intensifs en main-d'oeuvre. Leur pouvoir d'achat est trop faible pour l'acquisition des intrants et ils n'ont comme alternative que d'exploiter leur environnement. Le paysan engagé dans l'agriculture basée sur des intrants externes, doit être prudent pour que leurs résidus ne polluent pas l'environnement. Du point de vue écologique, l'agriculture peut donc faire des dégâts aux ressources naturelles, n'importe quel niveau d'intrants est utilisé (LEIA ou HEIA). Du point de vue social, une production élevée de cultures basée sur des intrants crée une production à grande échelle et a tendance à baisser les prix. Les paysans à faibles moyens qui ne peuvent pas suivre ce type de développement risquent d'être exclus de l'agriculture. Du point de vue économique, les intrants ne peuvent être utilisés que sur les cultures de rente ou dans le cas de prix élevés des produits cultivés. Autour des grandes villes, une production basée sur une forte utilisation de capital est appropriée parce que le pouvoir d'achat des citadins permet des prix attractifs. A la campagne, les systèmes de production indépendants des infrastructures et des marchés, et basés sur la main-d'oeuvre locale, avec une faible production, sont appropriés pour assurer la sécurité alimentaire locale. Les systèmes qui sont basés sur les cultures de rente et l'exportation, peuvent être organisés de façon industrielle avec un niveau d'intrants élevé. Il semble donc plus approprié de viser une gamme de systèmes de production, chacun répondant à des demandes spécifiques de la société, que de viser au système unique, le système mixte.

Rôles du bétail pour le financement

Dans le modèle proposé, le rôle du bétail est réduit à la traction animale, le fumier et la valorisation des résidus de récolte. Les paysans du Burkina Faso et de l'Afrique de l'Ouest en général, utilisent leur bétail pour financer des besoins imprévus. Leur système de production dépend d'une pluviométrie irréguliere et le bétail est un moyen de transfert des surplus d'une année de pluviométrie abondante à une année déficitaire. Cette fonction de bétail est associée avec des ventes à jeune âge et ainsi implique des coûts ou des pertes notamment en potentiel de reproduction (manque des petits) et de croissance (manque de poids vifs). La vente forcée peut aussi coïncider avec une période dans laquelle les prix sont bas. La vente forcée peut aussi affecter le système de production entier parce qu'avec l'animal, son fumier et son énergie de traction sont enlevés de la production végétale. Une comparaison entre plusieurs alternatives pour financer des dépenses imprévues a montré que le bétail est l'option préférée, malgré le fait qu'un crédit pris dans une coopérative d'épargne et de crédit soit l'option la moins chère dans la province du Zoundwéogo. La sécurité, la liquidité, l'accessibilité et la profitabilité sont plus élevées pour le bétail que pour les alternatives explorées. L'accès au crédit dans une coopérative est conditionnée par une garantie de 150 % de crédit, ce qui est une contrainte pour les paysans à faible revenu. Financer à travers le bétail est donc plus intéressant que de prendre un crédit dans une coopérative.

La traction animale

La traction animale est présentée comme un élément clé du modèle de l'intégration agriculture-élevage. L'utilisation de la traction animale est associée à des fermes de superficies totales élevées, de superficies en culture de rente élevées, et un nombre élevés de bétail, donc avec des paysans plus aisés. Au Zoundwéogo et au village Kaïbo Sud V5, le nombre de bétail déjà sur place est suffisant en vue d'équiper toutes les familles et de travailler la superficie totale en cultures. Dans cet objectif, un nombre additionnel de boeufs doit être formé et transféré du Foulbé aux Mossi. Les boeufs utilisés jusqu'à maintenant étaient faibles par rapport aux tâches demandées, ce qui donnait lieu à des jours de travail de 2 à 3 heures, donc très courts. Leurs performances peuvent être améliorées quand des races plus lourdes seront utilisées ou lorsque la nutrition sera améliorée. L'utilisation de boeufs supplémentaires peut avancer la date de semence et celle du désherbage. Chaque solution dépend des ressources des paysans donc les possibilités réelles d'amélioration sont limitées.

