MULTIPLE USE OF RANGELANDS WITHIN AGROPASTORAL SYSTEMS IN SOUTHERN MALI

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Stellingen

1. De conditie van de natuurlijke weiden in zuidelijk Mali staat niet alleen onder zware druk van begrazing en op verkeerde tijden afbranden maar ook van houtkap en akkerbouw.
(Dit proefschrift)

2. De paradox van een hogere veedichtheid ondanks een degraderend weidelandschap in zuidelijk Mali laat zich verklaren uit de ontwikkeling van de akkerbouw.
(Dit proefschrift)

3. In zuidelijk Mali zijn veranderingen in de akkerbouw gedurende de laatste decennia de aanzet geweest tot de degradatie van zowel de akkers als de weiden.
(Dit proefschrift)

4. Veranderingen in de sociaal-economische situatie en de landgebruiksrechten zijn voorwaarden voor de ontwikkeling van duurzame landbouwsystemen in West Afrika.
(Dit proefschrift)

5. De consumptie van boomblad ("browse") aan het einde van het droge seizoen in zuidelijk Mali hangt samen met zowel een lagere kwaliteit van het gras als een hogere kwaliteit van "browse" gedurende deze periode.
(Dit proefschrift)

6. Het gedrag van (vee)boeren in semi-aride gebieden is gemakkelijker te begrijpen door analyse van jaarlijkse regenvalverdeling, opbrengsten en economische omstandigheden gedurende een aantal opeenvolgende jaren, dan door analyse van gemiddelde jaarlijkse waarden gedurende enkele decennia.

7. In de automatiserings wetenschap dreigt het middel vaker geheiligd te worden dan het doel.

8. Een hogere mate van participatieve observatie door modelbouwers zal de betrouwbaarheid van de simulatiemodellen ten goede komen.

9. Naarmate een bureaucratie zich meer ontwikkelt is er minder ruimte voor de creativiteit van het individu.

10. De betekenis van graslandkunde voor de ontwikkeling van duurzame landbouwsystemen wordt onvoldoende erkend.

11. Een "goede" zomer zal de integratie tussen "wel" en "niet" rokende vakgroepsleden van Agronomie bevorderen.

12. In plaats van "het gras is altijd groener aan de andere kant van de heuvel" is het in Nederland gepaster om te zeggen " zoals het gras thuis groeit, groeit het nergens".

Multiple use of rangelands within agropastoral systems in southern Mali.

Susan Leloup. Wageningen, 9 juni 1994.

ABSTRACT

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The communal rangelands in southern Mali constitute important grazing areas, provide fruit, timber and fuel and protect the cultivated fields against run off. During recent decades the rangelands experienced increased pressure caused by periods of droughts, growth of the human and livestock population and an encroaching cropping system. This thesis focuses on various aspects of relevance to the condition of the rangelands. The main findings were: 1) that the condition of the rangelands with regard to their multiple functions has declined since recent decades, 2) that animal productivity is increasingly dependent on the cropping system and 3) that the influence of the cropping system on animal productivity leads to the deterioration of the rangelands.

The suitability for this region of a recently developed method to estimate primary production in Sahelian countries was analyzed by the comparison of measured and theoretical data. Consistent differences were found. Changes in the vegetation were presumably caused by recent droughts and increased exploitation.

The impact of the multiple forms of exploitation of the woody vegetation was investigated. Species were classified according to growth form and use for fruit, browse, timber and fuel wood. Of each species the contribution to accumulative canopy cover and abundance was determined. The contribution of more useful species generally was lower when the exploitation pressure was high. Tree species fulfilled more often several uses at the same time than did shrubs.

The influence of nutritional factors on seasonal and relative palatability of browse species was investigated. It was found that the highest N and P concentration of DM of browse occurred during the season of browse consumption, while the most palatable species showed the highest concentration. More palatable species were also more deciduous than less palatable species.

The importance of the cropping system on animal production was shown by observations on seasonal fodder availability and consumption, farmers intervention, and liveweight changes of sedentary cattle. Farmers attitude towards the use of crop residues was related to land tenure, climate and cattle density.

A comparison of measured and simulated liveweight changes of cattle showed that consumption of crop residues is of vital importance to animal production. Correspondingly, the availability of crop residues determined the grazing capacity during the dry season. This grazing capacity may result in an overgrazing of the rangelands.

Finally the decline of the condition of the rangelands was described and attributed to recent droughts and increased exploitation. A suggestion to the development of a method to evaluate multifunctional rangelands is given and the interdependence of crop and livestock systems and the causes of the over-exploitation of the ecosystem are discussed. It is highlighted that macro-economic changes together which changes in land use management, social security and education are indispensable to develop a more sustainable land use system. A suggestion to an alternative land use system is presented.

Key words: animal production, browse, crop residues, fodder consumption, fruit trees, fuel wood, land use, liveweight changes, palatability, primary production, savanna, timber, woody vegetation.

To: My late father,
my mother and Dean.

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During my enjoyable time in Mali, many people have been of importance to accomplish the often tiring but unforgettable field work. I would like to thank them all but in particular "les pastoralists": Mouhamadou Traoré, Siaka Bagayogo, Brehima Diarra, Maimouna Sanogo-Diabaté and the car driver N'golo. Then I am much indebted to Dr. Henk Breman of AB-DLO, Wageningen, The Netherlands, who supervised the work at that time and acted as a peer reviewer of chapters 2 to 5 of this thesis.

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Susan Leloup.

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Chapter 1

General introduction

1. GENERAL INTRODUCTION

Topic of study

The condition of the communal rangelands in southern Mali is a subject of increasing concern. Since recent decades, a strong increase of exploitation pressure has been enforced by drought periods, growth of the human and livestock population and expansion of the cultivated area (Berthé *et al. 1991*). Besides being grazing areas the rangelands provide timber, fuel and fruits and they should protect the lower situated cultivated fields against run off (Budelman and Huijsman 1991). Under the present exploitation pressure these functions are not sustainable therefore, the development of land management systems at the village territory level has received attention from research and extension organizations since the 1980's (Guindo and Van Campen 1994, Hijkoop *et al.* 1991). However, progress is relatively slow and many problems have been encountered (Van Campen 1991).

This thesis focuses on various aspects relating to the condition of the rangelands in southern Mali with the objective to contribute to the development of reliable evaluation methods and land management systems. Field work was carried out in three villages (Figure 1.1.) between February 1987 and October 1990. Characteristics of these villages are to be found in the following chapters of this thesis.

Southern Mali, its land and its people

Southern Mali (Figure 1.1.) covers 10% (122.000 km^2) of Mali's territory and accommodates 30 % (2.500.000) of the human population (Berthé et al. 1991). The climate, soils and vegetation gradually change from North to South. Rainfall increases from an annual average of 500 mm in the northern part to 1300 mm in the south and falls mainly in a distinct period between May and September. Lowest mean daily temperatures occur during the early dry season (22 to 25 °C) and highest during the late dry season (31 to 35 °C). The soils, lixisols (FAO 1991), originate from differential erosion of the Precambrium shelf, show varying depths and textures and are classified as infertile. Arable loamy plains have an organic matter content of 0.6 %, a pH of 5.3 and a cation exchange capacity of 2.8 meq/100g (Anonymous 1983). The landscape undulates slightly and is located on an altitude of 300 to 400 m above

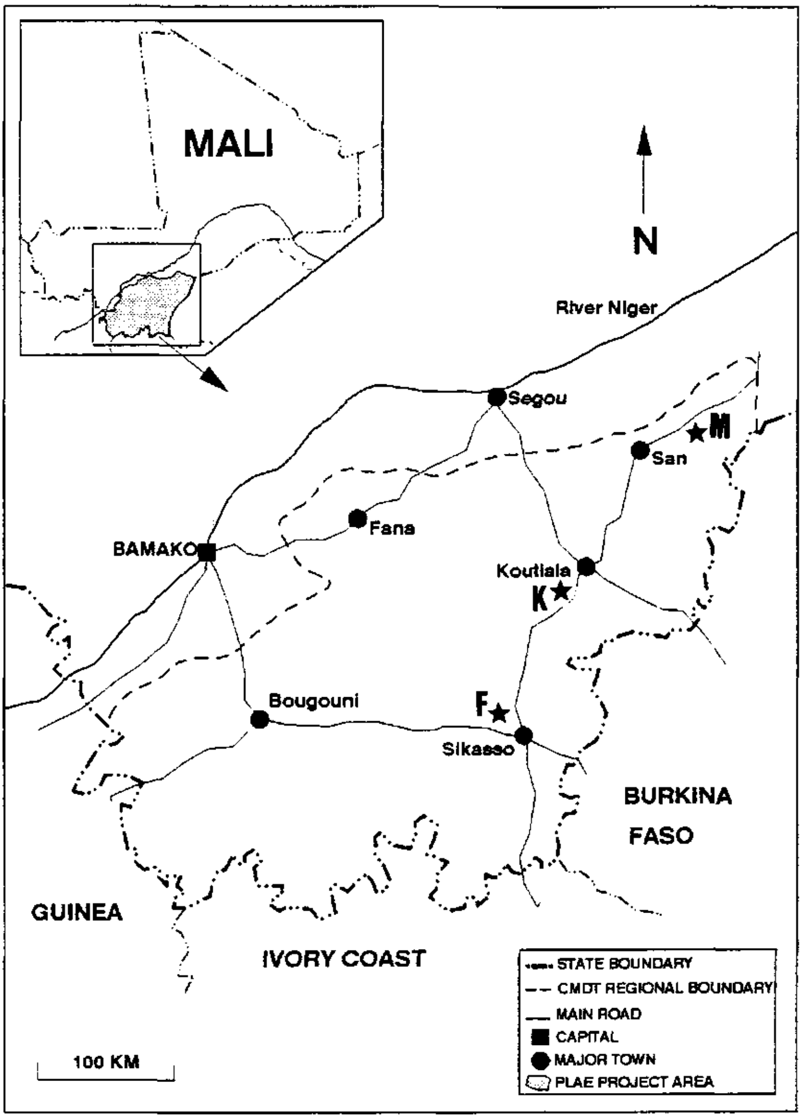

Figure 1.1. Map of Mali, with indicated the villages of study.
★M: Minso, K: Kaniko, and F: Fonsebougou.

Source: Guindo and Van Campen, 1994.

sea level. The Sudan savanna vegetation (White 1983) changes from grass-shrub lands in northern parts to woodland savannas in the south.

The agropastoral systems range from transhumant pastoralism to sedentary agriculture. Many mixed variants of both systems exist in the region. The transhumant pastoralists are represented by the Peulh people whereas the agriculturists comprise several ethnic groups: Bambara, Bobo, Minianka and Senoufo (Traoré *et al.* 1980)

Land is officially owned by the state, but its cultivator gains certain rights (Hijkoop *et al.* 1991, Le Bris *et al.* 1991). Access to the natural rangelands is free and bush fires, initiated by people, are common (Geerling 1983).

Recent developments

Since the early 1970's, the government of Mali actively promoted the growing of cash crops - mainly cotton and to a lesser extent also groundnut - and the use of animal traction. This resulted in a relatively rapid increase of the cultivated area at the expense of the natural rangelands. During the same period average rainfall in the region decreased by 200 mm compared to the preceding 30 years. Both aspects have encouraged the suppression of the tse-tse fly, as was the case in Nigeria (Bourn 1983), thereby allowing the increase of the human and animal population. The number of livestock present in the region was estimated at 1992000 in 1977 and at 3359000 in 1986 (Berthé *et al.* 1991). This increase in livestock numbers is generally attributed to the introduction of animal traction, investment of income from cash crops in animals, and an immigration of transhumant pastoralists coming from the North in search for fodder and water because of recent droughts. Despite official prohibition of bush fires since 1984, they still prevail in the region.

Outline of the thesis

In this thesis the following aspects relating to the condition of the rangelands have been dealt with.

Chapter 2 contains an assessment of the suitability for the region of a recently developed method for primary production estimates in Sahelian countries. Theoretical estimates were compared with the results of measurements in the field.

Chapter 3 treats the multifunctionality of the woody species on rangelands and the apparent consequences of their continuous exploitation.

Chapter 4 presents results on seasonal and relative quality and palatability of several browse species.

Chapter 5 describes seasonal availability and consumption of fodder, farmers interventions and liveweight changes of sedentary cattle.

Chapter 6 compares measured liveweight changes of cattle with the results of simulation modeling based on the availability and consumption of the different sources of fodder, including crop residues. The grazing capacity during the dry season is calculated and discussed.

Finally in chapter 7, a synthesis of the findings in the preceding chapters is presented and the consequences for future research and land use planning are discussed.

Chapter 2

Primary production of rangelands in southern Mali: a study of methodology

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Tropical Grasslands (accepted)

2. PRIMARY PRODUCTION OF RANGELANDS IN SOUTHERN MALI: A STUDY OF METHODOLOGY

Abstract

The primary production of rangelands in the Sudanian zone of Mali was estimated using a method which aims to describe the situation in an average and/or a dry rainfall year. This method proposed by Breman and De Ridder (1991) distinguishes three approaches differing in accuracy level. Two of them, the "rough" approach and the "semi-detailed" approach were applied on the rangelands near three villages. With the "rough" approach primary production is derived from purely theoretical functions and available data on rainfall and soil parameters, while with the "semi-detailed" approach data from one year of field work are included.

In one village the theoretical functions of the method did and in two other villages did not apply. It is argued that this was due to changes in the vegetation as a result of recent developments in the land use systems of the two villages. These developments consist of a more intensive use of rangelands. As this is generally the case in the Sudanian zone of Mali, it was concluded that the method of Breman and De Ridder is not suitable for this region. However, the "rough" approach can be used as a reference to quantify for vegetation changes.

Introduction

Recently a handbook appeared on the evaluation of natural rangelands in the Sahelien countries (Breman and De Ridder 1991). It describes the estimation of the primaryproduction of rangelands as an important element in the process of their evaluation. With respect to the variability of the primary production, related to the rainfall patterns and to the dominance of annual species within the vegetation, the authors of the handbook stress the need for the estimation of the primary production for an average rainfall year and for a dry year, instead of measuring the primary production of one particular year only. The handbook gives a method to estimate the situation in these rainfall years by using a limited base of information.

Three approaches, differing in accuracy levels, are described. One, a "rough" approach is based purely on theoretical functions and data from the literature, the second, "semi-detailed" approach includes measured data from one year of field work, and the third, more detailed approach, includes data from a few years of monitoring in the field. The method is based on the results of a study conducted in the Sahel zone (Penning de Vries and Djitèye 1982), while some additional studies served the authors to extrapolate the method for the situation in the Sudanian zone. However the method has so far not been tested thoroughly in this zone.

In this study both the "rough" approach and the "semi-detailed" approach, were applied to the natural rangelands in three villages, situated in the Sudanian zone of Mali. Only the situation of an average rainfall year was estimated. By comparison of the results obtained by the two approaches the applicability of the method in this part of the Sudanian zone is discussed. In addition an interpretation is given concerning developments in the actual primary production in this region.

Materials and Methods

Villages

The villages Minso[1] (13°17'N, 4°35'W) , Kaniko (12°18'N, 5°33'W) and Fonsebougou (11°37'N, 6°16'W) are located in the Sudanian zone of Mali with rainfall ranging from North to South from 700 to 1050 mm. The soils, classified as lixisols (FAO 1991), originate from differential erosion of the Precambrium shelf. From north to south the vegetation changes from grass-shrub savanna towards woodland savanna. These landscapes, undulating slightly with gradients up to 2 degrees, are located about an altitude of 350 m above sea level. Locally the steepness of the slopes can be stronger as a result of drainage courses. The location of these villages within the landscape and their land use systems are similar in the way the settlements are built in a valley, near a seasonal stream surrounded by cultivated fields and natural rangelands. The structure of land use in the villages relates to the topography of the different soil types, with the more arable soil types positioned closest to the seasonal stream. The rangelands of these villages are under communal use and sometimes transhumant pastoralists settle here seasonally after approval has been given by the villagers. These rangelands are subject to different forms of exploitation: trees of several species are being cut for fuel wood or timber; both woody species and herbaceous species are being browsed or grazed by livestock, while the arable soil types were mostly crop fallow land. Although man-lit bush fires are officially prohibited they are still prevalent in Minso and Fonsebougou while in Kaniko, as a result of a strong influence of a rural development

[1]This village represents actually the area of two adjacent villages called Minso and Sokoro.

organization, they were more or less absent during the years of this study. This last village seems to experience the highest pressure on its natural resources (Table 2.1.).

Table 2.1. Characteristics of the village territories of Minso, Kaniko and Fonsebougou.

Characteristic	Minso	Kaniko	Fonsebougou
Average rainfall (mm)	700	850	1050
Total area (ha)	2703	3250	5882
Human density (number/km^2)	20	36	22
Livestock density (ha/TLU*)	4.6	3.0	7.0
Cultivated area (%)	17	45	12

* tropical livestock unit: 250 kg mature dry zebu kept at maintenance.
Source: Leloup and Traoré, 1989,1991.

Average rainfall in the area fell by about 200 mm during the last 30 years, while during the same period the cultivated area increased rapidly at the expense of the rangeland area. This was due to the promotion of the use of animal traction and the growing of cash crop cotton. The use of animal traction augmented the livestock numbers. The number of livestock also increased by the herds of transhumant pastoralists coming in from the north in search of fodder (Berthé *et al.* 1991).

Rough approach

Woody cover and herbaceous production (nitrogen production *Nb*, nitrogen concentration ‰ *N*, dry matter *DM*) of the rangelands in the villages, in a average rainfall year, were calculated according the theoretical functions given by Breman and De Ridder (1991). Soil and rainfall data were obtained from the literature (Anomymous 1983). The theoretical functions assume that 5% of the herbaceous biomass consists of legumes and that the vegetation is in a state of equilibrium.

Woody cover is directly derived from soil parameters and average rainfall, while calculation of *Nb* involves several equations. The main equation, adapted from one describing the situation in the Sahel, has been defined as follows:

$$Nlh = (0.0083xI)/(flh\text{-}0.13) = Nlign + Nb$$

Nlh represents the quantity of nitrogen in the biomass of the herbaceous layer and the leaves and fruits of the woody vegetation, *I* is the water infiltration rate, *flh* is the fraction of *Nlh* lost and *Nlign* is the quantity of *Nlh* taken up by the woody vegetation. All parameters are annual means and the necessary information to calculate their values are given in the handbook. *DM* is calculated from the *Nb* and an assumed value of ‰ *N*, is given by the handbook.

Semi-detailed approach

The following steps were executed according to Breman and De Ridder (1991):

a: Canopy cover of woody vegetation was measured in the field and the herbaceous production (*Nb, ‰ N (Nb), DM (Nb)*), in an average rainfall year was derived according to the handbook.

b: The herbaceous production was measured in the field (*Nm, ‰ N (Nm), DM (Nm)*).

c: The herbaceous production, measured under "b" was standardized (*Ns, ‰ N (Ns), DM (Ns)*) to an average rainfall year with legumes constituting 5% according to the handbook

d: The herbaceous nitrogen production calculated under "a" and under "c" were compared and by considering the rainfall distribution, the species composition and following the questionnaire of the handbook a decision was made as to whether deviations were by chance or of a more permanent nature.

Field data were collected during 1987 (Kaniko, Fonsebougou) and 1989 (Minso). Rainfall data were obtained from gauges placed in each village. The observations on the woody vegetation and herbaceous layer were executed during the end of September or the beginning of October.

Representative plots of 120 x 5 m per soil type were marked (Table 2.2.) but not fenced. Representativeness was determined by studying aerial photographs and by visiting the villages. The codes of the soil types correspond to the classification given by Anomymous (1983). The hydromorphic plains (TH), the loamy plains (PL), the loamy-sandy plains (PS3) and the plains on laterite carapace (TC7) are considered arable. The first three are deep soils while the last one is moderately shallow. All of them are in general positioned at the lower end of the slopes. The non-arable soils on laterite carapace (TC6,TC4,TC5) are positioned higher up the slope, with the most shallow soil type TC5 at the top ("plateaux"). These soil types are often covered with a layer of gravel.

Table 2.2. Number of plots per soil type* in the villages.

	Arable				Non arable		
Village	TH	PL	PS3	TC7	TC6	TC4	TC5
Minso	-	-	6	6	-	6	6
Kaniko	-	4	-	-	4	-	6
Fonsebougou	2	3	-	-	4	-	7

* See text for explanation of codes.

The canopy cover of the woody vegetation was determined by an observer walking along three parallel lines, over the length of the site. At every step it was recorded whether there was cover of a canopy of woody vegetation vertically above the toe point. The percentage of positive results on the total of observations was considered the percentage of woody cover of the site.

To determine the fresh yield and botanical composition of the herbaceous vegetation, a quadrat of 1 m^2 was placed 18 times on the vegetation along a transect at a site, the quadrate positioned 10 steps apart. All herbaceous species present in the quadrate were listed. For every quadrate the total fresh weight of the aerial herbaceous biomass and the contribution in percentages of the following groups of species were estimated: perennial grasses, annual grasses, annual legumes and other annual dicotyledonous species . Perennial dicotyledonous species were rare, and not distinghuised. For every third quadrate these estimations were followed by a harvest of the material while keeping the biomass of legume species separate from the other species. Both samples were weighed and put in separate cotton bags. The data were used to correct the estimations. At the end the samples of the different sites of a soil type were combined, still keeping the legume species apart from the other species. The samples were air dried to constant weight. Subsamples were sent to a laboratory for determination of the percentage nitrogen (Kjeldahl method).

