Bridging the gap: computer model enhanced learning for natural resource management in Burkina Faso

Annemarie van Paassen

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Glossary

Actor-networks are ordered networks of human and non-human entities.

Actor Network Theory (ANT) has set itself the task to explore the properties and the process of translation of actor-networks, ordered networks of human and non-human entities. Knowledge and agency are emerging products of the process of translation. One is asked to think in terms of networks or nodes that have as many dimensions as they have connections. Their strength does not come from purity or unity, but from dissemination, heterogeneity and the careful pleating of weak ties (Latour, 1997).

Actor-oriented approach focuses on the elucidation of internally-generated strategies and processes of change, the links between the 'lived-in worlds' of local actors and the larger-scale 'global' phenomena and actors, and the critical role played by diverse and often conflicting forms of human action and social consciousness in the making of development (Long, 2001). Within the limits of information, uncertainty and other constraints (physical, normative or political-economic) that exists, social actors possess a certain knowledge and agency. Patterns of social organisation that emerge result from the interactions, negotiations and social struggles that take place between several kinds of actors.

Agency is the capability of doing things, to make a difference and influence the sequence of events.

Beolgsoba (Mooré) is an owner of a beolga. Literally, 'beolga' means 'individual cereal field'. Young men and women work at the household fields. When they attain the responsibility to provide for a means of subsistence they receive individual cereal fields.

Constructivism is an epistemology that recognises that all knowledge is socially constructed. The constructions evolve selectively; they are historically and culturally embedded and continuously recreated through experimentation and communication.

Enactment is about sense making through action. It concerns doing that produces knowing and doing that may be informed by prior knowing.

Emic or idiographic research wants to grasp the interpretation of the researched and what they perceive as feasible and valuable. The researched are invited to (re) construct reality, to define the objectives, selection criteria and indicators.

Epic or nomothetic research looks for the causes of socio-cultural differences and similarities. It imposes the 'reality' of the researcher: the researcher defines the research question, criteria for categorisation, indicators etc.

Epistemologies are 'ways or methods for knowing': theories of the methods or grounds for knowledge.

Espoused theories are explicitly communicated theories-of-action. They contrast with tacit, implicit theories-of-action, that people use in their everyday live. Together, they constitute the actual theories-in-use (Argyris & Schön, 1996).

Frames of reference refer to certain beliefs, norms and notions of self-efficacy. In their reasoning, individuals orient themselves to the frame of reference that they consider as appropriate. At a social level, various actors negotiate the appropriateness and applicability of certain beliefs, norms and power resources. Actors and actor-networks construct their frame of reference, which recursively organises their reasoning and behaviour.

Generic forms of sense making such as habitual behaviour, interlocking routines, organisational procedures, technology, etc. provide standard plots of types of encounters within an organisation, class or group to save energy for other tasks and to allow for a smooth integration and substitution of actors. Generic forms of sense-making exhibit ‘structural properties’.

Heuristics refers to an experiential way of understanding. Heuristics focuses on experimentation and observation as a way to discover the world.

Hermeneutics refers to an interpretive or explanatory way of understanding. Hermeneutics focuses on human practices and the understanding of the interpreting subjects. An interpreting subject orients his behaviour to the outside world to be able to survive. Social research concerns double hermeneutics: it includes and is driven by an interpreter (the researcher), who interacts and contemplates with other interpreters (the people studied). The interpretation of the researcher may be read by the people studied and this may subsequently influence their interpretation.

Inter-subjective sense making refers to the active processing of information, interaction, negotiation and social struggles that take place between several kinds of actors. Inter-subjective sense making leads to innovation. To manage transition is to manage the tension that often results when people try to reconcile the innovation inherent in inter-subjectivity with the control inherent to generic sense making (Weick, 1995; 2001).

Learning for coherence is linked to the reduction of ambiguity, to construct a consistent and shared vision about the desired situation.

Learning for correspondence is linked to the need to act in correspondence with one’s environment, to explore what action is best fit to attain the desired situation.

Life-worlds are the realities that people adaptively construct for themselves. They are the sum total of the mental maps and models that people have built to allow them to cope in their environments and, as such, are made up of past experiences and personal and shared understanding. A life-world embraces one’s perception, frames of reference and action.

Livelihoods are made up of practices by which individuals and groups strive to make a living, meet their consumption necessities, cope with adversities and uncertainties, engage with new opportunities, protect existing or pursue new lifestyles and cultural identification, and fulfil their social obligations.

Perspectives of actors or actor-networks consist of perceptions, beliefs, norms, notions of self-efficacy.

Positivism is an epistemology that notes that ‘things’ are as they are, which can be objectively known through research, and about which science can formulate generalisable ‘truths’.

Projects bundle strategic and future-oriented actions. ‘Par definition, un projet (…) est une fiction, puisqu’au début il n’existe pas’ (Latour, 1991: 115). In essence, projects do not exist but need to be realised.

Puugsoba *(*Mooré) refers to a farm head, somebody who owns land and manages the agricultural labour of the household members. Their first concern is the survival of their household. Most married men and elderly women attain the status of puugsoba.

Rationality refers to the rationalisation of action, the capacity to supply reasons for one’s behaviour.

Reflexive implies a subject’s action on himself or itself. An actor-network is reflexive if it applies something it has learned about its environment to its own internal working. Reflexivity, or self-critique, derives from monitoring and self-reflection or communication and critique by others.

Reflexive research implies that the researcher takes notice of, and is explicit about the interpretive act and considers the authority and relevance of the research vis-à-vis the people studied and the intended readers.

Stakeholder analysis aims at the identification of the stakeholders involved, their knowledge, interests and capabilities as well as the communication and organisational aspects that determine the importance and urgency of perceived problems and the possible ways to solve them**.**

Structure: In their action, networks of human and non-human entities produce and reproduce theories, normative rules, habitual behaviour/procedures and interlocking routines, communication channels, information systems, systems of incentives, practices/technologies and artefacts, which provide structure and order for future learning and action. It is called the frame of reference.

The theory of planned action, an extension of the theory of reasoned action, identifies three intermediate variables that account for the relations between external variables and a person's behaviour: 'attitude of behaviour', 'subjective norm' and 'perceived self-efficacy' (Ajzen & Madden, 1985). Current socio-psychological research, inspired on this theory, refers to 'beliefs', 'norms' and 'perceived self-efficacy'.

Uncertainty: Natural resources cannot be managed in convenient isolation; issues are mutually implicated; problems extend across many scale levels of space and time; and uncertainties of all sorts and all degrees of severity affect data and theories alike. To achieve a desired situation, actor-networks need to reduce uncertainties: to improve their knowledge about the outside world and to better distinguish the actions that lead to the desired situation.

Abbreviations

ANT	Actor-Network Theory
CA	Cellular Automata
CND	Commission National de Décentralisation
PANE	Plan d'Action National pour l'Environnement
CNRM	Communal Natural Resource Management
CVGT	Comité Villageois de Gestion du Terroir (village natural resource management committee)
GIS	Geographical Information System
GTV	Gestion de Terroir Villageois (village natural resource management)
IRDP	Integrated Rural Development Programme
MAS	Multi Agent System
MGLP	Multiple Goal Linear Programming
NARI	National Agricultural Research Institute
NRM	Natural Resource Management
PEDI	Programme d'Exécution du Développement Intégré
PRA	Participatory Rural Appraisal
RAAKS	Rapid Appraisal of Agricultural Knowledge Systems.
RAV	Représentant Administratif Villageois (government appointed village representative)
RRA	Rapid Rural Appraisal
RAF	Réorganisation Agraire et Foncière (agriculture and land reform law)
SWC	Soil and Water Conservation
TC	Technical Coefficients
TCG	Technical Coefficient Generator
VDC	Village Development Committee
WMS	Wageningen Modelling School

Preface

"A burning sun on a 4x4, bumping on a sandy road. Shrubs. Arrival at an empty meeting place. Being noticed. Slowly some people gather. The latest news. Amadou is severely ill; we pay a visit. Fati gave birth. Djibril is hunting. Gossip. Discussions about the rains of yesterday and the start of the ploughing season. A bad moment to meet. Nevertheless farmers arrive. A health worker arrives on his motor, to distribute sieves against guinea worms. We move to Mohamadou's compound. Sweeping aside goat droppings. Searching mats and shade. Lukewarm water. A glance at the fields. Zomkoom. The wind takes the blackboard and the paper. Dust and sweat. The Peulh gather at a nearby tree. Women finally show up. Crying babies. 'Ambiance'. Sorghum beer. Time to start. Exchange of ideas, wishes, frustrations. What will it provide?

A soudanese building. Salle informatique. Three colleagues behind their computer. Cold water. Administration of credits and subsidies. Processing of data. Writing reports. Market surveys. Extrapolation of present trends, but how do these trends interlock? What are we heading for? What choices to make? Is Multiple Goal Linear Programming an option? In the eighties I found it too simplistic: it did not cover the farm reality. Technologies advanced. Consideration of multiple goals and trade-offs between choices. Could it help our reflection?"

While working at development projects, I continuously wondered how to understand farmer reality and to identify development paths. How to make the best out of indigenous knowledge, organisational learning, scientific research and policy-making? After years of scepticism, I asked myself whether computer technology could help us to integrate knowledge and to facilitate learning.

My first respects and thanks go to Teunis van Rheenen of the Antenne Sahélienne, who provoked my enthusiasm and who generously offered the opportunity to get a grip on this issue. He introduced me to Leo Stroosnijder, and together they provided me with the SHARES model as well as the accompanying research support of Esther van Hoeve, Arianne Idzenga, Rouky Sondé and Madi Ouedraogo. When I struggled with my role as a PEDI employee and scientific researcher, their enthusiasm and drive energised PEDI staff and the research took off naturally.

I am also much indebted to the inhabitants of the villages Gainsa and Koglabaraogo, and still remember their scrutiny, hospitality, warmth and patience to bear with us. They regularly wondered where we were heading to but remained available, ready to give their opinion, to show their (PEDI promoted) achievements as well as their failures. Meanwhile, Pierre Bargo, the retired extension officer who defied ill-health and played a vital role during the fieldwork, started to enjoy the pleasant teasing, which provoked much openness, hilarious laughter and put everything in perspective. I owe him and Celestine Simporé, my enthusiastic translator, friend and, occasionally, co-researcher.

The research would not have existed without the interest and support of my PEDI colleagues. I thank the managing directors that they made room for the research on the extension approach. At present, they are busy restructuring institutions and funding procedures; I hope this thesis provides them with ideas about how to integrate pro-poor, gender and natural resource management concerns in future development ventures. What was of crucial importance, was the drive, curiosity and warmth of my companions-in-arms, the agricultural staff: Bilfifou Sandwidi, Brigitte Ouedraogo, Roger Kaboré and Abel Agba. To our joint surprise, everybody managed to free him/herself for the field work, spend free evenings on the preparations, felt committed and involved oneself in intense debates. I also remember the scrutinizing look and the feedback I got from my counterpart and sparring partner Claude Pacere. Thanks to him and 'our' cheerful league of facilitators, Kaya became my home in Burkina Faso. I hope, Claude will be around during the last phase of our joint enterprise to support me in the quality of paranimph. But for those who cannot make it to the Netherlands, my sincere thanks for the generous support and friendship.

At the Wageningen University, the theoretical work and the hard labour of writing started. Nico de Ridder kept close track of my work, introduced me to the world of computer models and showed me the need for Beta-Gamma sciences. Niels Röling was a tower of strength. He urged me to dive into the scientific literature and debates, to swim around but to end up with one theory, some key-variables and a strong straightforward story. The wandering was hard, but thought-provoking and his kindness and enthusiasm helped me finish the job. Leo Stoosnijder put me on the trail of critical thought about natural resource management. He expected constructive critique and pointed out beta-gamma parochialism. He encouraged me to re-frame, to formulate a common perspective. He, on his turn, made the effort to digest the social jargon. Three supervisors guided the research, but I also owe much to the talks and social gatherings with all 'inhabitants' of the department of Communication and Innovation Studies. As my base was Rotterdam, my visits were irregular but I surely enjoyed the discussions, which often put me on new tracks. Everybody, thanks for the joint learning!

Back in the Netherlands, I enjoy the proximity and warmth of family and friends. With some (Margaret, Rob, Aicha, Bert, Hans, Ineke, Ton, Sylvia, Halilou, Willemijn, and many others), I shared my Burkina adventure while for others it remained a 'PhD-thing'. But what is of more importance: you kept me in touch with the dutch, social and cultural life. It was and **is** a pleasure! Unfortunately, Alzheimer kept my father from really sharing this last period. I was glad to be home when he died, but I regret his absence now that the work is near completion. I hereby like to thank him and my mother for their continual availability, interest and support of my choices.

And last but not least, my gratitude and love are for Sef. He encouraged me to start the research, introduced me to MGLP programming, was always available for questions, doubts and discoveries, and bore with me when I struggled. When necessary, he put things in perspective and ensured the nice part of life (though the salsa-dancing stopped because of knee-problems). Sef, thanks for the editing, the layout and the (joint) cover-design, but more so for your inspiring presence.

Annemarie van Paassen
26 November 2003

P.S. Claude Pacere and Dominique Hounkounnou, thanks for the french editing!

1 Introduction

1.1 The issue

Everybody was hot, sweaty and tired of the day. With their minds still on the previous discussions, project staff members and farmers ate their 'couscous', steamed maize flour of the USAID food programme, served by the village women.

That morning, the project staff managed to free themselves from administrative duties and headed for the weekly field visit in the test village Gainsa. The farmers, who rose early to dig some extra zaï (plant pits), gathered at the community centre as soon as they spotted the project's shiny four-wheel drive. They had had intense discussions around the pictures of 'possible farm strategies' presented by the project staff. The staff claimed that computers had suggested these farm strategies, and they wanted to know how they fitted with the farmers' actual practices and envisaged future.

The farmers hesitated. The pictures were interesting: they portrayed a clear, concrete overview of their present farm situation and provided hypothetic alternative farm strategies. This was something to think about. But who wants to make his embarrassing situation public? Was it wise to show your management practices and resources to the project staff? Staff members were committed to the project-promoted technologies and might not appreciate deviant farm practices. It became very silent. Then, Roger, an R&D staff member who regularly strolled through their fields and knew them personally, insisted and challenged them. Finally, the leader of the farmer group, Hamadou Sawadogo, still grateful for the project's assistance to bring the thief of his cow to the town's court, agreed to describe his farm strategy. Others followed. Reluctantly they revealed their farm secrets and explained their reasoning. Fellow farmers agreed and assisted in defending their logic: "No, we will never buy fertiliser, even if we could afford it". They were frank, even confrontational and the discussion intensified. After an hour, everybody was exhausted, confused or satisfied. Hamadou thanked the staff: "We are amazed that we have now entered the era that we are able to 'talk' with machines. Thanks for the trouble you took to show us these pictures. Please leave them with us."

In short, this is what this thesis will dwell on: the use of computer based modelling in agricultural extension in developing countries with particular reference to the West African country Burkina Faso. A country where young ambitious project staff members sign up for every computer training course offered, and long for e-mail connection. It is also a country, where farmers are predominantly illiterate. Some of them know of the existence of computers. When they represent the village at project seminars, they use the air-conditioned computer room for their siesta. They sleep comfortably, while the secretary battles with her computer and the fluctuating electric tension.

1.2 Relevance of the research topic

1.2.1 Present concerns of agriculture

Agriculture is about the use of natural resources for food production. Before the 19th century, agricultural development was tightly linked to population growth and followed a tidal movement due to pest epidemics and wars (Rabbinge & van Latesteijn, 1992; Van der

Woude 1992). In the northern hemisphere, the industrial revolution marked a new era. The urban population provided a market for agricultural products. In agriculture, the mechanisation, chemical fertilizers and pesticides increased land productivity as well as the labour productivity (Grossmann, 1998). In Europe and the United States, price protection measures enabled agriculture to develop into a highly productive sector supplying food for the growing urban population (Koning, 1999). Economic logic fostered innovation: as price takers farmers had to increase their efficiency to improve their profit and the overall increase in efficiency was passed on to the consumer in the form of lower prices. As a result, 'inefficient farmers' were forced to stop and the agricultural sector increased its competitiveness vis-à-vis other countries. At present, the United States and Europe have a small but highly mechanised, productive agricultural sector.

The southern hemisphere followed a different development path. During the colonial era, several parts of the South functioned as providers of agricultural produce (spices, tea, coffee, sugar, rubber etc.). This produce was bought from local peasants or produced at plantations managed by western investors, but in neither case the local population benefited from favourable agricultural prices and the development of the local economy stagnated. The Second World War marked a change. While enduring the Second World War, the colonial powers became increasingly convinced of the right for national autonomy and slowly they started to recognise the right for independence of their hinterland. Inspired by cold war sentiments they nurtured friendly relationships with their former colonies and became increasingly interested in the development of their southern partners. The term 'underdeveloped countries' and the profession 'development planning' emerged.

At first, development planners saw industrialisation as the way to remedy poverty. It seemed the only way for poor countries to avoid the deteriorating terms of trade of primary products compared to manufactured goods (Escobar, 1995). Industrial development was the key for progress as it produced items with higher exchange values. Agriculture was regarded as instrumental for, and subordinate to, urban and industrial development. The reality proved to be more complex. The poor harvests in Asia in the 1960s and Africa in the 1970s demonstrated structural development imbalances and drew attention to the crucial role of agriculture. From then on, donors concentrated on the rural areas and adopted 'basic needs' strategies, 'redistribution with growth' strategies and 'integrated rural development' strategies. In Asia, it seemed to work: the Green Revolution provided food self-sufficiency and the economies caught up. However, in (the semi-arid areas of) Africa neither the green revolution nor the grass-root strategies triggered the development longed for. This induced donors to change their focus and they concentrated on the macro-economic environment. From the 1980s onwards, donors urged for structural adjustment and privatisation to increase the efficiency and competitiveness of the local economies. In this light, agricultural input subsidies and subsidized grain markets, installed to enhance local food production for reasonable prices, were perceived as too costly and were abolished to restore the trade equilibrium (Van Keulen *et al.*, 1998). As international agricultural prices deteriorated, local farmers more and more concentrated on regional markets and partly retreated into subsistence agriculture.

From the 1970s onwards, environmental concerns featured dominantly in the international agricultural development debate. The report 'Limits to growth' by the Club of Rome (Meadows *et al.,* 1972) announced an era of hunger, scarcity and numerous environmental problems. This resulted in a growing concern for the finiteness of the world's natural resources and the damage that agriculture is causing to the environment: soil and water pollution in the high income countries and deforestation and land degradation in the developing countries. Environmental concerns culminated in the United Nations Conference on Environment and Development (UNCED) and the Agenda 21 in the year 1992. The World Commission on Environment and Development (WCED) called for 'sustainable development': development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs'.

Ever since its conception the term 'sustainability' has been criticized as being ambiguous and open to a wide range of interpretations, many of which are contradictory (Olembo, 1994). The main dichotomy concerns the ecological versus the social dimension of sustainability: a livelihood is 'environmentally sustainable' when it maintains and enhances the local assets on which a livelihood depends, and is 'socially sustainable' when it can maintain a decent livelihood and provide for future generations (Chambers & Conway, 1992). Scientists, policy makers and farmers searched for solutions for these contradictory objectives. At the World Summit for Sustainable Development in Johannesburg in 2002, it was noted that progress had been made at the level of pollution and biodiversity, but there still remained a problem of land degradation and hunger in Africa.

1.2.2 Land Use Analysis to meet societal demands

Land use analysis[1] is a method to identify options for sustainable agricultural development. Land use analysis has its origins in soil science and agronomy. It started with land evaluation, which involved multidisciplinary assessment of the capability of land for different uses (FAO, 1976). In the 1960-70s, land use suitability maps provided rough indications of the agronomic potential of different types of soil and landscape. To improve the utility for agricultural decision makers, land use plans had to be more precise and indicate the 'best' land use option. This required the use of quantitative data on yield prospects, labour requirements, economic returns, etc. (Fresco *et al*., 1992). The first quantified land use plans were technical-economic feasibility studies for regional policy makers. Soon after computer technology enabled the integration of additional environmental and societal objectives.

The first land use plans were normative in character, but experience taught land use planners modesty and they limited their ambitions to the provision of 'land use analyses' to support the reflection of decision makers. By the 1990s, the aim of land use analysis was to provide quantified information on optimum land use allocations under given sets of societal goals and constraints, to enable transparent discussion, negotiation and decision making amongst the stakeholders (Roetter *et al*, 2000).

1.2.3 Computer-based modelling for land use analysis

Crop simulation modelling is useful for 'land evaluation', but 'land use analysis' requires a match between the quality of natural resources and the various societal demands placed on them (Kuyvenhoven *et al.,* 1998). In 1988, De Wit *et al.* showed the potential of Multiple Goal Linear Programming (MGLP). Economists were acquainted with linear programming or so-called input-output modelling, but De Wit et al. proposed this method to confront

[1] The FAO definition (1976) for land: Land refers to all natural resources in an area. Land does not only refer to the soil in its topography (landscape), but also the natural organisms living in and on it (plants and animals), to the natural water resources (rainfall, streams and water bodies) and to weather parameters like sunshine and air humidity. Thus the land is the natural biological and physical environment in which people make their living. An equivalent that is often used for the term land is natural resources.

biophysical and technical potentials with societal objectives and priorities. Major components of MGLP were:

- A database on biophysical and socio-economic resources;
- Input-output coefficients for all conceivable agricultural activities (including current and promising future production technologies);
- A set of constraints and balances;
- A set of goal variables;
- A multiple criteria decision method.

MGLP could explore trade-offs between competing goals identified by stakeholders in a region and hence seemed an appropriate scientific device to support policy negotiation. Many researchers and research groups took up the challenge, amongst others the International Benchmark Sites Network for Agro-technology Transfer (IBSNAT) group in the USA and the Wageningen Modelling School (WMS) in the Netherlands (Bouma & Jones, 2001).

MGLP has been one of the most common tools to explore options for land use. Land use models can be grouped into projective, speculative, predictive and explorative (Figure 1.1). The distinction is based on the criteria of 'uncertainty' and 'causality'. Uncertainty relates to the time horizon of the study and the process involved.

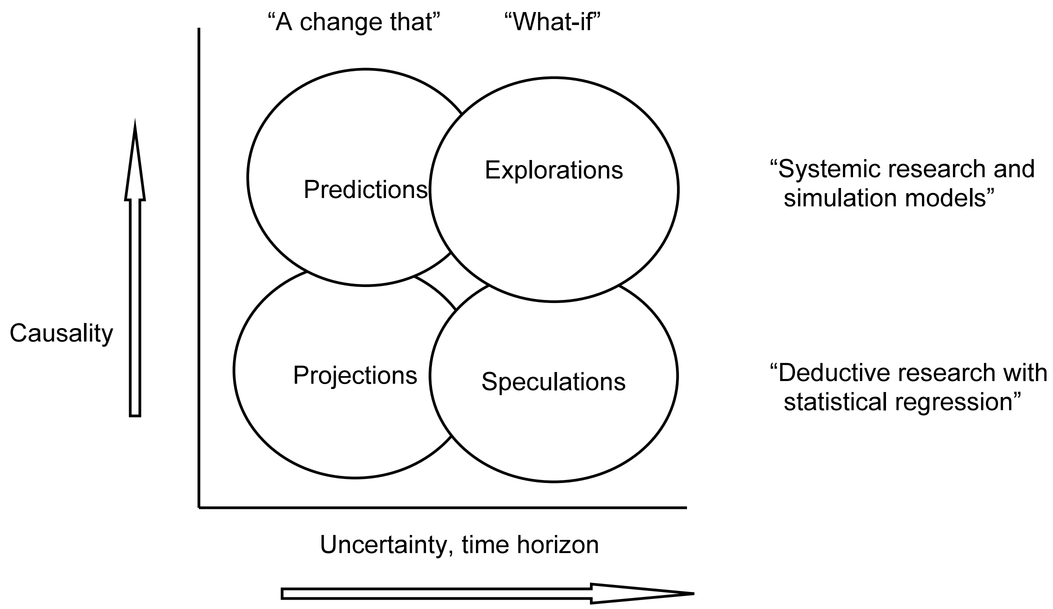

Figure 1.1: Typology of land use models (Becker & Dewulf, 1989)

The level of causality reflects the type of model that is used for the study: models can have a statistical basis or a more mechanistic basis with information on causes of certain developments. Simulation models fall in the category of predictive models, while MGLP models are explorative in nature.

1.2.4 The functionality of land use modelling

Land use modelling is historically anchored in a positivist paradigm and an instrumentalist rationality, characterised by goal-directed, feedback-controlled intervention in the world

(Habermas, 1984; Woodhill & Röling, 1998). The instrumental rationality goes together with a 'transfer of knowledge' approach, whereby science is assumed to influence decision makers in a rather linear fashion: experts make prognoses and advise policy makers and farmers (Keeley & Scoones, 2000). The aim of land use modelling is to integrate scientific knowledge to reveal 'windows of opportunity' to stakeholders, policy makers and farmers.

Characteristic for instrumental reasoning is the step-by-step problem solving approach: identifying the problem, defining objectives, designing solutions and implementing the action (Woodhill & Röling, 1998). Modellers developed different models for different phases of the problem solving process: projective and predictive land use models were supposed to be useful for problem identification; explorative models for the definition of objectives; and predictive models for the assessment of the feasibility and desirability of possible solutions (Van Ittersum *et al.,* 1998).

At present, agricultural modelling has matured and is at the crossroads of its existence. After three decades of heavy investment in the development of land use models, there is an increasing pressure from agricultural funding agencies 'to prove the operational applicability of modelling' (Bouman *et al*., 1996). So far, most land use models were scientific endeavours to increase scientific collaboration and understanding. They accelerated systemic research in understanding of biophysical processes. Furthermore, several agricultural research centres use the models to select promising technologies and orient their operational research. But what is still cumbersome, is the use of land use models, developed with the objective to support policymaking or farm management. Up till now, they do not provide the envisaged decision support. Decision-making processes and actual use of land use models take different forms than those anticipated by the modellers. For example, the use of an explorative model did not lead to the delineation of objectives, but rather triggered a debate on the assumptions, the problem definition and the included range of solutions (Van Ittersum *et al.,* 1998; Walker & Zhu, 2000). Operational research revealed a limited use of land use models by policy makers and farmers due to (a) an emphasis of the models on problems of a scientific rather than practical interest; (b) poor functionality for non-specialist users; and (c) an evolutionary development path, which did not accord with modern software engineering standards (Hilhorst & Manders, 1995; Walker & Zhu, 2000).

To increase the functionality of land use models for non-specialists such as policy makers and farmers, model designers now struggle with questions such as 'what are the stakeholder's information needs' and 'how make models fit the stakeholder's learning style' (McCown, 2002a). Model designers hope that stakeholder involvement at an early stage of the development process will solve these problems (Newman *et al.,* 1999; Roetter *et al*., 2000). However, it is yet unclear how to involve stakeholders (direct users and beneficiaries) and how to keep them motivated to collaborate until the end of the development process. Another possibility is to learn from research on the use of existing land use models by non-specialists.