Ressources naturelles

Mossi et Foulbé utilisent le terroir villageois chacun à leur façon dépendant des espèces de bétail, des objectifs de production et de la saison. La croissance de la population humaine augmente la demande d'espace pour la production des céréales et diminue la superficie disponible pour le pâturage, dans la saison de pluie. La gestion des résidus de récolte, comme proposée dans le modèle d'intégration, augmente le contrôle des Mossi sur cette ressource. La stratégie que les Foulbé appliquent pour nourrir leur bétail est basée sur le concept de mobilité du troupeau suivant les changements de qualité et quantité de la végétation suite aux événements climatiques. Cette stratégie est en danger parce que la superficie (quantité) de pâturage est limitée en saison de pluie, et la qualité des ressources est diminuée quand les résidus de récolte ne sont plus disponibles en saison après-récolte. En saison sèche, les animaux sont obligés de manger des herbes naturelles qui sont de pauvre qualité. La mobilité des troupeaux des Foulbé est également limitée parce qu'ils sont exclus de l'utilisation des puits de village, pendant la saison sèche. Finalement, les troupeaux des Foulbé doivent quitter le terroir villageois plus fréquemment et plus longtemps, ou bien les Foulbé doivent accepter une baisse de production de leurs troupeaux. Quand les paysans Mossi transforment leur système de production végétale en système mixte, le nombre de bétail dans leur système doit augmenter. Quand le berger transforme son système de production de bétail en système mixte la présence de son bétail sur le terroir augmente. L'augmentation du nombre de bétail et la limitation de superficie de pâturage augmente le risque de dégradation. Les espèces animales, qui sont capables de bien sélectionner dans la base fourragère, notamment les ovins et les caprins, et dont le choix de nourriture est complémentaire, sont forcées d'accepter plus d'espèces végétales, et entrent ainsi en compétition avec les espèces animales qui acceptent toujours de grandes quantités d'une large gamme d'espèce végétale, comme la vache. La croissance de la population humaine et l'urbanisation augmentent la demande en bois de feu. Ce bois doit être fourni par les terroirs villageois et peut causer une dégradation des ressources de ces terroirs et une diminution des ressources fourragères, notamment pour les caprins qui dependent largement des espèces ligneuses pour leur nutrition.

Conclusion

Le modèle de l'intégration agriculture-élevage, et spécialement le modèle système mixte, n'a qu'un potentiel limité pour le développement des systèmes de production. Au Burkina Faso, la population rurale est dominée par un nombre élevé de paysans à faibles ressources qui sont incapables d'adopter des technologies associées à un système mixte parce qu'ils n'ont pas le pouvoir d'achat pour l'acquisition de charrues, de boeufs de labour, d'engrais, etc. C'est pourquoi le système mixte comme modèle complèt a échoué, malgré le fait que plusieurs de ses composantes ont été acceptés par plusieurs paysans. Le concept de recyclage des nutriments à travers la gestion de résidus et de fumier, en vue de la diminution des pertes, est valable, mais les intrants externes sont néanmoins nécessaires pour garantir la production des céréales pour nourrir la population en croissance rapide. En principe l'échange entre résidus de récolte et fumier entre systèmes de production spécialisés a la même potentialité que le recyclage à l'intérieur d'un système mixte. L'échange entre les systèmes séparés, permettant une distribution de main-d'oeuvre entre les systèmes, peut être préféré. Le développement des systèmes de production, surtout pour la production végétale, demande un contexte optimal concernant l'infrastructure financière, une structure de connaissance agricole qui s'adresse aux besoins des paysans, une infrastructure pour l'approvisionnement en intrants et la vente des produits, des prix attractifs au niveau ferme, etc. La production animale peut être facilitée à

travers des prix rémunérateurs pour le lait et la viande, une infrastructure vétérinaire, une protection des droits de pâturage renforcée par la loi et limitant le droit d'agriculture dans les aires de pâturages et les pistes de bétail, etc. Le développement de la technologie devrait déjà prendre en compte les aspects d'environnement. La recherche et la vulgarisation devraient stimuler la participation des paysans à faibles ressources et les pastoralistes au développement de la technologie et soutenir une large variation de systèmes de production parce qu'ensemble ils peuvent satisfaire toutes les demandes de la société.