Results

Rainfall in the years of measurement was low compared to the average rainfall in all villages (Minso 570/700 mm, Kaniko 538/ 850 mm, Fonsebougou 730/1100 mm).

The cover of the woody vegetation measured in the field (Table 2.4.) was always higher than the one estimated by the rough method (Table 2.3.), except for TC5 in Minso. The differences were most pronounced in the villages Kaniko and Fonsebougou and on arable soil type PL/TC7 in all villages.

Table 2.3. Rough approach. Woody cover and related Nb, ‰ N and DM of the herbaceous vegetation per soil type* in the rangelands of a) Minso, b) Kaniko and c) Fonsebougou.

a) Minso

Soil	Woody cover (%)	Nb (kg/ha)	‰ N (g/kg)	DM (t/ha)
PS3	26	14.3	6.3	2.3
TC7	26	16.9	6.8	2.5
TC4	24	12.3	6.8	1.8
TC5	24	8.9	6.8	1.3

b) Kaniko

Soil	Woody cover (%)	Nb (kg/ha)	‰ N (g/kg)	DM (t/ha)
PL/TC7	27	12.8	6.5	2.0
TC6	27	8.5	6.5	1.3
TC5	27	8.4	6.5	1.3

c) Fonsebougou

Soil	Woody cover (%)	Nb (kg/ha)	‰ N (g/kg)	DM (t/ha)
TH	45	7.7	5.0	1.5
PL	30	8.8	5.6	1.6
TC6	29	8.2	5.6	1.5
TC5	28	8.5	5.6	1.5

* See "Materials and Methods" for explanation of codes.

Table 2.4. Semi-detailed approach. Woody cover and related Nb, ‰ N(Nb), and DM(Nb) of herbaceous vegetation as well as Nm, ‰ N(Nm) and DM(Nm) with Ns, ‰ N(Ns), DM(Ns) per soil type in the rangelands of a) Minso, b) Kaniko and c) Fonsebougou.

a) Minso

	Woody cover (SD)	Nb	‰ N (Nb)	DM (Nb)	Nm	‰ N(Nm)	DM(Nm)(SD)	Ns	‰ N(Ns)	DM(Ns)
Soil*	%	kg/ha	g/kg	t/ha	kg/ha	g/kg	t/ha	kg/ha	g/kg	t/ha
PS3	29 (19)	11.7	6.3	1.9	12.8	12.0	1.1 (0.2)	13.8	6.3	2.2
TC7	49 (8)	10.0	6.8	1.5	10.7	10.8	1.0 (0.5)	11.6	6.8	1.7
TC4	31 (5)	11.1	6.8	1.6	6.8	8.5	0.8 (0.5)	7.4	6.8	1.1
TC5	18 (6)	9.8	6.8	1.4	11.4	8.1	1.4 (0.4)	11.4	6.8	1.7

b) Kaniko

	Woody cover (SD)	Nb	‰ N(Nb)	DM(Nb)	Nm	‰ N(Nm)	DM(Nm) (SD)	Ns	‰ N(Ns)	DM(Ns)
Soil	%	kg/ha	g/kg	t/ha	kg/ha	g/kg	t/ha	kg/ha	g/kg	t/ha
PL/TC7	61 (23)	5.6	6.5	0.9	10.9	8.7	1.3 (0.3)	12.4	6.5	1.9
TC6	49 (14)	4.6	6.5	0.7	7.9	7.2	1.1 (0.6)	8.6	6.5	1.5
TC5	49 (11)	6.2	6.5	1.0	9.4	6.7	1.4 (0.4)	9.5	6.5	1.7

c) Fonsebougou

	Woody cover (SD)	Nb	‰ N(Nb)	DM(Nb)	Nm	‰ N(Nm)	DM(Nm) (SD)	Ns	‰ N(Ns)	DM(Ns)
Soil	%	kg/ha	g/kg	t/ha	kg/ha	g/kg	t/ha	kg/ha	g/kg	t/ha
TH	51 (6)	6.6	5.6	1.3	13.6	13.5	1.0 (0.3)	13.6	5.0	2.7
PL	60 (2)	1.5	5.6	0.3	13.8	9.8	1.4 (0.3)	15.8	5.6	2.8
TC6	37 (19)	6.0	5.6	1.1	10.5	10.1	1.0 (0.4)	10.6	5.6	1.9
TC5	45 (24)	6.5	5.6	1.2	15.5	12.5	1.2 (0.6)	15.5	5.6	2.8

* See "Materials and Methods" for explanation of codes.

Table 2.5. Semi-detailed approach. Contribution (in %) of groups of herbaceous species to dry matter production: perennial grasses (PG), annual grasses (AG), legume species (LEG) and other dicotyledonous species (DIC) per soil type* in the rangelands of a) Minso, b) Kaniko and c) Fonsebougou.

a) Minso

Soil	PG	AG	LEG	DIC
PS3	-	73	19	8
TC7	-	72	10	8
TC4	-	86	4	10
TC5	-	92	5	3

b) Kaniko

Soil	PG	AG	LEG	DIC
PL/TC7	5	65	16	14
TC6	-	86	-	14
TC5	-	95	-	5

c) Fonsebougou

Soil	PG	AG	LEG	DIC
TH	14	7	26	53
PL	26	37	19	18
TC6	-	51	16	33
TC5	14	23	23	40

* See "Materials and Methods" for explanation of codes.

Regarding the results of the semi-detailed estimation (Table 2.4.), the *Ns* and *Nb* were reasonably close for most soil types in Minso, whereas in Kaniko and Fonsebougou *Ns* always substantially exceeded the *Nb*. When differences between the *Nb* and the *Ns* values are small - as is the case in Minso- according to the procedure of the semi-detailed approach, the *Nb* values should be used in the evaluation of the rangelands. However the absence of perennial grasses in the herbaceous biomass in Minso (Table 2.5.) suggests a change in species composition compared to figures given by the handbook (Breman and De Ridder 1991, p178). When the differences between the *Nb* and the *Ns* values are large - as in Kaniko and Fonsebougou- the question is whether these differences are caused by chance or are of a more permanent nature. These differences are remarkable, knowing that the *Ns* values are derived from measurements in an area under grazing pressure. It is unlikely that the rainfall of the year of measurements, being low, can explain the much higher *Ns* values in the herbaceous vegetation. Thus it is assumed that the differences are of a more permanent nature and therefore the *Ns* values should be considered as the actual average production. This assumption is supported by the relatively low percentage of perennial grasses in the herbaceous dry matter production (Tables 2.5b., 2.5c.) on all soil types compared to the figures given in the handbook (Breman and De Ridder 1991,p178).

Discussion

Rough and semi-detailed approaches

The primary production in the village of Minso estimated by the rough approach was reasonably close to that determined by the semi-detailed approach. Therefore the method proposed by Breman and De Ridder (1991) seems suitable for this village.

In the villages of Kaniko and Fonsebougou, however, the semi-detailed approach showed always higher woody cover and equal or higher *Ns* than the *Nb* values obtained by the rough approach. Thus the rough approach was not suitable to estimate the present situation in these villages. In relation to the semi-detailed approach it has been concluded that the *Ns* data did not fit the theoretical estimations. Therefore, all calculations based on the theoretical approach become disputable, including the standardization of the measured data. Thus the only reliable production data for these villages are the *Nm* values.

Because the situation in these latter villages may relate to general changes in the Sudanian zone of southern Mali, as argued below, the method is considered not suitable for this region. However, assuming that the rough approach, developed on empirical data of earlier studies, describes the situation in the past, it is suggested to use its results as a reference for vegetation changes.

Primary production

No important recent changes in primary production in Minso were evident. However an increase in primary production in Kaniko and Fonsebougou is indicated when the measured data are compared to those estimated by the rough approach. In all villages changes were larger on arable soils and the importance of perennial grasses decreased.

These changes in the vegetation likely relate to the recently decreased rainfall averages and increased pressure on the rangelands in the region. In Minso changes would be minor as a result of its position at the northern edge of the region.

These assumptions are supported by the literature. Increased woody cover and decreased importance of perennial grasses in similar regions have been attributed to droughts, increased grazing pressure, and reduction in bush fires (e.g. Kelly and Walker 1976, Skarpe 1990). Also clearing of trees, has been shown to cause a higher density of young woody individuals (McIvor and Orr 1991). However this probably caused decreased productivity of the woody cover since this relates to the diameters of the individual trunks (Burrows and Beale 1970). The effect of land clearance would explain the larger changes found on the arable soils. The relatively high *Nm* found on some soils may relate to temporarily increased nutrient availability caused by clearing of trees and/or disappearance of perennial grasses (e.g. Gillard 1979, Knoop and Walker 1985, Winter *et al.* 1989). However the shift from perennial to annual herbs leads to unstable productivity and provokes soil degradation.

Thus, although at first sight the primary production in Kaniko and Fonsebougou appears to be increased, we conclude that the primary production is in a downward trend and that the plant species composition is shifting towards a situation where it becomes less valuable to mankind. Therefore, development of sound management systems of these rangelands is highly important and urgent.

Further research

The changes in the vegetation of rangelands in southern Mali are not sufficiently captured by the theoretical functions proposed by Breman and De Ridder (1991). Although they suggest to adjust the theoretical functions when field observations indicate this to be relevant, this cannot be done objectively. To be able to do so more knowledge would be needed on the effects of human interventions on savanna ecosystems, as mentioned by Frost *et al.* (1986).

The question is whether a rangeland evaluation, which considers distinguishable alternating states of the vegetation (e.g. Ellis and Swift 1988, Westoby *et al.* 1989, Behnke and Scoones 1992), would not be more appropriate than the evaluation of the situation in an average and dry rainfall year.

Chapter 3

Human-induced pressure on the woody vegetation in southern Mali

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Vegetatio (submitted)

3. HUMAN-INDUCED PRESSURE ON THE WOODY VEGETATION IN SOUTHERN MALI

Abstract

Number of species, abundance and cumulative canopy cover of the woody vegetation of rangelands in southern Mali were investigated. The contribution of each species population to abundance and cover was determined. Species were classified according to growth form and value for fruit, timber and/or fuel (TF) and browse production. The study was conducted in three villages which differ slightly in population pressure, climatic, edaphic and land use history.

Fruit species populations' contribution to abundance and canopy cover was relatively high in all villages, that of TF species varied per village and that of browse was relatively low. In general, tree species appeared to fulfill more often several purposes at once than did shrub species.

It is argued that the results reflect the influence of human interventions and therefore the methodology applied may be of interest to the monitoring of man-induced changes in similar vegetations. In such vegetations more intense use of tree species versus shrub species is assumed to favor "bush encroachment".

Introduction

Many products generated by the woody vegetation of natural rangelands in the Sahel countries are used by the local people. Widespread is the use of wood for timber and fuel, browse (twigs,leaves, flowers and fruits) for fodder, and leaves and fruits for human consumption or medicinal purposes (Von Maydell 1983). In view of the growing population these forms of exploitation are likely to reach the point of over-exploitation.

Since the 1970s the increase of pressure on the woody vegetation in southern Mali was accelerated by the loss of rangeland area for cropping and by the increase in livestock numbers (Berthé *et al.* 1991). Analyses of the dynamics of the woody vegetation in the region is complicated by variable rainfall, bush fires, intensive grazing and the prevailing cropping system. All of these affect the productivity of the woody vegetation (Frost *et al.* 1985).

This paper reports on the contribution of each species population to abundance and cumulative canopy cover of the woody vegetation of rangelands in southern Mali. Species were classified on the basis of growth form and usefulness regarding fruit, timber and/or fuel and browse production. Growth form was taken into account because many studies on changes in woody vegetation in similar vegetations refer to the concept of "bush encroachment". The study was carried out in three villages differing slightly in population pressure, climate, edaphic circumstances and land use history.

Materials and Methods

Villages

The villages Minso (13°17'N, 4°35'W), Kaniko (12°18'N, 5°33'W) and Fonsebougou (11°37'N, 6°16'W) are located in Mali in the Sudanian zone. During the last 30 years average rainfall in the area declined by 200 mm and ranges from 700 to 1050mm in a North to South direction. A more detailed description of the village territories and their land use can be found in an earlier paper (Leloup and 't Mannetje, 1994a). The most relevant data are shown in table 3.1.

Table 3.1. Characteristics of the village territories of Minso, Kaniko and Fonsebougou.

Characteristic	Minso	Kaniko	Fonsebougou
Average rainfall (mm)	700	850	1050
Total area (ha)	2703	3250	5882
Human density (number/km^2)	20	36	22
Livestock density (ha/TLU*)	4.6	3.0	7.0
Cultivated area (%)	17	45	12

* tropical livestock unit: 250 kg mature dry zebu kept at maintenance.
Source: Leloup and Traoré, 1989,1991.

These data suggest the highest pressure on natural resources in Kaniko. The productivity of the woody vegetation of the rangelands in these villages was estimated to cover the needs for timber and fuel wood for 86% in Minso, 45% in Kaniko and over 100% in Fonsebougou (Leloup and Traoré 1989, 1991). These estimations were based on figures relating to the productivity of the woody vegetation and timber and fuel needs in the area given by Kessler and Ohler (1983).

In Kaniko an effective control of bush fires during about 5 years prior to this study had been practiced.

Measurements and Calculations

Data collection in Minso took place in September 1989 and in Kaniko and Fonsebougou in September 1987. Several unfenced plots (120 x 5 m) - corresponding to the ones described

Table 3.2. Number of plots per soil type* in the villages.

	Arable				Non arable		
Village	TH	PL	PS3	TC7	TC6	TC4	TC5
Minso	-	-	6	6	-	6	6
Kaniko	-	4	-	-	4	-	6
Fonsebougou	2	3	-	-	4	-	7

* See text for explanation of codes.

in an earlier paper (Leloup and 't Mannetje, 1994a) - were investigated for each soil type (Table 3.2.). The codes of the soil types correspond to those given by PIRT (Anonymous 1983). The hydromorphic plains (TH), the loamy plains (PL), the loamy-sandy plains (PS3) and the plains on laterite carapace (TC7) are considered arable and are in general positioned at the lower end of the slopes. The first three soils are deep while the last one is moderately shallow. The non-arable soils on laterite carapace (TC6, TC4, TC5) are positioned higher up the slope, with the most shallow soil type TC5 at the top ("plateaux"). These soil types are often covered with a layer of gravel.

In each plot, name and class of the diameter of the canopy (0-0.5; 0.5-1; 1-2; 2-5; 5-10, 10-15m) of each woody specimen were recorded. The nomenclature of the species followed Geerling (1982) and for *Bridelia micrantha, Byrsanthus Brownii, Landolphia Heudelotii, Ochna membranancea, Psorospermum glaberrimum*, not present in the former document, Berhaut (1967). The number of species and abundance and cumulative cover of all species and the contribution of each species population were calculated per soil type. From the distribution pattern, arbitrarily three clusters of contribution -high, average and minor- were distinghuised separately for abundance and for cover for each soil type. Species populations were grouped according to their ordination by abundance and cover. Four levels of contribution were distinghuished and defined as follows:

Important: species showing a high or average contribution in abundance and cover.

Average: species showing an average contribution in abundance and cover or an average contribution in one and a low contribution in the other parameter.

Disturbed: species showing a low contribution in one and a high one in the other parameter.

Minor: species showing a low contribution in abundance and cover.

Table 3.3. Classification of species regarding growth form and use for timber and/or fuel (TF), browse and fruit.

Legend:

	Non	TF	Browse	TF and browse	Fruit
Tree	○	◐	◑	●	★
Shrub	□	◩	◪		

Species	Class
Bombax costatum (Bco), Burkea africana (Baf), Cassia sieberana (Csi), Combretum molle (Cmo), Cordyla pinnata (Cpi), Daniellia oliveri (Dol), Detarium microcarpum (Dmi), Entada africana (Eaf), Ficus sur (Fsu), Holarrhena floribunda (Hfl), Isoberlina doka (Ido), Lannea acida (Lac), Pericopsis laxiflora (Pla), Sterculia setigera (Sts), Stereospermum kunthianum (Sku), Terminalia avicennoides (Tav), Terminalia laxiflora (Tla), Terminalia macroptera (Tma), Terminalia glaucescens (Tgl), Vitex doniana (Vdo), Vitex madiensis (Vma), Ziziphus mauritiana (Zma)	○
Diospyros mespiliformis (Dme), Prosopis africana (Paf), Tamarindus indica (Tin)	◐
Cussonia arborea (Car)	◑
Balanites aegyptiaca (Bae), Khaya senegalensis (Kse), Pterocarpus erinaceus (Per)	●
Lannea microcarpa (Lmi), Parkia biglobosa (Pbi), Sclerocarya birrea (Sbi), Vitellaria paradoxa (Vpa)	★
Acacia dudgeoni (Adu), Acacia macrostachya (Ama), Albizzia chevalieri (Ach), Annona senegalensis (Ase), Bridelia ferruginea (Bfe), Bridelia micrantha (Bmi), Byrsanthus Brownii (BBr), Calotropis procera (Cpr), Combretum fragrans (Cfr), Combretum micranthum (Cmi), Combretum nigricans (Cni), Commiphora pedun-culata (Cpe), Crossepteryx febrifuga (Cfe), Dichrostachys cinerea (Dci), Erythrina senegalensis (Ese), Fagara zanthoxyloides (Fza), Gardenia erubescens (Ger), Gardenia sokotensis (Gso), Gardenia ternifolia (Gte), Grewia flavescens (Gfl), Grewia venusta (Gve), Guiera senegalensis (Gse), Hexalobus monopetalus (Hmo), Hymenocardia acida (Hac), Landolphia Heudelotii (LHe), Lannea velutina (Lve), Leptadenia hastata (Lha), Maytenus senegalensis (Mse), Mimosa pigra (Mpi), Ochna membranacea (Ome), Opilia celtidifolia (Oce), Ozoroa insignis (Oin), Pachystela brevipes (Pbr), Pavetta crassipes (Pcr), Piliostigma reticulatum (Pre), Piliostigma thoninghii (Pth), Psorospermum glaberium (Pgl), Psorospermum senegalensis (Pse), Pteleopsis suberosa (Psu), Saba senegalensis (Sse), Sarcocephalus latifolius (Sla), Securinega virosa (Svi), Strophantus sarmentosus (Ssa), Strychnos innocua (Sin), Syzygium guineense (Sgu), Ximenia americana (Xam).	□
Anogeissus leiocarpus (Ale), Combretum glutinosum (Cgl), Dalbergia melanoxylon (Dme), Mitragyna inermis (Min), Pterocarpus lucens (Plu), Securidaca longepedunculata (Slo)	◩
Boscia angustifolia (Ban), Feretia apondanthera (Fap), Grewia bicolor (Gbi), Parinari curatellifolia (Pcu), Strychnos spinosa (Ssp)	◪

Classification of species

Growth form of the species was derived from Geerling (1982) and Berhaut (1967). Only "tree" and "shrub" were distinghuised. The classes "tree or shrub" or "shrub or tree" or "liane" given in the literature were classified in this study as "shrub". Regarding the value of species for the different purposes, only species which seemed highly appreciated were distinghuished as such. Valuation of species for fruit was based on observations and interviews with local people, only those protected in the cultivated fields were considered. For timber-and or fuel wood (TF) the study of Von Maydell (1983) was used and for browse the same studies were used as in an earlier paper (Leloup and 't Mannetje, 1994c) viz. Piot 1969, Boudet 1970, De Leeuw 1979, Toutain 1980, LeHouérou 1980, Von Maydell 1983, Asare *et al.* 1984, Anonymous 1984, Lehouérou 1989, Bayer 1990, Breman and De Ridder 1991. Browse refers to cattle only. The classification of species present in the plots are shown in Table 3.3.

Results

Woody vegetation

In Minso the number of species, the abundance and cover were generally lower than in the other villages (Table 3.4.). In Minso values of all parameters were higher on the arable soils than on the non arable soils whilst in Kaniko and Fonsebougou only abundance was higher on the arable soils. A lower ratio of cover/abundance on arable soils was found in all villages, indicating smaller sized individuals.

Growth form

The contribution of number of "tree" species increased in the order Minso, Kaniko, Fonsebougou (Table 3.5.). In Minso a lower proportion of "trees" was found on the non arable than on the arable soil types. In the same order of the villages the contribution of "tree" species within "important" species increased (Table 3.6.). Both "tree" and "shrub" species were found within the populations which showed a "disturbed" contribution.

Fruit species

The contribution of number of "fruit" species was very low in all villages (Table 3.5.). Nevertheless, only one soil type (TC4 in Minso) did not include any of these species. All other soil types, except PL in Fonsebougou, showed either "important" (*Vpa*) and/or "average" contribution of "fruit" species populations (*Vpa*, *Sbi*, *Lmi*, *Pbi*). The "important" ones were present only in Minso and Kaniko on arable soils. In Minso the category of "fruit" species "disturbed" occurred on most soil types.

TF species

The contribution of number of "TF" species was higher in Minso than in the other villages (Table 3.5.).

"TF" species, "trees" and "shrubs," were present on all soils in all villages (Table 3.6.). Some of these were also classified as "browse trees" (*Pte* and *Kse*). "Important" and/or "average" TF species populations were found on most soils in Minso, except on TC7, and in Fonsebougou, except TH. In Minso it concerned mainly "shrub" populations and in Fonsebougou both a "browse tree" and "shrub" species populations. In Kaniko TF species were ranked as "minor".

Browse

The contribution of number of "browse" species was highest in Minso and lowest in Kaniko (Table 3.5.).

All browse species in Minso and Kaniko were in the category "minor", while in Fonsebougou two species (*Per, Ssp*) showed also higher contributions on several soil types.