Initial user research revealed that the use of land use models depends on its compatibility with the needs of the stakeholders, the capacity of the users and the institutional context in which decisions are made (Walker & Zhu, 2000; Walker, 2002). Politicians of the European Union require a different kind of model than European or African farmers. Therefore, it is crucial to do context-specific research. So far, user research focussed on the industrialised countries, where there is a widespread use of computers. Despite the increase of modelling projects in Africa, still little is known about the utility of land use models in the African context. This prompted this research.

1.3 Research background

1.3.1 The development of SHARES

In 1992, Wageningen University started a Sahelian research programme in Burkina Faso: the Antenne Sahélienne. Under direction of the Erosion, Soil and Water Conservation Group, the Antenne started multi-disciplinary research on natural resource management. Initially the research focused on pastoral land, but soon arable lands were included to cover all agricultural activities.

In 1997, the Antenne Sahélienne had acquired a wealth of data on natural resource management at village level. It was deemed appropriate to integrate the disciplinary and interdisciplinary knowledge in a computer model to carry out holistic land use analyses. At the time, there were other land use models for the Sahel but they lacked the features to understand the land use dynamics at the village level. The Antenne Sahélienne took the challenge and decided to develop SHARES (SHAred RESources), a village level MGLP model (Nibbering, 1996). The development and the scientific use of the SHARES model are documented by Stroosnijder & van Rheenen (2001).

While developing the SHARES model, the idea came up to research the operational utility of the model and the land use analysis methodology. In line with the instrumental rationality, the Antenne elaborated the 'SHARES land use analysis procedure' that consisted of (a) a descriptive and comparative study, (b) an explorative study and (c) a planning study (Rabbinge & van Ittersum, 1994). In the descriptive and comparative land use study, the functioning of the village natural resource system was investigated. The aim of the explorative study was to define the long-term options for village natural resource management. The planning study would answer the question how to achieve optimal land use alternatives. The SHARES model covered the descriptive and explorative study. The envisaged additional research would cover the planning study. Aim was to assess the feasibility of the 'facts-alternatives-choices' methodology for village planning and to integrate the soft side of land use in it (Nederlof, 1999).

1.3.2 The Integrated Development Project PEDI

In 1999, the Antenne Sahélienne asked me to test the use of SHARES by doing the planning study. At that moment, I worked at the section 'Communication, Planning and Gender' of the integrated development project PEDI (Programme d'Exécution du Développement Intégré)[2] funded by the Netherlands Development Co-operation. The PEDI project intervened in 61 villages of Sanmatenga province in Burkina Faso, one of the two provinces for which the SHARES model had been developed.

The study on the possible use of SHARES interested me. I had studied Development Economics at Wageningen University in the 1980s and I was familiar with the concept of linear programming. Up till then I had been sceptical about the practical use of linear

[2] The 'P' of PEDI stands for 'programme', but I refer to PEDI as a project because at the time of the study it had the features of a project. Initially PEDI supported various provincial government departments to stimulate multi-sector integrated development. However, when the PEDI programme did not manage to improve the coordination and collaboration among the various provincial government departments it evolved into a project, with its own budget, staff and extension workers, focussing on integrated village development.

programming for agricultural extension as it reduced farm management to an economic equation while the reality was far more complex. Furthermore, I doubted whether this technology was appropriate in a context where farmers were predominantly illiterate and baseline data were hard to get. However, a decade had gone by, MGLP models now covered various aspects of farm management, and my colleagues at the PEDI project were very much interested in agronomic models. Furthermore, in the past years PEDI had focussed on the participatory and gender dimensions of agricultural extension but a clear idea about the production potential of a category of farmers in a specific location was lacking. Could the MGLP model help to integrate social and technical dimensions?

Crucial to studying the use of SHARES, was the interest of the agricultural staff members in the use of the model. In general, staff members had a personal interest in computer literacy skills, out of pure curiosity but also to enhance their future chances of employment. However, to justify the use of SHARES, it should be relevant for the project activities. At that moment, PEDI was in the process of formulating a new project phase (2001-2005): the Programme du Développement Local (PDL). In the PDL phase, the local population would have the ultimate responsibility for the elaboration and execution of village development plans. During the preparation of the PDL, I joined the agricultural section to redefine the extension methodology. The agricultural staff already used several participatory techniques in the agricultural extension programme, but this happened in an ad-hoc fashion. What lacked, was a comprehensive participatory method for problem identification and planning. We decided to start an action-research to elaborate such a method, and see whether SHARES could be of use for participatory problem identification and planning.

1.3.3 The research method

In this research I played a double role. I was both subject and object of the research (the ultimate participatory observation). At the time of the field tests, I was part of the PEDI project staff. During the three previous years, we had shared concerns and jointly explored possibilities for improvement of the agricultural extension programme. By the time of the research, most technical staff members of the agricultural section were familiar with various participatory methodologies[3] and were convinced that they needed to develop a comprehensive participatory approach in the project philosophy of the next phase[4].

I subscribed to the need for a participatory extension methodology but felt that my colleagues were knowledgeable enough so that I could keep a low profile when discussing the testing of the future extension approach and the use or non-use of SHARES. To avoid to get too much involved and biased, I preferred to limit my influence on the decision making process and to play a facilitating and stimulating role. Nevertheless, it is inevitable that my presence has influenced the processes that I have studied. The very fact that for further explanation about and support with the SHARES model, they could always fall back on me and/or my husband (he was familiar with MGLP models and worked at PEDI as an consultant), gave them the

[3] PEDI was a member of the Indigenous Soil and Water Conservation (ISWC) research programme in Africa. The second phase (ISWC 2) paid special attention to the training of scientists and extension workers in Participatory Rapid Appraisal and Participatory Technology Development, to identify farmer innovators and their innovations, to network between farmer innovators, to undertake participatory research, to develop and validate improved techniques and systems of land husbandry, and to disseminate ideas and methods through farmer-to-farmer exchange (Reij & Waters-Bayer, 2001).

[4] By that time, the donor had informed the project that the next phase would put first priority to the decentralisation process and install Local Development Funds. This enabled the local population to contract private enterprises and/or government agencies to provide extension and other services.

confidence and trust that we would be able to handle the model. However, I think this does not pose a major problem. We kept a low profile, when the project had to decide whether and how to use the model. Furthermore, at the time I was not yet familiar with the latest theoretical insights on model use and learning. In this respect, I functioned as an ordinary staff member. It was only after the field test and after the contract with PEDI had expired that I had time to focus on the research and to update my theoretical background in learning and land use modelling. At that time, the research question was narrowed down and the field reports, minutes, and my diary were analysed.

The research principles for reflexive social research were applied (Chapter 5). My position within PEDI had several consequences for the research method. Firstly, I was in an excellent position to acquire the empirical material about the context, reasoning and feelings of PEDI staff members, but it hampered the communication with the local farmers. This is the reason, why the research is less detailed and conclusive about the learning of the farmers. Secondly, it made me very much aware of the interpretive act and the continuous dialogue between the perspectives of staff members and the researcher. Thirdly, my long-time commitment to development work and embeddedness in the PEDI project had its effect on the political-ideological character of the research: the study had an explanatory function as well as an interventionist emanicipatory-reconstructive task. This ensured its relevance for the academic world as well as for the research objects.

1.3.4 The research question

In this study, I analyse the use of SHARES from a constructivist perspective. This means that I distance myself from the positivist paradigm, the instrumental rationality, the linear problem solving and the transfer of technology approach. I believe there is not one objective reality but numerous 'subjectively constructed realities'. Behind scientific results, also in the field of hard science, we can trace assumptions or presuppositions that account for what is important and what is not and consequently need to be dealt with (Van Woerkum, 1999). Development is not the accumulation of knowledge. Knowledge is embedded, cultured, and encoded. Learning processes are mediated, situated, provisional, pragmatic and contested.

Learning is not a linear problem solving process, but non-deterministic and path-dependant (Van Meegeren & Leeuwis, 1999). We become aware of a problem as soon as we perceive a more desirable and achievable situation (Nelissen, 1998). As multiple stakeholders have various perspectives on the problem and the desired outcome, problem solving encompasses an exchange of perspectives, joint fact-finding and continuous negotiation while iterating between the problem definition and satisfying solutions. Solutions are not just produced by scientists to be disseminated to the beneficiaries (Röling, 1988a; Leeuwis, 1993). In this study I will not assess the utility of SHARES for science-based policy-making and planning. This study concentrates on utility of SHARES as a tool to enhance co-learning of the extension staff and the local stakeholders.

The overall question is whether computer based modelling enhances co-learning concerning natural resource management in Sanmatenga province, Burkina Faso:

a. The initial situation: Does the model trigger the interest of the potential users?
b. The process: How does the use of the model affect the learning process of the users?
c. The outcome: What is the outcome of the learning process?

To describe and analyse the unfolding learning process, I applied an eclectic theoretical approach and developed the theoretical framework of 'the learning actor-network'. From this theoretical perspective, the research question became: Can model use enhance coherence (convergence of knowledge, interests and resources, in order to define a clear (shared) objective for action) and correspondence (improved knowledge and/or action to attain the envisaged objective)?

1.4 The structure of the thesis

1.4.1 The context

After this introductory chapter, there will be two chapters describing the context. Chapter 2 describes the history of computer models as developed for land use planning, agricultural research and extension services. Only few of the models were used, so model designers reconsidered their modelling goals and engaged in user research. Chapter 3 describes the research area: the intervention zone of the PEDI project in Sanmatenga province, Burkina Faso. The chapter first introduces the area, its population and their livelihood. Then, it provides an overview of the national policies and the PEDI project activities that had a bearing on the local natural resource management.

1.4.2 The theoretical framework and research method

Chapter 4 introduces the theoretical framework. Several social and socio-psychological theories were considered, but the researcher finally opted for an eclectic approach and constructed the theory of the 'learning actor-network'. This theoretical framework provides the variables and the analytical tools to study model-use and learning. Chapter 5 clarifies the research principles that were applied. I opted for reflexive social research, which means a continuous iteration and gliding between various levels of concerns: systematic handling of the empirical material, consciousness of the interpretive act, consciousness of the political ideological dimension of the research and the authority and relevance of the research results.

1.4.3 The case study

The fieldwork covers four chapters. Chapter 6 is devoted to the first research question: the relevance and attractiveness of SHARES for the PEDI extension staff and the local population. It describes the first acquaintance of the agricultural staff with the SHARES model, and what motivated them to put SHARES to the test. The chapter also describes the farmer discussions about natural resource management; the problems they encounter and the issues they are willing and capable to act upon. Is SHARES of any help to explore these problems and to move forward?

Chapter 7 analyses the learning process of the PEDI staff. For the next project phase, staff needed to know how to trigger and to support co-learning. Staff launched an action-research on this subject and tried various extension tools. The chapter describes when and why staff members decided to use SHARES, and what they had to do to prepare the SHARES model for use in the test villages.

The next two chapters present the effective use of the SHARES model for the villages Gainsa (Chapter 8) and Koglabaraogo (Chapter 9). The chapters start with the explorations made with the SHARES model. The PEDI staff ran the model and matched the results with the observed farmer behaviour. In this way, they prepared themselves for the farmer discussions. They decided to visualise the SHARES scenarios and to ask the farmers to comment upon the results proposed by the model. The chapters end with an analysis of the learning effect triggered by the use of SHARES.

1.4.4 Conclusion

Chapter 10 starts with a short synthesis of the research and leads to the conclusions. It highlights the importance of a theoretical framework that enables β- and γ-scientists to jointly study ‘computer-model enhanced learning’. The case study is analysed and interpreted to answer the research questions. Some general conclusions are drawn about MGLP modelling and its prospective role for learning about NRM.

2 Context: Computer models for natural resource management

Computer based modelling enlarges the human rationality, as it enables us to consider a gamut of different data, relations and non-linear time sequences (Dörner, 1989) and it helps us to deal with invisible and abstract dimensions of an issue (Hamilton, 1995). By the end of the 1960s, computer technology had evolved sufficiently to allow for agronomic modelling. In the industrialised countries more than a century of institutional data collection has taken place and computer technology was used to stock and organise the data of farm enterprises to provide useful feed-back. Simultaneously, Wageningen scientists used computer technology to undertake systemic research and develop comprehensive crop growth simulation models (De Wit *et al.*, 1978, Penning de Vries & Djitèye, 1982; Stroosnijder, 1982). From the 1980s onwards, these models were simplified for operational use. They formed the basis for various land use models, developed for a variety of countries and regions. At the start of the modelling epoch, much progress was made and the expectations were high; computer models were thought to be the tool par excellence for tackling contemporary problems. However, time learned that models have their limitations, some of them inherent in the modelling methodology, some of them deriving from the local context.

This chapter gives and overview of land use modelling with specific reference to the work of Wageningen University, a leader in the agronomic modelling scene. In the seventies modelling boosted agronomic research and led to much interdisciplinary collaboration (§2.1). In the eighties attention shifted to the operational use: land use planning (§2.2), technical engineering (§2.3) and farm management (§2.4). Increasingly designers recognised model limitations and had to tackle model deficiencies. Modesty was required, but models seem still useful as discussion facilitation- and stakeholder learning tool (§2.5). Section 2.6 focuses on the role of land use models within the Sudano-Sahelian context. Here food crises and land degradation are a main concern, and we pose the ultimate question: can computer-based modelling enhance learning for natural resource management? Finally, Section 2.7 zooms in on the test case: the SHARES model developed by the Antenne Sahélienne, a research programme of Wageningen University in Burkina Faso.

2.1 Modelling to enhance scientific understanding of biophysical processes

With his classic publication on "modelling photosynthesis of leaf canopies", De Wit (1965) introduced the use of modelling to increase scientific understanding of the crop growth process. Between 1965 and 1980, the 'school of De Wit' developed crop growth simulation models determining the potential, attainable and actual crop production (Figure 2.1). Knowledge about plant physiological and dynamic soil processes was expressed using mathematical equations and integrated in simulation models. These models explained crop behaviour in terms of the underlying physiological mechanisms; descriptive processes at lower levels became explanatory at a higher level. Only when knowledge was lacking, statistical relations were used until new research supplied the lacking information. Modelling enabled scientists to quickly identify knowledge gaps and systemise the research on biophysical processes. By 1980, plant growth simulation models had developed into comprehensive models in which essential elements were understood and which contained large amounts of information (for an overview see Bouman *et al.*, 1996).

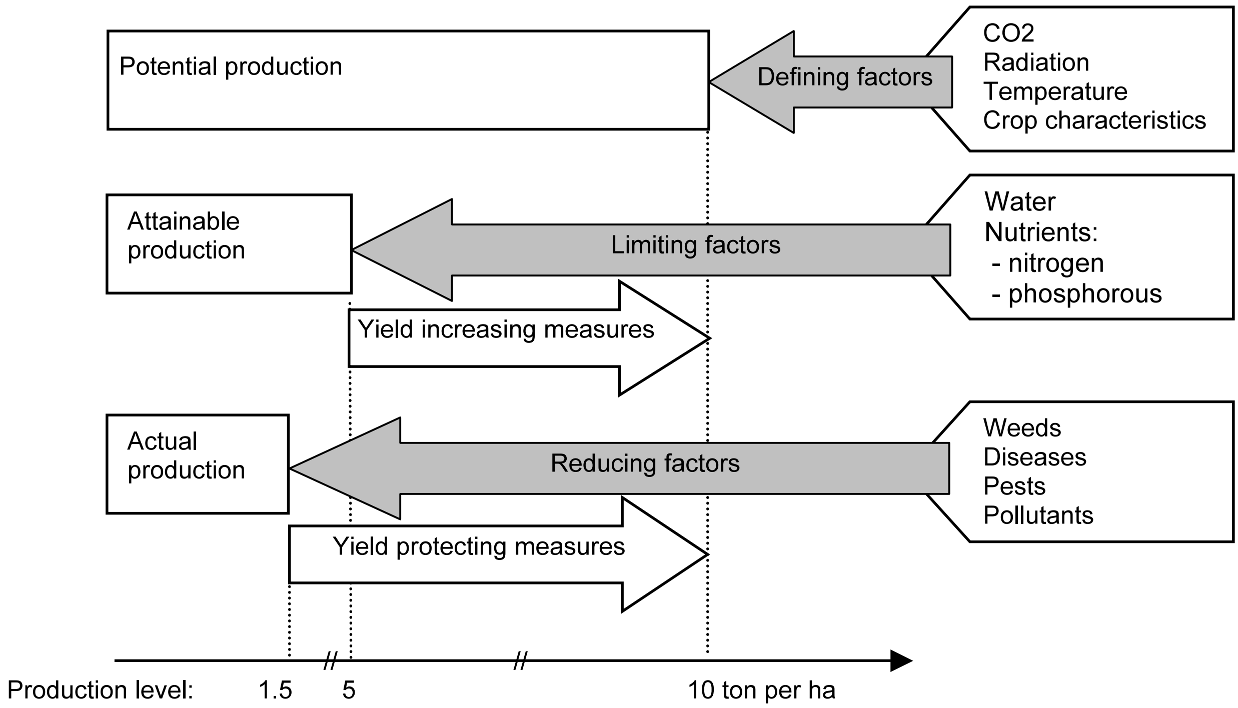

Figure 2.1: The relationship between potential, attainable and actual yields and defining limiting and growth reducing factors (Rabbinge, 1993)

2.2 Science-based models for policy makers and planners

2.2.1 The origin of land use planning

In the beginning of the 1980s, research concentrated on the application of the models. The first application was the use of biophysical modelling for land use planning.

An economic crisis and two world wars between 1914-1948 had convinced national governments that they should leave liberalism and the 'laissez-faire' approach and start with active planning and intervention (Escobar, 1995). Development should be fostered, especially in the 'underdeveloped countries'. In the 1970s it became clear that the industrialisation projects did not lead to balanced growth and instead poor, rural regions should develop their natural resources and focus on export. This gave rise to the profession of regional agricultural planning, a specific form of intermediate level planning of sectors and regions within the national economy. Regional agricultural planning links macro objectives with local farming systems, and compares constraints and opportunities of local agricultural development with those in other economic sectors or regions (Fresco *et al*., 1992). Regional agricultural plans often consist of land use plans.

Land use planning has its origins in soil science because it started with land evaluation, a method to assess the suitability of land for different uses. The main units of analysis were 'land units', physical areas of land that are uniform in characteristics and qualities (FAO, 1983; Driessen & Konijn, 1992) - and 'land use types', such as pasture, rice production, millet production, etc.. Land evaluation resulted in land suitability maps. However, the need was felt to quantify the assessment and soon land evaluation was coupled with simulation modelling for yield prediction and economic feasibility analysis.

In the 70s-80s, most land use studies were based on an economic framework and aimed at improved agricultural revenues (Schipper, 1996), but this scope proved too limited. In practice, policy makers and regional planners were confronted with a range of societal issues such as the cultural-political history, population growth, environmental concerns, the multi-functional use of the natural resources and conflicting stakeholder interests. The question was how to deal with the complex reality. Could modelling help to integrate knowledge, to develop a comprehensive analysis of the present situation and the possible future to guide policy makers and regional planners?

Nowadays, land use models aim to support policy makers and regional planners. They address the following questions (Bouman *et al.* 2000: 220):

1. Projective or diagnostic models: What are the likely changes in future land use if current relationships between land use and their drivers were to continue?
2. Explorative models: What is the biophysical and economic potential of the natural resource base and what are the technical options for future land use?
3. Predictive or assessment models: Which effective agricultural policies would induce farmers to adjust their land use in such a way as to satisfy certain policy objectives?

2.2.2 Projective or diagnostic models

The most common way of planning is the extrapolation of current trends into the future and the identification of measures to adjust these trends to a desirable development. Up till now most planning officers apply this method and elaborate optimistic, plausible and pessimistic scenarios. The Conversion of Land Use and its Effects (CLUE) modelling framework (Veldkamp & Fresco, 1996; 1997) provides a dynamic and integrated model approach for these kinds of projections. CLUE starts with a multi-scale statistical analysis of past and present land use to determine the biophysical and human land use 'drivers'[5]. A base scenario consists of the extrapolation of present trends. Alternative scenarios are made assuming changing relations between land use and its drivers, including feedbacks between variables and processes at the different scales (local, regional and national level). These changing relations may be due to intervention (policy oriented scenarios such as urbanisation, abolition of national parks, etc.) or internal dynamics such as system sensitivity scenarios for prolonged soil erosion, crop disease, volcanic eruption, population growth and commodity demand, etc. (Veldkamp & Fresco, 1997; Kok & Veldkamp, 2000).

CLUE has been used for national land use studies in Costa Rica (Veldkamp & Fresco, 1997), China (Verburg & Veldkamp, 1997) and for regional land use studies in Indonesia (Verburg *et al.*, 1999) and the northern Atlantic zone of Costa Rica (Kok & Veldkamp, 2000).

2.2.3 Explorative models

Explorative land use models explore the biophysical and technical production boundaries of a land use system. The production boundaries cannot be extrapolated from actual production trends but derive from scientific understanding of soil, crop and livestock growth processes.

[5] Important biophysical drivers are local biophysical suitability and their fluctuation, land use history, spatial distribution of infrastructure and land use, and the occurrence of pests and diseases. Important human drivers in CLUE are population size and density, regional and international technology level, level of affluence, target markets for products, political and economical conditions, attitudes and values and the applied land use strategy (Veldkamp & Fresco, 1996: 253).

In 1988, de Wit *et al.* showed the potential of computer based Multiple Goal Linear Programming (MGLP). MGLP is able to explore outer boundaries of the agricultural potential and to identify trade-offs between various socio-economic objectives and ecological sustainability. Essential for an MGLP model is the input-output module for all relevant agricultural activities. The input-output module is expressed in technical coefficients (TC). The input coefficients of an arable farm activity are defined by the choice of a crop variety and a specific management practice or technology (e.g., soil conservation measures, fertilisation, land preparation and weeding, harvest techniques and the use of equipment, labour and other inputs). Depending on the soil quality (and weather conditions) the agricultural activity produces certain outputs: products, crop residues, nutrient balance, etc. The outputs of the activity provide the output coefficients. For livestock production the same logic is applied. The input-output module of an explorative MGLP model covers current agricultural activities and promising future activities.

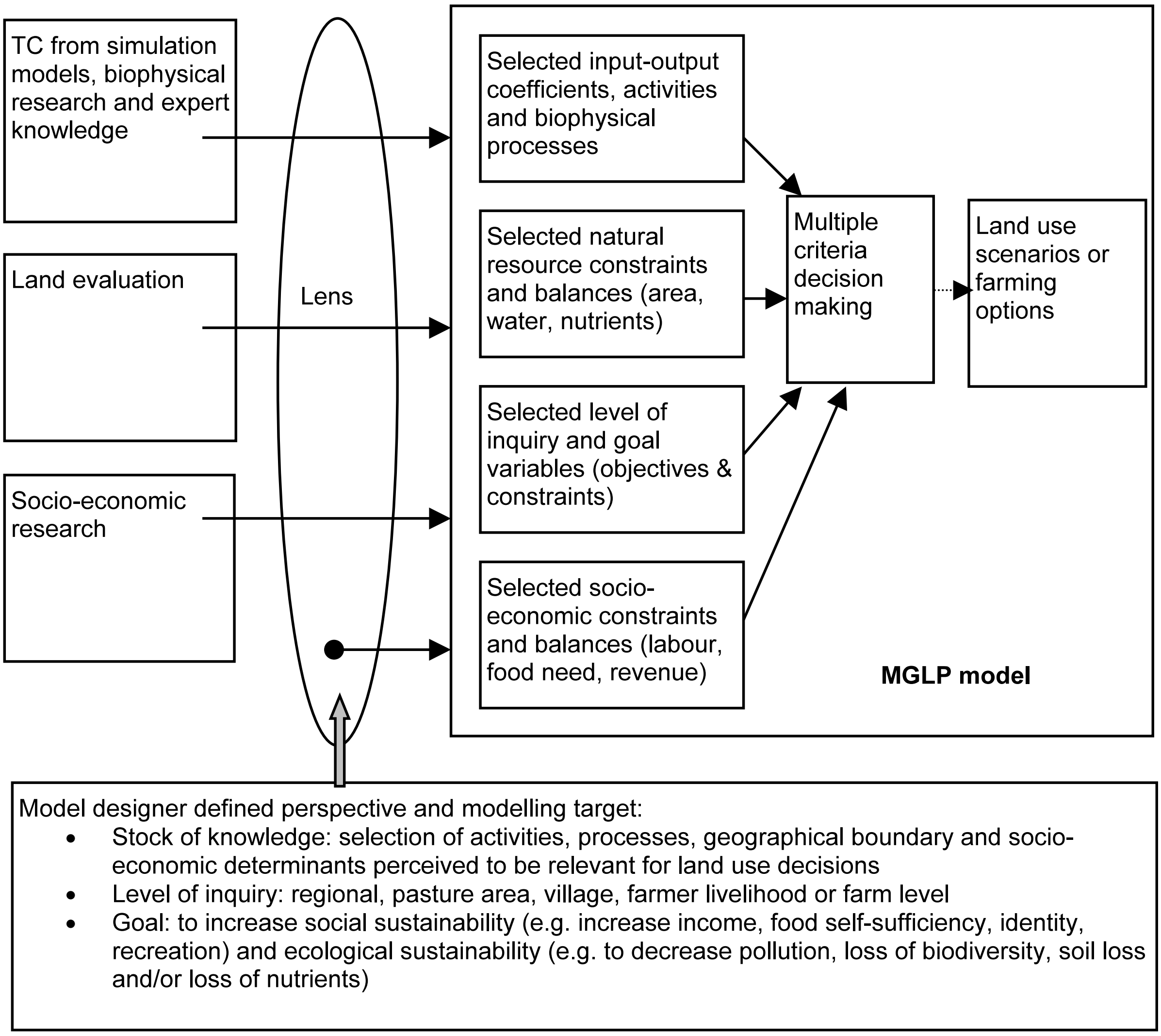

Figure 2.2: The general methodology for explorative land use analysis using an MGLP model: the target-oriented approach

The technical coefficients of the input-output module are computed by a Technical Coefficient Generator (TCG). The coefficients for current activities are derived from simulation modelling calibrated on actual field measurements. The coefficients of potential future activities are based on simulation modelling complemented with expert knowledge. The selection of promising future activities is done through the target-oriented approach: target production (e.g., required ecological sustainability and labour intensity) is predefined and the required combination of inputs is quantified (Van Ittersum & Rabbinge, 1997).

As demonstrated by the 'lens' in Figure 2.2, the perspective and modelling objective of the model designer determine the level of inquiry, the model boundary, the present and promising future agricultural activities to be included in the model. This makes MGLP an inherently biased analysis or modelling approach.

The SHARES model, which is object of this study, is an example of a 'Wageningen MGLP model'. Some other examples are discussed in Box 2.1.