CURRICULUM VITAE

Marrigje Adriana (Maja) Slingerland was born on 16 February in Lekkerkerk, the Netherlands. She studied tropical animal production at Wageningen Agricultural University (WAU). Main subjects were animal traction, animal nutrition, extension sciences and tropical crop production. In 1985, she went to Mali to study backyard poultry production in three agro-ecological systems: rainfed millet, irrigated rice, and urban. She was hosted in Niono, by the International Livestock Centre Africa (ILCA) now called the International Livestock Research Institut (ILRI). In 1987 she went to Niger to supervise an experiment on comparison of different soil tillage techniques and of mixed, pure and rotational cropping. She was hosted by the International Crop Research Institute for Semi-Arid Tropics (ICRISAT) in Niamey. In collaboration with Hohenheim University (Germany), she conducted animal traction experiments at Sadoré research station in Niger, to compare performances of different animal species and different soil tillage tools.
She obtained her Masters degree (Cum Laude) in 1988.
Immediately after graduation she became employed by International Agricultural School "Larenstein" in Deventer to teach both Dutch and international students in tropical animal production and agriculture at BSc-level. In March 1990 she married Andi Tan. In 1990 she became rangeland expert for SNV in a FAO land-use evaluation and planning project on village level with emphasis on forestry management in Banamba, Mali. From November 1992 to March 1993 she did a consultancy in a SNV project collaborating with the Malian cotton company (CMDT) in Fana, to study the impact of the construction of small waterworks on animal production possibilities.
From 1993-1999 she worked for Wageningen Agricultural University (WAU) at the Antenne Sahélienne, a research project on sustainable agriculture, financed by WAU and executed in collaboration with the University of Ouagadougou in Burkina Faso. She was employed as rangeland specialist, education co-ordinator, co-ordinator of the research group on Use of Natural Resources and, since January 1997, also as General Director. Apart from her management and co-ordination tasks, her main occupation was to conduct her PhD research in Zoundwéogo province in Burkina Faso.
In June 1994 she participated in an evaluation and reformulation of national research on animal production at INERA Ouagadougou, Burkina Faso, on behalf of the World Bank. In May 1997 she participated in an evaluation of *l'Ecole de Faune* in Garoua, Cameroun, on behalf of the Dutch Embassy in Yaoundé, Cameroun.
From January 1999 she came to Wageningen to write her thesis. She was hosted at the Plant Production Systems Group but she held a part-time job at the Animal production Systems Group of Wageningen University consisting of supervising Dutch students and co-ordinating international MSc students. She followed some PhD courses and participated in several seminars.
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PREVIOUS PUBLICATIONS OF THE AUTHOR

Wilson, T., Traoré, A., Traoré, A. and M.A. Slingerland, 1987. Backyard poultry keeping in the Niono area in Central Mali, *Tropical Animal Health and Production*

Slingerland, M.A., 1989. Selection of Animals for work in Sub-Saharan Africa: Research at the ICRISAT Sahelian Centre, in: Draught animals in rural development, ACIAR proceedings No. 27

Timmer, L.A., Kessler, J.J., and M. Slingerland, 1996. Pruning of néré trees (Parkia biglobosa (jacq.) Benth.) on the farmlands of Burkina Faso, West-Africa, *Agroforestry Systems* 33: 87-98

Slingerland, M.A., 1996. Mulching in Burkina Faso, *Indigenous Knowledge and Development Monitor* 4 (2): 3-5

Slingerland, M., and M. Masdewel, 1996. Le paillage sur le plateau central du Burkina Faso: une technique très utilisée et bien adaptée aux moyens des paysans, in: Reij, C., I. Scoones and C. Toulmin (Eds.), *Techniques traditionnelles de conservation de l'eau et des sols en Afrique*, CTA, Wageningen, CDCS, Amsterdam, Karthala, Paris, pp. 127-132

Begemann, J., Nibbering, J.W., Slingerland, M., Munck, E. de, Stroosnijder, L., and W. Hoogmoed, 1996. *Rapport annuel 1995 et perspectives 1996*, Antenne Sahélienne, UAW/UO.

Slingerland, M., and K.F. Wiersum, 1996. *Management practices for trees in farmed parklands in Burkina Faso*, Poster International Conference Domestication and commercialization of non-timber forest products in agroforestry systems. ICRAF, Mairobi, Kenya.

Wiersum, K.F., and M. Slingerland, 1997. Use and management of two multipurpose tree species (*Parkia biglobosa* and *Detarium microcarpum*) in agrosilvopastoral land-use systems in Burkina Faso, Antenne Sahélienne, Serie Rouge No. 41, UAW/OU

Hien, F.G., Slingerland, M.A., and V. Hien, 1997. *Le paillage traditionel dans la gestion de la fertilité des sols en milieu soudano-sahélien: fonctions biophysiques et incidence sur la production de sorgho*, Communication for the Regional Workshop on Soil Fertility Management in West-African Land use Systems, Niamey, 4-8 March 1997.

Kessler J.J, Slingerland, M.A., and M. Savadogo, 1998. Regeneration of sylvopastoral lands in the Sahel zone under village management conditions, *Land Degradation and Development* 9: 95-106