Table 3.4. Number of species, abundance and cover of the woody vegetation on different soils* on rangelands in Minso, Kaniko and Fonsebougou.

a) Minso

	Number of species	Abundance (SD)	Cover (SD)
Soil		Number of individuals/ha	m^2/ha
Arable			
PS3	40	2033 (1016)	4348 (2083)
TC7	45	6314 (2299)	7430 (2216)
Non arable			
TC4	21	995 (402)	2882 (1533)
TC5	18	516 (228)	2232 (1166)

b) Kaniko

	Number of species	Abundance (SD)	Cover (SD)
Soil		Number of individuals/ha	m^2/ha
Arable			
PL/TC7	49	15560 (7847)	9746 (2482)
Non arable			
TC6	45	5614 (2416)	9679 (4015)
TC5	53	4382 (1589)	11112 (4398)

c) Fonsebougou

	Number of species	Abundance (SD)	Cover (SD)
Soil		Number of individuals/ha	m^2/ha
Arable			
TH	34	10113 (1516)	10046 (2266)
PL	51	8330 (5764)	8247 (5048)
Non arable			
TC6	62	4565 (2699)	10396 (6148)
TC5	56	5365 (3932)	9213 (6847)

* See 'Materials and Methods' for explanation of codes

Table 3.5. Contribution (in %) to total number of species of those with a "tree" growth form, highly valued for fruit, for timber and/or fuel and for browse on different soils on rangelands in Minso, Kaniko and Fonsebougou.

a) Minso

Soil	Tree	Fruit	Timber/fuel	Browse
Arable				
PS3	40	8	18	8
TC7	39	9	20	15
Non arable				
TC4	29	0	14	10
TC5	22	6	17	6

b) Kaniko

Soil	Tree	Fruit (%)	Timber/fuel	Browse
Arable				
PL/TC7	40	6	10	6
Non arable				
TC6	38	4	9	4
TC5	43	6	11	6

c) Fonsebougou

Soil	Tree	Fruit	Timber/fuel	Browse
Arable				
TH	53	6	9	9
PL	39	4	10	8
Non arable				
TC6	48	5	11	6
TC5	45	5	13	4

Table 3.6. Grouping of species populations regarding their contribution to abundance and cover of the woody vegetation per soil type in a) Minso, b) Kaniko and c) Fonsebougou.

a) Minso

PS3 (arable)	TC7 (arable)	TC4 (non arable)	TC5 (non arable)
Important	**Important**	**Important**	**Important**
Gse 28.6, 18.7 □	Vpa 12.7, 25.9 ★	Cmi 29.6, 26.2 □	Cgl 26.6, 39,4 □
Cfr 11.6, 10.1 □	Tma 18.1, 4.0 ○	Plu 13.1, 32.5 ◩	Plu 10.2, 26.4 □
	Psu 15.8, 2.7 □		
Average	Gse 9.5, 9.0 □	**Average**	**Average**
Cni 13.8, 2.0 □		Gse 18.2, 12.7 □	Cmi 12.9, 4.3 □
Hmo 7.3, 0.3 □	**Average**	Cni 13.1, 9.4 □	Lmi 1.1, 11.0 ★
Cmi 5.0, 5.7 □	Svi 4.7, 8.9 □		
Ama 3.0, 5.2 □	Cfr 4.6, 5.4 □	**Minor**	**Disturbed**
Plu 2.6, 5.9 ◩	Dmi 4.5, 8.3 ○	Ama 7.8, 5.8 □	Cni 24.7, 5.7 □
Vpa 1.8, 6.3 ★	Pre 4.1, 7.7 □	Psu 5.0, 0.1 □	
Bco 0.4, 7.9 ○	Cni 3.9, 1.3 □	Gso 3.9, 1.2 □	**Minor**
Paf 0.3, 7.8 ◐	Sku 3.4, 0.3 ○	Cfr 2.0, 2.6 □	Fap 4.3, 0.6 ◪
	Cmi 1.8, 2.5 □	Gfl 1.4, 0.3 □	Ama 4.3, 2.1 □
Disturbed	Sbi 0.6, 3.3 ★	Mpi 1.4, 2.2 □	Dmi 3.8, 1.4 ○
Sbi 1.1, 14.8 ★		Gbi 0.8, 0.1 ◪	Gve 3.2, 0.4 □
	Disturbed	Pre 0.6, 0.0 □	Gse 2.7, 0.7 □
Minor	Lmi 0.4, 10.1 ★	BBr 0.6, 0.2 □	Dme 1.6, 1.3 ◐
Svi 4.0, 3.1 □		Gve 0.6, 0.2 □	BBr 1.1, 0.1 □
Dmi 2.3, 1.1 ○	**Minor**	Sku 0.3, 0.0 ○	Svi 1.1, 0.0 □
Pre 2.1, 1.9 □	Fap 1.7, 1.0 ◪	Dme 0.3, 0.0 ◐	Cfr 0.5, 1.2 □
Tav 2.1, 2.9 ○	Gve 1.4, 0.7 □	Ban 0.3, 0.9 ◪	Lac 0.5, 5.5 ○
Lmi 2.1, 0.0 ★	Gso 1.3, 0.7 □	Bco 0.3, 0.2 ○	Gfl 0.5, 0.1 □
Bae 1.8, 0.2 ●	Plu 1.3, 0.3 ◩	Ale 0.3, 0.9 ◩	Cpr 0.5, 0.0 □
Fap 1.7, 0.5 ◪	Per 1.1, 0.1 ●	Lac 0.3, 4.3 ○	Tma 0.5, 0.0 ○
Slo 1.4, 0.1 ◩	Cmo 0.9, 0.2 ○	Per 0.3, 0.0 ●	
Cpe 1.1, 0.0 □	Tav 0.9, 0.2 ○		
Gso 0.8, 0.2 □	Ama 0.8, 0.9 □		
Gve 0.8, 0.4 □	Ase 0.7, 0.6 □		
Tma 0.4, 0.0 ○	Hac 0.7, 0.0 □		
Ale 0.4, 0.8 ◩	Gte 0.5, 0.1 □		
Sku 0.4, 0.0 ○	Gbi 0.5, 0.1 ◪		
Gte 0.4, 0.0 □	Slo 0.4, 0.0 ◩		
Mpi 0.3, 0.0 □	Bco 0.4, 0.1 ○		
Gfl 0.3, 0.0 □	Vma 0.4, 0.4 ○		
Gbi 0.3, 0.0 ◪	Pgl 0.4, 0.0 □		
Dci 0.3, 0.1 □	Ach 0.3, 0.1 □		
Dme 0.3, 0.2 ◐	BBr 0.3, 0.3 □		
Cmo 0.3, 0.1 ○	Sin 0.3, 0.0 □		
Zma 0.1, 0.1 ○	Csi 0.2, 0.5 ○		
Mse 0.1, 0.0 □	Pcu 0.2, 0.1 ◪		
BBr 0.1, 0.0 □	Hmo 0.2, 0.1 □		
Ach 0.1, 0.6 □	Ale 0.2, 0.3 ◩		
Sts 0.1, 2.8 ○	Lac 0.1, 0.4 ○		
Hfl 0.1, 0.0 ○	Bae 0.1, 0.1 ●		
Lac 0.1, 0.0 ○	Dme 0.1, 0.1 ◐		
Psu 0.1, 0.0 □	Kse 0.1, 1.7 ●		
	Mpi 0.0, 0.0 □		
	Cfe 0.0, 0.0 □		
	Pbi 0.0, 1.7 ★		
	Ani 0.0, 0.0 ◩		
	Dci 0.0, 0.0 □		

Ranges of clusters distinghuised:

PS3:	Abundance: 28.6, 13.8-11.6, 7.3-0.0.	Cover: 18.7-10.1, 7.9-5.2, 3.1-0.0.
TC7:	Abundance: 18.1-9.5, 4.7-3.4, 1.8-0.0.	Cover: 25.9, 10.1-2.5, 1.7-0.0
TC4:	Abundance: 29.6, 18.2-13.1, 7.8-0.3.	Cover: 32.5-26.2, 12.7-9.4, 5.8-0.0.
TC5:	Abundance: 26.3-24.7, 12.9-10.2, 4.3-0.5.	Cover: 39.4-26.4, 11.0, 5.7-0.0.

Table 3.6. b) Kaniko

PL (arable)	TC6 (non arable)	TC5 (non arable)
Important	**Important**	**Important**
Tav 31.4, 10.3 ○	Dmi 27.7, 19.0 ○	Dmi 30.8, 12.8 ○
Gse 17.8, 23.8 □	Gse 10.4, 7.5 □	
Psu 10.6, 2.4 □	Tma 6.1, 10.0 ○	**Average**
Vpa 5.8, 17.2 ★	Ama 5.0, 11.8 □	Dol 6.3, 3.5 ○
Tma 5.3, 8.4 ○		Cmo 4.3, 5.3 ○
	Average	Ama 3.9, 6.7 □
Average	Tva 7.2, 3.4 ○	Psu 6.9, 0.7 □
Ase 4.6, 3.0 □	Cfr 5.5, 8.3 □	Ase 4.7, 2.8 □
Dci 3.3, 4.9 □	Ase 3.6, 2.5 □	Cmi 4.1, 2.0 □
Ama 2.1, 1.8 □	Cmo 3.3, 2.9 ○	Cfr 2.5, 3.7 □
Cfr 1.8, 2.1 □	Xam 3.3, 2.7 □	Eaf 2.4, 6.1 ○
Svi 1.8, 4.2 □	Vpa 3.0, 3.0 ★	Pla 1.9, 8.2 ○
Dmi 1.4, 3.1 ○	Lac 1.4, 6.0 ○	Lac 1.2, 4.4 ○
Gve 1.2, 1.6 □	Baf 0.9, 7.3 ○	Pbi 0.1, 3.2 ★
Xam 1.2, 2.1 □	Cmi 0.7, 2.2 □	
Cmo 0.7, 2.6 ○	Eaf 0.6, 3.4 ○	**Disturbed**
Lac 0.5, 3.0 ○		Csi 1.7, 18.8 ○
Sse 0.2, 4.6 □	**Minor**	
	Psu 3.2, 0.5 □	**Minor**
Minor	Tla 3.0, 0.5 ○	Gse 3.1, 1.4 □
Gte 1.9, 0.3 □		Cni 2.9, 0.7 □
Hac 1.3, 0.1 □	Gve 2.3, 1.1 □	Gve 2.6, 1.0 □
Tla 0.7, 0.1 ○	Cni 2.3, 0.5 □	Baf 2.4, 2.7 ○
Bmi 0.6, 0.1 □	Vma 2.2, 0.5 ○	Pse 1.8, 0,6 □
Ome 0.6, 0.0 □	Gte 1.0, 0.9 □	Lve 1.5, 0.9 □
Mse 0.6, 0.8 □	Hac 0.9, 0.0 □	Ssp 1.4, 0.3 ◪
Per 0.5, 0.0 ●	Pse 0.9, 0.6 □	Vpa 1.2, 2.8 ★
Ger 0.4, 0.0 □	Sku 0.6, 0.1 ○	Tav 1.1, 0.7 ○
Vma 0.4, 0.1 ○	Ssp 0.6, 0.3 ◪	Tma 1.0, 1.1 ○
Dol 0.3, 0.2 ○	Per 0.5, 0.2 ●	Gso 1.0, 0.1 □
Pse 0.3, 0.1 □	Hmo 0.4, 0.1 □	Svi 1.0, 0.4 □
Cni 0.3, 0.2 □	Svi 0.4, 0.9 □	Hmo 0.8, 0.3 □
Pre 0.3, 0.4 □	BBr 0.4, 0.1 □	Bbr 0.7, 0.4 □
BBr 0.2, 0.1 □	Pla 0.3, 0.8 ○	Ger 0.6, 0.4 □
Bfe 0.2, 0.1 □	Min 0.3, 0.5 ◩	Pre 0.4, 1.1 □
Sbi 0.2, 0.4 ★	Dol 0.3, 0.4 ○	Cgl 0.4, 1.2 ◩
Sku 0.2, 0.0 ○	Bco 0.2, 0.1 ○	Per 0.4, 0.0 ●
Eaf 0.2, 0.6 ○	Pre 0.2, 0.0 □	Ale 0.4, 0.0 ◩
Dme 0.1, 0.0 ◐	Dci 0.2, 0.5 □	Dme 0.4, 0.0 ◐
Gbi 0.1, 0.1 ◪	Ome 0.1, 0.0 □	Lha 0.4, 0.1 □
Pla 0.1, 0.0 ○	Gbi 0.1, 0.0 ◪	Dci 0.4, 0.3 □
Lve 0.1, 0.0 □	Ale 0.1, 0.0 ◩	Gte 0.3, 0.2 □
Ssp 0.1, 0.0 ◪	Gso 0.1, 0.1 □	Cpi 0.3, 2.6 ○
Min 0.1, 0.2 ◩	Bmi 0.1, 0.2 □	Vma 0.3, 0.2 ○
Pbi 0.1, 0.0 ★	Oin 0.1, 0.1 □	Ido 0.3, 1.1 ○
Baf 0.1, 0.1 ○	Slo 0.1, 0.4 ◩	Cfe 0.3, 0.1 □
Paf 0.1, 0.1 ◐	Lve 0.1, 0.4 □	Pcr 0.2, 0.0 □
Pcr 0.1, 0.0 □	Pbi 0.1, 0.4 ★	Sse 0.2, 0.2 □
Slo 0.0, 0.0 ◩	Ger 0.1, 0.0 □	Pbr 0.2, 0.1 □
Pth 0.0, 0.0 □	Cpi 0.1, 0.0 ○	Gbi 0.1, 0.0 ◪
Zma 0.0, 0.4 ○		Bco 0.1, 0.0 ○
Pbr 0.0, 0.0 □		Lmi 0.1, 0.1 ★
Bco 0.0, 0.0 ○		Paf 0.1, 0.0 ◐
		Ssa 0.1, 0.2 □
		Sts 0.1, 0.2 ○
		Oce 0.1, 0.2 □
		Kse 0.1, 0.0 ●
		Tla 0.1, 0.0 ○
		Ome 0.1, 0.0 □

Ranges of clusters distinguished:

PL:	Abundance 31.4-10.6, 5.8-3.3, 2.1-0.0.	Cover: 23.8-8.4, 4.9-1.6, 0.8-0.0.
TC6:	Abundance 27.7-10.4, 7.2-5.0, 3.6-0.0.	Cover: 19.0-10.0, 8.3-2.2, 1.1-0.0.
TC5:	Abundance 30.8, 6.9-3.9, 3.1-0.0.	Cover: 18-12.8, 8.2-3.2, 2.8-0.0.

Table 3.6. c) Fonsebougou

TH (arable)

Important			
Ger	25.5,	12.1	□
Tla	13.3,	26.4	○
Average			
Cfr	7.8,	2.3	□
Psu	11.5,	1.2	□
Ase	3.5,	2.3	□
Sgu	2.1,	3.8	□
Dmi	1.7,	5.0	○
Vpa	0.3,	3.7	★
Disturbed			
Dol	4.4,	38.3	○
Minor			
Pre	5.6,	0.6	□
Per	5.2,	0.3	●
Dci	5.1,	0.4	□
Pth	4.0,	1.2	□
Tav	2.4,	0.1	○
Svi	1.8,	0.7	□
Car	0.7,	0.0	◕
Min	0.7,	0.0	◩
Lac	0.6,	0.2	○
Fsu	0.6,	0.3	○
Tma	0.6,	0.7	○
Csi	0.5,	0.0	○
Lmi	0.4,	0.0	★
Mse	0.3,	0.0	□
Ido	0.2,	0.0	○
Bco	0.2,	0.0	○
BBr	0.2,	0.2	□
Paf	0.2,	0.0	◕
Lve	0.1,	0.0	□
Baf	0.1,	0.0	○
Gbi	0.1,	0.0	◪
Oce	0.1,	0.0	□
Sku	0.1,	0.0	○
Eaf	0.1,	0.0	○
Bfe	0.1,	0.0	□

PL (arable)

Important			
Tma	18.3,	12.2	○
Ido	14.3,	17.1	○
Psu	25.7,	3.9	□
Average			
Dol	7.2,	5.2	○
Tla	4.7,	1.2	○
Per	3.7,	0.2	●
Ase	3.2,	1.6	□
Bmi	1.7,	4.0	□
Pla	1.2,	3.1	○
Bfe	0.9,	8.1	□
Vdo	0.4,	9.1	○
Csi	0.4,	9.1	○
Gse	0.3,	4.3	□
Cni	0.2,	3.1	□
Oce	0.1,	3.0	□
Minor			
Mse	2.1,	0.3	□
Dmi	1.7,	1.2	○
Vpa	1.7,	1.4	★
Gte	1.5,	0.9	□
Dci	1.1,	0.1	□
Lac	0.9,	0.1	○
Cpi	0.9,	0.8	○
Cfr	0.7,	0.1	□
Eaf	0.7,	1.0	○
Hac	0.7,	1.7	□
Pth	0.7,	0.9	□
Pcr	0.6,	0.3	□
Slo	0.5,	0.1	◩
Car	0.5,	0.1	◕
Vma	0.4,	0.7	○
Cmo	0.3,	0.0	○
Ssp	0.3,	0.2	◪
Bco	0.2,	0.0	○
Svi	0.2,	0.1	□
Sin	0.2,	0.8	□
Pgl	0.2,	0.0	□
Fca	0.2,	0.7	○
Ama	0.2,	0.3	□
Pse	0.1,	0.7	□
Cgl	0.1,	0.0	◩
Pre	0.1,	0.0	□
Min	0.1,	0.1	◩
Paf	0.1,	0.1	◕
Gve	0.1,	0.0	□
Pbi	0.1,	0.6	★
Gso	0.1,	0.0	□
Ese	0.1,	0.0	□
Ome	0.1,	0.1	□
Sla	0.1,	0.6	□
Pcu	0.1,	0.6	◪
Tav	0.1,	0.0	○

TC6 (non arable)

Important			
Per	9.5,	4.5	●
Dmi	8.0,	4.0	○
Cmo	6.9,	3.8	○
Ido	2.8,	9.1	○
Average			
Ale	3.4,	3.5	◩
Eaf	2.6,	3.6	○
Dol	2.3,	2.5	○
Ase	2.0,	2.6	□
Svi	3.1,	2.0	□
Tma	2.6,	1.6	○
Ssp	2.3,	0.6	◪
Vpa	2.0,	0.6	★
Cgl	1.5,	2.9	◩
Lac	1.3,	3.7	○
Dme	0.5,	3.5	◕
Pbi	0.1,	4.0	★
Sts	0.1,	3.9	○
Disturbed			
Psu	13.4,	1.9	□
Cni	6.9,	1.9	□
Tla	4.4,	0.7	○
Pla	1.7,	6.2	○
Pth	1.5,	6.2	□
Lmi	0.4,	9.4	★
Minor			
Bpr	1.7,	0.3	□
Csi	1.6,	1.2	○
Ama	1.5,	0.9	□
Bfe	1.4,	0.1	□
Pse	1.4,	0.5	□
Sku	1.3,	1.0	○
Hac	1.2,	1.3	□
Vma	1.0,	1.9	○
Ger	0.9,	0.7	□
Baf	0.7,	0.5	○
Pcr	0.6,	0.1	□
Lve	0.6,	0.1	□
Adu	0.5,	1.4	□
Bco	0.5,	0.6	○
Min	0.5,	0.0	◩
Mse	0.5,	0.0	□
Gse	0.4,	0.2	□
Gso	0.4,	0.1	□
Car	0.4,	0.1	◕
Dci	0.4,	0.2	□
Cfr	0.4,	0.4	□
Fca	0.3,	0.4	○
Bmi	0.3,	0.4	□
Tav	0.2,	1.4	○
Gbi	0.2,	0.0	◪
Pre	0.2,	0.0	□
Gve	0.2,	0.1	□
Oin	0.1,	0.1	□
Oce	0.1,	1.4	□
Ome	0.1,	0.0	□
Fxa	0.1,	0.0	□
Vdo	0.1,	0.0	○
Paf	0.1,	0.0	◕
Ese	0.1,	0.3	□
Tgl	0.1,	0.0	○
Pgl	0.1,	0.0	□
Sin	0.1,	0.1	□
Kse	0.1,	1.4	●
Cpi	0.1,	0.0	○

TC5 (non arable)

Important			
Dmi	10.0,	5.0	○
Ido	2.6,	8.9	○
Vma	1.7,	6.3	○
Baf	1.6,	7.9	○
Average			
Cgl	2.9,	4.7	□
Eaf	1.2,	4.2	○
Tma	4.7,	1.8	○
Adu	3.8,	2.2	□
Dol	3.6,	2.6	○
Ase	3.5,	2.1	□
Tav	3.2,	0.3	○
Dci	2.9,	3.1	□
Sku	2.3,	0.3	○
Lve	2.1,	2.4	□
Pth	2.0,	1.2	□
Cmo	1.8,	2.9	○
BBr	1.5,	0.5	□
Ssp	1.3,	0.2	◪
Bmi	1.3,	0.6	□
Gte	1.2,	0.6	□
Lac	1.2,	3.5	○
Pla	1.2,	3.5	○
Cni	1.1,	0.5	□
Bco	0.5,	5.7	○
Lmi	0.4,	5.8	★
Disturbed			
Psu	17.4,	2.6	□
Per	14.7,	0.4	●
Minor			
Vpa	0.8,	0.3	★
Pse	0.7,	0.1	□
Pgl	0.6,	0.1	□
Min	0.6,	0.0	◩
Csi	0.6,	1.0	○
Dme	0.5,	1.2	◕
Pbr	0.5,	0.1	□
Tin	0.4,	3.5	◕
Ama	0.4,	2.9	□
Pre	0.4,	0.1	□
Mse	0.3,	0.1	□
Svi	0.3,	0.2	□
Paf	0.3,	0.1	◕
Ale	0.3,	0.0	◩
Cpi	0.2,	3.7	○
Gve	0.2,	0.3	□
Bfe	0.2,	0.0	□
Tla	0.1,	0.3	○
Ome	0.1,	0.0	□
Oce	0.1,	2.3	□
Cfr	0.1,	0.0	□
Sin	0.1,	0.0	□
Gse	0.1,	1.1	□
Cmi	0.1,	3.2	□
Car	0.1,	0.0	◕
Gso	0.0,	0.0	□
LHe	0.0,	1.1	□
Sts	0.0,	0.2	○
Pbi	0.0,	0.0	★

Ranges of clusters distinguished:

TH:	Abundance	25.5, 13.3-7.8, 5.6-0.0.	Cover	38.3-12.1, 5.0-2.3, 1.2-0.0.
PL:	Abundance	25.7-14.3, 7.2-3.2, 2.1-0.1.	Cover	17.2-12.2, 9.1-3.0, 1.7-0.0.
TC6:	Abundance	13.4-4.4, 3.4-2.0, 1.7-0.0.	Cover	9.4-6.2, 4.5-2.5, 2.0-0.0.
TC5:	Abundance	17.4-10.0, 4.7-1.1, 0.8-0.0.	Cover	8.9-6.3, 5.8-4.2, 3.7-0.0.