Box 2.1: Examples of exploratory models

The European study for rural development, 1992
The Netherlands Scientific Council for Government Policy (WRR) has initiated a study on perspectives of rural development in the European Union (EU) called Ground for Choices (1992). The increasing agricultural productivity and budgetary consequences for the EU, the tension on the EU during GATT negotiations, and the increasing societal attention for environment, nature and landscape motivated the WWR to initiate the study. The aim was to stimulate the political debate amongst Dutch and European policy makers. The model contained the following components:

- The main objectives were the satisfaction of the food demand under a regime of food self-sufficiency or free trade. Based on prevailing data on population, trade and diet habits, food requirements were estimated for the current average diet and a more affluent diet. Additional objectives were soil productivity, economic costs, (regional) employment, nitrogen surpluses and pesticide use.
- The data base of the natural resources of the twelve EU countries: land was evaluated for its suitability for grassland, cereal or root/tuber production;
- The input-output module of three alternative farming types: yield oriented agriculture that aimed at high productivity, environmental-oriented agriculture that aimed at low emissions of pesticides and nutrients, and land use-oriented agriculture that consisted of a very extensive form of agriculture with no use of pesticides.

The study developed four scenarios for rural development: a free trade scenario, a regional development and employment scenario, a nature and landscape scenario and an environmental protection scenario. This analysis revealed that agriculture in the north-western part of Europe was close to its potential, while the southern part had still possibilities to increase its productivity. The four scenarios generated considerably different optimum situations and room for development for the various regions. It revealed a clear conflict of interest between regionally defined policies and EU policies, and heated the political debate; politicians and scientists started to question the definitions and assumptions of the model (Van Ittersum et al., 1998).

The Atlantic zone models
In the 1990s, the research programme of Wageningen University at the Atlantic Zone of Costa Rica heavily invested in the development of MGLP-related land use analyses:

- REALM: Regional Economic and AgriculturaL Model;
- GOAL-AZ: General Optimal Allocation of Land use for the Atlantic Zone.

The input-output module of the models included future technologies that aimed at ecological sustainable and profitable forms of agriculture.

REALM had only one objective function (the economic surplus) and studied the impact of various scenarios on the economic surplus. The following scenarios were elaborated: technical innovation, zero soil nutrient depletion, limited biocide use, taxing biocides, forest conservation, lowering interest rates and increasing real wage (Schipper et al., 2000). GOAL-AZ had four objective functions (maximising producer surplus, maximising employment, minimising biocides and minimising N losses) and could show trade-offs between these objectives. Detailed analyses were made of the optimum economic surplus, while simultaneously balancing biocide use and N-loss (Bessembinder et al., 2000).

2.2.4 Predictive or assessment models

While MGLP modelling gained momentum, ambitions rose. At Wageningen University economic and biophysical scientists joined efforts to develop MGLP models, integrating biophysical and economic knowledge in their equations to simulate the interaction between the socio-economic and ecological phenomena. The short-term economic relations change the nature of the explorative models and give them their predictive qualities.

MGLP models are level-specific and have an aggregation problem for the levels that surpass the farm level. Though this plays a role in explorative models as well, it is of particular importance for predictive models. Schipper (1996) noticed the following aggregation issues:

- The use of land is often considered without sufficient knowledge regarding the behaviour of farm households responsible for the actual land use.
- There is an aggregation bias, when the aggregated farms differ in farm objectives and access to resources.
- Optimisation of the objective function of the aggregated area ('the big farm') will always be higher than the result of the optimisation of the various objective functions of the disaggregated farm categories.
- Variables that are exogenous on the micro-level become endogenous on higher levels.

Some examples of predictive models are discussed in Box 2.2.

Box 2.2: Examples of predictive models

The predictive model for policy support at the Atlantic zone
Apart from the explorative models REALM and GOAL-AZ (Box 2.1), the research programme of Wageningen University at the Atlantic Zone of Costa Rica also developed the predictive model UNA-DLV. Aim of the UNA-DLV model was to assess the effect of various policy measures on sustainable land use and food security. UNA-DLV consisted of an MGLP complemented with economic equilibrium functions.

To limit the aggregation problem, most MGLP models work with four or five farm categories. The REALM and the GOAL-AZ models just aggregated the number of farms they found in each category, but UNA-DLV opted for a more sophisticated approach: the study worked with farm households and equilibrium functions for regional traded products and factors.

While REALM and GOAL-AZ explored the technical possibilities, the UNA-DLV method concentrated on the political measures needed to induce change at the farm household level. Policy simulation included a 20% decrease in transaction costs, a 40% tax on the price of biocides and a 20% increase in credit availability. The tax on biocides induced a shift to pineapple and palm heart; cultures that are low in biocide use and N-loss. The decrease in transaction costs as well as the increase in credit availability induced more cash crop production, more use of biocides and more N-loss. This last result contrasted with the results of REALM and GOAL, because UNA-DLV worked with endogenous prices and incorporates the price lowering effect when farmers collectively opt for the cash crops with a positive N and biocide effect. In general, the results of UNA-DLV show lower prices for internally traded products, labour and profit (the dampening effect) than the models that work with exogenous prices (Roebeling *et al.*, 2000).

The predictive model for the Koutiala region in South Mali (bio-economic modelling)
The predictive model for Koutiala was part of the UNA-DLV project and related to the work in Costa Rica described above. This model aimed at the enhancement of agricultural income and simultaneous reduction of soil mining. As the UNA-DLV method in Costa Rica, the model of Koutiala consisted of (1) an MGLP model and (2) economic equilibrium functions for regional traded products and factors. The

partial equilibrium modelling was used to generate a data series, which was subsequently analysed using statistical techniques. This is called metamodelling: modelling is used to generate values for the exogenous values instead of relying on empirical data as is common in econometrics. (See Kruseman, 2000: 68).

But the Koutiala variant also had an additional third component: (3) agricultural household models focussing on farm household behaviour. This latter part consisted of (Kruseman & Bade, 1998; Kruseman, 2000):

- an expenditure module, derived from econometric analysis of cross-sectional budget surveys;
- a savings and investment module, with production investments (inputs, capital goods, land improvement and soil conservation) and near liquid assets to smoothen income in adverse periods (food reserve, small livestock). This module worked with subjective discount rates to quantify the phenomenon that poorer households feel inhibited to save and invest and concentrate on short-term production and food security.

To account for the obstacles of the imperfect market and the additional obstacles that poor, less-informed households tend to meet, the regional market functions worked with transaction costs (differences between off-farm prices and market prices).

Aim of the bio-economic modelling effort was to identify possibilities to simultaneously improve the ecological sustainability of farm practices and the welfare of the farm household. The model designers selected the 'soil organic matter' (SOM) balance as the most relevant indicator for ecological sustainability, and the 'farm revenue' as the indicator for the household welfare. Now the research objective was: (1) to identify the appropriateness of (different) combinations of ecological sustainable technologies for the farmers, and (2) to identify policy measures that influence the likelihood of farmers adopting ecological sustainable farm activities (crop choice and management practices). The first research question would be important for technical experts at the national agricultural research institutes and the agricultural extension services, while the second research question targeted at national policy makers.

To identify the most promising combination of technologies, the researchers used the MGLP assessment and the bio-economic assessment. The MGLP assessment showed that the SOM and income effects were different for the various household categories. The MGLP model suggested that the well-off and poorest farm households could expect substantial increases in income when applying the SOM enhancing technologies. However, when bio-economic modelling was applied, it became clear that high 'subjective discount rates' and 'transaction costs' inhibited the poor and poorest farms from adopting the SOM enhancing technologies (Kruseman, 2000).

To induce technology change by the less and least endowed households while avoiding increased income inequality, the researchers proposed complementary policy measures. The model showed that the policy measures had a somewhat negative effect on the SOM balance and a varied income effect: price policies and market development instruments (e.g. infrastructure investment leading to a reduction in transaction costs) had a positive effect on net revenues, while increased credit supply and tax policies resulted in negative effects on net revenues. It was concluded that technology innovation was the prime factor determining options of maintenance of soil organic matter balances, while policy measures could mitigate income inequality (Kruseman & Bade, 1998; Kruseman 2000).

2.3 Science-based models for agronomic research institutes

Apart from land use planning, economic biophysical models are mainly used by agricultural experts and national agricultural research institutes (Hilhorst & Manders, 1995; Walker & Zhu, 2000). These models can be used for:

- Diagnosis: the farmer situation and knowledge gaps

The idea of MGLP modelling originates from the linear programming technique that economists used for farm planning. The combination of farming system research and economic linear programming gave way to the development of farm level MGLP model or so-called Quantified Farming System Analysis (QFSA). In 1995, Van Rheenen used the QFSA to describe the farming systems in South Malang, Indonesia to identify research priorities (Stroosnijder *et al*., 1994, Van Rheenen, 1995).

- Exploration: promising technologies and optimum farm structures

In the UNA-DLV projects in Costa Rica and Mali, scientists selected promising technologies from the Technical Coefficient Generator and used the MGLP model to find the optimum land use system. Van de Ven (1996) applied a similar approach when screening the potentials for development of dairy farming on sandy soils in the Netherlands.
There is one case, where scientists invited stakeholders (flower bulbs growers and environmentalists) to jointly define the research targets and promising technologies to be included in the MGLP model (Rossing *et al.,* 1997a; 1997b). After the completion of the MGLP analysis, the association continued discussions and formulated a proposal for testing and improvement of prototyping systems of integrated flower bulb farming that was widely supported.

- Assessment: to evaluate the desirability of proposed new technologies

The most commonly used methods to assess the attractiveness of technologies are financial Cost-Benefit Analysis (CBA) at the farm level and Multi-Criteria Analysis (MCA) at the society level (De Graaff, 1996). These kinds of studies narrow assessment down to the economic dimension. MGLP modelling enables a multi-dimensional assessment. The input-output module of the MGLP model consists of current technologies and promising future technologies. Future technologies may be proposed by farmers as well as experts and model designers select the corresponding coefficients from a TCG. After a base run with the current technologies, it is possible to assess the effect of alternative technologies on various criteria, such as economic profit, food production, labour use, land use, financial input, ecological sustainability, etc. Several agricultural research institutes use MGLP models to assess the relevance of new technologies for various farm categories, e.g. INERA in Burkina Faso (Maatman *et al.,* 1996; 1998a; 1998b) and the GRANO agro-environmental extension project for the German federal state of Brandenburg (Von der Heiden, pers. comm.).

2.4 Science-based models for extension services and farmers

The relevance of computer models for farm management differs greatly between the predominantly illiterate farmers in the developing countries and the well-educated farmers in the industrialised countries. In a country like Burkina Faso, the average farmer and extension worker hardly know of the existence of computers, whereas in a country like the Netherlands, farmers use the computer to register their farm activities. Here, farmer organisations and input supplying industries collect the farm data and provide detailed feedback to individual farmers.

Apart from the computerised treatment of data, most European farmers have access to agronomic models for tactical and strategic farm management. Tactical or diagnostic models use crop- and livestock growth simulation modules to identify the limiting factors of the actually used production method and generate new options for more efficient input use (Rossing *et al*., 1997a.). Strategic or farm optimisation models use linear programming to identify promising technologies and the optimal allocation of farm resources. When using

MGLP models, farmers tend to focus on operational/tactical issues such as input efficiency, rather than the reorganisation of their farm resources (Rossing *et al.,* 1997b; Hamilton, 1998). But when they consider the allocation of their resources, they rather investigate present options than to explore possible future technologies (NLRO, 1997).

Despite their availability, only few farmers make direct use of agronomic models as they find them difficult to comprehend and to control. The models are mainly used by extension workers who make the effort to master the model and use the results for their extension activities. They use the models in a flexible way: they interpret the results relative to the context of the farmers and use them as discussion material (Leeuwis, 1993).

2.5 Modelling to enhance co-learning about socio-technical processes

2.5.1 The need to integrate the 'soft factor'

Most MGLP models are developed by biophysical scientists and focus on the biophysical properties and boundaries of an agricultural system. These models include the 'best' future technologies as identified by scientists to realise a specific production target. Some models couple biophysical properties with an economic rationality (Section 2.2.3), but it is hard to find MGLP based models paying attention to differences in norms and values, emotions, (e.g. perception of risk and trust), human interaction and organisational constraints. If included, socio-economic parameters are considered as soft constraints that will adapt in due course (Veldkamp & Fresco, 1997; Van Ittersum *et al*., 1998: 314; Leeuwis, 1999b). Nevertheless, 'soft' factors are very influential in determining the process of change. Socio-cultural and political forces are powerful as they create development narratives that affect the perspective and action of decision makers, policy makers as well as natural resource users (Foucault, 1980; Blaickie 1985; Leach & Mearns, 1996; Keeley & Scoones, 1999; Lomborg, 2000).

Model designers struggled with this issue, especially as social scientists were reluctant to join modelling efforts. The latter refused to reduce the human behaviour to computable generalisations: social actors have different perceptions, norms, interests and preferred practices, hence their action and interaction is difficult to predict. Environmental issues are complex and surrounded with uncertainty, because they involve multi-level interaction between multiple human actors and biophysical factors.

2.5.2 A new modelling objective: to understand emerging behaviour

The nineties were marked by a growing awareness of the complexity and uncertainty of natural resource management. Funtowicz *et al.* (1999: 6) put it aptly:

> "Let us take a system, a collection of elements and sub-systems, defined by their relations within some sort of hierarchy or hierarchies. The hierarchy may be one of inclusion and scale, as an ecosystem with (say) a pond, its stream, the watershed, and the region, at ascending levels. Or it may be a hierarchy of function, as in an organism and its separate organs. A species and its individual members form a system with hierarchies of both inclusion and function. Environmental systems may also include human and institutional sub-systems, which are in themselves systems. These latter are a very special sort of system, which we call reflexive. In those, the elements have purposes of their own, which they attempt to achieve independently of, or even in opposition to their assigned functions in the hierarchy.

> Anyone trying to comprehend the problems of the environment might well be bewildered by their number, variety and complication. There is a natural temptation to try to reduce them to simpler, more manageable elements as with optimisation models, but the complexity of environmental problems prevents reductionists approaches from having any but the most limited useful effect. Nothing can be managed in convenient isolation; issues are mutually implicated; problems extend across many scale levels of space and time; and uncertainties of all sorts and all degrees of severity affect data and theories alike" (Funtowicz *et al*., 1999: 6).

The heightened awareness of complexity and uncertainty called for modesty at the side of the model designers. The attention shifted from target-oriented modelling for technical and social engineering to modelling for improved understanding and adaptive management. It was recognised that a model did not provide 'the solution', but was just a tool to enlarge the 'bounded human rationality' (Dörner, 1997). MGLP models were now referred to as 'discussion facilitation tools to enhance learning'. New simulation models, so-called Multi-Agent System (MAS) models, were developed to better understand how simple processes and activities of agents at low hierarchical levels are mutual interfering and lead to the emergence of complex behaviour at higher hierarchical levels. This would help stakeholders to gain more understanding of the human and biophysical processes they were dealing with (Morecroft, 1994; Vennix, 1996; Gilbert & Troitzsch, 1999). Simulation models enhance learning because they provide rapid systematic feedback to actions in a relatively low-risk setting (Isaacs & Senge, 1994).

For NRM the combination of Multi-Agent System (MAS) and Cellular Automata (CA) or Geographical Information System (GIS) seems promising as it combines human reasoning and action with biophysical system dynamics. MAS-based models cover the following aspects (Ligtenberg *et al*., 2001):

- *Actors/Agent*: Individuals and groups, with their position, norms and values, access to resources and intentions.
- *Actor-based processes*: Actors perceive the ecological environment and each other. They reflect, communicate, negotiate and coordinate the (spatial specific) use and management of natural resources. This process is characterised by multi-actor, multi-goal, multi-scale and multi criteria facets.
- *Spatial environment*: Not all locations are equally suitable for various types of ecological services. A location may show restrictions, opportunities or threats.
- *Autonomous processes*: The environment itself hosts processes that change its nature, e.g. erosion, mineralisation, vegetation growth, ground water flows, etc.

Several research institutes started to develop MAS (and CA/GIS) models for policy makers. In Europe, the French CIRAD institute is active in this field and produced MAS studies on the 'stockbreeding wastewater system' in Reunion; the economic impact of various policy measures on woodcutters, traders and consumers in Niger; and water allocation issues in the Republic of South Africa, Tunisia and France[6]. Ligtenberg *et al*. (2001) made a survey of the spatial preferences of three prominent stakeholders of a regional land use planning exercise and explored the potential effect of different decision-making procedures on the escalation of conflict or convergence of ideas amongst the stakeholders.

[6] These studies were not published but presented during the CIRAD organised MAS course at the Wageningen University, September 17-28, 2001.

2.5.3 Enhancing stakeholder involvement

Land use modellers were not only confronted with the issue of complexity. They also had to deal with the limited functionality of their models. Science-based models triggered discussion at the level of policy makers, planners and farmers, but very few of them were actually used for decision making. User research pointed to the limited relevance of models: models often generated answers for questions that the envisaged model users did not pose. Users had a different perception of the issues at stake, judged other processes and activities as crucial, used other evaluation criteria and fancied other solutions. For models to be relevant and be used, it was essential to include problems, processes and activities, evaluation criteria and the kind of solutions that stakeholders deemed important (David, 2001). These findings made model designers conscious that it was crucial to integrate stakeholder knowledge and it heralded the start of participatory and integrated modelling. Social experts were called for and finally, encouraged by the recent developments in participatory modelling by learning organisations, they joined their technical colleagues.

The start of integrated modelling coincided with the era of democratisation, decentralised governance, interactive policy-making and the privatisation of extension services. Natural resource management responsibilities (partly) devolved to the local stakeholders. The new challenge for land use modelling was to enhance stakeholder learning. Model designers encouraged stakeholders to define the relevant elements and activities to be included in the model. These models would enable stakeholders to integrate and structure knowledge and learn about natural resource management.

The first attempts for integrated modelling were done in the field of MAS and GIS/AC modelling. These types of models are capable of covering a wide range of information and allow the model designers to include all types of knowledge deemed important by the stakeholders. GIS/AC models use a spatial grid to store information. They are handy to organise, visualise and confront all kinds of site specific knowledge. MAS models cover actor-based and environmental processes and can treat a wide range of stakeholder knowledge. One of the earliest attempts of integrated modelling took place in 1987, when GIS was used to study traditional Balinese irrigation and rice-cropping practices. During the Green revolution, the Indonesian government had persuaded farmers to cultivate the 'miracle' rice and use fertilisers and pesticides. However, this led to increased pest damage and crop failure. With the use of GIS, farmers and extension workers re-learned old management practices (Lansing, 1991; Lansing & Peterson, 2003). In Australia, the Herbert Resource Information Centre used GIS to integrate the knowledge of various stakeholders of the catchment's area of the Herbert river and to provide the various stakeholders with the information pertinent for decision making, negotiation and conflict resolution (Walker *et al*., 2001). In the northern Philippines, Gonzalez (2000; 2002) engaged rural farmers of Ifugao to collectively interpret aerial photographs and integrate their knowledge of traditional terrace agriculture in a GIS, with the aim to improve the management of the Ifugao watershed. In Senegal, the CIRAD started with an exploratory research of an irrigation scheme, developing a preliminary MAS model and a corresponding card game (Barreteau *et al.,* 2000; 2001; D'Aquino *et al.,* 2002). Farmers were asked to play card and propose changes when necessary. This enabled participants to understand the different interests of various full-time and part-time farmers and the consequent (mal-)functioning of the irrigation scheme and helped them to improve their management. Still ongoing is the research of Boissau, which couples stakeholder role-plays with MAS modelling to explore links between individual and collective natural resource management in northern Vietnam (Boissau, pers. comm.).

MGLP models treat biophysical information and aim at technical innovation; they are more focussed than GIS/AC and MAS models. Hence, model designers cannot use MGLP modelling to organise unstructured stakeholder knowledge to identify and better understand all kinds of emerging issues. MGLP modelling is useful when the preliminary consultation and a joint analysis point at problems to be solved by technical measures. Integrated MGLP modelling is still in an infant stage.

2.6 Land use modelling in the Sudano-Sahel

2.6.1 The emergence of the concern for land degradation

The concerns started around 1800, when Malthus warned that population, if left unchecked, grew more rapidly than food production (Koning & Smaling, 2002). It would take another century before this issue emerged on the political agenda.

Around 1930, experiences of land degradation in America (the Dust Bowl) and India heightened the concern for inappropriate exploitation of land in colonial Africa, but this only resulted in the increased control and regulation of indigenous farm practices (Leach & Mearns, 1996; Koning, 1999). It was after the economic crisis and the Second World War that the European countries recognised that development was not an inevitable historical process but had to be fostered, especially in the underdeveloped countries (Escobar, 1995). Between 1948 and 1965, development economists elaborated several development theories about the 'underdeveloped countries'. With respect to the agricultural sector, two development theories influenced the scientific debate:

- Geertz (1963) elaborated the idea of social involution. It seemed that in subsistence economies, population growth and effective food demand were the driving forces for change. Increased food demand required an expansion of the cultivated area, increased cropping intensity or new cultivation techniques. Farmers were able to find the necessary technical and institutional adjustments in due time, except when facing plagues, internal conflicts, exceptional variability of weather, etc. A critical situation could be mitigated by emigration or alienation of resources by other communities. If no escape were found, the Malthusian path would lead to land degradation and social involution: adjustment through the sharing of poverty, a vicious downward spiral (Koning, 1999; Koning & Smaling, 2002).
- Boserup (1965) suggested a more positive perspective: population growth would accelerate agricultural innovation. Increased population growth would lead to higher cropping intensity and more labour intensive production. Additionally, a high population density would reduce transport costs, facilitating the local specialisation between towns, the commercialisation of agriculture and a change from feudal land tenure to a private land property system. When this development proceeded, farmers would earn enough to mechanise and use chemical inputs; increased labour use and diminishing returns on labour would induce technology development. Changes in technology would happen at certain thresholds, increasing land productivity in a staircase stepwise pattern.

Up until 1974, there was a scientific interest in African agriculture, but development interventions concentrated on the industrial sector. Then severe droughts and food crises alarmed the world. The Sudano-Sahel was one of the most affected areas. Besides of France, several other western countries offered development aid. The aid aimed at food self-sufficiency and improved livelihoods of the rural population. The first requisite was to determine the exact cause of the food crisis.

2.6.2 Modelling to enhance scientific understanding

The question of the cause of the food crisis triggered a flux of agronomic empirical research with mixed results. The poor rains made water as an obvious choice as being the most limiting resource. However, plant growth simulation models quickly showed that, except in years with severe drought, soil nutrient status was the most limiting resource both for agriculture in the Soudano-Sahel as well as for the pastoral systems in the Sahel (Breman & de Wit, 1983; Van Keulen & Breman, 1990). Initially, Malthusian visions dominated: research seemed to show that both animal and human carrying capacities where exceeded, mainly by an increasing population entirely dependent on natural resources (Van Keulen & Breman, 1990). Respected research and development institutions like the FAO concluded that population growth, widespread poverty and lack of agricultural intensification were the main causes of soil degradation and food scarcity (Cleaver & Schreiber, 1994; Bationo *et al*., 1998). But some comments were made: according to Kessler (1994) it is still hard to quantify nutrient balances despite detailed research and Breman *et al*., (2001) state that African soils are inherently poor in nutrients. Instead of identifying population growth as such as a problem, the idea was refined to 'overpopulation at low population density' (Breman *et al*., 2001), implying that Boserupian aspects play a role as well.

2.6.3 Science-based models for operational use

The Malthusian diagnosis formed the basis of a wide array of development interventions. Initially donors provided relief through food aid and large-scale infrastructure and industrial projects. Then, in 1973, the World Bank president McNamara presented the Integrated Rural Development (IRD) and Basic Human Needs approach. The idea was to enhance the productivity of the small farmers through sound economic and scientific planning of regional development. Successful experiences of agricultural development would be duplicated in other less fortunate areas. This approach heavily relied on geographical zonation and crop growth simulation modelling. Land use plans consisted of technical-economic feasibility studies for regional policy making.

The ideas of IRD became mainstream around 1980. Donors started to focus on multisectoral development of specific regions and drew up regional development plans. In the Sudano-Sahel, the regional plans gave priority to environmental restoration and protection measures; extension systems promoted soil and water conservation (SWC) measures at the individual farm level and community projects provided food-for-work and other incentives to mobilise people for large scale anti-erosion works (Zanen, 1999).

In the nineties, MGLP models became available in the Sudano-Sahel. Most models aimed at the improvement of the agricultural productivity, while maintaining ecological sustainability. North-South research cooperation projects provided the National Agricultural Research Institutes (NARI) in the Sudano-Sahel with the necessary models. These models would enable NARI's to identify promising new technologies and improve regional land use planning. Nowadays, INERA (Institut des Recherches Environnementales et Agricole) in Burkina Faso, ESPGRN (Equipe Système de Production et Gestion de Ressources Naturelles) and IER (Institut Economie Rural) in Mali have MGLP models at their disposal but the actual use of these models is limited.

2.6.4 Modelling pitfalls

In the Sudano-Sahel, MGLP modelling encountered various setbacks. Some were inherent to the methodology used; others could be attributed to the context of the Sudano-Sahel.

Limited validity

Crop growth simulation modelling for the African context is troublesome because the theoretical generated 'attainable yields' of current techniques greatly exceeded those realised in the field (Penning de Vries *et al*., 1995). As the accuracy of official statistics were unknown, it was impossible to separate the effects of unrealistic simulation from statistical errors (Bouman *et al*., 1996). To get 'guesstimated realistic' attainable yield levels, model designers decided to downscale the simulation results in a linear way or with a fixed percentage (Van Duivenbooden, 1995; Veldkamp & Fresco, 1997) or to extrapolate data from other geographical areas.

Time and expertise consuming

Modelling is time and expertise consuming. The overall inaccessibility of reliable data in the Sudano-Sahel made that modelling scientists even lost more time in the collection of data and often relied on rough guestimates (Stroosnijder, pers. comm.).

Failure to capture the diversity and complexity of the farm reality

MGLP models work with soil nutrient balances and carrying capacities. This method extrapolates nutrient balances at plot level to higher scales such as the farm level and the regional level. This method uses a snapshot approach when trying the understand long term dynamics and has the danger of extrapolating limited, locally specific data to wider scales, thus ignoring local diversity and the mutual interference of biophysical and socio-economic processes at various scale levels (Scoones & Toulmin, 1998; Marcussen & Reenberg, 1999; Speirs & Marcussen, 1999; Mazzucato & Niemeijer, 2000).

Inappropriateness of the underlying theories of human behaviour

The model designers indicated the limited explanatory capacity of the biophysical-economic models for the coping behaviour of the poor households (Kruseman & Bade, 1998; Kruseman, 2000). In fact, the model focuses on the economic value of transactions, while in African societies, even when they become more integrated into market economies, transactions continue to have multiple meanings and are often used to establish or maintain social relationships (Berry, 1993; Mazzucatto & Niemeijer 2000). Especially poor households invest in social relations that provide them with resources in time of need. Another problem of models is their ignorance of farm practices in the Sudano-Sahel, that consist of a combination of family farming and individual farming: gender, age and marital status define an individual's farm responsibilities and resources, and the subsequent intra-household dynamics (Ruben *et al.*, 2000).

Limited use due to lack of modelling skills

An inventory of modelling efforts in the Sudano-Sahel revealed that the limited availability of reliable data and the lack of programming skills of the African counterparts hindered the adaptation and use of models by African research institutes. In the year 2000, INERA used the MGLP model they had acquired to assess the desirability of new techniques, but ESPGRN was still investigating how to use the model and IER decided to opt for another more simple economic model (Struif Bontkens, pers. comm.).