Discussion

Woody vegetation and growth form

In Minso the lower number of species, abundance and cover of the woody vegetation as a whole, and of "tree" species populations in particular, correspond with a lower average rainfall and lower water holding capacity of the sandier soils.

Similar levels of productivity were indicated in Kaniko and Fonsebougou, whereas higher values were expected in Fonsebougou because of better rainfall. Although the soils in Kaniko may induce higher water availability, it is assumed that human interventions increased woody canopy cover in both villages but strongest in Kaniko (Leloup and 't Mannetje, 1994a).

A younger woody vegetation on arable soils was indicated by the lower cover per individual in all villages. Their status of fallow land seems to explain this. In Kaniko lowest cover per individual coincided with shortest fallow periods as indicated by a high ratio of cultivated area and arable land. A difference in species composition may be involved as well.

Fruit species

Protection of adult fruit trees on cultivated fields, probably explains their relatively important position within the woody vegetation, in particular on arable soils. The greater importance of fruit trees in the northern villages may be because of the increased risks of crop failure which make fruits a welcome additional source of income, as mentioned by van de Poel *et al.* (1992). The relatively high contribution of the *Vitellaria paradoxa* (*Vpa*) population may be attributable to its widespread use for oil and soap processing (De Beij, 1982). The placing of some fruit species populations in the category "disturbed", showing a high cover/abundance ratio, suggests that regeneration of these populations may be insufficient.

TF-species

The relatively high number of TF-species in Minso does not agree with the assumption of over-exploitation in this village. The important contribution of TF species on the non arable soils in this village supports the perception of the local people who denied the existence of a fuel wood problem. The difference of their opinion with scientific estimations was assumed to reflect a difference between a short and a long term view (de Poel *et al.* 1992). More precise studies are needed for accurate estimations of the situation at village level. Foley (1987) also assumed exaggeration of the fuel wood problem around some villages in the Sahel. However the assumed much greater shortage of timber and fuel in Kaniko is supported by the minor contribution of all "TF" species. In Fonsebougou some important "TF" species were present which agrees with an expected absence of over-exploitation in the short term.

Browse

The presence of some "important" or "average" browse species in Fonsebougou in contrast to the situation in Minso and Kaniko reflects the differences in cattle density. However browsing pressure is assumed also in Fonsebougou because (not presented) data on the "important" and "average" *Pterocarpus erinaceus* (*Pte*) populations showed a few adult trees and a large number of individuals within the smallest canopy diameter class. Thus a high instability of this species population can be assumed.

Bush encroachment

As "tree" species more often than "shrubs" appeared to fulfill several purposes at the same time, the pressure on "tree" species may be higher. In addition, their architecture makes them very attractive for timber purposes which implies a very rigorous exploitation. When the same species is also browsed or sensitive to fire, regeneration will be poor. "Shrubs" are less interesting to exploit as a whole and probably have better establishment strategies under harsh conditions (Chapin 1980). Thus bush encroachment may be favored not only by heavy grazing (Skarpe 1990), droughts (Skarpe 1986), fire control (Trollope 1980) and fruit dispersal (Brown and Archer 1987), but also by suppression of "tree" species.

Disturbance

Species showing "disturbed" contributions represented both trees and shrubs and were either or not classified as highly useful. Probably other stress factors or intensively used species which have not yet been identified as such may be concerned.

Conclusion

The human interventions in the region seem to direct the composition of the woody vegetation towards a less desirable one. The presence of useful species, suggests a potential to reverse the trends. The approach of this study, which took usefulness, growth form and contribution to abundance and to cover of species populations into account, may be applicable to other studies on human-induced changes in woody vegetations.

A management system should be developed towards a controlled use of the woody vegetation in the region. Important directions of research are:

- Classification of species regarding their use to local people.
- Analyses of the influence of variable rainfall, bush fires and intensive grazing on useful woody species.
- Solving the regeneration problems of fruit tree species.

Chapter 4

Seasonal and relative palatability of browse in southern Mali

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Tropical Grasslands (submitted)

4. SEASONAL AND RELATIVE PALATABILITY OF BROWSE IN SOUTHERN MALI

Abstract

Monthly relative dry matter yield, and dry matter-, N-, P-, crude fibre- and ash-concentration of dry matter of browse material of 19 woody species from rangelands in southern Mali were measured and analyzed in search of factors directing seasonal and relative palatability.

Both seasonal and relative palatability were positively related to high N- and P-concentrations of the dry matter of available browse. Species with highest N- and P-concentrations during the late dry season, generally had a lower relative dry matter yield during this period. These species were less dominant in the region which may be due to a high exploitation pressure. No relation was found between palatability and the other studied parameters.

More systematic research on the nutritive value during late dry season of the species constituting different woody communities, seems of interest to the evaluation of rangelands in semi-arid and subhumid regions. Simultaneously species of interest for cultivation and/or for protection could be discovered from this kind of studies. Deciduousness of the woody species may be an indicator in the monitoring of rangeland condition. Some suggestions relating to the management of browse material are expressed in this paper.

Introduction

Browse consumption by cattle in the arid to subhumid climates can reach substantial levels (Rose-Innes and Mabey 1964, Van Raay and De Leeuw 1974, Rees 1974, Leloup *et al.* 1994). In southern Mali a contribution of browse of up to 54 % of the total diet was recorded during the late dry season (Leloup *et al.* 1994). High expectations of this fodder resource have been expressed because of its relatively high protein concentration year round (Gray 1970) and in particular during the late dry season compared to that of herbaceous fodder (Brinckman and De Leeuw 1979, Walker 1980, Bamualim *et al.* 1982). However evaluation of its exact nutritive value has been problematic to date due to a not fully understood influence of anti-nutritional parameters (Wilson 1969, Harrington and Wilson 1980).

The seasonality of browse consumption by cattle raises the question whether, apart from a declining quality and availability of herbs (Connor *et al.* 1963), a change in the quality of browse may be involved. This seems likely because the period of browsing coincides with the flush of new leaves (De Leeuw, 1979). Although generally browse has lower or similar quality during the dry season compared to the rainy season (Bamualim *et al.* 1982, Skarpe and Bergström 1986), monthly measurements of browse quality in North America (Blair and Epps 1969, Blair *et al.* 1980) showed the highest protein, ash, and phosphorus concentrations, lowest crude fibre concentration and the highest digestibility during the early growing season.

Controversial data are found in the literature on the relative palatability of woody species, partly as a result of its dependence on the surrounding woody and herbaceous components and other factors acting on the relative availability during the year (De Leeuw 1979, Walker 1980, Bayer 1990). Palatability also varies with the species of the consumers. It is not possible to determine palatability independent of relative availability and animal species. The literature on palatability reflects both relative nutritive value and availability, as indicated by Bayer (1990). Walker (1980) stated : "Palatability is a complex characteristic and there is no single factor which can be used to assess it. Characteristics which seem to be positively related to it are protein concentration, a high percentage of minerals (especially Na) and moisture content. Negative characteristics include a high crude fibre content and the presence of tannins and aromatic substances".

In this study an attempt was made to identify factors determining seasonal and relative palatability of species within a woody community. Therefore monthly relative dry matter yield and dry matter- N-, P-, crude fibre- and ash concentration of the dry matter of browse were determined of 19 woody species. These species were from different palatability classes and were sampled in a heavily grazed zone in southern Mali.

Materials and Methods

Woody species and palatability

Species were selected from the rangelands of the village of Minso, in the Sudanian zone of southern Mali, with an average annual rainfall of 700 mm. The nomenclature given by Geerling (1982) was followed. A more detailed description of the woody community is given by Leloup and 't Mannetje (1994b). The selected species represent a mix of species differing in palatability. The palatability of the species was derived from published studies pertaining to the West African Sahel zone, Sudanian zone and the Guineene zone. The reports from each study were translated into four palatability classes (* highly , + average, ^ limited, - non) and the data regarding the selected species were tabulated. The palatability of sampled species of which no data were found in the literature, were just estimated from our own observations (Leloup *et al.* 1994). Finally the species were grouped into three palatability classes (*, +, ^) as derived from all studies together (Table 4.1.). Only the studies of

Table 4.1. Code and classification of sampled species in four and three classes of palatability (highly *, average +, limited ^, non -) per literature source and as summarised in regard of this study (total) respectively.

Species	Code	Piot 1969	Boudet 1970	De Leeuw 1979	Toutain 1980	LeHouerou 1980	Von Maydell 1983	Asare et al. 1984	KEW 1984	Le Houérou 1989	Bayer 1990	Breman and De Ridder 1991	TOTAL
Pterocarpus erinaceus	Per		+	+	*	*	*				*	*	*
Feretia apodanthera	Fap		+	*	*	+	*		*	*		*	
Sclerocarya birrea	Sbi				+	+	^		+			+	+
Bombax costatum	Bco		+		+	^						+	
Piliostigma reticulatum	Pre		+		^	+	*					+	
Anogeissus leiocarpus	Ale			+	^	^	*				+	+	
Combretum fragrans	Cfr			+				-			^	+	
Guiera senegalensis	Gse		+		+	^	^		+			+	
Terminalia avicennoides	Tav			+		^	^	*			+	+	
Securinega virosa	Svi					^	^				+		
Acacia macrostachya	Ama												
Pterocarpus lucens	Plu		+			*	*		^	*		*	
Detarium microcarpum	Dmi			-		^						^	^
Combretum glutinosum	Cgl					-	^			-		-	
Combretum micranthum	Cmi					-	^			-		+	
Combretum nigricans	Cni					-				-		-	
Terminalia macroptera	Tma	^				^							
Lannea microcarpa	Lmi												
Pteleopsis suberosa	Psu												

De Leeuw 1979, Asare *et al.* 1984, and Bayer 1990 based their classification purely on their own investigations.

Data collection and calculations

During the period of September 1988 until May 1990, each month, except for October 1988, for each species a number of twigs (between species varying from 5 to 30) of a particular diameter (5 to 10 mm) was sampled and all green parts (twigs, leaves, fruits) were collected, weighed and air dried according to the method used by Cissé (1986). This material, whether browsed or not has been called "browse" throughout this paper. From these data the relative dry matter yield and the dry matter concentration of each species were calculated, while subsamples were analyzed in the laboratory for N-, P-, crude fibre- and ash concentration. Relative dry matter yield was defined as the percentage of the highest dry matter yield measured during the study period. N- and P- concentrations were determined from the extracts from Kjeldahl digestion, using titration and spectrophotometry respectively, crude fibre from the residue after reaction of a triacid concentrate solution at boiling point for 30 minutes and ash from the residue in the oven at 600°C. For each parameter the mean, the minimum and the maximum value per month of all species together were calculated. For each parameter the average value during the observed browse consumption period, April-June 1989, was calculated for each species and the results were graphed with the species ranked in order of decreasing value of the parameter. The browse consumption period was identified from the study of Leloup *et al.* (1994).

Rainfall during the study period was recorded by gauges placed in the village territories.

Results

Relative dry matter yield

The relative mean, maximum and minimum dry matter yield of browse of all woody species (Figure 4.1a.) showed a strong seasonality with highest values during the rainy season and lowest values in mid dry season. The period of browse consumption coincided with a strong increase of relative dry matter yield, starting just before the first rains (Figure 4.1g.). Most of the "more palatable" species (* or +) showed low relative dry matter yields during this

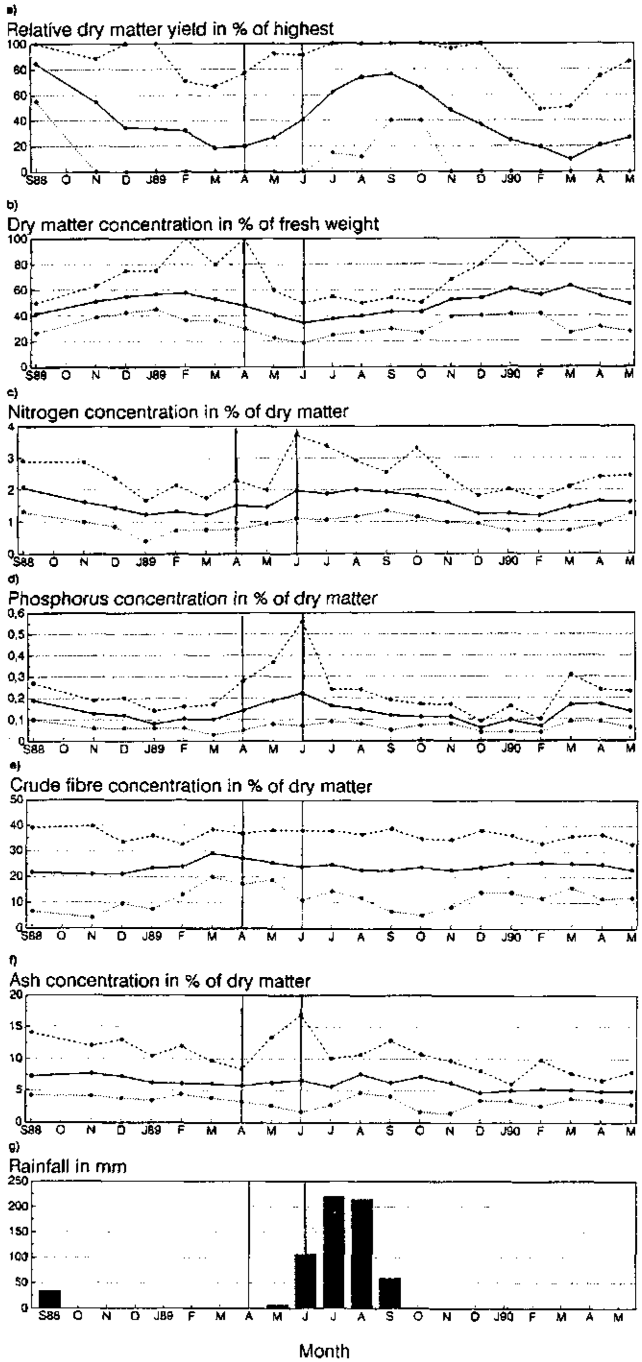

Figure 4.1. Mean, minumum and maximum values of the different parameters of the species and rainfall between September 1988 and May 1990. The main browsing period is indicated by the vertical lines.

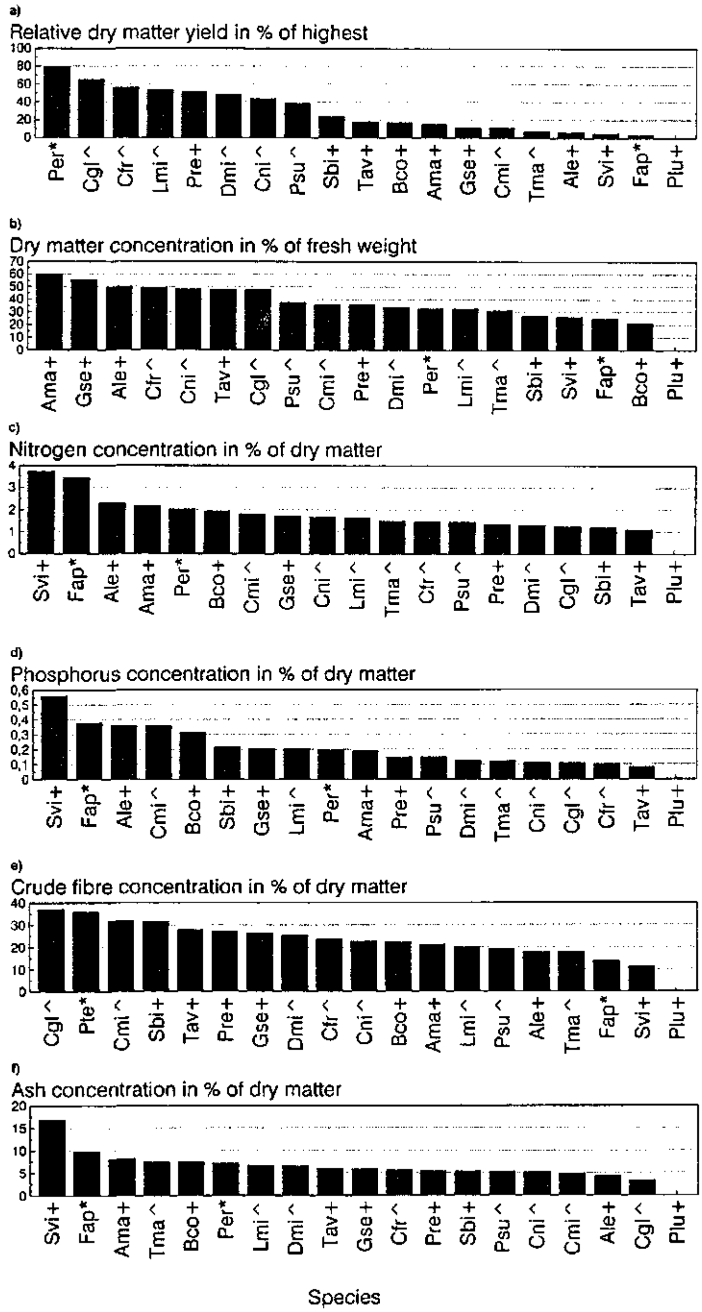

Figure 4.2. Mean values of the different parameters per species, between April and June 1989. For species codes see Table 4.1. Palatability classes: * high, + average, ^ limited.

period (Figure 4.2a.). A notable exception was Pterocarpus erinaceus (*Per*), marked as highly palatable, which had the highest value of all species. *Pterocarpus lucens* (*Plu*), ranked as palatable, showed no browse production at all during the browse consumption period.

Dry matter concentration

Seasonality was found also for the dry matter content of browse (Figure 4.1b.), showing increasing values during the first part of the dry season and lowest values at the end of the dry season. Intermediate values were found during the rainy season. The browsing period corresponded with the period of decreasing and lowest dry matter concentration. During this period the "more palatable" species were evenly distributed over the whole range of measured dry matter concentration (Figure 4.2b.).

Nitrogen and phosphorus concentration

The mean values of N- and P- concentration again showed seasonality with lower values during the dry season and higher values during the rainy season. The highest values can be found at the end of the dry season, when browse consumption is also at its highest (Figure 4.1c., 4.1d.). The species with highest N- and or P- concentration were among the "more palatable" (Figure 4.2c., 4.2d.). The exception was *Terminalia avicennoides* (*Tav*) which although of average palatability had low N- and P- concentrations.

Crude fibre concentration

The crude fibre concentration did not vary during the year except for the minimum values (Figure 4.1e.). The latter showed higher values during the second part of the dry season and lowest at the beginning of the dry season. During the browse consumption period, the minimum values were decreasing. The palatable species were distributed over the whole range of measured crude fibre concentration values (Figure 4.2e.).

Ash concentration

The mean ash concentration did not vary during the year. Both the minimum and maximum value showed a more erratic pattern with highest as well as lowest values found during the browse consumption period (Figure 4.1f.). There was no relation between ash concentration and palatability of species (Figure 4.2f.).

Discussion

Palatability

Browse consumption during the latter part of the dry season coincided with the regrowth of young browse, as reflected by a strong increase of relative dry matter yield during this period. This has been recognized by many others (De Leeuw 1979). Compared to the other seasons browse material during this period showed the lowest dry matter and highest N-, P- and ash concentration. This is in agreement with the earlier mentioned research on the seasonality of nutrient quality of deer browse species in North America (Blair and Epps 1969, Blair *et al.* 1980). Ranking of the woody species, in order of decreasing mean values of studied browse parameters during the consumption period indicated that "more palatable" species often showed higher N- and P- concentrations, but did not show a higher ash concentration and or a lower dry matter concentration. Apparently, palatability is positively related to N- and P- concentration, while the role of a relatively high ash and low dry matter concentration can not be excluded. These findings are supported by Walker (1980), who stated that moisture, mineral and protein concentrations may be of importance to palatability. However in contrast to his statement we found no role of crude fibre in palatability. It seems justified to conclude that the seasonality of browse consumption relates, not only to a declining availability and quality of herbage (Conner 1963), but also to a higher absolute nutritive value of browse. Moreover, the N- and P- concentrations of fodder are regarded as the limiting factors to cattle productivity (Brinckman and De Leeuw 1979, Breman and De Ridder 1991). Furthermore a relatively high digestibility of browse during this season was found by others (Blair *et al.* 1980, Leloup *et al.* 1994). Although some authors did express their doubts on the nutritive value of browse in general because of anti-nutritional factors involved (Harrington and Wilson 1980, De Bie 1991) it is hypothesized here that these factors may be of minor importance during the main browsing period coinciding with early regrowth. De Bie's results (1991) showed that the lowest tannin content in browse is found during the early growing season. He also found large differences between species. Apparently, studies on the nutritive value of browse based on the mean of several species together will not reveal the potential nutritive value that browse of some woody species represent.

Trends in the vegetation

The apparent strong differences in nutritive value of different woody species unfortunately may result in relatively high exploitation pressure on these species. The existence of this phenomenon in the region of study is indicated by the relatively high dominance of the "less palatable" species in the region (Leloup and 't Mannetje 1994b). At the same time these species showed higher relative dry matter yield, indicating a trend towards evergreenness, while the "more palatable" species were more deciduous. Chapin (1980) already indicated evergreenness of species -with some reserves regarding conifers- as a response to nutrient stress and mentioned also that evergreen leaves are protected by high concentrations of anti-herbivore defense compounds. Therefore it is suggested that evergreenness or deciduousness of the species constituting a woody community may be a good indicator for rangeland condition.

Exceptions

A more in depth study of the results per species shows some exceptions to the above stated trends and raises new questions. The exceptions probably can be divided into "false exceptions", which relate to confusion about the palatability of the species, and "true exceptions", which relate to particular characteristics of the species. Examples of "false exceptions" are probably *Pterocarpus lucens* (*Plu*) and *Sclerocarya birrea* (*Sbi*). Both are ranked as average or highly palatable to livestock in some studies but only to camels and goats in another study. A true exception seems the highly palatable *Pterocarpus erinaceus* (*Per*) which did show a high N- and P- concentration but also had the highest dry matter production of all species. This explains the lopping of this species in the area by herdsmen, and may unfortunately also explain its low contribution to the productivity of the woody vegetation (Leloup and 't Mannetje 1994b). The status of *Terminalia avicennoidus* (*Tav*) ranked as of average palatability whilst having low N-and P-concentrations remains unclear. From the literature it would appear that either fallen dry leaves (Asare *et al.* 1984) or recently emerged leaves (Von Maydell 1983) are consumed, while in our case live leaves from adult trees were sampled.

Further research

To be able to evaluate more precisely the woody component of rangelands in semi-arid to subhumid regions it is suggested to focus future research on the recognition of woody communities- or transition states of vegetations as defined by Westoby *et al.* (1989) and to estimate relative palatability and nutritive value of the constituting woody species more systematically. The studies should concentrate on the late dry season and consider both abundant and rare species. From these studies species of interest for cultivation or protection may be identified.

Management

Lopping and storing of young material during good rainfall years could be of interest for future stress periods. Some browsing was observed also during the other seasons and certain parts of browse material of particular species seemed highly appreciated by cattle and therefore these could also be useful for similar management strategies. In the area herdsmen were observed making pods from *Acacia macrostachya* (*Ama*) available to their cattle by beating a stick against the shrubs, which resulted in the dropping of dry pods. As mentioned above the cultivation and/or protection of some "more palatable" species seems already of interest.

Chapter 5

Seasonal fodder consumption and liveweight changes of sedentary cattle in southern Mali

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Tropical Grasslands (accepted)

5. SEASONAL FODDER CONSUMPTION AND LIVEWEIGHT CHANGES OF SEDENTARY CATTLE IN SOUTHERN MALI

Abstract

The fodder situation and its influence on sedentary cattle productivity in southern Mali was described and discussed from data on seasonal fodder availability, farmers interventions, fodder consumption and liveweight changes of cattle in three villages.

During the rainy season patterns were similar in all villages and cattle gained weight. Throughout the dry season differences in interventions of farmers related to fodder availability as influenced by climate, land tenure and livestock density. Fodder consumption patterns differed little. During the early dry season, a temporary recovery of decreasing liveweight gains could be attributed to consumption of crop residues while during the late dry season weight losses were less when animals were given water and supplements. Browse consumption then was substantial.

The study indicates the positive influence of crop residues and by-products on live weight changes during the dry season, when quality of available fodder limits cattle productivity.

Introduction

Southern Mali (122.000 km^{2}) is located within the Sudanian zone with rainfall averages ranging from 700 to 13OO mm in a north-south direction. The rainy season -starting earlier and ending later going south- covers the period from about May until October. Production systems in the area are mixed livestock- arable crop systems, varying in degree of integration. As common in the tropics, cattle productivity in the region would be limited by the fodder situation ('t Mannetje 1982, Breman and Traoré 1987). In this paper the influence of the fodder situation on the productivity of sedentary cattle is described and discussed on the basis of data regarding seasonal fodder availability, farmers interventions, fodder consumption and liveweight changes of sedentary cattle from three villages.

Materials and Methods

Villages

The villages studied, Minso (13°17'N, 4°35'W), Kaniko (12°18N, 5°33W) and Fonsebougou (11°37'N, 6°16'W), are located in southern Mali. Due to varying climatic and edaphic conditions, there are differences in land use (Table 5.1.), cropping system (Table 5.2.) and livestock composition (Table 5.3.).

Table 2.1. Characteristics of the village territories of Minso, Kaniko and Fonsebougou.

Characteristic	Minso	Kaniko	Fonsebougou
Average rainfall (mm)	700	850	1050
Total area (ha)	2703	3250	5882
Human density (number/km^2)	20	36	22
Livestock density (ha/TLU[*])	4.6[**]	3.0	7.0
Cultivated area (%)	17	45	12

[*] tropical livestock unit: 250 kg mature dry zebu kept at maintenance.
[**] Including 30% (rainy season) to 50% (dry season) transhumant cattle coming from different places depending on the season.

Source: Leloup and Traoré, 1989,1991.

Table 5.2. Contribution of different crops to total cultivated area and crop yields in Minso, Kaniko and Fonsebougou.

	Minso		Kaniko		Fonsebougou	
	Area	Yield[a]	Area	Yield[b]	Area	Yield[b]
Crop	(%)	(kg/ha)	(%)	(kg/ha)	(%)	(kg/ha)
Sorghum/ Millet	73	770	49	980	43	910
Maize	-	-	9	1480	5	1160
Fonio	7	700	-	-	-	-
Rice	-	-	2	1800	1	1800
Cotton	-	-	27	1150	47	1290
Groundnut	18	650	7	730	3	1010
Cowpea	-	-	6	440	1	250

[a] Measured during 1989 by the agronomy section of the Division de Recherches sur les systemes de production rurale, Volet Fonsebougou.

[b] Average regional values of cereals, cotton and groundnut obtained from litterature (Anonymous 1983) and regional values regarding 1987 of cowpea according to an internal report of the Compagnie Malienne de Developpement des Textiles.

Source: Leloup and Traoré,1989,1991.

Table 5.3. Contribution (in %) of different classes of animals to total tropical livestock units of sedentary livestock present in Minso, Kaniko, and Fonsebougou.

Class of animal	Minso	Kaniko	Fonsebougou
Cattle	64	87	90
Goats	12	3	2
Sheep	13	7	5
Donkeys	7	3	3
Horses	4	-	-

Source: Leloup and Traoré, 1989, 1991.

Supply of draught animals seems to be the primary production goal of sedentary cattle husbandry in the region. Cattle breeds are Zebu in Minso and Kaniko and mainly Méré, a cross breed of Zebu and N'dama,
in Fonsebougou. The latter breed has greater tse-tse fly tolerance.

The study periods in Minso were from August 1988 until May 1990, in Kaniko from April 1987 until March 1988 and in Fonsebougou from February 1987 until January 1988.

Fodder availability

The fodder resources distinghuished were: browse (twigs, leaves and fruits of woody species), herbs, crop residues of moderate quality (residues of cereals and cotton) and crop residues and by-products of good quality[1] (pulse crop foliage, cotton seed cakes). Of each fodder resource the contribution to the amount of fodder available annually was estimated and varying per village the quality of some of these fodder during different months was determined. The quality parameters considered were N-concentration and digestibility of dry matter.

The amount of herbaceous fodder available was measured in Minso in September 1989 and in Kaniko and Fonsebougou in September 1987 (Leloup and 't Mannetje, 1994a). Material for quality measurements was sampled in Minso every second month from

[1]Cereal bran being also an agricultural by-product of high quality was not considered because in this region it was mainly used for poultry.

September 1988 until May 1990 and in Kaniko and Fonsebougou in April, July and September 1987. N concentration was measured (Kjeldahl) while digestibility was estimated from the relation (100 - crude fibre - ash) according to Boudet (1991).

The quantity of browse available was derived from the canopy cover of woody plants (Leloup and 't Mannetje 1994c), while nitrogen concentration was measured on material sampled in Minso every month from September 1988 until May 1990, except October 1988 (Leloup and 't Mannetje 1994b) and in Kaniko and Fonsebougou in April, July, September, and November 1987. Digestibility was measured (van Soest 1982) on samples of different species collected in Fonsebougou and in Kaniko in April (16 samples) and in July 1987 (13 samples).

The amounts of crop residues and by-products annually available were calculated from the cultivated area, the crop yields and the conversion factors from crop yields to crop residues available as fodder. Various unpublished reports and agronomic textbooks give conversion factors of 3 for sorghum (*Sorghum bicolor*)/millet (*Pennisetum americanum*) stover, maize (*Zea mays*) stover and rice (*Oryza sativa*) straw, 3.8 for fonio (*Digitaria exilis*) stover, 0.6 for cotton (*Gossypium hirsutum*) leaves, 1 for groundnut (*Arachis hypogaea*) foliage and 0.4 for cowpea (*Vigna unguiculata*) foliage. For cotton seed cake the quantity purchased was used. N-concentration of crop residues of moderate quality was obtained from a limited number of samples collected during November 1989 in Minso. Digestibility was calculated as for herbaceous fodder.

Farmers interventions

Herding, stabling, supplementation and watering of the animals by the owners were recorded. Also occurrence of storage of crop residues and purchase of cotton seed cake was noted. In each village two observers were stationed to interview cattle owners and to observe their actions during the year.

Fodder consumption

Cattle herds (in Minso 3, in Kaniko 4 to 5, in Fonsebougou 3 to 6), either or not accompanied by a herdsmen, were followed in the field to observe the relative importance of consumption of the different fodder resources during the year. Within a certain month each herd was followed once during a particular morning and during an afternoon. Every ten minutes, two observers estimated the number of animals grazing, while specifying the fodder resources consumed (browse, herbs or crop residues). These observations included the supplementation with crop residues of moderate quality, but did not include the supplementation with crop residues and by-products of high quality, which was irregular and concerned often particular animals. The procedure was carried out in Minso every month from September 1988 until May 1990; in Kaniko during April, May, September and November 1987 and in Fonsebougou during these same months and in July.

Liveweight changes

Every two to three months, the liveweight changes of 1-3 year old animals in Minso (20-54) from August 1988 until April 1990 and in Fonsebougou (10-46) from February 1987 until January 1988 were weighed. For Kaniko the data from May 1987 until March 1988 obtained by Berckmoes (unpublished data) were used.

Results

Fodder availability

There was more fodder[2] from rangelands (herbs and browse) than from crop residues and by- products in all villages (Table 5.4.). In Kaniko the amount of fodder available from crop residues of moderate quality exceeded that of herbaceous origin.

The N concentration and digestibility of the different fodder during several months (Figure 5.1.) suggest:

-highest N levels during all seasons for browse, and higher or about equal values for herbs compared to crop residues of moderate quality during the dry season.

-highest digestibility for herbaceous fodder during the rainy season, for crop residues of moderate quality just after harvest and for browse towards the end of the dry season.

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[2]Browse availability is probably overestimated, the reasons of which are discussed in an earlier paper (Leloup and 't Mannetje, 1994a).

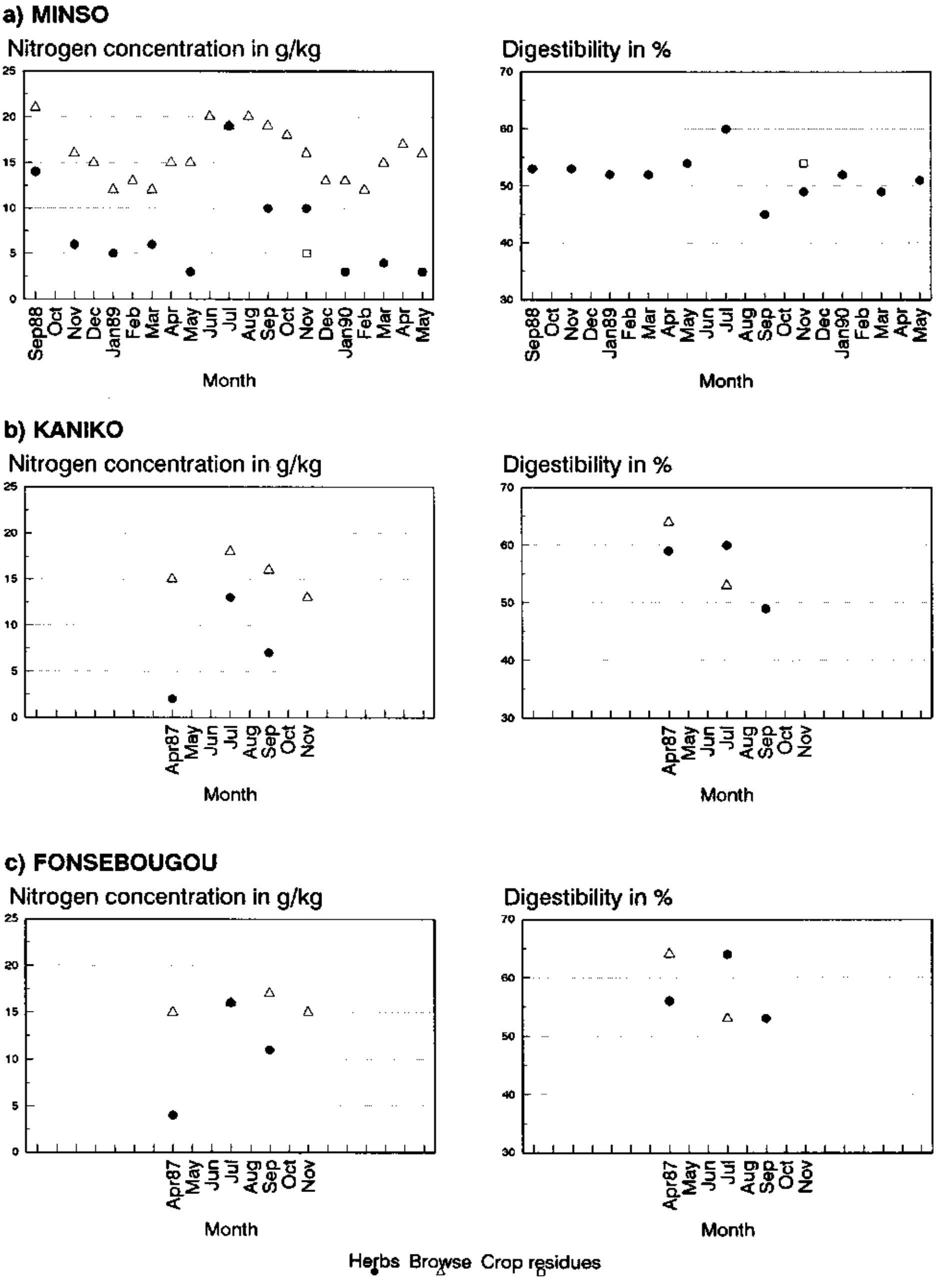

Figure 5.1. Monthly nitrogen concentration and digestibility of DM of herbs, browse and crop residues of moderate quality as far as measured in a) Minso, from September 1988 until May 1990, b) Kaniko, from April 1987 until November 1987, and c) Fonsebougou from April 1987 until November 1987.

Table 5.4. Contribution (in percentages) of the different fodder resources to total available fodder (DM) within the villages' territory of Minso, Kaniko and Fonsebougou.

Fodder resource	Minso	Kaniko	Fonsebougou
Herbs	36	21	28
Browse	50	46	66
Crop residues of moderate quality	12	31	6
Crop residues and by-products of high quality	2	2	+

Farmers interventions

In all villages during the rainy season cattle were herded during the day, stabled during the night and not supplemented or actively watered. Interventions differed between villages from harvest time till the end of the dry season. During the dry season herding and stabling of all cattle continued in Kaniko while this was only the case for less than half the animals in Minso and in Fonsebougou. Storage of crop residues after harvest was common in Minso (pulse crop foliage and cereal residues) and in Kaniko (pulse crop foliage) while this was rare in Fonsebougou. Towards the end of the dry season water was given once or twice a day to all animals in both Kaniko and Minso while this was rare in Fonsebougou. Supplementation during this period was given to all animals in Kaniko (pulse crop foliage, cotton seed cake), about half of the animals in Minso (residues of cereals, cotton seed cake) and only draught animals in Fonsebougou (cotton seed cake).

Fodder consumption

In all villages herbaceous material constituted the most important fodder consumed during the rainy season (Figure 5.2.). After the crop harvest in October-November consumption of crop residues of moderate quality was predominant, although in Kaniko herbaceous material still constituted an important proportion of the diet. As the dry season progressed the

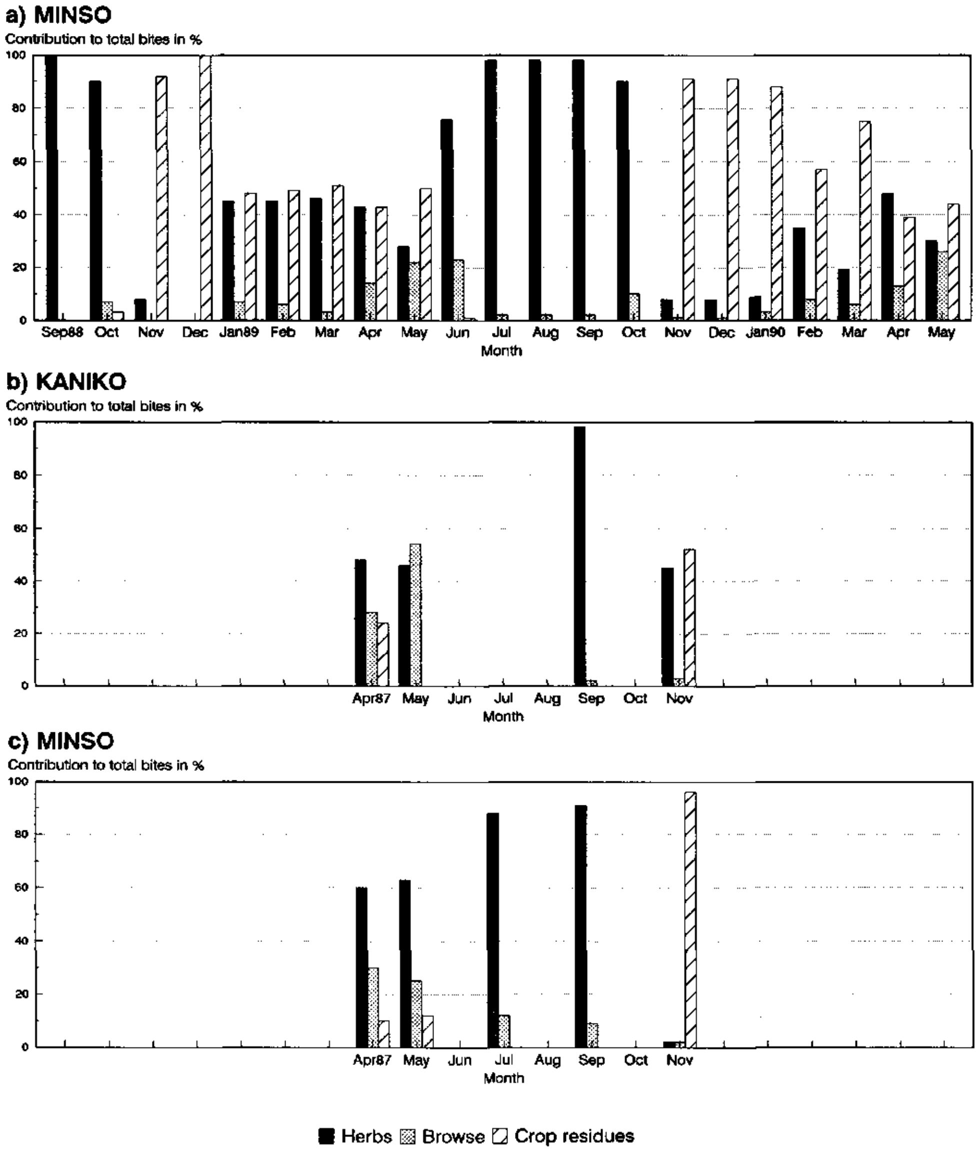

Figure 5.2. Contribution of herbaceous fodder, browse and crop residues of moderate quality to total number of bites as far as recorded in a) Minso, from September 1988 until May 1990, b) Kaniko, from April 1987 until November 1987, and c) Fonsebougou from April 1987 until November 1987.