Limited relevance for regional planners and policy makers
Many models remained purely scientific enterprises. Those models that aimed at operational use, proved to be of disappointing relevance for regional planners and policy makers. In Mali, the models provided answers for questions, which were not posed. Despite the generous material support and the availability of the computers, the land use models remained unused.

2.6.5 Can computer models enhance learning for natural resource management?

The notion of land degradation was based on the idea that ecosystems had static equilibrium states with a climax vegetation[7]. When empirical research suggested that soil nutrients rather than rainfall were the limiting factors for the growth of the vegetation, the equilibrium theory was expanded with concepts like nutrient balances and carrying capacity. When baseline data was lacking, scientists 'interpreted' field measurements that were made under very different circumstances and in different areas (Scoones & Toulmin, 1998). For regional planning purposes, field level nutrient balances were aggregated to higher scale levels, ignoring the scale and time related natural resource processes (Rasmussen, 1999). Scientists usually noted the limitation of the research data and aggregation problems, but policy makers and media demanded sweeping statements neglecting the premises (Leach & Mearns, 1996, Lomborg, 2001). In the eighties and the nineties, the notion of land degradation was firmly anchored in the development practice.

Nowadays modern technologies expand the possibilities of scientific understanding and scientists challenge former hypotheses and assumptions. Historical analyses of field measurements, aerial photos and satellite images demonstrate a high spatial variability of land quality, dynamic natural resource processes and dynamic human cultivation patterns. As the period of detailed scientific research is short in comparison to the times scales of climate and soil erosion processes, scientists stress the uncertainty of the eco-system equilibrium concept. Semi-arid areas are now alternatively described as highly variable, event-driven systems (Ellis & Swift, 1988; Leach & Mearns, 1996; Rasmussen, 1999).

For eastern Burkina Faso, Mazzucato & Niemeijer (2000; 2001; 2002) made a historical analysis of the land use patterns, soil quality and agricultural production at field, provincial and national level. They concluded that the agricultural production per cultivated hectare did improve rather than aggravate[8]. Critics however noted that the study omitted the relation between pastoral and cultivated areas, while the expansion of the cultivated area and the transport of manure from pastoral areas to the fields would have deteriorated the pastoral areas. It is not yet clear whether the Malthusian or the Boserup theory applies. Environmental issues are complex and have a high spatial variability. All analyses operate with certain selection criteria, a certain scale and time level and with certain built-in values and commitments; none of them can encompass the whole system (Funtowicz *et al*., 1999). Either theory will find spots to confirm its hypotheses.

The question whether present agricultural development leads to soil mining and deteriorating agricultural production remains unsolved. Nevertheless, it is clear that the Sudano-Sahel

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[7] Climax vegetation is an ecological concept describing the final stage of a succession of plant communities. It is the vegetation, determined by the inherent soil and climate conditions.
[8] For the period of 1961 to 1998, Mazzucato and Niemeijer (2000) calculated national yield trends. Yield figures for the two main staple crops, millet and sorghum, show an increase from about 350 kg/ha and 500 kg/ha to 700 kg/ha and 1000 kg/ha, respectively. During this period the average annual rainfall decreased some 150-200 mm.

deals with a high level of undernourished people. For the period of 1996-1998, the percentage of undernourished people was about 31% in both Burkina and Mali, 38% in Chad and 47% in Niger (FAO, 2000). The countries have limited development prospects: they are land-locked and have limited trade opportunities; they are confronted with low world market prices for mineral resource and agricultural produce; and their labour migrants slowly return because of the increasing instability in Ivory Coast. To feed the growing population, it is obligatory to invest in agriculture and natural resource management. Because both government and development projects lacked the necessary resources to implement, monitor and control natural resource management, the authority and responsibility have now devolved upon local stakeholders, notably the Comités Villageois de Gestion du Terroir (CVGT) and individual farmers (§ 3.2.4). Agricultural extension systems are supposed to play a supportive and facilitating role.

2.7 The test case: SHARES

Aim of this thesis is to shed a light on the potential of computer-based models for learning about natural resource management in the Sudano-Sahel. Modelling is a time and expertise consuming enterprise and it is impossible for a researcher to develop and subsequently test all possible kinds of models. This thesis, therefore, limits itself to the analysis of the use of an existing model and will only provide a partial answer. As modelling developments still proceed, the answer is also a product of its time and consequently not conclusive. The study started in 1999 and used a model developed in the period 1998-1999. At that moment some user-studies on GIS modelling were underway (Lansing 1991; Lansing & Peterson, 2003; Gonzalez, 2000; 2002; Walker *et al*., 2001); MGLP modelling was at its height but still lacked user-studies; and MAS modelling was still at an experimental stage. In this context, it was deemed appropriate to concentrate on the added value of MGLP modelling for practical extension work.

In 1992, Wageningen University had started a research programme Antenne Sahélienne. Aim of the programme was to execute "strategic research oriented on ascertaining the technical, economic and social conditions under which villagers are able and willing to improve the productivity of their communal silvo-pastoral area and subsequently use and manage it sustainably" (van Rheenen & Stroosnijder, 2001, prologue). The guiding principle was that agriculture should intensify selectively if the Sahel was to break out of the vicious circle of natural resource degradation. Such intensification should, at least eventually, be self-supporting, meaning that it would have to be financed from the sale of agricultural produce (Stroosnijder, 1994).

In 1998, seven years of agro-silvo-pastoral research of the Antenne Sahélienne in Zounweoogo and Sanmatenga province of Burkina Faso was integrated in the computer model SHAred RESources. The development of the SHARES model was a scientific challenge to arrive at a more holistic analysis of natural resource management (Van Rheenen & Stroosnijder, 2001; prologue). The initial idea was to develop a computer model that would serve as a research guide. Modelling endeavours forced scientists to select knowledge that they value as essential. To integrate the knowledge the scientists had to deal with aspects usually treated by other disciplines. Multi-disciplinary modelling required communicative learning: scientists developed a more holistic perspective and formulated broad research questions. The validation of the model results enabled them to discover the relative importance of essential aspects and to identify knowledge gaps. Scientists perceived multidisciplinary modelling as a worthwhile but strenuous affair: it demanded much effort and disciplinary modesty of the collaborating scientists. Furthermore, not all scientists were very committed to these kinds of enterprises because it remained difficult to publish multi-disciplinary findings in scientific journals, which tend to have a disciplinary focus (Collinson, 2001).

Like all multi-disciplinary modelling, the SHARES modelling demanded communication and negotiation amongst the designers. It took much effort to develop a balanced perspective from the available data and disciplinary interests. The idea was that the comparison of model results and field data would enable scientists to verify hypotheses, to identify knowledge gaps (divergences of generated scenarios with actual management practices) and focus future modelling and field research by the Antenne (Begemann et al., 1995; Nibbering, 1996). This idea did not materialise when it became clear that the Antenne would be closed. The modelling exercise was accelerated and model validation was limited to the comparison with available research data. SHARES would not serve as a research guide.

When confronted with the closure of the research programme the SHARES designers thought about alternative use of the SHARES model. At the same time, research institutes were questioned about the relevance and practical utility of agronomic models. There was increasing pressure from agricultural funding to ‘prove’ the operational applicability of modelling (Bouman *et al.,* 1996: 183). This inspired the SHARES designers to formulate a research to study the operational utility of SHARES. This provided the opportunity to test whether an MGLP model could enhance stakeholder learning.

This chapter gave an overview of the history of land use models. In the Sudano-Sahel, agronomic modelling advanced scientific understanding of natural resource problems and guided technical engineering, but it also experienced several setbacks. Modelling is especially troublesome in the Sudano-Sahelian context where it is hard to get reliable data and most scientists still lack the necessary computer programming skills. These experiences call for modesty, not for pessimism, as this would deprive African professionals a potential tool for learning. It rather demands a proper, context-related analysis of the added value of computer based modelling for natural resource management.

Photo i: Group discussion in Gainsa

3 Context: Farmers, policy makers and rural development projects

The aim of this study is to see whether computer based modelling enhances co-learning between agricultural extension officers and the local population in the intervention zone of the Integrated Rural Development Project PEDI (Programme d'Exécution du Développement Intégré), in Sanmatenga province. This chapter introduces the local context of the research.

The chapter consists of three sections. Section 3.1. gives a geographic description of the PEDI intervention zone, its population and their livelihood. Section 3.2. provides an overview of the national policies and donor strategies in Burkina Faso, with a major impact on natural resource management and agricultural production. Section 3.3. presents the evolution of the intervention by the PEDI project and concludes with the motivation and the expectations of the PEDI staff concerning a forthcoming agricultural extension experiment.

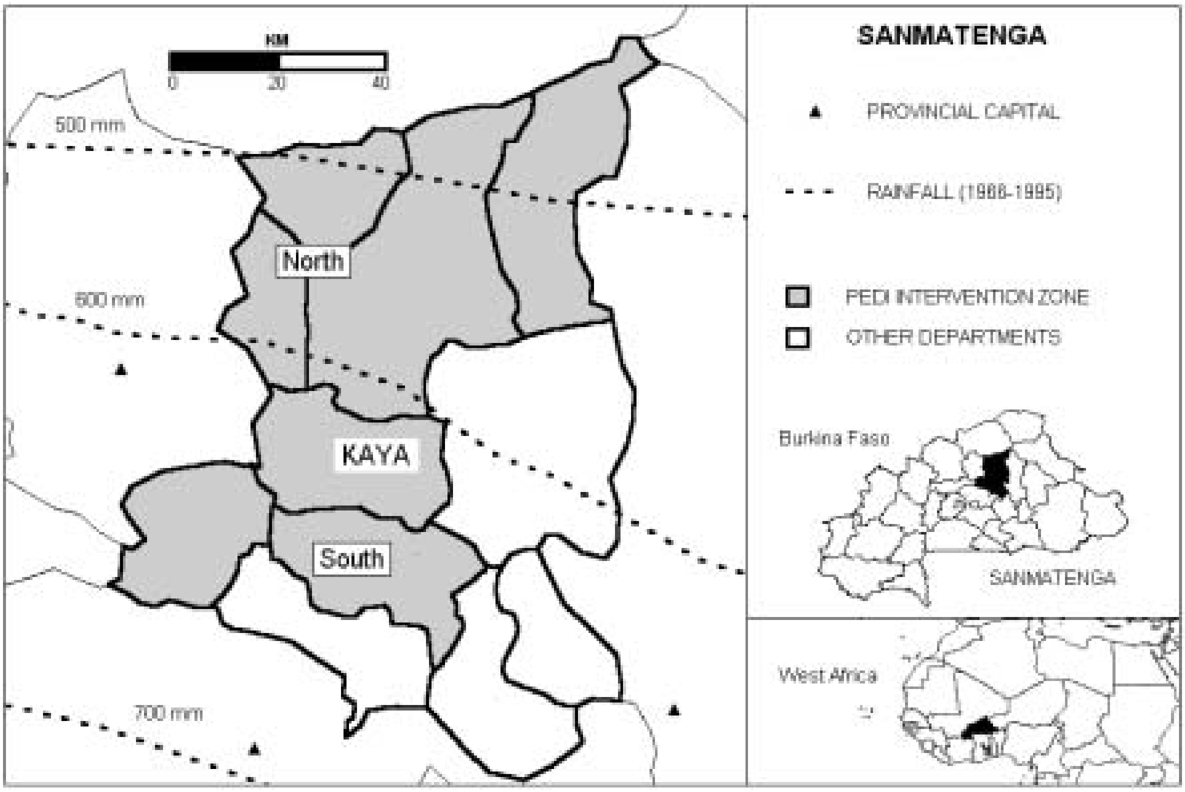

Figure 3.1: The PEDI intervention zone: seven departments of Sanmatenga province

3.1 The intervention area

3.1.1 The location

The United Nations Human Development Index identifies Burkina Faso as one of the poorest countries in the world (World Bank, 1999). The South-western part has a reasonable agro-ecological potential and expanding industrial and service sectors. The natural resource base and commercial potential of the semi-arid zone of the central plateau is limited.

PEDI intervenes in 7 of the 11 departments in Sanmatenga province. The province covers an area of 9.219 km^2 in between the 12°40′ and 14°05′ northern parallels at about 250-300 m above sea level. The intervention zone is situated in the Sudano-Sahelian zone and has one (short) rainy season with an irregular spatial pattern and a high variability from year to year. The annual average ranges between 500 to 700 mm from North to South (See Figure 3.1). The four northern departments Barshalogho, Dablo, Namissiguima and Pensa receive an annual rainfall of about 500 mm and have steppe vegetation with thorny Acacia species. The three southern departments Kaya, Boussouma and Mané have an average annual rainfall of 600-700 mm and are covered with savannah shrub and tree vegetation.

The intervention zone covers various land types with varying landscape and soil qualities. Land types with deeper topsoils are suitable for arable farming: the sandy soil (Moore: *Bissiga*), the clayey soil (Moore: *Bolé*) and valleys (Moore: *Baongo*). The slopes (Moore: *Zegdega*) have a gravely topsoil of less than 40 cm but are still used for arable farming. The stony hills (Moore: *Tanga*) have a shallow soil formation (less than 45 cm deep). The stony plateaus (Moore: *Rassempuego*) have shallow soils on iron crust. Both soils are used for sylvo-pastoral activities. About 36% of the land is assumed suitable for arable farming (For more details see Mulders *et al.,* 2001).

3.1.2 The population

In 1996, the government census counted 464.032 inhabitants in Sanmatenga province and registered an annual population growth of 2.4% for the last decade (INSD, 1998). About 91% of the population is registered as Mossi and 8% as Peulh. Those who are registered as Peulh are in reality Peulh and Rimaïbè (singular Dimadio), the former slaves of the Peulh.

In the 15th century, the *Nakomse* migrated from Gambaga in northern Ghana to the central plateau in the western part of present Burkina Faso. Historical narratives talk about continuous warfare and strife for political power and the establishment of a hierarchy of Mossi cantons and kingdoms. The original non-Mossi population groups were gradually incorporated into the Mossi society and nowadays they identify themselves as *Tengbiisi*. Descendants of the *Nakombse* lineage segments hold political authority in the person of the *Naaba* or village chief, while descendants of the submitted *Tengbiissi* retained the exclusivity of the cult of the earth, personified by the *Tengsoba* or land chief (Izard, 1985). When French rule pacified the region and imposed colonial rule in 1896, the Mossi society consisted of 19 kingdoms (Izard, 1982). The current territory of Sanmatenga province corresponds more or less with the territory of the Boussouma kingdom. The king inaugurates the *Kombere Naaba* or canton chiefs, who at their turn nominate the village chiefs (Breusers, 1998).

Not much is known about the history of the Peulh in Sanmatenga province. It seems that they originate from Mali and arrived around the 17th century (Diallo, 1996). Mossi are arable farmers while the Peulh are herdsmen, who wander around in search for good pastures. Compared to the Mossi, the Peulh have a somewhat loose social organisation, but several Peulh settlements pay tribute to a *Jooro* chief. These *Jooro* maintain political relationships with the Mossi chiefs at village and canton level. Their main task is to negotiate access to pastures and watering points for the cattle herds. This is of increasing importance as population growth puts pressure on the natural resources.

3.1.3 Land tenure

The Peulh recognise the fact that Sanmatenga is Mossi territory. The Mossi chiefs authorised Peulh lineages to use certain areas for settlement and for pasture. However, the migratory lifestyle of the Peulh made them gradually loose claims to land to the growing Mossi population. They respect the principle of the Mossi that everybody who settles in the area is entitled to cultivate sufficient land to provide food for his family. Land use rights are allocated according to three principles: the moment of arrival of the kin group, the actor's seniority rank within the kin group and the actor's preference to farm his father's place. The first two are patrilineal seniority principles. The third principle follows from the fact that when a man leaves a plot fallow, he maintains a right of access to it, which is transferred to his younger brothers and/or sons who farmed that plot with him (Breusers, 1998; Graaff *et al*., 2001). Pasture is not a form of land use that establishes future land use rights.

Land tenure arrangements are not static: though the ultimate control of land is vested in the first kin group that arrived, arriving kin groups can 'autochtonise' through the negotiation of identity and shed their status of 'strangers' by referring to their ancestors who were the first to clear certain tracts of the village territory or by the long-standing use of land by their kin group. The distribution of land rights changes through the mobility of actors and fields within and outside the village. The head of a household can obtain access to arable fields through: (1) the inheritance of a 'birth right' along patrilineal lines (from fathers or elder brothers who control rights to land); (2) borrowing land controlled by other kin groups; and (3) newcomers in a village are entitled to use land to provide for their household and their future dependants. For more details see Breusers (1998).

3.1.4 The Mossi livelihood

Arable farming

The Mossi head of household (Moore: *puugsoba*)[9] uses the collective fields (*puugo*) to grow staple foods like millet, sorghum and maize, as well as some cash crops like groundnut, bambara nut and cowpea. All household members work at the *puugo*, but they also attend their individual fields (*beolga*). They are called *beolgsoba*.

Each year the *puugsoba* allocates small parts of the *puugo* to women, to grow spices and vegetables and some groundnut or cowpea. As soon as a woman has given birth she is entitled to have her personal *beolga*. It depends on the local culture, the woman's age and the household's food situation, whether a woman has a responsibility to provide cereals for home consumption or is allowed to concentrate on cash crops (Reij-Weeder, 1983; Pacere, pers. comm.; Thorsen, 2002). Young men without family responsibilities tend to cultivate cash crops like cowpea and groundnut.

[9] In the rural areas Mossi live in compounds (*zaaka*): huts clustered around a communal millet grinding table. The compound is headed by a *zaksoba*, a man with his wives, children and sometimes his younger brothers and their families. Often they work together at the *puugo* and share their meals. At a certain age and marital status, brothers and sons receive their own *puugo* to start their own household. From being a *beolgsoba* they get the status of *puugsoba*. In due time they will move out, start their own *zaaka* and become a *zaksoba*. A man can marry several women and takes care of the widows of his father and brothers (levirate). All these women live at the compound, but at a certain age they are exempt of working the collective field. At this moment, their status changes from *beolgsoba* to *puugsoba*, but they remain a member of the compound. It depends on the family situation and a woman's personality whether she prefers to run her own household or continues to share her food and take care of the children of the compound. In this thesis I use the term 'compound' when referring to a '*zaaka*'. The term 'household' refers to a group of people who collectively cultivate a *puugo*; a 'head of household' refers to a *puugsoba*; 'farmer' refers to *puugsoba* and *beolgsoba*.

The Mossi are subsistence farmers and it is perceived as humiliating when someone is not able to feed his family[10]. For the period of 1984 to 2001, the average cereal production covered 91% of the provincial food requirement (Van den Elshout, 2002). Considering the fact that 8.4% of the population lived in Kaya city (INSD, 1998), one might conclude that the rural population almost attained food self-sufficiency. However erratic rainfall leads to very different annual food situations: in 1988, the cereal production covered 142% of the provincial food requirements, while in 1997, the cereal production only covered 43% of the food requirement. In 11 out of the 18-recorded years Sanmatenga farmers did not produce enough food to feed the population (derived from MA, 2002).

Labour Migration
Apart from arable farming, Mossi earn their living with labour migration and livestock husbandry. Mossi labour migration started with the French colonisation in 1896. The colonial administration ruled the population through the existing chieftaincies and developed a system of 'prestations': forced labour for the development of infrastructure, military service and the cocoa plantations in Ivory Coast (Gregory *et al.*, 1989). In addition, the French installed cotton quota and taxes. The need for cash to pay taxes pressed local households to send some of their members temporarily to Gold Coast. Around 1950 the situation changed: forced labour was abolished, the taxes were relaxed and it became simply lucrative to migrate to Ivory Coast[11]. From then on, young men migrated for one to three years to earn some money and to free themselves from parental authority and get some new experiences.

The migration pattern changed in the sixties when men started to migrate with their family. They prolonged their stay and some even started to buy land. This coincided with an increasing migration towards the southern and western areas within Upper Volta[12], where the rainfall and soil fertility allow the cultivation of cash crops like cotton, groundnut and sesame. Sawadogo (1994) notes that at the end of the sixties 47% of the Mossi migration had a destination abroad, 41% a rural destination in Upper Volta and 12% an urban destination in Upper Volta. In the seventies internal migration even outnumbers external migration and internal migrants tend to settle for longer periods. The 'saturation of the Mossi country' encouraged migration: between 1975-1985, one out of six people left Sanmatenga (Breusers, 1998).

Livestock farming
Migrants maintain close relationships with their relatives at home and regularly send remittances to buy additional food and/or to buy livestock. Livestock is the preferred investment in the rural areas as it provides both security and profit. During the French occupation, the Mossi had few cattle, probably because of the risk that the colonial administration confiscated cattle for transport purposes (Breusers, 1998). In 1960, Upper Volta became independent and the Mossi increasingly used the remittances for investment in livestock. In the seventies, this process was accelerated by the famines: the relative price of cereals increased and Peulh had to sell a substantial part of their herd to buy food. Mossi

[10] In 1997/98, when the harvest covered only 43% of the food needs (estimated at 190 kg per person, per year), people ate less and women secretly left to collect leaves and other edibles but nobody admitted their hunger. Only in case of extreme urgency, small stock was sold to buy additional food.
[11] During the colonial period, the local population preferred to migrate to the successful indigenous cocoa farms in Gold Coast instead of going to the faltering European cocoa plantations in Ivory Coast. The situation changed in the 1950s when infrastructure like the Abidjan port and the Abidjan-Ouagadougou railway was completed and Houphouet-Boigny organised the syndicate of indigenous plantation owners in Ivory Coast, the producer price of cocoa surpassed the Gold Coast price level (Breusers, 1998; 182).
[12] Before the coup of Sankara in 1983 Burkina Faso was called Upper Volta.

bought the cattle but left them under the custody of the Peulh herders, who in return received the milk and a number of heifers. Nowadays the Mossi fatten one or two sheep and/or bulls at the compound. Some goats and sheep graze in the surroundings of the village and cattle is entrusted to Peulh herders.

Mossi have a considerable interest in livestock farming, but they conceal their wealth to diminish the tensions within the Mossi society. The Peulh are considered as reliable accomplices[13]. In public, Mossi stress the importance of millet production and the differences and conflicts with the Peulh to affirm the Mossi unity and hide their internal divisive interests. Back stage they have friendly, mutual beneficial, informal relationships with the same Peulh they publicly condemn (Breusers, 1998; 286).

3.1.5 The Peulh livelihood

The Ministry of Agriculture and Animal Resources (MARA) recorded the following livestock ownership for resident, mostly Mossi, households (hh) in the central corridor[14] as compared to the transmigrant, mostly Peulh, households (Table 3.1).

Table 3.1: Livestock ownership in relation to household size[15] and livelihood in 1993.

Household size/ type Livestock	2-3 people		10-14 people		15-19 people	
	Resident	Transmigrant	Resident	Transmigrant	Resident	Transmigrant
Goats	2	8	7	10	8	11
Sheep	1	6	6	8	8	10
Cattle	0.5	10	2.5	17	4	18

Adapted from: Enquête national de statistiques agricoles 1993. Rapport d'analyse (MARA, 1996b).

In the more spacious northern Gorom-Gorom province, the Peulh indicated that you need at least a herd of 10 head of cattle to be able to combine herd growth and the sales of animals to buy millet in most years. With more than 20 head of cattle, a household was considered well off and able to 'solve one's problems'. Recalculating the data, this means that a household (assuming a minimum size of about 10 people) should have at least 1.5 TLU[16] per capita to live comfortably, provided no severe droughts occurred. For poor and middle category households, livestock provided for the cash income but the income in-kind from cereal production was about as important as the milk production. Sales of milk and livestock were determined by household cash needs (Zaal, 1998).

It is hard to find reliable data on the livelihood of Peulh households in Sanmatenga province. Like the Mossi, the Peulh are reluctant to declare the number of their animals, especially to

[13] According to Breusers (1998; 286) Mossi dislike the migratory life of a cattle herder and they recognise the Peulh's intimate knowledge of procreation and fecundity of cows.

[14] MARA (1996b) amalgamated the data of provinces Yatenga, BAM, Sanmatenga, Ganzourgou Kouritenga and Boulgou (together the central corridor) to enable statistical analyses of different farm styles.

[15] The household size generally corresponds with the life phase of the household: a household starts with 2-3 persons; an average household has 10-14 members; and a household of 15-19 household members consists of an elderly household head with adult children.

[16] TLU stands for Tropical Livestock Unit. The official conversion coefficients for West Africa are as follows: a head of cattle is 0.75 TLU, a sheep is 0.1 TLU and a goat is 0.08 TLU. Poor household have relatively more sheep and goats; animals that cost less and have a high birth rate.

government surveyors in view of the possible taxes[17]. The situation of the Peulh in the North of Sanmatenga seems to correspond to their situation in Gorom-Gorom. However, herd size is a dubious wealth indicator, as it is unclear which part of the herd is owned by the Peulh and which part is entrusted to him. For the South, the picture becomes even more obscure as Peulh tend to settle permanently, are increasingly involved in arable farming and entrust their cattle to transmigrant family members.

Both Breusers (1998) and Zaal (1998) remark that labour migration is not an important source of income for the Peulh. In colonial times, the French administration had difficulties to gain control of the transmigrant Peulh: Peulh had a rather loose social organisation, they frequently changed their location and they regularly moved to the northern areas, which were beyond French control. Therefore, the Peulh did not suffer much from the confiscation of cattle nor from taxes and forced labour recruitment. Today, Peulh labour migration remains limited and remittances are low.

3.1.6 Land use

The current land use in Sanmatenga province varies according to the population density, land quality and climatic conditions. About 36% of the area is estimated to be suitable for arable farming, 45% is pasture, 9% is forest and 10% is left for human habitation. The northern departments have an annual rainfall of 500-600 mm, are less suitable for arable farming, and have a low population density (see Table 3.2.). Here we find the major forests and pastoral areas. The southern departments receive more rain and have a higher population density. They are predominantly used for arable farming with some additional livestock husbandry.

Table 3.2: Population density of the intervention zone of PEDI in 1996 (INSD, 1998)

	Department	Surface (km^2)	Population	Density (inhabitants per km^2)
North	Pensa	1000	26.888	27
	Dablo	550	15.546	28
	Namissiguima	420	7.089	17
	Barsalogo	1720	55.553	33
South	Kaya	922	86.085	93
	Mané	730	38.272	52
	Boussouma	780	69.186	89

A household survey of the Antenne Sahélienne and PEDI gives an idea about the land and labour use of farm households in the North as compared to the South of Sanmatenga. The households in the North had less active household members and cultivated fewer fields, but the fields were larger (see Table 3.3.). The cultivated area per agriculturally active member was larger in the north than in the South.

[17] Zaal (1998) notes that the Peulh believe that disclosure of the number of animals would cause the death of at least one animal.

Table 3.3: Average size and land use of 40 households (hh) in Sanmatenga, 1998-1999

	# Active members[1)]		# Cultivated fields		Average area cultivated per hh		Average field size		Average area per hh member	
	1998	1999	1998	1999	1998	1999	1998	1999	1998	1999
hh North	6	8	6	8	4.59 ha	7.2 ha	0.77 ha	0.90 ha	0.72 ha	0.90 ha
hh South	8	9	9	11	5.32 ha	6.7 ha	0.59 ha	0.67 ha	0.66 ha	0.81 ha

1: An active household member was defined as a member of 12 years and older, present during the agricultural season of 1998 (not on migration).