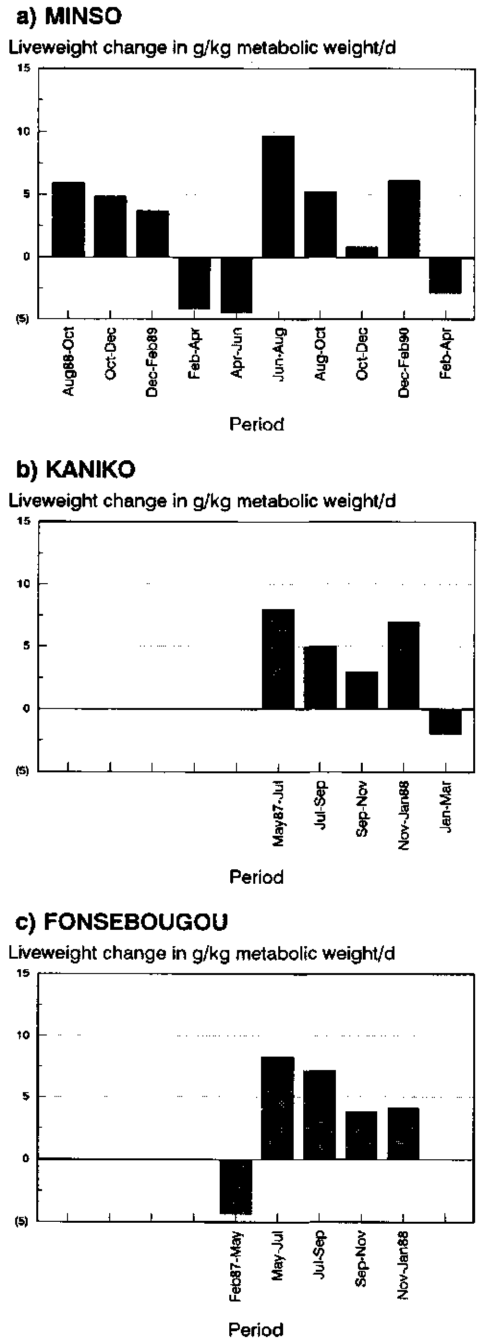

Figure 5.3. Liveweight changes of cattle per period of 2 to 3 months in a) Minso, during August 1988 until April 1990, b) Kaniko, from May 1987 until March 1988, and c) Fonsebougou from February 1987 until January 1988.

importance of crop residues of moderate quality decreased while that of herbaceous and browse increased. This was the only period when browse seemed to be of importance.

Liveweight changes

In all villages cattle liveweight gains were highest in the middle and decreased towards the end of the rainy season (Figure 5.3.). After the crop harvest in October-November liveweight gains stabilized in Fonsebougou, whilst a temporary increase was measured in Minso and Kaniko. However, it was not observed at Minso in 1988. Towards the end of the dry season liveweight losses were recorded in all villages. Standard deviations of the measured mean liveweight changes were high in Minso (range: 2-6 g/kg metabolic weight/d) and in Fonsebougou (range:4-11 g/kg metabolic weight/d), and not known for Kaniko.

Discussion

During the rainy season the aspects studied appeared similar in all villages with green herbage consumption resulting in liveweight gains. Neglect of browse during this period, despite large amounts available and high N-concentration, is commonly reported (Brinckman and De Leeuw 1979), and attributed to low digestibility and or anti-quality parameters (Wilson 1969). Herding and stabling of cattle during this period primarily serves the protection of crops while absence of watering and supplementation relates to sufficient natural supply.

Throughout the dry season differences between the villages regarding farmers interventions were probably caused by differences in climate, land tenure and cattle density. Year round herding and stabling of all cattle only in Kaniko corresponded with highest percentage of area under cultivation and highest cattle density. Access to the fields after crop harvest in this village was arranged between land and cattle owners while in Minso it was free after a certain date and in Fonsebougou it was totally free. In the same order of the villages the feed storage, watering and supplementation of the animals decreased. Absence of feed storage in Fonsebougou may also relate to a higher air humidity and the presence of perennial grasses (Leloup and 't Mannetje 1994a) which make storage less needed and profitable (Peyre de Fabrègues and Dalibard 1990). A similar development of a land access system related to increased pressure on the natural resources was described by Connelly

(1992) for a case in Kenya.

During the early dry season consumption of crop residues seemed to recover decreasing liveweight gains in all villages. Predominant consumption of this fodder during this season was also described by others (e.g. Van Raay and De Leeuw 1971, Quilfen and Milleville 1983). Only when selection of crop residue leaves are taken into account (Powell 1985) does this fodder resource reveal a convincingly higher quality than herbs or browse during this period. That the positive effect of crop residues on cattle liveweight in Fonsebougou was only small, despite high consumption, could be related to health problems of the animals or to lower quality of the crop residues (Thorne and Carlaw 1992). This could also explain the absence of crop residue storage in this village. Browse contribution to the diet during late dry season corresponded with a relatively high quality. The digestibility values of browse were high compared to those reported by Le Houérou (1989) and Breman and De Ridder (1991). During this period all animals showed weight losses which were less when animals received water and supplements.

High standard deviations of liveweight changes throughout the study periods indicate large differences in diet, as well as differences in genetic background of the animals.

This study supports the concept that low quality of available fodder during the dry season represents the nutritional constraint to cattle productivity in the region. During this period consumption of crop residues and by-products positively affected liveweight changes of cattle, therefore further research on its potentials seems promising.

Chapter 6

The effect of crop residues on cattle productivity within agropastoral systems in southern Mali

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6. THE EFFECT OF CROP RESIDUES ON CATTLE PRODUCTIVITY WITHIN AGROPASTORAL SYSTEMS IN SOUTHERN MALI

Abstract

The effect of crop residues on cattle productivity - expressed in terms of liveweight changes and cattle density- was studied in the village of Minso in southern Mali. A comparison of measured and simulated liveweight changes of cattle proved that crop residue consumption is indispensable for animal production. Correspondingly, grazing capacity during the dry season appeared to be limited by crop residue availability. The number of tropical livestock units present in the village during the dry season was only slightly below the estimated grazing capacity. Apparently crop residue availability determines cattle productivity in this village as is likely to be the case in most of southern Mali. Ecological sustainability of the resulting grazing pressure, however, is doubtful.

Rangeland evaluation and rangeland management programs in agropastoral production areas should reflect the integration of livestock and crop systems.

Introduction

An understanding of the influence of fodder availability on cattle productivity in Africa will help to solve problems in rangeland evaluation (Behnke and Scoones 1992). The present paper studies the role of crop residues in annual liveweight changes of cattle and in grazing capacity of available fodder during the dry season in southern Mali.

For the case of a particular village, liveweight change during the year was simulated from the quality of the diet consumed and grazing capacity during the dry season was estimated from the diet composition and the availability of each fodder resource during this period. The results were compared with measured data.

Materials and Methods

Village

The village of Minso (13°17'N, 4°35'W) is located on the northern edge of the Sudanian zone of Mali with an average rainfall of 700 mm and a dry season from about October until May. A more detailed description of the soils and vegetation was given by Leloup and 't Mannetje (1994a).

Of the village territory (Leloup and Traoré 1991) of 2703 ha 17 % is cultivated, 73 % for the production of sorghum (*Sorghum bicolor*) and millet (*Pennisetum americanum*), 18 % for groundnut (*Arachis hypogea*) and 7 % for fonio (*Digitaria exilis*). The natural rangelands are for common use. Although the number of tropical livestock units (TLU) present during the different seasons did not vary much, the origin of the animals did. Up to half the TLU belonged to transhumant herds in both seasons, those present during the rainy season came from near the river Bani in Mali while those present during the dry season came from the dryer north. During the dry season of 1989/1990, 595 TLU were recorded in the village. Of the sedentary livestock 64% TLU consisted of cattle while the rest were small ruminants (25%), donkeys (7%) and horses (4%).

Available fodder

Four fodder resources were distinghuished: browse (twigs, leaves and fruits of woody species), herbs, crop residues of moderate quality (cereal straw) and crop residues and by-products of good quality (pulse crop foliage, cotton seed cakes). The use of crop residues and by-products of good quality was ignored because they are not used to any extent as feed for cattle. The availability of the different fodder during the dry season was obtained from the study of Leloup *et al.* (1994). They based fodder availability of herbs (1.0 t/ha) and browse (1.3 t/ha) on measurements of September 1989 and on total rangeland area. An estimate of the supply of crop residues was based on cultivated area, crop yields in 1989 (sorghum/millet: 770 kg/ha, fonio: 700 kg/ha) and conversion factors from grain yields to residues (sorghum/millet: 3, fonio: 3.8) as given in unpublished reports and agronomic textbooks. The crop residues were eaten in situ immediately after crop harvest and out of storage later. No corrections were applied for losses during the season (e.g. from bush fires, decomposition, wilting, physical inaccessibility, livestock trampling, termites and locusts, collection for household use). Nor was any correction made for regrowth of browse and herbs after bush fires.

Simulated liveweight changes

Average liveweight changes (LWC) of young cattle were simulated for the two months periods between consecutive weighings of cattle in Minso from August 1988 until April 1990 (Leloup *et al.* 1994). The method of simulation was based on the N concentration and digestibility of DM of the fodder consumed as described by Breman and De Ridder (1991).

The fodder consumed (Figure 6.1.) and its average quality (Figure 6.2.) was derived from Leloup *et al.* (1994). The fodder consumption in August 1988 was not available, but it was assumed to be similar to that in September 1988. The missing data on quality of the fodder, mostly concerning browse and crop residues, were estimated based on data from other villages. When it was clear that simulated data based on average quality of the fodder did not fit the measured data, another simulation was conducted assuming selection for leaves of crop residues. The quality of these leaves was derived from the literature: viz. 9 g N/kg DM (Powell 1985) and a DM digestibility of 53 % (ILCA cited by Diarra and Bosma 1987).

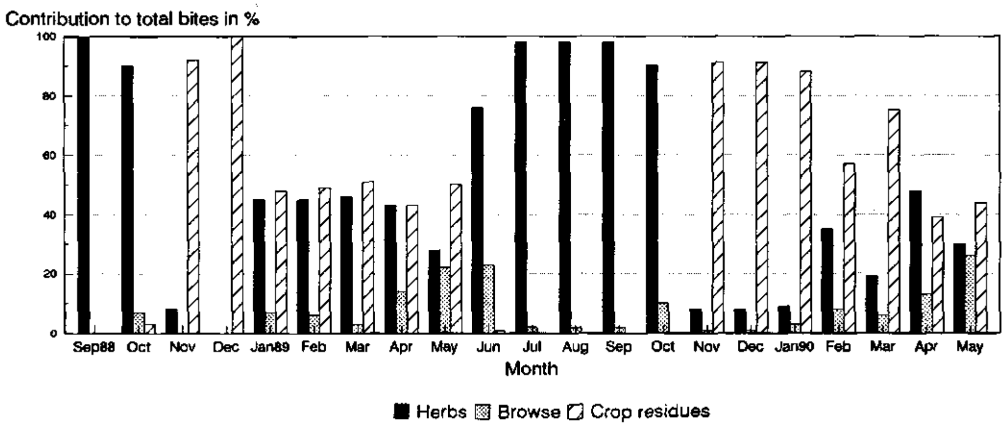

Figure 6.1. Contribution of herbs, browse and crop residues to total number of bites from September 1988 until May 1990 in Minso.

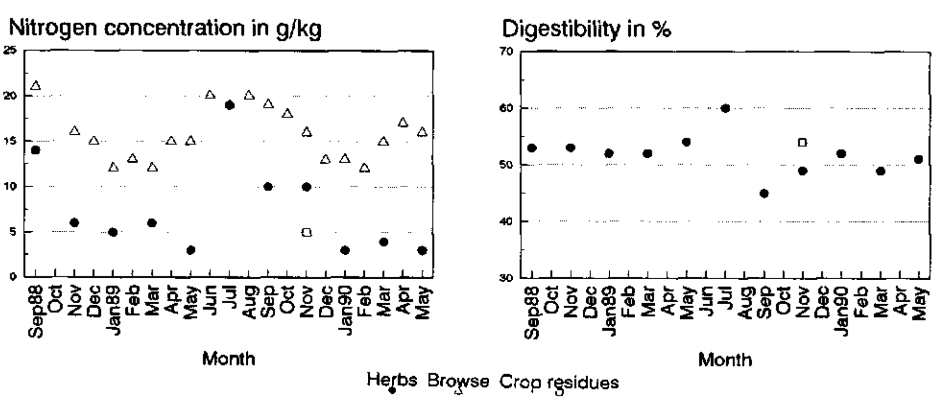

Figure 6.2. Monthly nitrogen concentration and digestibility of DM of herbs, browse and crop residues from September 1988 until May 1990 in Minso.

Grazing capacity

Grazing capacity (cf Zonneveld 1984) of fodder available during the dry season of 1989/1990 in Minso was defined as: the number of TLU that can be fed based upon the diet composition and the amount of fodder available from November 1989 until May 1990 (see above). A consumption of 6.25 kg of DM a day per TLU was assumed (Boudet 1991). From the division of total material available for each fodder resource and the amount of this fodder consumed per TLU, the total number of TLU that can be fed per fodder, according to the observed diet composition, was calculated. Grazing capacity then was equated to the lowest number of TLU that could be fed.

Results

The simulated LWC (Figure 6.3) without taking into account selection for leaves in crop residues corresponded with the measured data only during the rainy season (June-September). For the dry season (October-May) the simulated values were well below those measured, in particular just after crop harvest. Simulation with selection for leaves of crop residues underestimated LWC at the beginning and overestimated LWC at the end of the dry season, but there was a big improvement on the simulated values without selection for leaves.

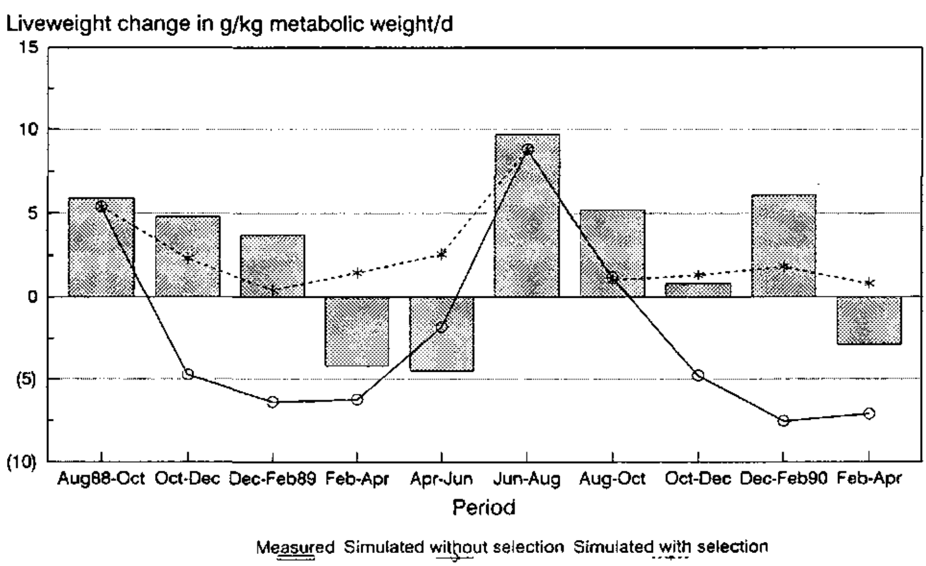

Figure 6.3. Liveweight changes of cattle per period of two months measured and simulated without and with accounting for selection for leaves in crop residues from August 1988 until April 1990 in Minso.

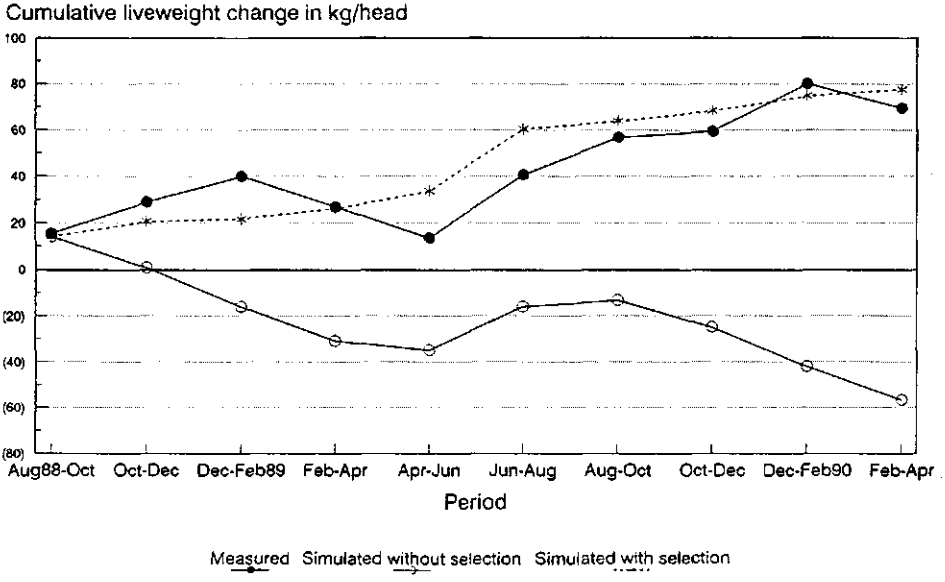

Figure 6.4. Cumulative liveweigh changes of cattle measured and simulated without and with accounting for selection for leaves in crop residues from August 1988 until April 1990 in Minso.

Simulated cumulative LWC over the whole period resulted in a loss of nearly 60 kg/head when selection for leaves of crop residues was not taken into account. When it was, the values were comparable to the measured cumulative LWC (Figure 6.4.).

Relatively there was a very low amount of crop residues available during the dry season, whereas the diet composition consisted for 70 % of crop residues (Table 6.1). The lowest number of TLU could be fed from crop residues and therefore, they determine the grazing capacity during the dry season. This grazing capacity was higher than the observed grazing pressure.

Table 6.1. The total amount available per fodder resource, the diet composition, the maximum number of TLU to feed per fodder resource and the grazing pressure from November until May 1989 in Minso.

Fodder	Availability(tonnes)	Diet (kg/TLU)	Maximum number (TLU)
Herbs	2103	294	7153
Browse	2848	110	25891
Crop residues	720	921	782
Grazing pressure (TLU)			592

Discussion

Crop residues and cattle productivity

The comparison of the simulations and measurements shows the vital importance of selection within crop residues for animal performance. The occurrence of selection for crop residue leaves is supported by other research (Quilfen and Milleville 1983, Powell 1985). The differences between the measured data and the simulations based on selection can be explained by an even more intensive selection of plant parts at the beginning of the dry season and by a limited availability of the leaves in the late dry season. Except for leaves also some grain heads were left in the fields after harvest. Another factor of influence may be a rapid decrease in quality of the crop residues from the beginning until the end of the dry season.

Not surprisingly, the estimated grazing capacity during the dry season appeared to be determined by crop residue availability. Although accuracy of the availability of each fodder resource - on which the grazing capacity estimation was based - can be disputed, the importance of crop residues on grazing capacity was already shown by its influence on LWC: the animals would have died if no crop residues had been consumed. In earlier years the difficulties of the dry periods were probably not as severe because of fewer animals and because of regrowth of the perennial grasses in depressions or as a result of bush fires. However, most of the perennial grasses seem to have disappeared in the area because of land clearing and as a result of drought periods (Leloup and 't Mannetje 1994a). Since there is no strict regulation on the number of animals allowed within the village, the actual LWC and relating grazing capacity nowadays are both functions of crop residue availability and the number of cattle present in the village. This view is supported by the actual number of TLU in the village, which approaches the estimated grazing capacity during the dry season. A lower grazing pressure than grazing capacity was expected because the estimation of grazing capacity did not correct for losses of fodder. In fact the values of grazing pressure and grazing capacity are remarkably close. It is concluded that crop residues limit cattle productivity in this village. This may be the case in most of southern Mali where extensive agropastoral production systems prevail and perennial herbs are decreasing.

Implications and complications

The finding of the importance of crop residues on cattle productivity may explain how a relatively high cattle productivity and apparent degradation of natural rangelands (Scoones 1992) can co-exist. Increasing crop residue availability during the dry season, because of increased cultivated area, enables more animals to survive and thus the pressure on the natural rangeland will increase. Because the fodder situation during the rainy season normally is relatively favorable, it will take some time before the positive influence of crop residue availability on cattle productivity will be overruled by the degrading fodder situation on the rangelands during the rainy season. Finally, the condition of the rangelands during the rainy season may become limiting and force a decrease in animal productivity. In certain areas of Tanzania the development of arable cropping already forced the exodus of cattle to the discontent of the farmers (Van Campen, pers com.). Analogous is the indirect influence of mineral or protein supplements to cattle during the dry season on the condition of rangelands in Australia (Mott 1987, Gardner 1990).

The effect of crop residues on cattle productivity can be used as a management tool. The choice of crop (e.g. cotton, peanut or cereals) and the varieties, with regard to leaf/stalk ratios (Thorne and Carlaw 1992), will be of influence. Also in the case of crop failure a cereal will be of more use to cattle than for example cotton.

As annual LWC is determined by two consecutive fairly unpredictable rainfall seasons, with the dry season limitations to be overcome, it would be wise not to depend merely on crop residues but also to conserve grazing areas on natural rangelands which show relatively early (re)growth. Unfortunately these usually lower lying areas are becoming more often cultivated and the agropastoral production systems are more dependent on the effects of the variable rainfall.

Conflicts between transhumant pastoralists and sedentary livestock owners (Van Driel,

1994) are understandable knowing that many grazing areas have been cultivated and access to crop residues can be restricted by the farmers (Leloup *et al.* 1994, Van Driel 1994).