The agricultural season of 1997 had been very difficult (43% food self sufficiency) and this induced labour migration. As a result, only a small labour force was available during the agricultural season of 1998. The good harvest of 1998 (107% food self sufficiency) had a positive impact on the strength and availability of the labour force and resulted in a larger cultivated area in 1999[18]. Table 3.4 shows that in the North, there was still enough fallow, so people enlarged the cultivated area (Tapsoba, 2000).

Table 3.4: The inclination to lend or give land by 40 households in Sanmatenga, 1998-1999

	% Cultivated fields borrowed		% Cultivated fields received	
	1998	1999	1998	1999
hh North	19%	16%	17%	47%
hh South	5%	7%	0%	0%

Source: the Antenne Sahélienne & PEDI household study 1998-1999

In the North, the farm heads exercise more control over the household resources than in the South (see Table 3.5.). In the North, women were only able to spend 17% of their agricultural labour hours on their individual fields. The women in the South could spend 31% of their agricultural labour hours on their individual fields. Furthermore, the northern farm members worked more hours: they spent 25% more hours per hectare while the cultivated area per member was also larger in the North than in the South (see Table 3.3.).

Table 3.5: Distribution of land and labour within the household (hh) in North and South of Sanmatenga, 1998

		Composition hh	Distribution of land	Distribution of labour
North	Farm head	16%	80%	87%
	Active women	54%	10%	8%
	Active men	31%	10%	5%
South	Farm head	13%	59%	72%
	Active women	66%	29%	20%
	Active men	22%	12%	8%

Source: the Antenne Sahélienne & PEDI Plough Impact Study 1998-1999

[18] From 1998 to 1999, respondents received a subsidised plough. One could argue that this explains the increase in cultivated area. However, the research data revealed that the acquisition of a plough did not cause a change in farm practices. Not the plough, but the donkey is the critical factor for ploughing, as a donkey can only work 2-3 hours a day. In 1998 the households already owned donkeys and they borrowed their neighbour's plough to cultivate their field. In 1999 few farmers used the plough, because the heavy rains at the start of the season made it hard to use ploughs especially in the clayed soils of the valleys.

In 1993, the Ministry of Agriculture registered 22.8% of the fields in Sanmatenga as treated with stone rows. About 23% of the households own, or have access to a donkey and a plough. Ploughs facilitate land preparation and weeding. However, when the rains start early farmers do not want to loose time on land preparation and start sowing. As a consequence, in a good agricultural season like 1993, only 6.7% of the cultivated area was prepared with the use of a plough; 14.1% was prepared manually and 79,2% of the fields had not been prepared (MARA, 1996a).

Farmers use small amounts of manure, compost, phosphate, NPK and urea. For the period 1998-1999, the Antenne-PEDI household survey registered an average use of manure and compost of 1060-1170 kg ha^{-1} in the South and 230-270 kg ha^{-1} in the North; an average use of Burkina Phosphate of 10-30 kg ha^{-1} in the South and 40-45kg ha^{-1} in the North; and an average use of NPK of 3 kg ha^{-1} (Tapsoba, 2000; 83). About 50% of the cultivated area was not fertilised (Van den Elshout *et al*., 2001). As the respondents were relative wealthy, we assume that the average fertiliser use in Sanmatenga is lower than in this sample.

Farmers intercrop cereals with legumes like cowpea, bambara nut and groundnut. Table 3.6. shows the relative importance of the various crops for Sanmatenga farmers. It presents the production of the good agricultural season of 1993 (116% food self sufficiency), and the bad season of 1997 (43% food self-sufficiency). The relative importance of the crops remained the same.

Table 3.6: Production in tonnes and relative importance of various crops in a wet and a dry agricultural season (1993 respectively 1997), Sanmatenga province

	Cereals (millet, sorghum, maize)		Other food crops (bambara nut, cowpea)		Commercial crops (groundnut, sesame)		Total	
1993	96874	85%	8782	8%	7902	7%	113558	100%
1997	41494	87%	3789	7%	2652	6%	47935	100%

Source: MARA (1996a) and MA (1998)

3.2 The policy context

National policies set macro-political priorities and provide a framework for local level intervention. Local intervention, in turn, provides experience to nurture future policy making. In Burkina Faso, the national government and the donor agencies intervene at both levels. This section provides an overview of the most prominent policies and intervention strategies of the last two decades. They determined the context and the guiding principles of the PEDI project.

3.2.1 From colonial rule to development intervention

External intervention in local natural resource management dates from the 1920-40s. The French colonial administration started agricultural extension activities to promote cotton cultivation and modernise the cultivation techniques through the introduction of ploughs. After the successive poor harvests and the collapse of the world prices in 1929, the colonial administration classified Sanmatenga as a labour reserve (Breusers, 1998). From that moment, they had little interest to intervene directly in agricultural production of drylands but they wanted the area to be self-reliant.

External involvement intensified in the 1960-70s. At independence, the government of Upper Volta inherited the colonial infrastructure but had few resources. This changed in the seventies when severe droughts and famines, coupled with cold war sentiments and the urge to gain political influence, triggered large scale donor support from the United States and European countries. Apart from food aid, donors initiated development projects in the area of infrastructure and industry. Soon afterwards the ideas of multi-sectoral rural development became mainstream and donors started to concentrate on Integrated Rural Development Programmes (IRDPs) in specific regions.

Zanen (1999:108) provides a vivid description of the policy context of this period: "The government functioned badly, corruption flourished, state funds were misused and civilian society eroded. Agricultural extension promoted cash crops (cotton and rice) rather than food security. The coup on 4 August 1983 and the establishment of the revolutionary military regime of President Sankara, brought a new spirit of development, which was of great psychological value to the people. To indicate the break with the past, the country was renamed Burkina Faso, 'land of the incorruptible people'. Villages had to organise themselves in development committees, Groupements Villageois, and the Ministry of Planning sent interviewers to gather ideas of the peoples priority needs for the first Five-Year Plan. The government launched so-called commando actions in the fields of public health, adult education, water supply and natural resource management."

3.2.2 The nationwide campaign to combat land degradation

The recurrence of droughts in the 1970-80s in Burkina Faso were attributed to a process of land degradation: the impoverishment of the vegetation, soil erosion by water and wind, depletion of soil nutrients, changes in the soil structure and salinisation of the irrigated areas. The main causes identified were population growth, extension of the cultivated area, the cutting of vegetation for fuel wood, bush fires and overstocking with livestock (Swift, 1996; Speirs & Marcussen, 1998; Rasmussen, 1999). Natural resource management became top-priority, and the revolutionary government reinforced the regulatory role of the state on this subject. They proclaimed 'les trois luttes', a nationwide battle against uncontrolled grazing, uncontrolled wood harvesting and bush fires. The campaign encompassed consciousness raising activities, the control of bad practices and the promotion of regenerative activities.

The forestry department played a pivotal role in the national campaign. It introduced new activities such as communal tree nurseries, a national tree planting day and improved wood-stoves, while simultaneously patrolling against abusive woodcutting. Everybody was entitled to collect fuel wood, but if someone intended to cut wood for construction or for commercial purposes a permit from the forestry department was needed. This national policy was not popular with the rural population. Firstly, they did not experience fuel wood shortages (Ouedraogo, pers. comm.). Secondly, government rules interfered with local management practices. Now, they had to pay for cutting their own trees and, on top of it, allow outsiders to cut trees in their territory. This resentment was fuelled by the fact that the forestry department did not use the permit system to monitor and manage the wood resources (Dorlöchter-Sulser *et al.,* 2000). If you paid for a permit, you could harvest anywhere you wanted and wood evolved from a common property resource to an 'open access' resource, with disastrous consequences in some places (Hardin, 1968; Nederlof & Dangbegnon 1998).

3.2.3 Land tenure reform

The 'Réorganisation Agraire et Foncière' (RAF) of 1984 was the first attempt to codify rural land ownership and land use. The RAF heralded a break with customary law as it declared land to be the property of state. The new political leaders promulgated laws favourable towards those who actually used the land, at the expense of non-exploiters who claimed to have ancestral rights. In addition, the RAF secured pastoral land use, while pasture corridors had never enjoyed a particular status in the perception of the communities (Lund, 1997; Breusers, 1998).

To break customary law, the government needed to replace the judiciary. At the village level, they appointed the 'Représentant Administratif Villageois' (replacing the traditional chiefs) to settle all conflicts in consultation with the local stakeholders. Land disputes that could not be settled at the village level would go to the tribunal. Formerly, these tribunals were presided by the government representative of the department, the 'prefect', assisted by customary chiefs and notables. From that time on, the 'Comités pour la Défense de la Révolution' took control of the legislation, the execution and the judiciary (Lund, 1997).

The RAF did not change the local land tenure practices. The revolutionary ideology created social unrest in the rural areas where the elimination of the traditional chiefs was perceived as a fundamental attack on Mossi values. After the murder of the president Sankara in 1987, the revolutionary ideals quickly diluted and the political debate calmed down (Zanen, 1999). In 1991, the RAF was modified: the government remained in the ultimate control of land but recognised that decentralised, local management would be a more appropriate and feasible option for the state as well as for the farmers (Lund, 1997). The tribunals were now presided by the 'prefect' and four lay assessors, generally retired schoolteachers or government officers and occasionally younger high school graduates. Traditional chiefs remained respected judiciary advisors and they gradually regained political power through their educated children, who joined the national political parties and took office at various government departments. Nowadays, land tenure disputes are increasingly politicised and influenced by the elite who control the connections between the national government in Ouagadougou and the regional service centres and their surrounding villages (Lund, 1999).

The most recent revision of the RAF in 1997 aims at laws that are relevant and understandable to the general public, while simultaneously curbing the excessive power of the customary chiefs. Articles of the RAF-97, promulgated in February 2000, refer to "the election or designation of a Comité Villageois de Gestion du Terroir (CVGT), in accordance with the local history and social-cultural reality"[19].

3.2.4 Local intervention strategies

The IRDP approach

The national law and policy were complemented by the activities of IRDPs. Like the government, donors considered land degradation as the most urgent rural problem and put high priority to the construction of stone rows along contour lines, semi-permeable rock dams, tree planting, the 'resting' of degraded bush land and the diffusion of techniques like composting. In general, they applied a watershed planning approach and supported various

[19] The constitution and the attributions of the CVGT according to Article 46 and 139 of the RAF 1997 (Textes portant réorganisation agraire et foncière, Loi n° 014/96/ADP du 23 mai 1996, Décret 97-054/pres/pm/MEF du 6 Février 1997, Arrêté n° 0010/2000/AGRI/MEE/MEF/MATS/MRA du 3 Février 2000).

provincial government departments to coordinate the implementation. Food aid and other accompanying measures mobilised the local population to perform the construction work in accordance with the indications of the technical officers.

The IRDPs did not manage to attain their ambitious objectives. It proved hard to mobilise the population for standardised activities at watershed level and it was difficult to achieve coordinated action amongst the various sectoral departments (Bognetteau-Verlinden *et al*., 1992; Batterbury, 1998). During a regional seminar in Nouakchott, organised by CILSS[20], policy makers of the various Sahelian countries proposed a new approach: the Gestion du Terroir Villageois (GTV). The GTV approach tried to reconcile ecological and social sustainability and considered full participation of the local population a requisite and starting point of its implementation. To enable more involvement of the local population in the planning and execution, GTV left the watershed approach and opted for the village as an ecological, social and administrative unit (Mando *et al.,* 2001).

The GTV approach

In 1986, the Government of Burkina Faso proclaimed the GTV approach. It started with a test phase. Bognetteau-Verlinden *et al*. (1992) describe the GTV methodology, as it was tested by the forestry department in Sanmatenga province. First, the population was informed about the GTV approach through GRAAP sessions.[21] They were invited to participate in a joint analysis of the natural resources and the socio-economic situation of the village. Then, the technical officers used aerial photos to determine land units in the village territory, to define existing and promising forms of land use and to identify more efficient and sustainable village land use options. Finally, the technicians and the village population assessed the socio-economic feasibility of the identified land use options and made a village land use plan.

The donor community embraced GTV and various projects developed their version of the GTV approach. In 1991 the World Bank and UNDP engaged themselves to support a long term (15-20 year) 'Programme National de Gestion de Terroir' (PNGT). The first phase (1992-1998) of the project covered 42% of the villages in eight provinces and the second phase intends to reach another 10, on a total of 45 provinces.

In the 1990s, GTV became a guiding principle for rural development. In the GTV approach, technicians take the lead. They look for economic and biophysical solutions, while involving local stakeholders in the search and decision making processes. In the 1990s, the awareness of the importance of socio-cultural and political forces in determining the development process grew: the soft side of land (see § 2.5). From this perspective, GTV had some intrinsic weaknesses with which the projects had to deal:

- The notion of a village territory is cumbersome. Firstly, the village is an administrative notion, which does not automatically coincide with customary law: a village of 'immigrants' has no full control of their land and is not entitled to enlarge property claims (for example by the construction of soil and water conservation measures). Secondly, GTV has to deal with overlapping land use by different villages, ethnic groups and social categories. Villagers easily cross the village boundary and use land beyond the village territory: they borrow outside land for cultivation, they gather medicinal herbs and fruits

[20] CILSS: Comité permanent Inter états de Lutte Contre la Sécheresse dans le Sahel

[21] The 'Group de Recherche et d'Action pour l'Autopromotion Paysanne' (GRAAP) method was developed in Bobo-Dioulasso, Burkina Faso. The method works with pictures of natural resources, people, etc., and has a manual for extension workers. Everything is visualised and with the use of questions, extension workers encourage and guide the audience to reflect upon past practices, the consequences and future possibilities.

in nearby forests and send their livestock on transhumance (Breusers, 1998; Batterbury, 1998).

- The GTV concept is based on the idea that individuals are united in ‘moral communities’, sharing common interests and a mutual dependency. In reality, GVT projects work in highly differentiated communities with community members benefiting in very different degrees (Leach *et al*., 1999). Individuals and households pursue diverse livelihood strategies. Their access to and interest in land is highly variable. For example: women and younger men benefit less from natural resource activities than others and may have other development priorities (Batterbury, 1998; Guijt & Kaul Shah, 1998).
- GTV intends to work with representative, democratic village committees, who have a high concern for land degradation. In practice, they have to deal with matters of power relations, trust and interdependency. Participation may be based on social motivations rather than land degradation concerns. GTV empowers certain individuals and groups, who can easily influence ‘community decisions’ in their own favour (PEDI, 1989; Batterbury, 1998). Pastoralists are often reluctant to engage themselves in GTV as earlier experiences taught them that land rehabilitation easily leads to their expulsion from the village area (Dorlöchter-Sulser *et al.,* 2000). Villagers may demonstrate hard work to gain land property claims, to honour their chief or to impress their neighbours, especially when being involved in all too common disputes (Zanen, 1996; Guijt & Kaul Shah, 1998). They may also just want to invest in a good relationship with a project, in anticipation of other future benefits (Michener, 1998).
- GTV is a planning approach. In reality, farmers have to cope in a very risky and uncertain environment and they operate in an adaptive rather than a planned manner. Opportunism, creativity and flexible management seem more appropriate to their style of farming than the GTV approach (Batterbury, 1998). Rapid changes in local politics, the market situation, national politics and policymaking demand a rather flexible and dynamic development approach (Guijt & van Veldhuizen, 1998).

Projects were the first to recognise that the GTV focus on the village level is cumbersome as it opted for administrative boundaries rather than technical (determined by the ecosystem) or social boundaries (determined by social cohesion and farmer livelihood activities). However, collective natural resource management is only possible when it makes sense to the local stakeholder, or when it seriously affects their livelihoods (Dangbégnon, 1998). Many GTV negotiations focussed on pasture areas and used Participatory Rural Appraisal (PRA) methods to involve local stakeholders. They made social analyses of the local power balances and the interests, they strategically involved customary chiefs[22], they encouraged stakeholders to discuss the problems that they perceived as important, and they facilitated negotiations amongst social groups and aimed at inter-village agreements (Banzhaf *et al*., 2000; Dorlöchter-Sulser *et al.,* 2000). There are some success stories, but these required a high level of staff involvement. On a more general level, projects had problems to adequately train the extension officers to apply participatory methods[23] and deal with the social diversity in a flexible and equitable way (Guèye, 1999).

[22] Multi-stakeholder negotiation may fail by mis-representation, when traditional leaders do not feel accountable to their constituency (Groot, 2002). However, when customary chiefs take their responsibility, they can break impasses amongst ethnic groups and facilitate negotiation processes (Banzhaf *et al.,* 2000).

[23] Depending on the skills of the extension officers PRA methods were used to improve the analytic and development capacity of the rural population or to guide village discussions towards the land rehabilitation activities (Guijt & van Veldhuizen, 1998; Cornwall, 2000).

The evolution from GTV towards Local Development
By the end of the 1990s, GTV projects had evolved in three different directions (PNGT, 1998): natural resource management projects, providing accompanying incentives and socio-economic services to satisfy the priority needs of the population; projects with a more global vision, aiming at the improvement of all aspects of local development; and projects giving priority to the decentralisation process and capacity building of the rural population.

The strategies of the various projects reflected different and changing donor priorities. Donors became increasingly responsive to local stakeholder needs and wanted to improve their claim making capacity. Sometimes this goes against the public interest. To justify intervention, one should consider the livelihood of the local population as well as the importance of the sustainability of the farming sector in a specific area for the future welfare of the country (Scoones & Toulmin, 1999; Hilshorst & Toulmin, 2000a). IFPRI (1995) recommended giving priority to natural resource management and food security in densely populated marginal areas. In high quality rain fed land, it should be possible to enhance agricultural production through economic incentives. Addressing degradation of soils in extensively managed agricultural land was considered a lesser priority.

3.2.5 New guiding national policies

The environmental policy
In Burkina Faso, environmental considerations could have gained momentum through the 'Plan d'Action National pour l'Environnement' (PANE). In 1994, The World Bank mobilised consultants to assist the 'National Committee for the Struggle against Desertification' in preparing a new PANE. Unfortunately, the PANE did not meet the expectations: the environmental issues were poorly defined, no priorities were set and the document produced little more than a shopping list of projects. The PANE was received with scepticism and failed to counterbalance decentralisation and structural adjustment policies (Swift, 1996; Speirs & Marcussen, 1998).

The decentralisation
In 1993, one year before the reformulation of the PANE, the government of Burkina Faso installed the 'Commission Nationale de Décentralisation' (CND) to start the reflections on the democratisation and decentralisation process. Much lip service was paid to the decentralisation process but the government was slow with the implementation (Speirs & Marcussen, 1998; 1999). Burkina Faso has a political history in which all sources of political power are seen to be potentially threatening and thus need to be 'contained' (Winter, 1998). The CND lacked dynamism and adhered to the principle that the projects first had to articulate and test the feasibility of various forms of rural organisation before the government could ratify and duplicate the successful cases. Projects, however, needed a legal framework to enable local committees to conclude contracts, open bank accounts, present themselves in court, etc. When the CND was unable to ratify the envisaged 'Conseil Villageois', donors put pressure on the government to ratify the CVGT as elaborated in the RAF-97, to provide local committees with the necessary legal framework (see section 3.2.3.).

In February 2000, the government promulgated the necessary laws concerning CVGT and one month later, a collective of important donors[24] signed an agreement to harmonise their intervention in the rural areas and give priority to decentralisation. The objective was to enhance 'Local Development, a process that enables a community (a village or a group of villages) to undertake activities contributing to a qualitative transformation of its area, to ensure a sustainable well-being' (own translation). In this agreement, the donors envisaged a guarantee funds as collateral to encourage commercial banks to provide credit to economic activities in rural areas, and the provision of Local Development Funds (LDF) to subsidise socio-economic infrastructure, training for capacity building, GTV and natural resource management. Donors would engage private consultants to support village communities to elect a CVGT, to elaborate a village development plan, to apply for LDF funding and to sign contracts with enterprises and training institutes. At the department level, a committee of CVGT representatives would allocate the LDF funds. The role of government officers would be reduced to the provision of technical advice about the feasibility of the proposed projects.

The Local Development philosophy was favourable to gender sensitive participatory methods and natural resource management, but left the initiative and the responsibility to the rural population and the private consultants helping them. The first priority was decentralisation, good governance and transparency at national and local level.

The Agricultural Policy

Many GTV projects, like the former IRDPs, involved the extension officers of the ministry of agriculture in the project implementation. Though the GTV approach emphasises local participation and self-help, it did not preclude active co-operation with existing on-farm extension programmes. The government and the projects assumed that the rehabilitation of degraded land would improve the agricultural potential and would indirectly encourage farmers to invest in agricultural intensification (Batterbury, 1998). The PNGT was affiliated to the Ministry of Agriculture and the latter incorporated GTV in their extension strategy: all interventions should start with a multidisciplinary PRA to enable villagers to select the most appropriate extension itinerary (MA & MRA, 1999a; 1999b).

During the IRDP and GTV period, the agricultural extension service applied the Training & Visit (T&V) system and promoted soil- and water conservation measures, composting and cereal production as well as the use of chemical fertiliser, pesticides, vaccination, improved seed and commercial farming. The idea was to promote intensive mixed farming to ensure food self-sufficiency and develop commercial farming. The ministry adhered to this approach, despite the emerging criticism on the T&V system and the inappropriateness of the technical messages for farmers in semi-arid areas.

In the 1990s, the ministry became increasingly subject to criticism and consequently lost resources and influence. IRDPs used to pay for the general overhead of the department, but GTV projects elaborated strict service contracts and only paid for specific fieldwork delivered by the extension officers. The ministry had problems in financing the overhead and the training institute for agricultural extension officers was closed down. This led to plans (also in the light of the Structural Adjustment Programme of 1991) to drastically reduce the size of the public extension system (Speirs & Marcussen, 1998). In 1995-1997, the ministry elaborated various action plans for agricultural reform. The action plans focused on farm

[24] The World Bank, FAO, the European Community, and the French, German, Swiss, Canadian, Danish and Dutch Embassies.

intensification, diversification and commercialisation. One of the action plans envisaged the installation of 'Organisations Professionnelles de l'Agriculture' (OPAs): farmers specialised themselves, participated in study groups and received additional support from 'research-farmers' and OPA-employed advisers. Initially the OPAs would receive financial support, but this would be gradually withdrawn to allow for a process of privatisation (CC/PASA, 1997; MA & MRA 1997).

At the time of the research, there was considerable doubt about the feasibility of farmer specialisation and role of OPA in the subsistence farming areas such as Sanmatenga province (Speirs & Rasmussen, 1998). In these areas, there hardly was any form of farmer organisation above the village level. Agricultural extension officers, being informed about their forthcoming discharge, wondered whether it was worthwhile to start an enterprise for agricultural advice.

3.3 The PEDI project

3.3.1 The history of the project

The Netherlands development cooperation with Burkina Faso started after the severe Sahel droughts in the1970s, with food aid and large projects in industry and infrastructure. In 1981, it was decided to concentrate on four IRDPs covering the three main ecological zones of Upper Volta: the desert-steppe (North), the dry savannah (central plateau) and the transitional zone to the humid tree savannah (Middle, South). At the central plateau, the Netherlands development cooperation started the 'Programmation et Exécution du Développement Intégré' (PEDI I, 1981-1985), which covered seven departments of Sanmatenga province. The name underlines the double mission of the project: the planning of integrated strategies and the execution of technical development activities such as water supply and natural resource management (Zanen, 1999).

In Sanmatenga province, PEDI was one of the main sources of support for rural development activities. Like most projects in the Sahel, PEDI initially focussed on fighting soil erosion. This resulted in watershed planning for two areas of 10.000 ha. Soil and Water Conservation (SWC) measures were the core activity of the project and soon PEDI was called the 'stone row project'. Villagers transported stones to build (permeable) barriers on contour lines in fields and in watercourses and gullies.

PEDI operated through the government agencies: the provincial department of planning and the technical departments. Originally, PEDI used short-term incentives like food aid to encourage villages to undertake SWC measures. This philosophy changed during the revolutionary period. The government stressed the importance of basing development on local needs, local initiative and own resources and the Ministry of Planning send interviewers to each village to gather information on the people's priorities. In several villages, other things than the battle against erosion appeared urgent and PEDI added components such as water supply, education and health to the project. However, the focus remained on the agro-pastoral programme: extension and credit activities to encourage SWC measures, intensification and mixed farming.

PEDI worked with village committees. In many villages, the local elite played a decisive role in the activities. The collective work for SWC measures, water pump installation, credit and training often favoured a small minority (PEDI, 1989; Zanen 1996; 1999). From 1985 onwards, the motivation and participation of ordinary villagers dwindled. This inspired PEDI II (1986-1990) and PEDI III (1990-1995) to apply the so-called process approach: to begin all project interventions with a small starter activity to test the village dynamism. Social studies became part of the project strategy and inspired PEDI II to change the target group from village to ward groups. Wards were considered the biggest social and territorial units with adequate social cohesion, mutual interest and a sufficient labour force to execute land use plans (Zanen, 1999). PEDI opted for the ward approach at the very moment when the government of Burkina Faso proclaimed the GTV a village level approach.

Whereas PEDI might have been one of the first projects to recognise social diversity, they were one of the last projects that continued to work through the government departments. Like the other IRDPs, PEDI did not lead to an integrated and coordinated functioning of the government departments. However, PEDI stemmed from a bilateral agreement between the Dutch Embassy and the Government of Burkina Faso and it was difficult to withdraw the support from the government departments. Finally, in 1995 it was decided to delegate planning responsibilities to the local communities. PEDI continued its affiliation with the provincial department of planning, but the collaboration with other departments was reduced to service-contracts.

The year 1995 was a turning point for the PEDI project. PEDI IV (1995-2000) reduced its intervention zone from 150 villages to the 60 most dynamic villages in order to concentrate its activities and to trigger a self-sustaining development process. As in the former phases, PEDI wanted to enhance economic production, to feed the growing population, to increase the monetary revenue and to improve the living conditions. The project's core strategy was (a) to strengthen the village organisation and ensure a participatory, gender sensitive planning and execution of development, and (b) to enhance sustainable agricultural production. For some activities, PEDI IV returned to the village level but for the agricultural activities the focus was on individual farmers instead of communal resource management.

Sections 3.3.2 and 3.3.3 further describe the functioning of the section Communication, Planning and Gender (CPG) and the section of Agro-Sylvo-Pastoral activities (ASP) of PEDI IV. They give a detailed account of the extension activities of both sections and the perspective and interest of the staff vis-à-vis participatory agricultural extension. The description of the organisation is important, because it enables the analysis of the fit between the computer-model and the organisation.

3.3.2 The section Communication, Planning and Gender

The CPG section consisted of two social experts and fifteen facilitators/co-ordinators[25]. Their main task was to strengthen the organisation of village groups and ensure democratic planning and execution of community development. Each facilitator was responsible for three to five project villages.

Community intervention started with a PRA, to acquaint facilitators with the village and its key actors. After this first acquaintance, the village was invited to form reflection groups: each ward would delegate someone to (a) the group of village leaders, (b) the group of men, (c) the group of women, (d) the group of young men and (e) the group of young women.

[25] In French, they were called 'animateurs-coordonnateur' (AC). This name was given to stress the difference with the more technically oriented agricultural extension officers. Because many ACs had been agricultural officers, it was important to stress their new role: they were not allowed to provide technical advice.