Chapter 7

General discussion

7. GENERAL DISCUSSION

Declining condition of rangelands

The communal rangelands in southern Mali represent grazing areas, provide fruit, timber and fuel and protect the arable fields against strong run off in cases of torrential rainfall. It is concluded from the present study that the condition of the rangelands with regard to these function has declined during recent decades.

Although the canopy cover of the woody vegetation increased during this period (Chapter 2) the species composition is shifting towards a less desirable one (Chapter 3). The contribution of browse species to the woody vegetation -expressed in terms of cumulative canopy cover and abundance -was relatively low in all three villages, but lowest where grazing pressure was highest. The contribution of timber and/or fuel species was very low where their exploitation was really high and average to high where there was no over-exploitation. Seemingly controversial, a low degree of over-exploitation was associated with a relatively high contribution (see below). Fruit trees had a relatively large contribution to canopy cover and abundance in all villages, as a result of their protection by the local population. Unfortunately, their long term persistence is threatened by a regeneration problem.

Trends towards shrub growth form and evergreenness of the woody vegetation were observed. Less useful species were relatively dominant and more often shrubs than the more useful and less dominant species (Chapter 3), whilst the less palatable browse species tended to be more evergreen than the highly palatable ones (Chapter 4). Shrub growth form and evergreenness are signs of nutrient stress according to Chapin (1980). "Bush encroachment" indicates a decline in the condition of the rangelands as grazing area, as it suppresses the productivity of the herbaceous layer (Knoop and Walker 1985). On the other hand it could favor the production of fuel wood, which seems to be the case in the village where a high contribution of fuel wood species was measured, while a slight over-exploitation was expected. Presently the condition of the rangelands in the region does not clearly show a suppression of the productivity of the herbaceous layer, although symptoms towards this stage were observed. The total biomass of the herbaceous vegetation increased whilst the presence of perennial grasses decreased (Chapter 2). In the long term, this is unfavorable, as it makes the yearly dry matter production instable and consequently increases the risks of soil erosion and run off. Perennial grasses by their regrowth before the start of the rainy season used to reduce the nutritional problems of livestock during the dry season. Thus, the decreasing importance of perennial grasses reduces the value of the rangelands as grazing areas and for the protection of the arable fields.

Influence of cropping system

The condition of the rangelands declined both directly and indirectly as a result of the expansion of the cultivated area.

Directly, the expansion of the cultivated area increased the pressure on the rangelands by reducing its total area. This happened during drought periods and whilst human and animal populations continued to grow. As the cultivated area increased, the proportion of rangelands that has been under cultivation previously has increased as well. On these mostly arable soil types within the rangelands, the earlier sketched increase in canopy cover of the woody vegetation and increase in dry matter yield of annual herbs was most pronounced. The woody vegetation seemed also relatively young on these soil types (Chapter 2). These aspects indicate also a direct influence of the cropping system on the condition of the rangelands.

Indirectly, the cropping system increased the pressure on the rangelands by accelerating the growth of the animal population caused by the introduction of animal traction, the investment in livestock of cash income generated by the cultivation of cotton, in livestock, the reduction of the tse-tse fly infestation as a result of land clearing and finally the availability of crop residues during the dry season (Chapter 5 and 6). The reduced disease problem and the improved fodder situation during the dry season eliminated the constraints to a year-round presence of livestock.

The influence of the availability of crop residues on the grazing capacity during the dry season (Chapter 6), implies different seasonal grazing capacities. During the rainy season the grazing capacity is determined by the herbaceous vegetation and during the dry season by the availability of the crop residues. The co-existence of an increased animal population and the declining condition of the rangelands is caused by a grazing capacity during the dry season which exceeds a sound exploitation of the rangelands during the rainy season (Chapter 6).

Evaluation of rangelands within the agropastoral systems

The condition of rangelands in agropastoral systems should be assessed according to their multiple functions. In general, however, they are evaluated for their use as grazing areas only. For this purpose the concept of "carrying capacity" (CC) has been introduced. However, confusion exists over its exact meaning as there are several definitions and because the methods used to estimate its magnitude vary considerably. FAO (1988) defined CC as the maximum number of stocking of herbivores that rangeland can support on a sustainable basis. De Leeuw and Tothill (1993) suggested that CC estimates should account for a) the proportion of total herbage livestock can harvest, b) forage losses and c) proper use, which is the maximum proportion of forage that can be grazed without rangeland deterioration. By comparing methods used by several researchers they concluded that often one multiplier was used to adjust for all aspects while multipliers varied between researchers within similar regions. An important shortcoming of CC estimates would be that its value can vary strongly in time, and in particular in West Africa, where the herbaceous vegetation is dominated by annual species. To counter this problem, Breman and De Ridder (1991), developed a new method which provides the tools to estimate the primary production in Sahelian countries for an average and a dry rainfall year, based on theoretical functions relating to edaphic and climatic characteristics. Unfortunately, it has been shown that this method was not suitable for the present studies, probably because of recent changes in the vegetation caused by the influence of droughts, a growing human and animal populations and an encroaching cropping system (Chapter 2). Observed trends in the vegetation, not only reflect the impact of grazing and bush fires, for which the method allows corrections, but also that of fruit tree protection, timber and fuel wood collection and fallowing. Questionable is also whether the situation in a theoretical average and/or dry rainfall year would describe the most common and a relatively extreme condition of the vegetation. This approach assumes a succession pattern of the vegetation which would directly relate to the rainfall. This, is unlikely as the state of the vegetation in a particular year will depend on the rainfall characteristics of several preceding years and the management applied. This implies that the vegetation can develop towards different states and that management of the vegetation should react according to the characteristics of the state and to the set management goals (Westoby *et al.* 1989). To be able to do so more knowledge of the vegetation dynamics, the different states and the impact of different management strategies are needed. Such knowledge would make it possible to react adequately to the variable situations in the field. It would also facilitate the evaluation and management of the rangelands with regard to their multiple functions.

Ecological constraints to the agropastoral systems

The increase in cultivated area, combined with droughts and growth of the human and animal populations, did not only deteriorate the condition of the rangelands but also the fertility of the arable soils. For the savannas in West Africa, Pieri (1989) found a decline in water permeability and organic matter content of the arable soils over the last 50 years. Nevertheless, an increase of the yields of cotton and a stabilization of the yields of cereals occurred during this period in Mali (Girdis 1993). This, was possible because newly cleared land was taken into production and better crop growing practices were used. The loss in soil fertility is attributed to the cultivation of marginal soils, a shortening of the fallow periods and an insufficient use of manure and chemical fertilizers. Rapp (1986) illustrated in Tanzania how the cultivation of millet increased soil erosion and water run off. On sandy loam soils on a slope of 3.5°, he found a soil loss due to erosion of zero on grassland and of 78 t/ha on millet fields as well as a run off of 1.9 and 26 % of rainfall on grassland and on millet fields, respectively. The increase in soil erosion and run off varies between crops (Roose 1986) and it is postulated that in southern Mali the growing of cotton and groundnut accelerated the loss of soil fertility as compared to the cultivation of cereals. The main reasons are that cotton and groundnut leave less dry matter in the field after harvest, the dry foliage of both crops is very frail and therefore easily blown away, the harvest of groundnut plants loosens the soil which increases wind erosion (Péhaut 1970) and both crops are more demanding on the timing of sowing in relation to rainfall (e.g. Péhaut 1970), so that crop failures will occur more often and therefore the soils are more often exposed to the forces of sun, wind and water. Thus, nutrients which may be gained by groundnut cropping through nitrogen fixation may be lost again. It is doubtful whether the simulated positive effects on the crop rotation of fertilizer use during cotton growing (Van der Pol 1992) in the long run will counter-balance the increase in soil erosion and run off postulated here. Of importance also to the actual situation in the field is that in southern Mali a decrease in fertilizer use and an increase of area under cotton cultivation was recorded when the ratio of the price of cotton and that of inputs decreased (Berckmoes *et al.* 1990). Of additional negative influence of cotton and groundnut growing on the agropastoral system is that they produce far less fodder material per unit area than do the cereals. Using the crop yields and conversion factors given in Chapter 5, the fodder produced in t DM/ha would be 0.7 to 0.8 of cotton leaves , 0.7 to 1.0 of groundnut foliage, 2.3 to 2.9 of sorghum/millet straw, 2.7 of fonio straw, 3.5 to 4.4 of maize straw and 5.4 of rice straw. During years of crop failure, the cash crops produce only negligible amounts of fodder while undeveloped cereal crops provide relatively good fodder. The importance of this to cattle husbandry is supported by the fact that transhumant pastoralists delay the sowing of cereals in order to produce feed for their animals (Van Driel, pers. comm.). Although the foliage of groundnut constitutes good quality, the higher risks involved and/or small amounts of fodder per ha produced , may explain why until now transhumant pastoralists did not adopt this crop. The catastrophic influences of extensive groundnut cropping on the cattle productivity during severe droughts in Niger was described by Franke and Chasin (1981). Thus, as both cash crops leave less protective material and produce smaller amounts of fodder, they have a lower potential to recycle soil nutrients and to feed domestic animals within the agropastoral systems.

The domestic animals not only constitute an important security in case of crop failure because of erratic rainfall, but they also produce manure for the cropping system. Comparing the number of TLU present in the villages to the estimated number of TLU needed to maintain the fertility of the soils of the cereal fields, it was shown that in Minso the actually number of TLU represented 33 % of the quantity needed, in Kaniko this was 15% and in Fonsebougou 31% (Leloup and Traoré, 1989,1991). These estimates were based on the situation that all animals are stabled for 8 hours during the night year-round. With this assumption 3.5 TLU would be needed to produce 500 kg cereals (Breman, pers. com.).

Thus, on the one hand it was shown that the year-round grazing pressure - increased by the development of the cropping system - leads to a declining condition of the rangelands, whilst on the other hand, more animals would be needed to provide enough manure to maintain the soil fertility of the cultivated soils. This is the essence of the unsustainability of the land use system in this region and a more efficient use of the available natural resources together with an increase of inputs is needed to create a sustainable land use system. This holds for most food production system in Sub-Saharan Africa (Reuler and Prins 1993)

Driving forces behind the over-exploitation

The situation of southern Mali fits the general trend of over-exploitation of tropical savanna ecosystems as highlighted by Young and Solbrig (1993). The compilation of studies presented by these authors indicate many driving forces behind this phenomenon. The most important actors are the growing human population, the commercialization of the agricultural products which are faced with unfavorable international and national pricing policies (Young 1993), underestimated ecological constraints (Solbrig 1993) and land tenure practices which create inequities between the different land users (Scoones *et al.* 1993).

The agropastoral systems in southern Mali experience similar constraints. Cotton (Raymond and Niang 1992), beef (Madden 1993, Wooning 1992) and cereal producers (Delgado *et al.* 1990) all have to compete with subsidized products from other continents, either on the national or on the international market. At the same time, as in most developing countries (Mulder 1993),the national pricing policies rather favor the urban consumers than the rural producers. The land tenure system and the economic situation favor the extension of the cultivated area of which the adverse ecological consequences were mentioned above. By putting no strict limits on the extension of the cultivated area, giving preferential rights to sedentary land owners to use of the crop residues for their own cattle and by the absence of any restriction to invest income earned by the urban and the sedentary rural population in more livestock, social inequity between these groups and the transhumant pastoralists is created which finally leads to further over-exploitation of the natural resources.

Towards a sustainable use of land

Technically, there are many solutions to solve the problems of the agropastoral systems in the region. Rangelands condition can be rehabilitated by the use of fertilizers, the sowing of grasses and/or legumes, the planting and protection of timber, fuel and fruit trees and the implementation of anti-erosion measures. The fertility of the arable soils also could be restored by the use of fertilizer and/or legumes in crop rotation systems. The adoption of many of these techniques, however, found little support from the local people. This is due to the relatively low profits in the short term, the labor requirements, the communal use of the rangelands and the free ranging of cattle (Hijkoop *et al.* 1991, Hoefsloot *et al.* 1993).

To develop sustainable land use systems in southern Mali changes in world trade agreements are indispensable. It is suggested that taking into account the ecological constraints, such changes should enable Mali to export either or both animal and cereal products whilst restricting imports of these commodities either as trade or as food aid. This could also be a remedy against the food problems on the African continent (Meller *et al.* 1992).

Assuming that the macro-economic situation would change as proposed above, the following measures on a national level could be taken to foster the development of more sustainable land use systems. As the variable rainfall characteristics of the climate and the low fertility of the soils have been shown to be the major ecological constraints, any risk of a further decrease in soil fertility and of increased vulnerability of production to erratic rainfall patterns should be avoided. The co-existence of pastoralism and arable cropping are an important adaptation to these ecological limits, which should continue to exist and now that the natural resources have become relatively scarce, a more ecologically efficient integration of both systems is needed.

Unfortunately, it has been shown that the recent developments such as the expansion of the cultivated area and the growing of cotton and groundnut, combined with droughts and the growth of the human and animal populations, not only caused losses of soil fertility of the arable soils, but also in the long run endangers extensive livestock keeping by the decline of the condition of the rangelands. However, aiming at an efficient use of natural resources, the maintenance of extensive livestock systems next to more intensive ones, is important to Mali as a whole. The exploitation of the rangelands in the northern Sahelian zone can only be sustained when the respective herds continue to be able to graze in the Sudanian regions during the dry periods. Although the availability of crop residues is highly important to these animals, it is undesirable for the animal production to become totally dependent on these, because of the possibilities of disasters occurring in the cropping system. Unfavorable rainfall years and damage from locusts or plant diseases are relatively frequent in the region. Early regrowth of browse and perennial herbs on rangelands in good condition would limit the fodder problems during difficult times. Thus it is advisable to put restrictions on the expansion of the cultivated area in favor of the rangelands and to discourage the cultivation of cotton and groundnut. A certain balance should be maintained between the area of rangelands and the area under cultivation. Cultivation should be restricted to the most fertile soils.

The rangelands should be maintained as grazing reserves, producers of timber and fuel wood and protectors of the arable fields against run off. To regenerate the rangelands as grazing reserves, either the grazing pressure would need to be reduced or inputs such as fertilizers and the sowing of grasses and/or legumes should be encouraged. However the feasibility of the use of these inputs on the relatively more unfertile communal rangelands will be low. Thus stocking rates should be reduced and bush fires should be used as a management tool ('t Mannetje 1993). The recently developed year-round high grazing pressure should be changed back to a seasonally different grazing pressures as was normal in the traditional grazing systems in Africa (Lane and Scoones 1993). This could be achieved if sedentary livestock owners were encouraged to reduce their number of animals and to invest in a more intensified cropping system. Once the number of sedentary cattle would be limited, the adoption of fodder legumes combined with fertilizer use in stead of cotton and groundnut in the crop rotation, may become feasible. During the dry season, grazing rights of the crop residues could be sold to the transhumant pastoralists whose herds would manure the fields during grazing. The use of the rangelands as grazing areas would then occur only in case of crops failures. The development of a reliable banking system should also be encouraged to secure the sedentary agriculturist against the effects of crop failure and to limit investment of cash income in livestock by urban and sedentary cattle owners. The regeneration problems of fruit trees within the agropastoral systems should also receive attention. The problem may be caused by cultivation, bush fires or browsing. The establishment and proper management of fruit orchards could be a solution. Expensive protection against browsing should be unnecessary when the sedentary and transhumant population feels committed to the proposed land use system.

Whilst these suggestions are not realistic in present day circumstances, they should be discussed on village, regional and national level to come to the best synthesis of measures to which the local people would feel motivated and committed. Probably the best would be to create a legislative system that authorizes control over the situation on different levels from the village, to the region to the nation (Hesseling 1994).

Such measures together with a social security system to achieve a certain degree of population control and a better education to create awareness, knowledge and motivation would probably the only policies saving Sub-Saharan Africa in the long run.

Further research

Still a great deal of disciplinary and interdisciplinary research needs to be done on these complex issues. The local people should be involved in selecting research topics and priorities. Some suggestions are:

- The development of criteria to balance the area for rangelands and cultivation. Some criteria could be the soil conditions, the area of the remaining rangelands compared to need of timber and fuel wood for the local population, the wish to maintain a certain cattle density in the area year-round and the expected pressure during the dry season by transhumant pastoralists.

- The identification of dry season grazing areas near water resources within the remaining rangelands.
- The identification of different states of the rangelands vegetation according to the approach described by Westoby *et al.* (1989).
- The evaluation of the effects of different management strategies on browse, timber and fuel species and on perennial grasses on the rangelands.
- The analysis of the applicability of the creation of fruit orchards.
- The analysis of the potential of different varieties of cereals with regard to the protection of the soils and to food and fodder production.
- The assessment of the effects on soil fertility and animal production of the introduction of fodder legumes combined with fertilizer use and manure of transhumant livestock within the cereal crop rotation.

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SUMMARY

Multiple use of rangelands within agropastoral systems in southern Mali

The rangelands of southern Mali fulfill several functions. Whilst they constitute important grazing areas, they also provide fruit, timber and fuel wood and protect the cultivated fields against run off. During recent decades the rangelands experienced increased pressure caused by periods of droughts, growth of human and livestock population and an encroaching cropping system. This thesis focused on various aspects of relevance to the condition of the rangelands. The main findings were: 1) that the condition of the rangelands with regard to their multiple functions has declined since recent decades, 2) that animal productivity is increasingly dependent on the cropping system and 3) that the influence of the cropping system on animal productivity leads to the deterioration of the rangelands.

The rangelands around three villages were the objects of study. Field work was carried out between February 1987 and October 1990.

The suitability for southern Mali, of a recently developed method to estimate the primary production of rangelands in Sahelian countries, was investigated (Chapter 2). The method provides mathematical functions to estimate the primary production on the basis of edaphic and climatic parameters. The validity of these functions for the region of study, was tested by comparing measured data with the theoretical estimates. Consistent differences were found. The measured data generally showed a greater canopy of the woody vegetation, higher yields of herbaceous dry matter and lower presence of perennial herbs than did the estimated values. The theoretical functions did not describe the situation in the region adequately. As the differences were more pronounced on the arable soil types and largest in the village where the highest cropping and grazing pressure existed and where the most extensive wood collection took place, the shortcomings of the theoretical functions were attributed to recent disturbance of the vegetation. This would be the result of the droughts and an increased exploitation pressure resulting from the growth of the human and livestock population and the encroaching cropping system. This interpretation is supported by similar trends reported in the literature on the effects of droughts, clearing, grazing and wood cutting in similar regions. Although, the measured increase of the woody canopy and of the herbaceous dry matter yield might be taken as an improvement of the conditions of the rangelands, the opposite is argued to be true. The increase in canopy cover of the woody vegetation is

associated with a shift towards a less useful species composition (Chapter 3) and a shift from perennial herbs to annual herbs means a less favorable fodder situation during the dry season and an increased risk of soil erosion.

To demonstrate the likelihood of such a shift (Chapter 3), each woody species was classified according to growth form, "shrub" or "tree", and usefulness in regard with the production of fruit, timber-and/or fuel wood and browse. Of each species the contribution to total cumulative canopy cover and abundance was determined. The results showed that the contribution in all villages was relatively high for fruit trees, varied for timber-and/or fuel species and was low for browse species. "Trees" fulfilled more often several uses at the same time than did "shrubs". The results corresponded reasonably well with the differences in exploitation pressure between the villages. Although the contribution of the fruit trees was relatively high, more detailed, but not presented data, indicated a regeneration problem of these species, probably caused by cultivation, bush fires and browsing. Taking this into account, it was concluded that the present pressure on the woody vegetation causes a shift in the species composition towards a less desirable one. The methodology developed could be of wider use in similar regions to monitor human-induced changes in the vegetation.

Since browse consumption is important during the late dry season (see next paragraph) and its absolute nutritive value is often questioned, attention was paid to the seasonal and relative palatability of browse species (Chapter 4). Of 19 browse species, differing in palatability, browse yields, dry matter, N-, P- crude fibre- and ash concentrations were measured monthly during the year. The mean, the minimum and the maximum values of all species per month were estimated. The seasonal development of mean values did not show any particular characteristics during the consumption period. However, the maximum values, showed the highest N-, P- and ash concentrations during this period. A closer examination of the results showed that the highest N- and P- concentrations were found in the more palatable species. The N- and P- concentration of the feed are limiting factors to animal production in the region. Therefore, it was concluded that consumption of browse during the late dry season is not only the result of a decreased quality of the available herbs, but also of an increased absolute quality of the browse material during this time of the year. Data in the literature support this view, as the lowest tannin content, an important anti-quality parameter of browse, was measured during this period. As the more palatable species were more deciduous it was suggested to use deciduousness of species as an indicator of rangeland condition.

The importance of the cropping system for animal productivity was shown by observations on seasonal fodder availability and consumption, farmers interventions and liveweight changes of sedentary cattle (Chapter 5). Whilst during the rainy season rangeland herbs constituted the main fodder consumed, this role was taken over by crop residues during the dry season. During the late dry season, browse was also an important fodder resource. Consumption of crop residues during the beginning of the dry season led to a temporarily recovery of decreasing liveweight gains. The attitude of farmers towards the use of crop residues appeared to be related to climate, land tenure and cattle density.

This attitude became understandable when a comparison of measured and simulated liveweight changes showed that crop residues were of vital importance to cattle productivity and even to survival (Chapter 6). In accordance with this, the availability of crop residues was shown to determine the grazing capacity during the dry season. Grazing capacity was defined as the number of tropical livestock units that can be fed, taking into account diet composition and the amount of fodder available during a particular period. This approach was followed to explain the existing grazing pressure. As there may be differences in grazing capacity between the seasons, unlimited expansion of the cultivated area, will result in overgrazing of the rangelands.