These groups were each asked to make a so-called problem-tree for the domain of natural resource management, water supply, health, education and infrastructure. The reflection groups analysed the situation, identified solutions and attached priorities to these solutions. During a plenary session, the facilitator calculated the ‘collective priority’. PEDI guaranteed logistical support and 75% of the execution costs; the other 25% remained the responsibility of the village community. Village meetings were called to amend the proposal and to discuss the village contribution. The village had to commit itself and elect a village development committee (VDC) for the execution. Initially, PEDI demanded a ‘democratic’ VDC, with representatives of all social groups and wards, but these VDCs lacked dynamism. Soon, PEDI relaxed the condition to allow for the inclusion of young and educated committee members. Chiefs were included as observers.

At the start, the planning procedure was very mechanistic but gradually the facilitators received more training and grasped the ideas of empowerment. The facilitators, on their turn, ensured training programmes for the village population and provided regular support to the local committees. Slowly PEDI transferred more responsibilities to the VDCs and limited itself to the funding. Progress was made, but participatory development remained a slow and tough process. Facilitators had to deal with power relations, social diversity and continuous bargaining: many villages never decided without the consent of their chief; most women remained shy in public and many ‘plenary decisions’ were heavily influenced by prior backstage meetings; water pumps were still located in the chief’s backyard; villagers rather built a superfluous village shop than to allow one ward to construct its water pump. Sometimes internal conflicts blocked all activity. Depending on their social integration, their anticipation and personal tact, facilitators were sometimes able to handle these issues. Finally, training in Rapid Appraisal of the Rural Knowledge System (an adapted version of the RAAKS tools (Engel, 1995; Engel & Salomon, 1997) enabled them to unravel conflicts and differences of interest and to put pressure on the community to find an agreement and regain dynamism.

The villages used the community programme to construct infrastructure. PEDI had withdrawn from the education and health sector, and the villagers, on their part, did not forward communal natural resource management issues. This puzzled PEDI. Was this a sign that the former environmental campaigns had effectively solved the issue or did villagers prefer not to involve external agents in internal management matters?

Apart from the community work, CPG was also co-responsible for the field activities of the technical sections of PEDI. The facilitators processed application forms for credit, subsidies and other forms of support of the technical sections. In addition to this logistic support, the sections also expected methodological advice and support from CPG. If time allowed, the social experts joined their meetings.

3.3.3 The section Agro-Sylvo-Pastoral

The ASP section consisted of a coordination team (a forester and livestock expert with general project experience) and an R&D team (two agronomists and two livestock experts). The ASP coordination team was responsible for (a) the execution and administration of the agricultural support programme, (b) the coordination of the R&D team and (c) the coordination of the 23 agricultural extension officers.

In PEDI IV, the agricultural programme changed from a ward approach to an individual approach but it still adhered to the principle that (a) farmers have to control soil erosion before improving soil quality and arable production, and (b) the increase of arable production encourages extensive subsistence farmers to become input-intensive commercial producers (PEDI, 1996a; 1996b). In line with these assumptions, the agricultural support programme applied a strict itinerary: (1) subsidised lorry transport to construct stone rows; (2) the application of (subsidised) rock phosphate; (3) free cement for the construction of a compost pit; and (4) a 50% subsidy on the purchase of a wheelbarrow, donkey cart and/or plough.

Like the support programme, the agricultural extension groups were open to everybody and the attendance surpassed the expectations. In general, puugsoba joined the extension groups together with one or more beolgsoba. In 1999, 27% of the men and 5% of the women older than 24 had constructed stone rows or vegetation bunds and applied rock phosphate, while 18% and 8% participated in the extension programme respectively. The mixed extension groups consisted for 32% of women[26]. Women appeared to be less informed about new techniques and eager to participate, but they were not allowed to talk in the presence of their husband and merely acted as observers (SAEC, 1999). Pastoralists hardly joined, except in a couple of Peulh villages.

The extension programme applied an adapted version of the T&V approach, based on study tours and demonstrations. The regional agricultural department provided the extension officers and most of them had a long experience with the T&V system. The large demand for extension forced the government to recruit an additional number of untrained extension officers to be able to fulfil their service-contract obligations. However, the regional department was reluctant to train and guide these officers, as they were dissatisfied with the strict contracts. At PEDI, the coordination team was absorbed in administrative matters and they delegated the training responsibilities to the R&D team. The R&D officers had a technical background and their main role was to be an innovative source of technical support. However, the T&V system was widely criticised and they felt the need to improve the extension approach.

3.3.4 Learning about participatory agricultural extension

R&D started with a study tour to the ESPGRN (Equipe Systèmes de Production et Gestion de Ressources Naturelles) in Mali to learn about the participatory learning and action-research (PLAR) approach for soil fertility management (Defoer *et al*, 1995; Defoer & Budelman, 2000; Defoer, 2000; 2002). On their return, they decided to adapt several parts of the PLAR approach for extension purposes. CPG had already made the territory maps, transect walks and community diagrams, hence, R&D concentrated on analysing soil fertility management strategies and classifying farms, the resource flow map and the planning map. The tools were simplified and visualised to serve the largely illiterate population[27]. The idea was that these tools would facilitate individual analyses and planning as well as farmer group discussions. The 'soil fertility management analysis and planning tool' was born. Soon afterwards this tool evolved into a general 'management analysis and planning tool' for arable production. Similar tools were developed for livestock fattening and dairy production.

[26] At the start of PEDI IV it was decided to have mixed extension groups, because women lacked bicycles and were not able to cover long distances to attend to specific women groups.
[27] About 84% of the men and 97% of the women in Sanmatenga province are illiterate (MARA, 1996a).

Box 3.1: The Indigenous Soil and Water Conservation (ISWC) project

The aim of the ISWC project was is to institutionalise the promotion of farmer innovation and Participatory Technology Development (PTD) within national agricultural research and extension systems in Africa. The first phase focussed on the analysis of dynamics of indigenous soil and water conservation practices in Africa. The second phase (ISWC2) of 1997-2000 operated in Burkina Faso, Cameroon, Ethiopia, Tanzania, Tunisia, Uganda and Zimbabwe, and aimed to improve the effectiveness of both indigenous and modern SWC practices through a joint process of joint experimentation involving farmers, scientists and development workers. It promoted the research on local practices, assisted in disseminating the results and supported the lobbying platforms to advocate the Farmer Innovation approach to policy makers. The coming third phase intends to anchor the Farmer Innovation approach in the national research and extension systems.
This ISWC2 project had the following components:

- *Training in PRA and PTD.* To change the vision of Transfer of Technology and the sense of superiority of scientists and extension workers, trainer-of-trainer workshops in PRA and PTD are organised.
- *Identifying and verifying farmer innovation.* Extension workers, NGO field staff, scientists, village leaders and farmers were asked to identify farmers, who develop or try out new ideas without the support of formal extension systems. The innovations had to be new for that particular locality and the farmers had to be first-generation innovators. Verification focussed on the usefulness of the innovation. The aim was to stimulate scientists and extension workers to recognise local innovation, and to encourage farmers to involve themselves in an innovation process.
- *Analysing innovators and innovations*. ISWC partners studied the social setting and resource endowment of the innovators, to assess whether innovations were likely to be widely accepted.
- *Setting up monitoring and evaluation systems*. ISWC partners defined indicators and monitored the process, (a) to promote local innovation as a source of learning and guidance for future work, and (b) to produce the necessary quantitative data for donor agencies and political decision makers.
- *Exchange visits and study tours for innovators*. The aim was to stimulate the innovation process.
- *Farmers´ evaluation of local innovations.* Innovators and their neighbours evaluated the innovations. It appeared that value and experience of communities strongly influenced the acceptance of local innovations. Evaluations were discussed in workshops to break the isolated position of innovators, to enhance their social standing and confidence. These workshops could be starting point for designing experiments implemented by farmers selected by the community.
- *Stimulating and supporting joint experimentation.* Farmers set the research agenda. Scientists had a role in (a) proposing elements for testing; (b) advising in the design of the experiments; (c) explaining the reasons for the farmer findings to help farmers to understand the principles and less visible factors influencing the outcome; and (d) generate 'hard data' to convince other scientists, donors and policy makers.
- *Farmer-to-farmer dissemination of innovations*. Especially in Burkina Faso, farmers developed a new farmer-to-farmer extension approach: one innovator initiated an annual market day to exchange information; another created a kind of 'field school' through the joint treatment of degraded land; and a third innovator coached farmers in neighbouring villages by working together with them in their fields.
- *Raising awareness and lobbying for policy change.* Much attention was given to documentation and publication in the form of project reports, workshop proceedings, articles in newspapers and journals and the production of video film. Policy makers were included in steering committees and invited for workshops and 'exposure tours'.

(After Reij & Waters-Bayer, 2001: 3-23).

Apart from the PLAR method, the R&D team experimented with the 'farmer innovation' and the Participatory Technology Development (PTD) methodology of the Indigenous Soil and Water Conservation project (ISWC2). The aim of ISWC2 was to link scientists, extension workers and farmer innovators in joined efforts to improve local practices of managing land and water (See Box 3.1). Initially, PEDI was a low profile member of ISWC2. However, the ISWC2 project inspired the R&D team and they soon became one of the active members (Kaboré & Kouraogo, 2000).

Within PEDI, the R&D officers tested and adjusted participatory extension tools for soil management and livestock breeding. Initially, the CPG staff had concentrated on the community programme but now they slowly increased their involvement in the agricultural extension programme. CPG initiated research amongst beneficiaries and organised farmer seminars on the accessibility and institutional set-up of the agricultural programme. Together with ASP, it organised training in participatory methods for extension officers. Gradually, the ideas of ASP and CPG matured towards an 'à la carte' extension programme that would start as a 'farmer field school' but would soon develop into a PTD approach (Van de Fliert, 1993; Van Huis & Meerman, 1997; Röling & van de Fliert, 1998; Leeuwis *et al,* 1998; Deugd *et al,* 1998; Ter Weel & van der Wulp, 1999).

3.3.5 Action-research on the agricultural extension approach

PEDI IV had strategic plans (1996a; 1996b) and within this framework, staff members were free to give a personal interpretation to their tasks. As staff members had different ideas about 'development', 'participation', and the desirability and priority of activities, the implementation varied according to the person in charge and joint activities often demanded deliberation and negotiation. With respect to the agricultural programme, the staff members had the following perspectives:

- The R&D livestock officer considered intensive livestock production important for the development of Sanmatenga. In her perception, participation meant the increased involvement of farmers in on-farm tests. In this way, farmers would discover the potential of new practices and be ready to use them.
- The R&D agronomist was eager to learn from the ESPGRN and ISCW2 project. He recognised the need of self-determination of the farmers, but thought that farmers shared his vision on the desired development path. He assumed that farmers first aimed at food self-sufficiency, but as soon as they had reached this production level, they would gradually engage in input intensive commercial farming.
- The manager of the ASP section had a more detached view. To be able to make a change the project needed involved and motivated farmers. Hence, he saw it as essential to consider the reasoning and interest of the farmers. At the same time, he observed a discord between the reasoning of the project and the farmers: farmers did not follow the project recommendations for fertiliser applications. However, he did not know how to tune the extension programme to the needs of the farmer or how to enhance farmer learning. He expected the CPG section to provide the necessary tools and organisational advice to improve extension.
- The extension experts of the CPG section recognised the need for self-determination of the people and gave priority to capacity building at the village level. CPG was primarily responsible for the coordination of the facilitators and the execution of the village community programme. It was only at the end of the project phase, when the community programme was on track, that the extension experts got progressively involved in the agricultural programme.

Except for the R&D livestock officer, the staff responsible for the agricultural programme recognised self-determination of the local population as the point of departure. This different vision created tension within the agricultural department and led to a somewhat isolated functioning of the R&D livestock unit. The break came in 1999. At that time, R&D livestock had started an experiment on communal natural resource management (CNRM). After some RRA sessions, she proposed the test village to treat a communal village area (a rocky valley) with SWC measures and to plant trees and fodder crops. The village started with enthusiasm but soon participation dwindled and finally only part of the plan was executed. At the evaluation, farmers complained about the distance to the communal site and demanded more individual and profitable activities. While being informed about this experiment, PEDI colleagues regretted the state of affairs and felt the urge to jointly elaborate a new extension approach. CNRM concerned the ASP as well as CPG and it was decided to start a joint action-research.

The unfortunate CNRM test was the immediate cause for the PEDI action-research, but there were more reasons and motivations behind it:

- The donor announced a change of strategy. The decentralisation had become top priority and the next project phase (2001-2005) would concentrate on local capacity building. Eventually, the agricultural section would have to develop a farmer-based learning approach.
- To acquire a legal status, CVDs had to be transformed into GVGTs. With this change, they obtained an explicit role in CNRM. To prepare this role, it was necessary to elaborate and test a CNRM extension approach;
- R&D had already invested heavily in the testing and development of PLAR and ISCW2 inspired methods and tools, but these efforts had remained isolated events. R&D needed a comprehensive extension approach in which the various tools would find their proper place.
- After several years of on-farm research, farmer seminars, impact studies and project reflection, there was a sense of urgency to draw conclusions and to come up with concrete recommendations for the next project phase. The ASP responsible felt comfortable to tackle the issue after CPG had promised to provide methodological back up.

This concludes the chapter on the local context, because it was at this point that the Antenne Sahélienne approached PEDI with the question whether the project was interested in the use of the SHARES computer model. The next chapters elaborate on the theory and the research question.

4 A theory of computer model enhanced learning

This chapter presents a theory of computer model-enhanced learning from a constructionist perspective. It is recognised that knowledge is historically embedded and socially constructed and negotiated (Section 4.1.). A review of operational research on model use suggests that the successful application of a computer model depends on the convergence of knowledge and interests of the model designers and users, the room for manoeuvre of model use and the interpretation of results (Section 4.2.). This implies that a theoretical framework is needed, that enables one to assess the initial situation and the process of convergence and distantiation between model designers, the direct users and the ultimate target group (Section 4.3.). People learn to reduce uncertainty and ambiguity. Uncertainty is about ignorance or gaps of knowledge. People learn to reduce uncertainty, to improve performance and to attain a desired situation. Performance improves when there is more correspondence between the action and the dynamics of the outside world. Ambiguity refers to vague, unclear and potentially conflicting perspectives and objectives. People learn to reduce ambiguity, to enhance the coherence of perspectives amongst interdependent actor-networks (Section 4.4.). To assess the outcome of model-enhanced learning, the impact of model use on the correspondence of the action and the coherence of perspectives is analysed (Section 4.5.)

4.1 The constructivist epistemology

The classical view of agricultural science and computer modelling is that it deals with 'things', which are as they are, which can be objectively known through research, and about which science can formulate generalisable 'truths'. These verifiable propositions underpin the effort to influence natural resource management. The goals of such an intervention are taken as unambiguous and not of scientific interest. The focus is on 'technical means' for achieving a stated goal (Röling & Wagemakers, 1998: 10-11). This way of thinking is embedded in a particular epistemology: the positivist way of knowing and the validation of knowledge.

The positivist epistemology is a coherent and internally consistent paradigm, but it is increasingly recognised that innovations demand another kind of knowledge. A positivist epistemology may be valuable to explain and influence biophysical components and processes, characterised by causal relations and built-in goals, but it is less apt in tackling contemporary agro-ecological phenomena that are highly influenced by human driven processes (Kuhn, 1970; Leeuwis, 1999a). Nowadays human-driven processes increasingly shape the world and human action cannot be captured in causal relations. Humans are sense making and intentional beings (Checkland, 1981). People change their activities when they have reasons to so: a belief, a normative or a social commitment. Unobservable reasons can have very real consequences. For the analysis of human behaviour, it seems more valuable to apply a logic of reasons: an interpretive or so-called hermeneutic epistemology (Röling, 1997). Hermeneutics is about correspondence: the conceptions of the interpreting subject should correspond with the outside world, as a basic way of existing, continuously orienting oneself to the situation and keeping alive (Alvesson & Skölberg, 2000).

Science has to deal with the fact that knowledge produced by science enters society through the production of criteria and procedures for action, technologies etc. The uncritical application of positivist science and technology sometimes had dislocating consequences. Science, as opposed to offering control and predictability created risks and uncertainties as side effects (Beck, 1992, 1995, 1997, Beck *et al*., 1994)[28]. Giddens (1990) talks about design faults in some of the major institutions of industrialised societies. The industrial mode of production and consumption focussed exclusively on factors as capital, technology and labour, making other factors such as ecological and socio-political aspects of secondary importance (Mol & Spaargaren, 2000).

The orientation of science, explained by its social organisation, contradicts the very premises of positivism whereby science was defined as neutral and objective. All sciences are rather constructive than descriptive: the products of science are contextually specific constructions which bear the mark of their situational contingency and the interest structure of the process by which they are generated, and can not be adequately understood without an analysis of their construction (Knorr-Cetina, 1984: 227). The period of 1980-1990 was characterised by a diminishing trust of the public in official and scientific positions[29] (Irwin, 1995; Wynne, 1992; 1993). Legitimacy and authority of scientific knowledge was undermined. A new epistemology was needed that recognised the socio-cultural and historical embeddedness of knowledge, that dealt with the fragmentary, partial and provisional nature of knowledge, and that tackled the issue of the divide between science and the lay public (Agrawal, 1995).

The constructivist epistemology recognises that all knowledge is socially constructed. The 'constructions' evolve selectively; they are historically culturally embedded and continuously recreated through experimentation and communication (Knorr-Cetina, 1981; Latour, 1987). This is as much true for scientific as well as for non-scientific, everyday forms of knowledge. Knowledge should not be equated with some professional, scientific set of ideas because everybody possesses knowledge, even though the grounds of belief and the procedures for validation of knowledge claims will vary (Arce & Long, 1992: 211).

Within the constructionist epistemology, learning for improved natural resource management concerns the production, negotiation and integration of knowledge by various stakeholders, to reduce the ambiguity of the joint goal (sustainable development) and their ignorance about how to achieve this goal.

4.2 The research question: Do computer models enhance learning?

There is little doubt that the development of models enhances learning. Modelling induces people to structure observation and reflection: to identify relevant variables and the relations between these variables, to articulate a consistent framework or theory of a situation and to identify solutions for various cases (Morecroft, 1994). Computers extend the limited human capacity or the, so-called, bounded human rationality (Simon, 1979). The human mind has a limited capacity to perceive time-related processes, to identify invisible processes and to infer the outcome of the interaction between multiple time and space-related processes. Computers enable us to consider the mutual interference of a gamut of relations or processes at various time and space intervals and to understand emerging properties at higher system levels (Isaacs & Senge, 1994; Dörner, 1997).

[28] Beck focuses on industrial countries and refers to genetic engineering, nuclear energy and industrial pollution, but the concept of risk society can equally be applied to a range of environment and development issues (Keeley & Scoones, 1999: 12).
[29] Irwin (1995: 115-6) gives the example of the 'mad cow disease' in the UK: no matter what scientists and politicians said, the public refused to buy beef.

Apart from the understanding of processes, computers facilitate experimentation. In real life, there is a long delay between decisions and effects: time is needed to prepare a test, to collect and interpret data. Furthermore, the high interdependency of actions makes it difficult to isolate the consequences of the test (Isaacs & Senge, 1994). Computers allow researchers to focus on specific relations and to compress time and space and they offer a safe space for experimenting: experimenting becomes less threatening as one does not need to consider the consequences, as would be the case in real life (Bakken *et al*., 1994).

The development of computer models enhances learning, but it is very time, energy and expertise consuming. The use of computer models, a less time and energy consuming enterprise, seems a more feasible learning method. Model use requires less effort as the user does not have to define all relevant variables, relations, theories and solutions, and is still able to refine one's observation and theory through virtual experimentation. Model use appeared a convenient way to take advantage of computer capacity and the tedious modelling work performed by others. Unfortunately, the history of the use of NRM-models has known many failures and very few models are actually used (Walker & Zhu, 2000). Hence, the question emerged whether computer models are useful for learning.

The constructivist epistemology provides a key to the answer of this question. Within the constructivist epistemology, a model consists of formalised knowledge, constructed by the model designer. A designer builds a model to pursue a project[30]; hence a model is intrinsically linked to the theories, values, interest and aspirations of the model designer (David, 2001). Research on computer models for business management revealed that effective use of models depended on the following aspects[31]:

- *A model should be relevant.* A model is designed to understand and act upon certain issues. The selected issues and actions incorporated in the model should be of interest to the potential users.
- *To retain the users' interest, the model should resemble the logic, values and preferences of the user.* To enter a joint learning and negotiation process, actors have to respect and (partly) share specific values and visions, relevant objectives and strategies (Hounkonnou, 2001). This also applies to models and their users. The crux of the problem is the fact that model designers and users tend to belong to different communities, characterised by a difference in knowledge, values, interests and power resources. A large share of the knowledge, values and interest is implicit, tacit, taken-for-granted by community members but difficult to observe by outsiders. Though designers assume that they know the needs and rationality of the users, they often do not, explicitly or implicitly build on the same theory as the users. This results in the 'prescription crisis' (Hatchuel and Molet, 1986; David, 2001). Divergence between the theories, norms and values incorporated in the model and those valued by the users will lead to a manipulation of the users' learning process, a debate on the underlying theories and values, or a rejection of the model by the users.

[30] "Par définition, un projet (…) est une fiction, puisqu'au début il n'existe pas" (Latour, 1991 : 115). In essence, a project does not yet exists but needs to be realised (Van der Ploeg, 1999: 19).

[31] Computer modelling for decision support first emerged in the area of operational research and management science. Operational research is the early label for the theory of monitoring, simulation and control, developed to provide the basis of 'scientific' management. Operations research became a significant movement in post-war industry and business. It later converged with the business management science and was often labelled OR/MS. Research on computer models in the domain of OR/MS tends to run ahead of agriculture for about a decade as the economic importance of OR/MS attracts more financial and intellectual resources (McCown, 2002a).

- *Model-use depends on the degree of contexualisation*: (a) the degree of assimilation of the tool by the user as well as the user by the tool; (b) the tool's capacity to make the user move towards the target situation (David, 2001). The degree of assimilation of the tool by the user depends on the capacity and willingness of the user to comprehend and use the model. Model use should encourage users to deconstruct their local specific knowledge: to move from the complex reality to the abstract structures of the model and infer possible solutions. Whether model users are able to abstract or decontexualise their problem, depends on the contexuality of the model: the degree of inclusion of background context and locally specific details in the model structure. This seems to call for very detailed and exhaustive models, but exhaustive models are complex and difficult to handle. Hence, one should look for the optimum balance between the level of detail and the ease-of-use (Vennix, 1996: 90; David, 2001: 467). When selecting the variables, relations and solutions to be included in the model, it is important to include those that users consider valuable to explore (McDermott, 1999; David, 2001). Whether a model enables a user to explore the situation and move forward depends on the level of inquiry, the relevance of included variables, relations and potential solutions and the model boundary. Every user has his[32] own specific perspective and information needs: e.g. a farmer explores a natural resource issue from the perspective of his farm or his household's livelihood while a policy maker might consider a natural resource issue from a regional ecological perspective or a national development perspective.
- *The model should leave room for manoeuvre to the users*. Apart from models geared towards highly structured, narrowly defined tasks, most models deal with a diversity of stakeholders and divergent situations and perspectives. To be able to handle this, model designers are recommended to be flexible and be prepared to modify their model (Leeuwis, 1993), or to shift the operation of the model from the user to an intermediary (McCown, 2002b). Intermediaries are able to adapt the model to a specific situation and to interpret the results. To be able to give advice and interpretations to the users, the intermediary needs to understand the context in which it will be used and has to draw on his own tacit know-how (McDermott, 1999). A farmer will only invite an intermediary for individual advice after an assessment of the relative costs and benefits of systemic reasoning compared to intuitive decision-making. Another possibility is the use of the model for collective multi-stakeholder learning. In that case, the intermediary uses the model in a critical way (presenting results, while stressing the subjectivity and limitation of the model) to trigger debate and an exchange experiences (McCown, 2002b).
- *Apart from the model, user-related variables determine the effective use of models.* In industrial sectors, research into the acceptance and the use of computer models is quite abundant. Most salient theories include the innovation diffusion theory (Rogers, 1998; Moore & Benbasat, 1991), the planned action theory (Fishbein & Ajzen, 1975; Ajzen & Fishbein, 1980; Ajzen & Madden, 1986) and the technology acceptance theory (Davis *et al.,* 1989; 1992, Venkatesh & Davis, 1996; 2000). In line with the planned action theory, the technology acceptance theory uses external variables (model, task, person and context related characteristics) as well as intermediate variables (perceived usefulness and perceived ease-of-use) to analyse the effective use of computer models[33].

The technology acceptance theory studies user behaviour across a broad range of end-user technologies to assess the influence of person and context-related variables. Research on

[32] For the sake of the readability, the thesis only uses the term 'his', while referring to 'his' or 'her'.
[33] In fact, they refer to 'perceived usefulness' (the cognitive dimension), 'perceived ease-of-use' (the affective dimension) and the 'perceived efficacy' (the regulatory dimension), but the perceived efficacy is correlated with the perceived relevance and the ease-of-use and difficult to discern separately (Pijpers *et al*., 2001).

computer use by senior executives revealed that 'personal computer self-efficacy', 'perceived fun/enjoyment' and the 'availability of organisational support when handling the model' were the most influential variables (Pijpers *et al.,* 2001). 'Computer self-efficacy' and 'perceived fun' seem to relate to the age and gender of the person, the professional education and computer experience and training.

In short, research on computer models suggests that effective use of, and learning with models is highly dependant on: (a) the convergence of the designer's and user's knowledge (selected details, level of enquiry, boundaries and underlying theories etc.), values and interests; (b) the room for manoeuvre; and (c) the perceived fun, ability and the support to use the model. In the case of the SHARES model, its use and subsequent learning of the PEDI agricultural staff is studied. To be able to this a theoretical framework is needed, that focuses on the learning of a group of actors, embedded within a specific institutional context. The theoretical framework should enable:

a) The assessment of the initial interest of potential users in the computer model: an analysis of the initial convergence/divergence of interest and knowledge amongst actor-networks and the likelihood of interaction aimed at the integration of interest and knowledge;
b) A study of the socio-psychological process of learning that emerges from model use.
c) The assessment of the outcome of the learning process: Did it lead to convergence of knowledge, interest and concerted action, resulting in more sustainable development?

4.3 Research question (a): What is the interest of potential users in the model?

4.3.1 The choice of the social theory

There are several social theories focussing on development processes: discourse theories[34] (Foucault, 1980; Apthorpe & Gasper, 1996), pluralist theories[35] (Dahl, 1961; Bachrach & Baratz, 1970; Lukes, 1974; Fraser, 1992; Hill, 1997), actor-network theories or ANT (Law 1987; 1992; 1994; Callon, 1987) and the actor-oriented approach (Long 1992; Long & van der Ploeg, 1989; 1994; 1995).

The actor-oriented approach and ANT focus on the construction of knowledge and action emerging from social interaction. The actor-oriented approach focuses explicitly on the behaviour of human actors, while ANT claims that human actors as well as non-human material determine interaction processes. The argument for using human and non-human material (such as a computer model, overhead projector, television etc.) is that both aspects *shape* the social interaction. For instance, a computer model mediates communication asymmetrically (no chance to answer) in a durable and transportable way (an utterance is

[34] Discourse theories elaborate on the power of discourse in framing how people behave in, and think about, the world. Ideas, concepts and categorisation are expressions of knowledge and power (Foucault, 1980), controlling human subjects by definitions and categories imposed on them. Discourses define the world in certain ways, in the process of excluding alternative interpretations (Apthorpe & Gasper, 1996).

[35] Pluralist theories focus on the interaction amongst groups with different political interest. According to liberal pluralists, interest groups compete openly and the more adept and better resourced are likely to win (Dahl, 1961; Hill, 1997). Critics argue that contests are not open, but the powerful will keep certain issues from the agenda (Bachrach & Baratz, 1970). Radical pluralists work on issues of identity and representation. The disadvantaged have less access to decision processes; consensus is likely to mask the differences in perspective and discount the input of marginalized groups (Lukes, 1974; Fraser, 1992).

local and momentary). Object networks participate in, and influence social interaction (Law, 1992: 384). ANT focuses on actor-networks: patterned networks of heterogeneous material.

The consideration of the non-human material makes ANT useful to study the mediating effect of computer models. However, ANT does not attribute agency to individual actors, while research results of organisational learning suggest that network structure and actors both influence learning processes. Therefore, in the next section, I will highlight the theoretical explanation of Giddens (1984) and Munters *et al.* (1985) concerning the mutual interference of structure and agency. This enables me to use the actor-oriented approach, while also integrating the concept of network structure and its enabling and constraining effect on human agency.

4.3.2 Structure and agency

For this study, I need a theoretical framework that reconciles the concepts of structure and agency. The concept of agency is central to this framework. Agency is the capability of doing things, the capability to make a difference and to influence the sequence of events. The 1960-70s were characterised by structuralists, who defined agency as a product of logical structures that are common in all societies (Levi-Strauss, 1970a; 1970b) or a product of the materialistic structure (Althusser & Balibar, 1970). Post-structuralists saw agency as a product of the cultural structure and tried to deconstruct fixed ideas, demonstrating that preconceived ideas rest on the exclusion of something (Boyne *et al*., 1990; Critchley *et al.,* 1996). In the 1990s, post-modernists rejected material and cultural structuralist theories because they did not provide practical help for those who want to initiate change: structuralists have a pessimistic view on change initiated by actors. Post-modernists emphasise plurality, ambivalence, open-endedness, indeterminacy and contingency. The society is fragmented and multiple; there are different actor-networks, life-worlds and rationalities and actors have the possibility to choose. ANT and the actor-oriented theory both study issues of order, agency and rationality but they take different perspectives. ANT draws on structuralism and post-structuralism (Law, 1994) while the actor-oriented approach is inspired by post-modern ideas (Van der Ploeg, 1999).

The actor-network theory (ANT) studies the interaction and continuous reshaping of 'collectifs', ordered actor-networks of human and non-human entities[36] (Steins, 2002). An actor-network may refer to a group of computer model designers, a market, a production activity, a discussion platform, an organisation, a formal department, etc. They vary in size and they are nested, interlocked and distantiated (Law, 1994). People and objects by themselves do not act (Ibid: 485). Social and technical relations, the meaning attributed to the management system, perceptions of the external environment and social experience all influence the reasoning and action. The process in which sets of relations between projects, interests, goals and naturally occurring entities are proposed and brought into being is called 'translation' (Law, 1992: 368). In the course of translation, different forms of knowledge and action emerge as 'necessary points of passage' (Callon, 1987). ANT considers knowledge

[36] ANT uses the words 'non-human entities' rather than material resources to underline the fact that particularised resources and technologies are the product of a history of human action, resource and technology development. Furthermore, Law (1992: 383) states: "that the dividing line between people and machines (and for that matter animals) is subject to negotiation and changes. Thus it is easily shown that machines (and animals) gain and lose attributes such as independence, intelligence, and personal responsibility. And, conversely, that people take on and lose the attributes of machines and animals."

and agency as emerging properties of the interaction between human and non-human entities (Steins, 2002).

The actor-oriented theory attributes knowledge and agency to the individual actors, actor groups and organisations: those who have the capacity to process social experience and to devise ways of coping with life (Long, 1992: 22). They are capable to choose amongst different discourses and rationalities and, at any phase of a given sequence of conduct, act differently (Giddens, 1984: 9; Long, 1992: 25).

The ANT and the actor-oriented approach take opposing positions concerning the attribution of agency. The bases of these theories lie in the sociology of science and technology, and the sociology of rural development, respectively. Another field of study (attracting many financial and intellectual resources) that deals with issues of development, structure and agency is 'organisational learning'. The explosion of empirical research on organisational learning in the late eighties and nineties demonstrated the mutual interference of structure and human agency (Easterby-Smith *et al.*, 2001). Through their interaction, actors produce mutual knowledge (taken-for-granted norms and values, procedural routines and knowledge embodied in artefacts) that recursively organises the conduct of these actors. Structures such as communication channels, information systems, the spatial environment, procedures and routines as well as systems of incentives shape the life-world and the learning of people (Argyris & Schön, 1996). Organisations and actor-networks move constantly between 'generic' and 'inter-subjective' sense making (Weick, 1995; 2001). Generic forms such as habitual behaviour, interlocking routines, technology, etc. provide standard plots of types of encounters. They enable people to save energy and time to occupy themselves with more difficult tasks. When uncertainty, ambiguity and conflict increase, inter-subjective processes of interpreting and enactment are needed. Inter-subjective sense making leads to innovation and change. Structures enable and constrain the inter-subjective sense making; the room of manoeuvre is limited and change is path dependent and incremental (Leeuwis, 1999b, Van der Ploeg, 1999).

Giddens (1984) was one of the first to theoretically problematise the issue of agency and structure. Instead of actor-network, he used the term 'social system'. Social systems are "reproduced relations between actors or collectivities, organised as regular practices" (Giddens, 1984: 25)[37]. Social systems provide meaning and order: they structure the conduct of knowledgeable actors. Structure is not only the medium, but also the outcome of the conduct it recursively organises[38]. In their interaction, and by the use of rules and resources, actors produce and reproduce 'structural properties' that can be conceptually divided in three components: signification, legitimation and domination (see Figure 4.1)

[37] A practice does not refer to a one-time event but to a continuing stream of purposive activity (Giddens, 1984).
[38] According to Giddens, social systems do not have structure but rather exhibit structural properties, while structure exists only in the instantiations of practices and as memory traces, orienting the conduct of the knowledgeable human agent (Giddens, 1984: 17). This is an important observation. It is only for reasons of readability that I continue to use the term 'structure' instead of 'structural properties'. Much literature uses the term 'institutionalisation' when referring to the structural properties of an actor-network or social system. Institutions are then defined as a "set of rules, decision making, procedures and program that define social practices, assign roles to the participants in these practices, and guide interactions among occupants of individual roles" (Young, 1994: 3); "cognitive, normative and regulative structures and activities that provide stability and meaning to social behaviour" (Scott, 1995: 33).

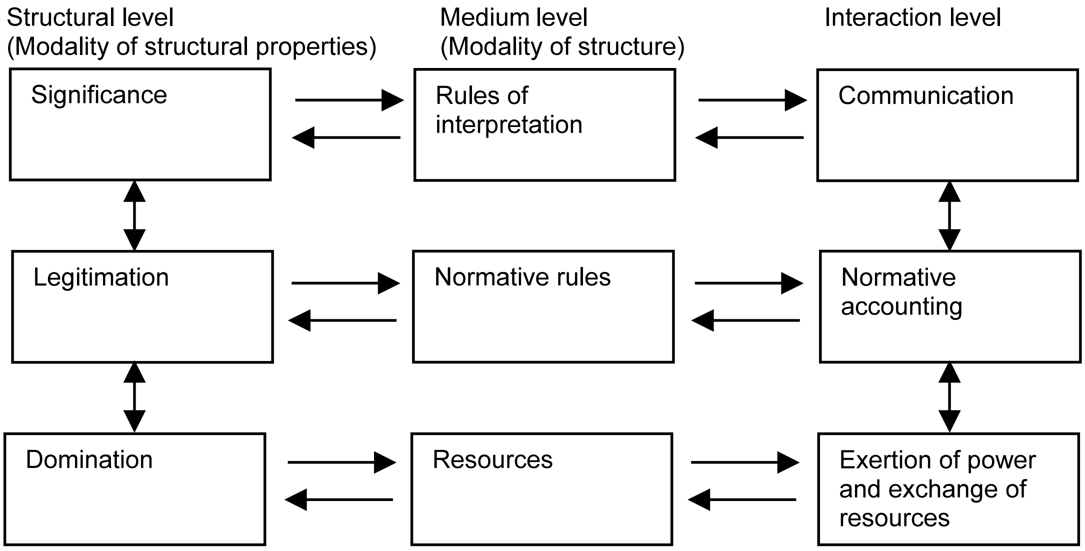

Figure 4.1: Conceptualisation of the relation between structural properties of social systems and human action (adapted from Giddens, 1984: 29; Munters et al., 1985: 87; Leeuwis, 1993: 102).

Everyday life is to some degree experienced as an ordered reality shared with others. People look for meaning and order to guide their action and social relations. There is variety of rules of interpretation, normative rules and resources that actor-networks and individual actors can create or draw upon. So, for every context actor-networks or individual actors orient themselves to a specific:

- *Stock of knowledge* called 'discourse' (Foucault, 1980), 'interpretive repertoire' (Gilbert & Mulkay, 1984), 'theories-in-use' (Argyris, 1992; Argyris & Schön, 1996), 'frame of meaning' (Long, 1992), 'theoretical frame or cognitive map' (Morecroft, 1994), 'belief' (Weick, 1995) or 'interpretive frame' (Aarts & van Woerkum, 2002);
- *Stock of norms and values* that have a relation with 'good' or 'bad', the actualisation of rights and the enactment of obligations (Giddens, 1976);
- *Stock of resources* consisting of specific material resources, finance, skills and competence, and networks (Van der Ploeg, 1999).

Each specific compilation of knowledge, norms and resources conveys certain structural properties or *mode of order*. The creation or use of a specific body of knowledge is inherently connected with the operation of norms and power in social interaction. Not only rules of interpretation, but also normative rules and resources are actively negotiated in interaction, and are no stable entities[39] (Leeuwis, 1993: 105).

Each network, time and locality has its own specific quality and quantity of order and agency (Law, 1994). People adhere to a mode of order and 'delegate' authority and agency to persons they trust, those who they recognise as knowledgeable and capable[40]. Each network attributes knowledge and capability differently. Hence, notions of authority and agency are socially and historically constituted, affecting the livelihood and interpersonal relations (Long, 1992: 9). Van der Ploeg (1999) elaborated some ideal-typical examples of modes of

[39] ANT insists that social structure is a process or an effect, rather than something that can be achieved once and for all. Therefore ANT assumes social structure to be a verb rather than a noun (Law, 1992: 385)

[40] Long (1992) and Van der Ploeg (1999) use the terms knowledgeability and capability in the sense as defined by Giddens (1976). Giddens notes that people are knowledgeable meaning that they successfully monitor the ongoing stream of purposeful activity in interaction. Capability refers to the capacity to decide, to act upon, and implement decisions.

order and agency: the traditional, the modern and post-modern society. In traditional societies, history serves as a guideline. Memory, norms and sanctions determine the actors' practices and projects[41]and are the main mode of ordering. Social cohesion derives from trust in institutions, organisations and representatives. Actors have little agency. In modernising societies, the mode of order has become cognitive rather than normative (Knorr-Cetina, 1981: 6). People trust their own knowledgeability and capability to realise future projects. Individual actors have agency as they can make a difference; they can choose amongst multiple routes of action and projects. Projects are future oriented and consist of fictional ideas about a combination of resources, entwined with the required relations. In fact, agency depends on the actor's anticipation of interaction and synergy with other projects (interlocking and distantiating networks) while defining his project. Success will depend on the availability of resources and the capacity to create virtual images that mobilise, inspire and energise people to collaborate. A modern society is characterised by heterogeneity and ex-post selection. This contrasts with a post-modern society, which is characterised by uniformity and ex-ante selection. Authoritative expert systems[42] define what is useful and rational and how the world, according to their assumptions, should be and function. They construct virtual mega-projects, an inevitable route with parameters for actors to refer to. Actors trust the system and parameters for rational action. The agency of expert systems is limited by institutional condensation; formal organisations define what is legitimate and realistic and produce bureaucratic gatekeepers who eliminate deviating activities.

To get back to the research question: to analyse the interest for model use by the agricultural staff, we need an interpretive or hermeneutic approach. This implies that we opt for the actor-oriented approach, while making the following revisions:

- Actor-networks consist of ordered networks of human and non-human entities;
- Network structure (formalised, material embodied or tacit knowledge, norms and power relations) shape human thinking and behaviour, determining the room for manoeuvre and the agency of individual actors. Structure and interaction are continuously changing, recursively organising one another.

4.3.3 The actor-oriented approach, revisited

An actor is a social, historical construction rather than simply a synonym for the individual (Long, 1992), hence the actor-oriented approach studies actor learning and communication within an historical cultural context.

People make cognitive maps that categorise the world of experience into classes of phenomena, which eliminate the necessity of responding to every unique event in the environment. Category systems help to reduce the complexity of the environment and to organise their behaviour. It permits to anticipate future events, give direction to instrumental activities and strategically deal with actors and actor-networks.

People's knowledge is partial and provisional. It is a result of a great number of decisions and selective incorporation of previous ideas, beliefs and images. Knowledge is situated within

[41] We are not interested in one-time events and action, but in day-to-day practices and envisaged future projects (longer term ambitions).

[42] 'Authoritative expert systems' do not just refer to the classical, hierarchical system of science based policy making, but also include forms of steering characterised by the principals of horizontal cooperation, consensual and dialogical decision making, less formal institutionalisation and the growing importance of actors at lower levels.

one's life-world. A 'life-world' is a lived-in, and largely taken-for-granted world (Schutz & Luckmann, 1973). Knowledge is primarily constructed through own experience and face-to-face encounters, and secondarily through more distant anonymous encounters (Ibid). People outside this life-world tend to have different cognitive maps and their solutions to the problems are therefore likely to be different (Arce & Long, 1992).

The actor-oriented approach focuses on processes of change and continuity that emerge from social interaction. Of crucial importance is the interaction at the *interface*: where different life-worlds intersect (Arce & Long, 1992). The discontinuity of social worlds is characterised by discrepancy in interest, knowledge, values and power. Successful interaction depends on the adequacy with which actors identify discontinuities between the social worlds of various networks and decide to bridge them or to reconceptualise them as essential demarcation lines (Snyder, 1984; 1992; Weick, 1995, 2001; Van der Ploeg, 1999). Interactions consist of communication, normative accounting and the exertion of power[43]. These processes may take the form of strategic or communicative learning. Strategic learning means that actors try to pursue their own life-world through strategic accounting and exertion of power. Integrated learning is based on the discovery of each other's life-world and the reframing of knowledge, norms and goals with the aim to find solutions that do justice to each other's interests.

For the choice of an actor-network[44], whether to opt for strategic or communicative action and learning, the valuation of the desirability and feasibility of a joint project is decisive. Action is future oriented and guided by envisaged projects. Most successful are actor-networks (a) that excel in their anticipation of interaction and synergy of projects and their entwined relations, while defining their own project, and (b) that have the resources (material resources, finance, competence and network relations) to mobilise/fight other actor-networks (Long, 1992; Van der Ploeg, 1999).

4.3.4 A complementary social-psychological theory of planned action

The former section highlighted the social aspects of knowledge construction. To come to grips with the phenomena of action and learning at the individual level, we need a complementary social-psychological theory. The 'theory of reasoned action' (Ajzen and Fishbein, 1980) and the subsequent 'theory of planned action' (Ajzen & Madden, 1986; Ajzen, 1988), which strongly influenced socio-psychological research of learning in the mid-eighties, is of use.

Up to the eighties, researchers had identified a gamut of different kinds of external variables to explain behaviour. To reduce the multitude of theories, the socio-psychologists Ajzen and Fishbein (1980: 6) identified a small set of *intermediate* variables that account for the relations between *external* variables and any kind of behaviour that is under an individual's volitional control. The first intermediate variable identified was the 'attitude towards the behaviour': a person's positive or negative evaluation of performing the behaviour. People have a belief about the outcome of behaviour and an evaluation of the desirability of this outcome. The second intermediate variable is the 'subjective norm': a person's perception of the social pressures put on him to (not) perform the behaviour in question. In 1986, socio-psychologists added the third intermediate variable 'perceived behaviour control' (Ajzen & Madden, 1986; Ajzen, 1988) or 'perceived self-efficacy' (Bandura, 1986): the (lack of)

[43] See Figure 4.1.
[44] This applies for an individual actor as well as an actor-network. To improve the readability of the thesis, I use the term actor-network when referring to the individual actor as well as actor-networks.

confidence in one's own capacity. Judgement of self-efficacy determines how much effort people will expend and how long they will persist in the face of obstacles or aversive experiences. Furthermore, when people form intentions they take into account how much control they have over the behaviour in question. People may refrain from practices that they regard as beneficial solely because they think they cannot properly and/or realistically perform them. Alternatively, they may continue with practices they regard as sub-optimal because they feel that they are "good at them" (Leeuwis, 2002: 397). All three variables are important determinants of the actual behaviour, though the relative weight of attitudinal, normative and efficacy factors may vary from one person to another.

The concept of attitude, as defined by Fishbein and Ajzen, poses a problem. The definition of attitude comprises of an evaluation component and a belief component. Behavioural theories that succeeded the reasoned action model separate attitudes from beliefs: beliefs relate to an individual's subjective assessment that performing some behaviour will result in specific consequences, while attitudes relate to an individual's positive or negative affective feelings about performing the behaviour (Pijpers *et al.,* 2001). Affective feelings, or emotions, are intimately related to the human need for security, stability and familiarity. Norms provide structure and the necessary sense of stability and security. Emotions arise from feelings of attachment to specific normative rules (Heymann, 2000). Therefore, current behavioural theories often talk about the cognitive, affective and regulatory components and refer to the intermediate variables 'beliefs', 'norms' and 'self-efficacy' (Vermunt, 1992; Vermunt & Verloop, 1999; Veldhuis-Diermanse, 2002).

The three intermediate variables are imaginary abstract constructs: they only exist as memory traces orienting the conduct of the knowledgeable human agent. The variables are also interdependent. For instance, norms and interests focus the attention, the perception and the construction of beliefs. The perceived self-efficacy also shapes beliefs in the sense that phenomena are perceived as a result of one's own behaviour (a person adheres to an internal locus of control) or a result of dynamics in the outside world (a person adheres to an external locus of control). On the other hand, the beliefs of people in one's vicinity are blended with normative expectations, which at least partly shape one's subjective norms (van Woerkum, 1997). Intermediate variables are imaginary in character, interdependent and inseparable. Together they constitute the frame of reference.

Similar to the observations about the social structure in section 4.4.2, it is noted that intermediate variables do not refer to fixed mental states. People tend to express different views on the same topic when dealing with different contexts and sometimes even within one conversation (Gilbert & Mulkay, 1984; Wetherell & Potter, 1992; Edwards & Potter, 1992; Te Molder, 1995). When people give their opinion, they design their view according to the functional context and the envisaged project. On the one hand people are flexible, expressing different opinions to fit the context, while on the other hand they feel more comfortable when their personal perception, frame of reference and action attain a certain focus and coherence (Gigerenzer & Todd, 1999).

For their behaviour, people draw on repertoires of knowledge, normative rules and ideas of self-efficacy: their frame of reference. They select and develop subjective beliefs, norms and ideas of self-efficacy according to their context. The question remains what external variables influence a person's construction of belief, norms and notion of self-efficacy and subsequent action. The actor-network theory emphasises the importance of one's own project and actor-network, other projects and related actor-networks, and the resources to implement projects and mobilise actor-networks. Inspired by the planned action theory, I further developed the external variables and this lead to the following theoretical framework (Figure 4.2):

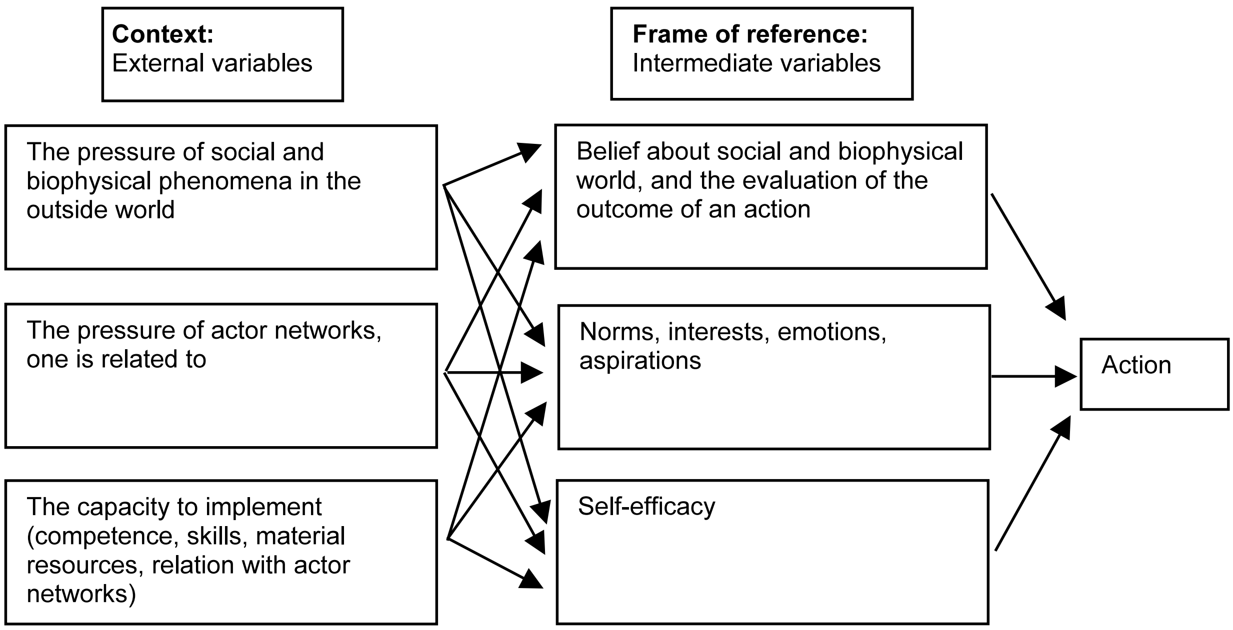

Figure 4.2: Variables to which actors orient themselves, when defining their action

Below the external variables and how they influence an actor's behaviour are explained:

The pressure of social and biophysical phenomena in the outside world
A person observes his social and biophysical world. The attention is captured, when there is a surprising mismatch between the desired and actually perceived and/or expected situation[45]. This is especially the case when this mismatch has a strong impact on the (future) livelihood of the actor himself or the ones he is related to. This means that a natural resource problem may be large scale, long term and irreversible, but is unlikely to be considered when being invisible, hard to measure and with little impact on the livelihood of the actor (Dovers, 1995). E.g., most people are less concerned about global warming than about a garbage dump near their backyard.

The pressures of related actor-networks
"Shared norms, judgement of value inherently guide the interest of an actor" (Kolb, 1984: 104). Knowledge and norms are primarily constructed through own experience and face-to-face encounters, and secondarily through more distant, anonymous encounters. An actor perceives the role/identity of his own and other actor-networks and the expectations and pressures actor-networks exert on members. When anticipating action, an actor considers the issues of interest and the tasks and responsibilities attributed to him by actor-networks he is related to.

[45] Action is future oriented and knowledge about the outside world therefore is anticipating the future, forward moving (Kolb, 1984: 132; Van der Ploeg, 1999: 19).

The capacity to implement a project and mobilise actor-networks
Problems can often be solved in various ways; people can choose between alternative solutions. The choice of the action depends on someone's own skills, competences and resources, as well as capabilities of the actor-networks he is able to mobilise (Van der Ploeg, 1999: 19). Let us take the example of application of soil and water conservation practices by female farmers in Burkina Faso. Female farmers may have the skills to apply stone rows to diminish the loss of soil and nutrients in their fields, but most of them are unable to mobilise enough labour to construct them, so they opt for the application of mulch and vegetation strips.

4.3.5 The theoretical framework of the learning actor-network

The adapted version of the actor-network approach coupled with the theory of planned action provides the framework as presented in Figure 4.3. This framework is applicable for individual actors as well as actor-networks, though the actual processes take a different form: internal reasoning (refer to Figure 4.2) and social interaction (refer to Figure 4.1).

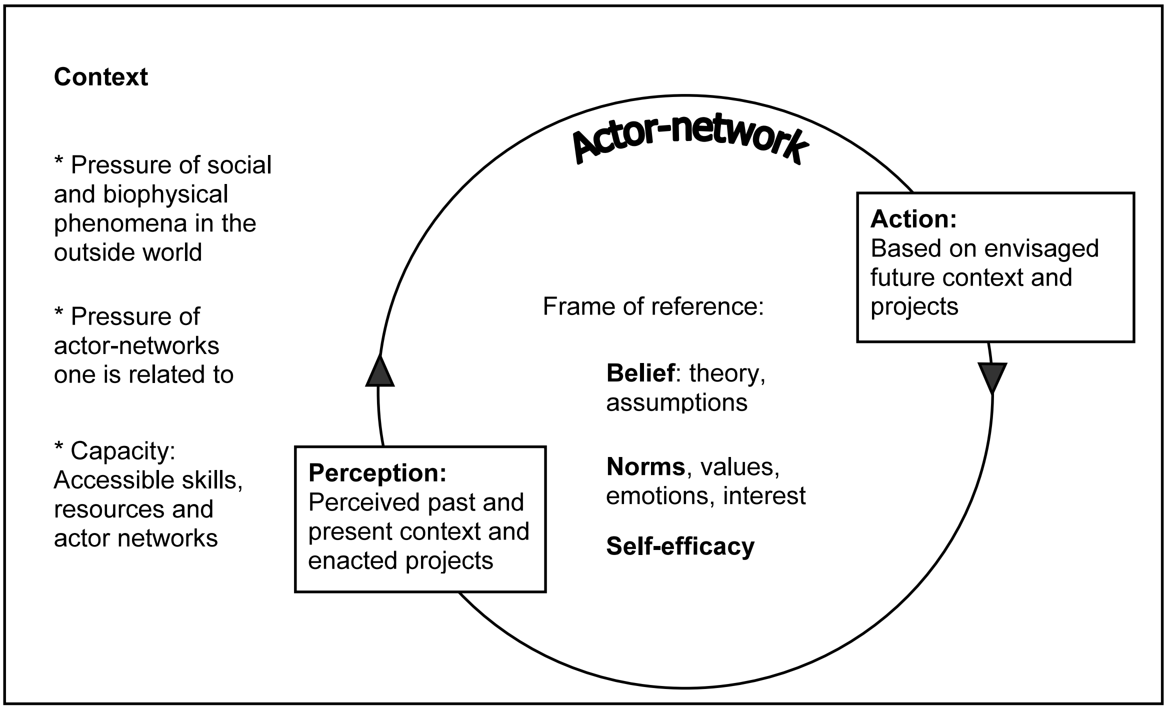

Figure 4.3: The learning actor (-network)

The framework provides the necessary (external and intermediate) variables to assess the beliefs and interest of model designers and users, and the potential of convergence or distantiation of their beliefs and interests. In our case, the scientists of Wageningen University in Burkina Faso were the model designers. They identified the PEDI agricultural staff as potential direct users and farmers as potential indirect beneficiaries. Another actor-network relevant for this case is the donor who expected that PEDI to reformulate the programme the next phase.