It was concluded (Chapter 7) that the conditions of the rangelands, with regard to their multiple functions, has declined during recent decades as a result of droughts, human and animal population growth and an unlimited expansion of the cultivated area. A suggestion is given for the development of a method to evaluate multifunctional rangelands. Simultaneously with the decline of the condition of rangelands, the soil fertility of the arable lands decreased. It is argued that besides the loss in soil fertility due to cultivation in general, this was due also to the growing of cotton and groundnut in particular, in addition to cereals. Compared to cereals, these crops are more prone to the effects of variable rainfall, are less protective to the soils and produce less fodder. Thus, they limit the nutrient cycling and increase the instability of the agropastoral system. As the agropastoral system already experiences a relatively high instability because of variable rainfall, this situation should be redressed. Although the present livestock density already overgrazes the rangelands, estimates showed that if the manure, produced during 8 hours of stabling of all livestock during the night, year-round, were applied to the cereal fields this would still not be sufficient to maintain their fertility. Thus while the present grazing pressure leads to a decline of the condition of rangelands, more animals would be needed to maintain the fertility of the cultivated soil. Thus a more efficient use of the available natural resources together with an increase of inputs is needed to create a sustainable land use system. Besides changes in world trade agreements also changes in national land use planning, social security and education are indispensable to achieve it. A suggestion to an alternative land use system is presented.

RESUME

L'usage multiple de parcours naturels dans les systèmes agropastoraux au Sud du Mali

Les parcours naturels dans le Sud du Mali comportent plusieurs fonctions. Non seulement ils représentent des pâturages importants, mais produisent aussi des fruits, du bois de construction et de chauffage, et en outre ils protègent les champs cultivés contre le ruissellement de l'eau. Pendant les dernières décennies, les parcours naturels ont été l'objet d'une augmentation de la pression causée par des périodes de sécheress, par la croissance démographique et celle du cheptel ainsi que par un envahissement du système agricole. Cette thèse est axée principalement sur les divers aspects concernant la condition des parcours naturels. Les résultats les plus importants sont les suivants: 1) la condition des parcours naturels concernant les multiples fonctions a été détériorée pendant les dernières décennies, 2) la productivité animale dépend du système agricole, ceci de plus en plus, 3) l'influence du système agricole sur la productivité animale mène à la détérioration des parcours naturels.

Les parcous naturels autour de trois villages ont fait l'objet d'études. Les observations en brousse ont été exécutées de février 1987 à octobre 1990.

L'applicabilité pour le Sud du Mali d'une nouvelle méthode quant à l'estimation de la productivité primaire des parcours naturels aux pays sahéliens, a été étudiée (Chapitre 2). Cette méthode donne des équations mathématiques pour l'estimation de la productivité primaire sur la base des paramètre édaphique et climatiques. En ce qui concerne la région d'étude, la validité des équations a été testée par la comparaison des résultats mesurés et des résultats estimés. De différences consistentes ont été constatées. Les résultats mesurés ont montré en général, un recouvrement de la couronne de la végétation ligneuse plus élevé, une plus grande quantité de la matière sèche des herbes ainsi que la présence plus limitée des herbes pérennes que ce qui avait été estime au départ. Les équations théoriques, apparement, ne décrivent pas de manière adéquate la situation dans la région. Les differences étant le plus prononcées sur les sols cultivables et étant plus fortes dans le village avec la plus grande exploitation par l'agriculture, l'élevage et la récolte du bois, les limites des équations ont été attribuées à la pertubation récente de la végétation. Ceci serait le résultat des périodes de sécheresse et d'une augmentation de l'exploitation à cause de la croissance de la population humaine et animale, ainsi que l'envahissement du système agricole. Cette interprétation est soutenue par des tendances comparables décrites dans la littérature au sujet des effets de la

sécheresse, du défrichement, de la pâture et de la coupe de bois dans des régions comparables. Tandis que l'augmentation mesurée de la couronne ligneuse et de la matière sèche des herbes donne l'impression d'une amélioration de la condition des parcours naturels, la réalité a prouvé le contraire. L'augmentation du recouvrement de la couronne de la végétation ligneuse est associée à un changement dans la composition des espèces qui est moins utile (Chapitre 3); un changement des herbes pérennes en herbes annuelles entraîne une situation fourragère moins favorable pendant la saison sèche ainsi qu'une augmentation des risques d'érosion des sols.

Compte tenu de l'existence d'une changement dans les espèces ligneuses (Chapitre 3), les espèces ont été classifiées selon leur apparence comme "arbre" ou "arbuste", et l'utilité concernant la production des fruits, du bois de construction et\ou de chauffe et de broutage. Pour chaque espèce a été déterminé le pourcentage sur le total de la végétation ligneuse du recouvrement cumulatif de la couronne ainsi que l'abondance. Les résultats démontrent que le pourcentage dans les trois villages était relativement élevé pour les arbres fruitiers, variait pour les espèces appréciées pour le bois de construction et\ou de chauffe et était limité pour ce qui est des espèces de broutage. Les "arbres" comportaient plus souvent de multiples usages par rapport aux "arbustes". Les résultats correspondaient raisonnablement avec les différences dans les niveaux d'exploitation entre les villages. Alors que le pourcentage des arbres fruitiers était relativement élevé, des résultats plus détaillés ont signalé un problème de la régéneration de ces espèces, probablement causée par la culture, les feux de brousse et le broutage. Compte tenu de ceci, il a été conclus que le niveau d'exploitation actuel de la végétation ligneuse provoque un changement dans la composition des espèces vers des espèces moins utiles. La méthodologie développée peut etre utile pour des régions comparables pour le suivi des changements dans la végétation causés par les actions humaines.

Comme la consommation du broutage est importante pendant la deuxième partie de la saison sèche (voire la prochaine paragraphe) et que la valeur nutritive a été souvent discutée, on s'est penché davantage sur l'appétibilité saisonnière et relative des espèces de broutage (Chapitre 4). Le rendement, la teneur en matière sèche, en N, en P, en cellulose brute et en cendres ont été mesurés chaque mois pendant une année chez 19 espèces, variant en appétabilité. La valeur moyenne, minimum et maximum des toutes les espèces ont été estimé par mois. L'évolution saisonnière des valeurs moyennes ne montraient pas de caractéristiques particulières pendant la période de consommation. Néanmoins, les valeurs maximum indiquaient des teneurs élevées en N, P et cendres pendant cette période. L'examen plus détaillé des résultats montraient que les teneurs les plus élevées en N et P se trouvaient dans les espèces plus appétibles. La teneur de N et de P dans le fourrage est le facteur limitant la productivité animale dans la région. C'est la raison pour laquelle il a été conclus que la consommation du broutage pendant la deuxième partie de la saison sèche n'est pas seulement liée à la diminution de la qualité des herbes mais aussi à une augmentation de la qualité du broutage pendant cette période. Les résultats dans la littérature appuyaient cette conclusion, parce que le contenu le plus limité du tannin qui est un indicateur important de la qualité inférieure du fourrage, a été mesuré pendant cette période. Comme les espèces plus appétibles étaient celles à feuilles caduques, il a été suggéré d'utiliser ce caractère comme un indicateur de la condition des parcours naturels.

L'importance du système agricole pour la productivité animale a été révelée par des observations sur la disponibilité saisonnière du fourrage, la consommation saisonnière du fourrage, l'intervention saisonnière des paysans et les changements du poids vif des bovins sédentaires (Chapitre 5). Tandis que, pendant la saison pluvieuses, les herbes des parcours naturels constituait le fourrage le plus consommé, ils étaient remplacés par les résidus de récolte pendant la saison sèche. Pendant la deuxième partie de la saison sèche, le broutage constituait aussi une ressource fourragère importante. La consommation de résidus de récolte pendant la première partie de la saison sèche entrainait un rétablissement temporaire d'une diminution de gain de poids. L'attitude des paysans envers l'utilisation des résidus de récolte parait être liée au climat, au droit foncier et à la densité animale.

Cette attitude pouvait se comprendre, lorsqu'une comparaison des changements de poids vif mesurés et estimés avait indiqué que les résidus de récolte étaient d'importance vitale pour la productivité animale, même pur la survie (Chapitre 6). Conformément à cela, on a démontré la disponibilité des résidus de récolte comme le facteur qui détermine la capacité de pâture pendant la saison sèche. La capacité de pâture a été definie tout autant que le nombre des unités du bétail tropical qui peut être nourri en tenant compte de la composition du menu fourrager et de la quantité disponible du fourrage pendant une certaine période. Cette approche a été suivie afin de clarifier le niveau de l'exploitation actuelle. Comme il peut exister des différences entre la capacité de pâture entre les saisons, l'expansion illimitée de la superficie cultivée engendrera une surexploitation des parcours naturels.

Il a été conclus (Chapitre 7) que la condition des parcours naturels, concernant leur multiple fonctions, a été détérioré pendant les derniers décades à cause des périodes de sècheresse, la croissance des population humaine et animale et un expansion illimitée de la superficie cultivée. Une suggestion pour le développement d'une méthode pour l'évaluation de parcours naturels comportant plusieurs fonctions a été donnée. Au fur et à mesure que la condition des parcours naturels se dégradait, la fertilité des sols cultivables diminuait. Il a été argumenté qu'à part le déclin de la fertilité des sols à cause de la culture en général, ceci était dû à la culture du coton et de l'arachide en particulier, en dehors des céréales. Comparées aux céréales, ces cultures sont plus sensibles aux effets de la variabilité de la pluviométrie, sont moins protectrices des sols et produisent moins de fourrage. Donc, elles limitent le cycle des éléments nutritifs et augmentent l'instabilité du système agropastoral. Comme le système agropastoral fait l'objet d'une instabilité relativement élevée à cause de la variabilité de la pluviométrie, cette situation devrait être évitée. Alors que la présente densité du cheptel cause déjà une surexploitation des parcours naturels, des estimations indiquaient que si tout le fumier, produit pendant 8 heures de stabulation des animaux pendant la nuit toute une année, était appliqué aux champs de céréales, cette quantité ne serait pas suffisante pour le maintien de la fertilité des sols. Donc, puisque la présente intensité de pâture entraine un déclin de la condition des parcours naturels, on a besoin de plus d'animaux pour le maintien de la fertilité des sols cultivés. Une utilisation plus efficace des ressources naturelles, ensemble avec une augmentation de l'utilisation des intrants, est nécessaire pour créer un système de l'utilisation durable des terroirs. Outre les changements dans les accords internationaux de la commerce, aussi les changement nationaux concernant la planification de l'utilisation des terroirs, la sécurité sociale et l'éducation seront indispensable pour atteindre le but fixé. Des suggestions portant sur un système de l'utilisation alternatives des terroirs ont été présentée.

SAMENVATTING

Meervoudig gebruik van natuurlijke weiden binnen gemengde bedrijven in zuidelijk Mali

De weidegronden in zuidelijk Mali vervullen verschillende funkties. Behalve dat zij belangrijke graaslanden vertegenwoordigen, leveren zij fruit, constructie- en brandhout en beschermen zij de akkers tegen afstroming. Gedurende de laaste tientallen jaren stonden deze weidegronden onder toenemende druk als gevolg van verscheidene droogte perioden, de bevolkings groei, een groeiende veestapel en een oprukkend akkerbouw systeem. Dit proefschrift behandelt verschillende aspekten die van invloed zijn op de konditie van de weiden. De belangrijkste bevindingen waren: 1) dat de konditie van de weidegronden met betrekking tot hun veelvoudige funkties acheruit is gegaan gedurende de laaste tientallen jaren, 2) dat de dierlijke produktie in toenemende mate afhankelijk is geworden de akkerbouw en 3) dat de invloed van de akkerbouw op de dierlijke produktie de aanleiding is tot de verslechtering van de weidegronden.

De weidegronden in de omgeving van drie dorpen waren het onderwerp van studie. Het veldwerk werd verricht in de period van februari 1987 tot oktober 1990.

Gekeken werd naar de geschiktheid voor zuidelijk Mali, van een recent ontwikkelde methode ter bepaling van de primaire produktie van weidegronden in de Sahellanden (Hoofdstuk 2). De methode geeft wiskundige formules waarmee, op basis van bodem en klimaatsfaktoren, de primaire produktie geschat kan worden. De geldigheid van deze formules voor deze regio, werd getoest door gemeten waarden te vergelijken met theoretisch bepaalde waarden. Er werden consistente verschillen gevonden. Over het algemeen gaven de gemeten waarden een hogere kroonbedekking van de houtige vegetatie, een hogere droge stof opbrengst van de kruidlaag en een lagere aanwezigheid van meerjarige grassen te zien dan de geschatte waarden. De theoretische formules beschreven de situatie in de regio dus niet juist. Omdat de verschillen sterker waren op voor akkerbouw bruikbare gronden en het sterkst in het dorp waar de hoogste druk van gewasproduktie bebouwing en begrazing en ook de meest uitgebreide houtkap plaatsvond, werden de tekortkomingen van de theoretische formules toegeschreven aan een recente verstoring van de vegetatie. Deze zou het gevolg geweest kunnen zijn van droogte perioden en een verhoogde exploitatie druk als gevolg van de bevolkingstoename, een groeiende veestapel en een oprukkend akkerbouw systeem. Deze uitleg wordt ondersteund door gegevens uit de literatuur die vergelijkbare trends in de

vegetatie toeschrijven aan droogte perioden, landontginning, begrazing en houtkap. Hoewel, de gemeten toename in kroonbedekking van de houtige vegetatie en in droge stof opbrengst van de kruidige vegetatie de indruk zouden kunnen wekken dat er een verbetering van de konditie van de weidegronden heeft plaats gevonden, is het tegendeel waar. De toename van de kroonbedekking van de houtige vegetatie is namelijk gepaard gegaan met een verschuiving in de soorten samenstelling die minder waardevol is (Hoofdstuk 3), en een verschuiving van meerjarige naar eenjarige grassoorten betekent een verslechtering van de voeder situatie in de droge tijd en verhoogt mede het risico van bodemerosie.

Op zoek naar een verschuiving in de houtigen soortensamenstelling (Hoofdstuk 3), werden alle soorten geklassificeerd naar groeivorm, "boom " of "struik", en bruikbaarheid met betrekking tot de produktie van vruchten, konstruktie- en brandhout en "browse". Van iedere soort werd de relative deelname aan de totale cumulative kroonbedekking en frequentie bepaald. De resultaten laten zien dat in de dorpen het aandeel relatief hoog was van vruchtbomen, varieerde van konstruktie en/of brandhout soorten, en laag was van "browse" soorten. Bomen werden vaker voor meerdere doeleinden gebruikt dan struiken. De resultaten kwamen redelijk overeen met de verschillen in exploitatie druk tussen de dorpen. Hoewel het aandeel van de vruchtbomen relatief hoog was, geven meer gedetailleerde maar niet gepresenteerde resultaten aan dat deze soorten een regeneratie probleem vertonen, hetgeen waarschijnlijk veroorzaakt wordt door ploegen, bosbranden en "browsing". Dit in beschouwing nemende, werd geconcludeerd dat de huidige druk op de houtige vegetatie een verschuiving naar een minder bruikbare soortensamenstelling veroorzaakt. De gebruikte methode, zou mogelijk ook in vergelijkbare gebieden van nut kunnen zijn om de gevolgen van menselijk ingrijpen aantoonbaar te maken.

Omdat "browse" een belangrijk voederbestanddeel is in het laat droge seizoen (zie volgende alinea) en de absolute voederwaarde vaak betwijfeld wordt, is er aandacht gegeven aan de seizoensafhankelijke en relative smakelijkheid van "browse" soorten (Hoofdstuk 4). Van 19 "browse" soorten, verschillend in smakelijkheid, werden per maand de eetbare opbrengst, droge stof-, N-, P-, ruwe vezel- en de as gehaltes bepaald gedurende het jaar. De gemiddelde, de mimimum en de maximum waarden van all soorten tesamen per maand over deze period werden bestudeerd. De seizoens ontwikkeling van de gemiddelden leverden geen bijzondere waarden op gedurende de "browse" konsumptie periode. Maar, de maximum waarden, lieten in deze periode de hoogste N-, P- en as gehalten zien. Een nadere bestudering van de soorten en de respectievelijke waarde van de gemeten parameters gedurende de "browse" konsumptie periode, lieten zien dat de hoge N- en P- gehaltes voorkwamen bij de smakelijkere soorten. N- en P-gehalten zijn beperkende faktoren voor de dierlijke produktie in de regio. Daarom werd gekonkludeerd dat de "browse" konsumptie in het laat droge seizoen niet alleen het gevolg is van een verlaagde kwaliteit van het kruidenmateriaal, maar ook van een verhoogde voedingswaarde van het "browse" materiaal in deze tijd van het jaar. Gegevens uit de literatuur versterken deze bevinding, omdat ook het laagste tannine gehalte, een anti-kwaliteits faktor, werd gemeten in deze tijd. Omdat de smakelijkere soorten bovendien vaker volledig bladval vertoonden wordt geopperd om deze eigenschap te gebruiken als een indicator ter bepaling van de konditie van weiden.

Het belang van de akkerbouw voor de dierlijke produktie werd gedemonstreerd aan de hand van waarnemingen aan voederbeschikbaarheid en -konsumptie, interventies van boeren en gewichtverandering van sedentair rundvee gedurende de verschillende seizoenen (Hoofdstuk 5). Terwijl in het regenseizoen de kruiden van de weiden de belangrijkste voederbron vormen wordt deze positie in het droge seizoen overgenomen door de gewasresten. In het late droge seizoen, bleek "browse" ook een belangrijke voederbron. Consumptie van gewasresten in het begin van het droge seizoen leidde tot een tijdelijk herstel van verminderende gewichtstoename. De houding van de boeren ten opzichte van het gebruik van de gewasresten bleek verband te houden met het klimaat, landgebruiksrechten en rundveedichtheid.

Deze houding werd begrijpelijk toen een vergelijking van gemeten en gesimuleerde gewichtsveranderingen aantoonden dat gewasresten van vitaal belang zijn voor de dierlijk produktie en zelfs voor overleving van de dieren (Hoofdstuk 6). In overeenstemming hiermee werd aangetoond dat de begrazings- draagkracht in het droge seizoen bepaald werd door de hoeveelheid beschikbare gewasresten. Begrazings-draagkracht werd gedefineerd als het aantal tropisch vee-eenheden dat gevoed kan worden, rekening houdend met het dieet en de hoeveelheid beschikbaar voeder gedurende een bepaalde tijd. Deze benadering werd gekozen om de bestaande begrazingsdruk te kunnen verklaren. Omdat er verschillen kunnen bestaan tussen de begrazingsdraagkracht van verschillende seizoenen, zal een onbeperkte uitbreiding van de akkerbouw uiteindelijk een overbegrazing van de weiden tot gevolg hebben.

Geconcludeerd werd (Hoofdstuk 7) dat de konditie van de weiden, met betrekking tot hun veelvoudige funkties, verslechterde gedurende de laatste tientalle jaren als gevolg van de 9droogte perioden, de bevolkingtoename, de groeiende veestapel en een uitbreiding van akkerbouw areaal. Een suggestie wordt gegeven voor de ontwikkeling van een methode ter waardering van de multifunktionele weiden. Tegelijkertijd met de achteruitgang van de konditie van de weiden, verminderde ook de bodemvruchtbaarheid van de akkers. Er wordt beargumenteerd dat behalve een verlies aan bodemvruchtbaarheid door akkerbouw in het algemeen, dit in het bijzonder te wijten zou zijn aan het telen van katoen en aardnoten naast graan. Deze gewassen zijn gevoeliger voor de effecten van een variabele regenval, beschermen de bodems minder tegen erosie en afstroming en produceren minder voeder. Dus, zij beperken de nutrienten recycling en verhogen de instabiliteit van het agropastorale systeem. Omdat deze agropastorale systemen toch al instabiel zijn als gevolg van de variable regenval, zou deze situatie vermeden moeten worden. Verder laten schattingen zien dat als al de mest die geproduceerd zou worden wanneer het vee iedere nacht 8 uur opgestald zou zijn, de hoeveelheid nog steeds niet voldoende zou zijn om de bodemvruchtbaarheid van de graanvelden op peil te houden. En dit terwijl de huidige veedichtheid al een overbegrazing van de weide bewerkstelligt. Dus een efficienter gebruik van de beschikbare natuurlijk hulpbronnen tesamen met een verhoogd gebruik van inputs is nodig om een duurzaam land gebruik te bewerkstelligen. Behalve veranderingen in wereldhandelsverhoudingen zijn er ook veranderingen in landgebruik, sociale verzekering en onderwijs nodig om dit te kunnen bereiken. Een suggestie voor een ander landgebruiksysteem wordt gepresenteerd.

CURRICULUM VITAE

Susanne Josée Leonie Emilie Leloup was born on 7 March 1957 in Hilversum, The Netherlands. She finished her high school in 1976 at the Katholiek Gelders Lyceum in Arnhem. Her first visit to Africa was as a biology student doing field work in Botswana. In 1985 she received her university degree in Biology at the University of Amsterdam, with ecology as her specialization. After following several courses relating to environmental problems in developing countries she worked in Mali from early 1987 until late 1990 as an associate expert for the Netherlands Ministry of Development Cooperation (DGIS) with the Division de la Recherches des Systèmes de Production Rurale. The first half year 1991 she wrote reports about the fieldwork at the Royal Tropical Institute in Amsterdam. After this she moved to the Department of Evolutionary Biology at the Harvard University in the United States where she started to work at her thesis. Late in 1992 she came back and finished her thesis at the Agronomy Department of the Agricultural University Wageningen, where she was supervised by Professor L. 't Mannetje.