The next part of this theoretical chapter provides some additional concepts that help to analyse interaction and learning processes and their subsequent outcome.

4.4 Research question (b): How does model use affect the learning process

Computer use stands for a unilateral form of communication. The question is how computer use influences (a) the perception, beliefs, norms, notion of self-efficacy and the action of the agricultural staff and (b) the process of interaction and subsequent convergence or distantiation of the life-world of the agricultural staff with the life-world of the SHARES designers, the donor and/or the farmers. The theoretical framework shown above provides some useful variables, but we need some additional ideas and concepts about the learning processes. Socio-psychological research on organisational learning offers some powerful tools for the analysis of learning processes.

4.4.1 What triggers learning

When do people shift from automatic to active thinking? Switching to a conscious mode is provoked if one experiences a situation as a 'surprise'. Either because something stands out of the ordinary, is unique and previously unknown, if one is confronted with an unexpected failure, or if acts are frustrated and troublesome. Another possibility is that cognitive action occurs through a deliberate initiative: an explicit exhortation of one person to another to pay attention: "what does this mean?" or "look at this" may trigger sense making.

Learning starts with a problem, some kind of gap, "a disparity between the way things are and the way one wants them" (Smith, 1988: 1491; Weick, 1995: 88; Argyris & Schön, 1996: xxiii). Smith argues that at least two other conditions must occur if a gap is to be pursued and has to become a cue for learning: the gap must be *difficult to close* and the gap must *matter*. The difficulty refers to the fact that the problem cannot be solved through available knowledge, routines and tools. A problem generates cognitive activity, a shift from automatic to active thinking. The significance of the gap or the problem depends on the envisaged project: "Problem constructions are invented and imposed in the interest of furthering one's project" (Weick, 1995: 89).

Learning or active sense making aims at the reduction of uncertainty and ambiguity. Weick notes: "The 'shock' in each case is somewhat different: in case of ambiguity, people engage in sense making because they are confused by too many interpretations, whereas in case of uncertainty, they do so because they are ignorant of a theory how to arrive at the desired situation." (Weick, 1995: 91).

Learning to reduce uncertainty is linked to learning for *correspondence*. The idea behind it is that our incremental body of knowledge and subsequent behaviour should increasingly correspond with the dynamics of the outside world. Learning to reduce ambiguity of interpretation means learning for *coherence*. At the individual level, actors strife for coherence between their identity, observations and actions. At the social level actor-networks converge or distantiate to create a univocal frame of reference for their activities.

4.4.2 Learning for correspondence: to reduce uncertainty

Instrumental learning
Uncertainty is about the ignorance of knowledge: not knowing the necessary details about how to arrive at the desired situation. Learning to reduce uncertainty is defined as instrumental learning.

Habermas defined instrumental reasoning as "goal directed, feedback controlled interventions in the world of existing states of affairs" (Habermas, 1984:11-12)[46]. In general, instrumental learning is control-directed: driven by the aspirations of the actor. However, it is also possible that the outside world has changed and the actor has to accommodate: either new knowledge and activities are searched to achieve the desired situation, or norms and aspirations are adjusted to content oneself with the actual situation. Instrumental learning consists of observation, experimentation and exchange of information to add elements, and refine or extend the theory or beliefs. This enables actors to better discriminate amongst different behaviours and the expected outcomes and to improve their performance. It is important to note that instrumental learning concerns the enrichment of a belief and small adaptations of aspirations, but no radical change of beliefs, norms or values. Instrumental learning is learning within a more or less stable frame of reference.

4.4.3 Learning for coherence: to reduce ambiguity

Individual learning to reduce ambiguity: Reflexive learning
Ambiguity is about too many interpretations and a lack of clarity on the objective of the search: "Which rules to apply and what role to play?" Ambiguity is part and parcel of an individual's reasoning and most actors flexibly pick arguments from various discourses to justify their (often) conflicting objectives.

Reflexivity refers to the continual monitoring of one's own role and practices in interaction with others and with the world of nature (Giddens, 1984). Reflexive learning refers to the awareness of one's historical, political and ideological position, and the discovery of tacit theories, assumptions, norms and values that shape one's behaviour (Delanty, 1997; Groot & Maarleveld, 2000).

Argyris (1992) distinguishes single loop learning (feedback controlled instrumental learning within a certain frame of reference) and double loop learning (learning about one's frame of reference). He points out that argumentation is often confusing because people tend to reflect on espoused theories and criteria, while in reality they also apply various tacit theories and criteria. 'Tacit theories-in-use' refers to feelings of embarrassment, threat, competence, win-loose behaviour, repression of emotions and attempts to appear rational. In addition, every organisation and network has rules that sanction and make topics taboo. To be able to learn

[46] Habermas (1984) distinguished instrumental, strategic and communicative rationality. In his definition, instrumental rationality implies that the learner perceives things and social actors as mere objects that can be manipulated, while the strategic and communicative rationality imply that learners acknowledge social actors as stakeholders with whom conflicts and agreements have to be settled in a rational manner. I more or less use the framework of Habermas, except for the connotation that instrumental reasoning is intimately related to social engineering and the manipulation of people. In this thesis instrumental learning refers to 'learning within a certain frame of reference' without implying that the learner perceives social actors as mere objects to be manipulated.

productively, it is necessary to discern tacit theories so that all theories-in-use are critically reflected upon. Double loop learning demands exquisite inquiry, advocacy and reflection skills, to uncover tacit knowledge and create an open exchange of sensitive issues (Argyris, 1976; 1992; Schön & Rein, 1994; Argyris & Schön, 1996; Senge, 1990; Senge *et al.,* 1994).

There are no clear-cut methodologies to enhance reflexive learning, except to focus on the reasons behind espoused theories and action. One could try to develop diagrams that spell the reasons that different actors have for doing what they do, or do not do. Various hermeneutic-oriented researchers note that for reflexive learning it is essential to take nothing for granted and to continuously oscillate the attention between the parts and the whole: the meaning of a part can only be understood if related to the whole. The 'parts' refer to elements such as spoken words, a technology or practice, social acts, issues of interest, while the 'whole' may refer to a frame of reference, a livelihood strategy or a model of interpretation that uncovers the meaning of a behavioural act within its broader context (Alvesson & Skölberg, 2000).

Interactive learning to reduce ambiguity: Communicative and strategic learning
Ambiguity often emerges in social interaction characterised by contradiction, conflict and the domination of actor-networks. Most problems in everyday life involve multiple stakeholders and actor-networks, which have different interpretations of the problem. The question emerges what interpretation to apply and what action to take. In fact, we are dealing with interaction at the interface, characterised by a discrepancy of interest, knowledge, values and power (Long, 1992). Actor-networks start to communicate, to apply normative accounting practices and to exert power, depending on whether they aim at convergence or distantiation. Actors become engaged in processes of communicative and strategic learning.

Communicative learning
Communicative learning is only possible in an ideal situation whereby conflicts of interests are solved by the "peculiarly unforced force of the better argument" (Habermas, 1973). In their interaction, actors focus on communication rather than the exertion of pressure through legitimation or domination practices (see Figure 4.1). Communicative learning aims at the convergence of the frames of reference amongst actor-networks (refer to Figure 4.4.).

Communicative learning follows multiple routes. It is a non-linear process and it is better to distinguish learning tasks than phases or stages of the learning process. Communicative learning has two learning tasks:

- Reflexive learning: The process involves the recognition of the problems and interests of the people involved. In the process of communication, actors learn to understand the assumptions, norms and mental models that underpin how they operate. In this way, someone develops an awareness of one's own thinking in relation to historically understandable views of one's own interests.
- Transformative learning: Actors no longer take their frames of reference for granted. Insights gained in one's own problem and the problems of others make it possible to put them in a new, broader frame or perspective (Aarts & van Woerkum, 2002). The development of a broader perspective, related to higher order objectives, permits to perceive more relevant elements, to deal with a broader range of experiences and to be open to other perspectives (Van der Veen, 2000; Groot, 2002). See Figure 4.4.

A broad perspective provides *room for manoeuvre* for divergent fact-finding and solution-finding activities and creates the possibility to identify win-win situations, a new converging concept or a satisfying compromise.

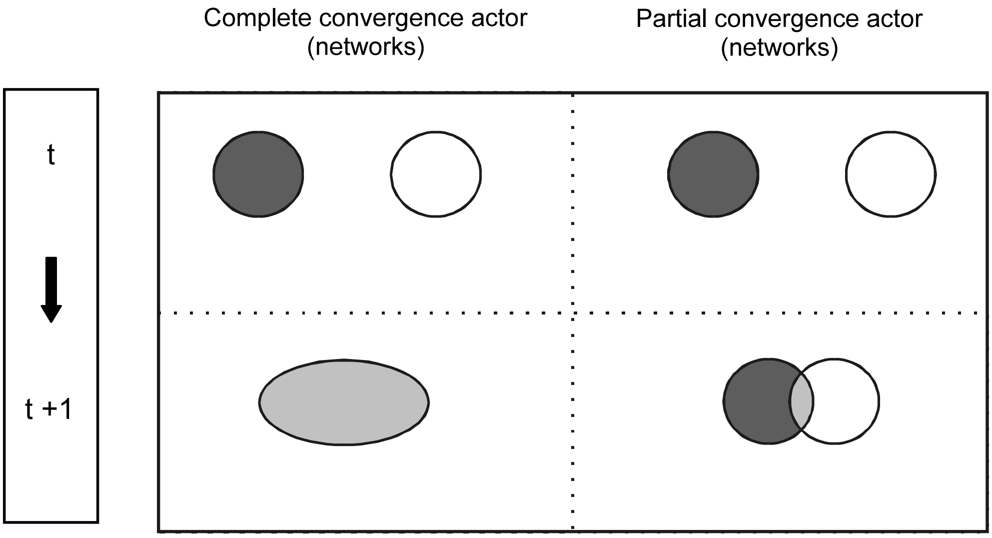

Figure 4.4: Process of convergence of actor (-networks) resulting from communicative learning

Strategic learning
In situations of considerable social and cultural heterogeneity and differences of power, communicative learning becomes difficult. Strategic learning prevails. Actors make little to no effort to exchange and understand each other's frames of reference and they stick to their narrow problem definition. From their positions, they will bargain a certain kind of collaboration or claim their autonomy and opt for separate projects (Figure 4.5). Actors focus on legitimation, domination or withdrawal, in order to pursue their own objectives.

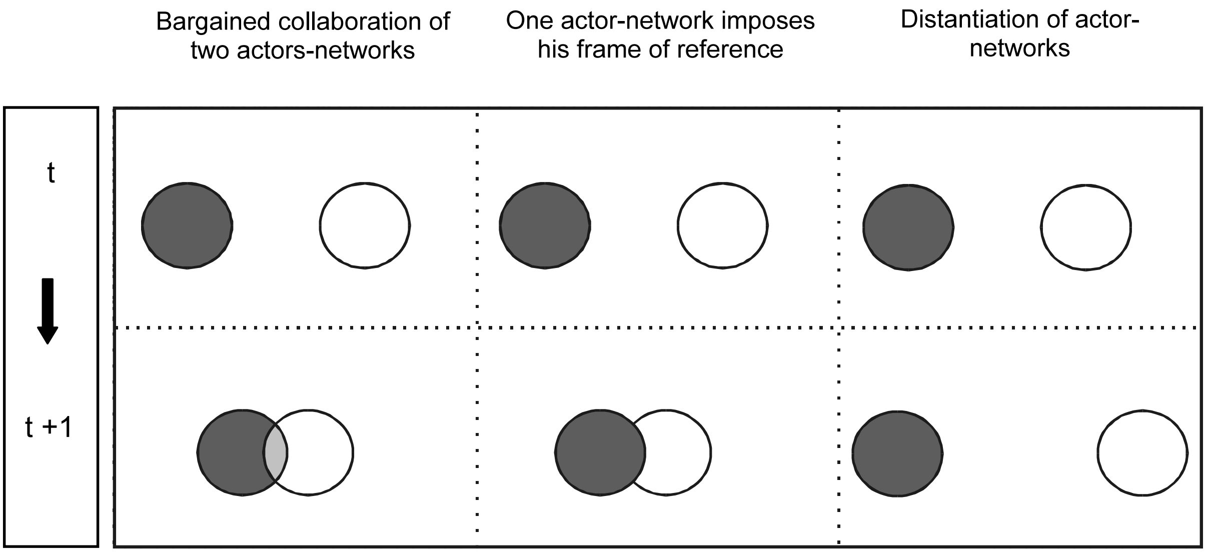

Figure 4.5: Convergence and distantiation of actor-networks resulting from strategic learning

Computer models are developed to enhance instrumental learning: they transfer information to refine and expand the knowledge base of the user, and to improve the effectiveness and efficiency of the user's activities. Now, it is crucial to know (a) how the agricultural staff used the model and (b) how it influenced their knowledge base, their frame of reference, and their interaction with the farmers.

Apart from the learning processes, we are interested in the result. What is the outcome of the learning process? Did it lead to improved natural resource management? Did it lead to convergence and improved collaboration between the extension programme and the farmers? So we come to the final part of the research question: Can computer models enhance learning for natural resource management?

4.5 Research question (c): Can models enhance coherence and correspondence?

The scientists, who developed the computer model, aimed at improved natural resource management; they hoped to inspire local farmers to become engaged in a more productive and ecological sustainable form of agriculture. Considering the limited use of agricultural models, the question was posed whether and how the SHARES model could trigger learning for economic profitable production, while not endangering the soil quality. This study pulls the question to a higher level: can model use trigger learning? Productive learning has two dimensions and types of outcomes: (a) *coherence* of perception, beliefs, norms, self-efficacy and action of the collaborating and learning actor-networks (Gigerenzer & Todd, 1999); and (b) *correspondence* of the action with the outside world.

4.5.1 The outcome: Coherence, reduced ambiguity

Through reflexive learning actors and actor-networks reduce discrepancies between perceptions, frames of reference and action. Interdependent actors-networks have the choice to opt for communicative or strategic learning. This results in different degrees of convergence or distantiation. In general, convergence and the bundling of knowledge and resources are positive as it improves the capacity of implementation of the actor-network. Sometimes autonomy is more fruitful, especially for disadvantaged people who do not have the possibility to make themselves heard and considered by others (Edmunds & Wollenberg, 2001). Therefore, the coherence of interdependent actor-networks needs to be considered in relation to the correspondence (whether actor-networks attained their desired situation). To assess the effect of model use on the coherence, I will consider:

- The coherence of the assumed role, observations and actions of the model users: the agricultural staff;
- The convergence of the frames of reference of the users and the model designers: the agricultural staff and the scientists of the Antenne Sahélienne;
- The convergence of the frame of reference of the users and the ultimate target group: the agricultural staff and the farmers.

4.5.2 The outcome: Correspondence and reduced uncertainty

How to assess the success of learning for correspondence? Correspondence can be judged at two levels: (a) the researched - all parties involved in the learning process - can judge whether or not they approached their desired situation, and (b) the researcher can assess whether the knowledge and the action of the researched enables them to attain the desired situation (as formulated by the researcher). This study is primarily concerned with the learning and action of the agricultural staff. We confront their learning and action with the desired situation as formulated by the researched as well as the researcher.

5 The research method

This study applies the reflexive research methodology. The choice of theoretical perspective more or less determines the research methodology. Section 5.1 introduces the principles for reflexive research. Section 5.2 gives an overview of the research process. It describes the origin of the research, the choices made and the final organisation of the study. Section 5.3 draws the link between the research principles and the actual research: It presents the researcher's interpretation and application of the research principles.

5.1 Principles for reflexive social research

The choice of a research methodology is intimately related to the epistemology, the way of knowing, and the theoretical orientation of the research. This study applies the 'learning actor-network framework', a compilation of the actor-network theory (ANT), the actor-oriented approach and the planned action theory. The planned action theory concentrates on individual reasoning and action. The actor-oriented approach and ANT broaden this perspective and study the actor's action and interaction within its ideological-political context. Neither of the two latter theories has strict research methodologies but they advise researchers to consider the following principles (Law, 1994: 9-17; Long, 2001: 240):

- *To apply the constructivist epistemology, recognising that all knowledge is socially constructed.* The 'constructions' evolve selectively; they are historically culturally embedded and continuously recreated through experimentation and communication (Knorr-Cetina, 1981; Latour, 1987).
- *To focus on issues that are of critical interest to the research subjects*. Science is a social phenomenon, embedded in its context. To be of relevance for society, scientific research should show an interest in the practices of its subjects.
- *To focus on recursive processes of interaction, situated within a cultural-political context.* The social reality is an ongoing process rather than a state of affairs. Giddens elaborated upon the recursive nature of social processes (Refer to section 4.3.2.). Actors, actor-networks and social relations are both medium and outcome, shaped by the historical, cultural and political context.
- *To analyse and explain everything (the principle of symmetry).* If you just assume that some knowledge is false or true, then you never get to analyse why and how the knowledge is constructed. Everything deserves explanation. This applies for both micro and macro phenomena: it needs to be explained why phenomena attained the size they have.
- *To take into account the heterogeneity of the reality, e.g. avoiding reductionism*. Though it is tempting to explain phenomena, objects and events on the basis of a few principles, simple cause-effect explanations often ignore crucial elements that determine the diversity and interrelatedness of the complex reality. Scientists look for patterns of generative relationships but they should avoid being dogmatic and assume that they are incomplete.

The main difference between the actor-oriented approach and ANT is the level of concern for reflexivity (Verschoor, pers. comm.). The actor-oriented approach entails "identifying analytically the discursive and practical underpinnings of newly emergent social forms and connectivities, and elucidating the process of knowledge and power construction" (Long, 2001: 240). The actor-oriented approach is analytical but not very explicit about the role and authority of a social scientist. This approach differs from ANT. The foundation of ANT lies in the sociology of science and technology. ANT problematises the role and authority of the scientists and calls for reflexivity (Law, 1994).

Giddens (1984) defined reflexivity as the continuous monitoring of one's own practices in interaction with others and with the world of nature. Considering the societal effect of a scientist's work, it is crucial that a scientist is aware of the problems and concerns of the research subjects, is aware of his/her interpretive act as situated within its context, and is aware of the reader while writing his text. A researcher should be explicit about his choices and tell a plausible and relevant story.

How to perform reflexive research? Reflexive research is a child of its time: it has learned from the earlier ideas of ethnomethodology, hermeneutics, critical theory and postmodernism. "Reflexive research has no strict methodology of data collection and interpretation, but pays due attention to the considerations of various epistemologies without becoming radical" (Alvesson & Skölberg, 2000: 248). Research implies a continuous iteration and gliding between various levels of concerns: the handling of the empirical material, the interpretive act, the political-ideological dimension, the authority and relevance of the research results.

5.1.1 Systematics and techniques in research procedures

Data-oriented epistemologies such as the Grounded Theory (Glaser & Strauss, 1967), ethnomethodology (Schutz & Luckmann, 1973) and inductive ethnography (Geertz, 1963) developed systematics and techniques to ensure authenticity of the empirical material and to handle biases of responses. An important issue is source criticism. Remnants, effects of an event and artefacts produced provide less distorted information than narrating sources. Narrating sources tend to embellish their own behaviour. The distortion often increases with the distance of the source (remoteness in time and place between act and the narrative account) and the dependence of the source (indirect narrative sources). Narrative sources demonstrate more bias and are usually of less value than remnants and observant participation. However, for political or ideological research, established biases are of special interest because they reveal the influence of ideologies and power on people's argumentation and action.

Data-oriented epistemologies claim that a researcher should not read too much theoretical literature and maintain an open mind for the empirical material. Theories are generated through induction from the empirical material. In this way, they distinguish themselves from theory-oriented epistemologies such as Critical theory. Critical theories question the established social reality and they study the political and ideological dimension of everyday life. They are more interested in narrative sources than remnants but even narrative sources hardly talk about things that are 'taken-for-granted' or 'taboo' (such as power differences). Therefore, it is crucial not to get trapped by the empirical material but to also look behind an actor's utterances and action. Interpretations should cover the context and how it shapes the reasoning of the individual. Critical scientists take a creative distance from the empirical material and use secondary material to consider the broader context, the political-ideological dimension. Furthermore they use social and psychological theories that reveal the deep structure of the 'taken-for-granted'. Theoretical frameworks provide criteria to systemise and analyse the empirical material. Empirical material is used to substantiate arguments to make a case for a particular way of understanding social reality.

Reflexive research departs from the problems and interests of the research subjects, rather than from theories. Every part of the empirical deserves its own explanation (principle of symmetry). A researcher looks for the best theory to tell the story and to explain the empirical material. Depending on the case, a researcher selects a specific theory or opts for a more eclectic approach.

5.1.2 Awareness of the interpretive act

Hermeneutic theories problematise the interpretive act. Hermeneutics focuses on human practices and the understanding of the interpreting subjects. Interpreting subjects orient their behaviour to the outside world to be able to survive. Social research concerns double hermeneutics: it is driven by an interpreter (the researcher) who interacts and contemplates with other interpreters (the people studied). The interpretation of the researcher may be read by the people studied and this may subsequently influence their interpretation.

A hermeneutic researcher is aware that he uses pre-understanding, when defining the research focus and the first questions. Through the study of the empirical material, such as the spoken words or social acts of the research subjects, the pre-understanding of the researcher will transform into understanding. This process implies (a) a continuous iteration between the understanding of both the parts and the overall pattern of the text[47]; (b) a continuous dialogue between researcher and researched (through argumentation and empathy) to attain a plausible interpretation of a behaviour; and (c) a continuous awareness of the researcher of the effect of his interpretation on the ultimate reader.

Hermeneutic science works with emic descriptions combined with a logic of reasoning, rather than with epic descriptions linked to a logic of statistical validation. A 'polyphonous' account based on the divergent lived-through interpretations of research subjects seems more honest towards the reader than a false pose of authority (Alvesson & Skölberg, 2000). However, the added value of more distanced theoretical insights should not be underestimated and a mixture of both approaches seems fruitful and realistic. Research is never a 'one way affair'. Theoretical development provides insights but methodological interactionism is needed in order to guarantee that the story remains interested in the practice of its subjects (Knorr-Cetina, 1981).

5.1.3 Awareness of the political-ideological character of research

Critical theory is a tradition in social science that includes the Frankfurter School. According to the Frankfurter School, social science should adopt a critical stance vis-à-vis social institutions and modes of thought. Research could help to demonstrate the historical and cultural context and to interpret empirical material as a constructed phenomenon partly shaped by a dominant ideology. Adorno and Horkheimer were pessimistic exponents[48]. Habermas, Marcuse and Fromm were critical but positive exponents, as they highlighted that people were able to act as architects rather than victims. They had a transformative interest in

[47] Hermeneutics refer to 'text' rather than data or facts, to emphasise that the empirical material is the product of the research subject's ideas, communication and meaningful action.

[48] They criticised the ideal of the Enlightenment, which was based on the capacity of scientific and technological knowledge to control nature. They noted that instrumental thinking turned the social domain into impersonal, calculative means-end reasoning and changed individuals into adapted, predictable consumers.

knowledge: they wanted to promote a social science capable of stimulating autonomy, a sense of responsibility, emancipation and democratisation.

In line with the critical theorists, reflexive scientists recognise that social science, like the research subject, is a social phenomenon embedded in a political and ethical context. "What is explored and how it is explored can hardly avoid either supporting (reproducing) or challenging existing social conditions. Different social interests are favoured or disfavoured depending on the questions that are asked, and how reality is represented and interpreted. Thus the interpretation and theoretical assumptions on which these are based are not neutral, but are part of, and help to construct ideological and political conditions" (Alvesson & Skölberg, 2000: 8). Reflexive research therefore pays due attention to the ideological and political context of the researched as well as the researcher.

5.1.4 Awareness of the problem of relevance and authority

Relevance is a relative concept: "a certain type of knowledge is more useful than other types of knowledge and some types of knowledge are more useful for specific actors than other types of knowledge" (Goudsblom, 1983: 4). Knowledge can have theoretical and practical significance. Practical knowledge can be more relevant for short-term operational problems or for long-term, societal problems. The relevance of the research depends on the actor-networks the researcher is associated with.

Much thought has been given to the authority of the research. Positivist scientists want to discover the truth through empiricism and deduction. They look for causal explanation. Radical post-modern scientists claim that there is no hidden truth and everything is appearance: what seems to be is what you get. Collective representations are ungrounded, and images circulate endlessly. Post-modern scientists look for interpretive explanations and emphasise the plurality, ambivalence, open-endedness, indeterminacy and contingency of social life. The individual, the researcher as well as the researched, has multiple identities and voices. Post-modern scientists are introspective and occupied with the reflection on their own position vis-à-vis the researched and the readers. They insist on avoiding the adoption of a definite viewpoint at the theoretical and interpretative level: not only patterns and context should be taken seriously but also contradictions and discrepancies. The researcher's interpretation is just one provisory account of the phenomenon. The danger of post-modernism is extreme fragmentation and relativism.

Critical realism attempts to integrate positivist and post-modern methodologies. It defends the possibility of causal explanation and accepts the hermeneutic notion of social reality as being communicatively constructed (Bhaskar, 1978; 1986; Sayer, 2000). They state that causal laws are not deterministic but contingent, and these causal laws and events are not necessarily reflected in experience. Experimental knowledge is partial: phenomena are identified and investigated; explanations are proposed and empirically tested. Relativists and realists use different metaphors for knowledge and science. Relativists use the metaphor of 'gestalt-switches' while realists portray science as a forever digging in the ontological depths of reality, collecting pieces of knowledge. Bhaskar defends the possibility of valid knowledge, while acknowledging that scientific knowledge is never entirely context-free and always falsifiable (Collier, 1994; Delanty, 1997).

Both, post-modernism and critical realism challenge the authority of scientists and they motivate them to become more modest, open-minded and reflexive. Researchers now recognise the need to be explicit about the choices they made during the research process, to enable the readers to judge the relevance and authority of the research results.

5.2 The research design

5.2.1 The origin of the research

The study is conducted under the auspices of the Antenne Sahélienne, a research programme of Wageningen University in Burkina Faso. In 1998, the Antenne Sahélienne developed SHARES. SHARES is a village-level MGLP model that generates land use options (Chapter 2). These options generally recommend concentrating and optimising agricultural intensification in the most suitable areas. During the development of SHARES the idea emerged to test its relevance for operational use. They contacted the author of this study, who worked at the rural development project PEDI, with the question to assess value of SHARES for the potential users (the agricultural staff) and the intended beneficiaries (the farmers).

The field research was executed in 1999-2000. The SHARES model became available for the PEDI staff at the very moment when they were busy designing an action-research to reformulate the agricultural extension programme. The PEDI action-research was executed in two test villages: Gainsa and Koglabaraogo (Figure 5.1).

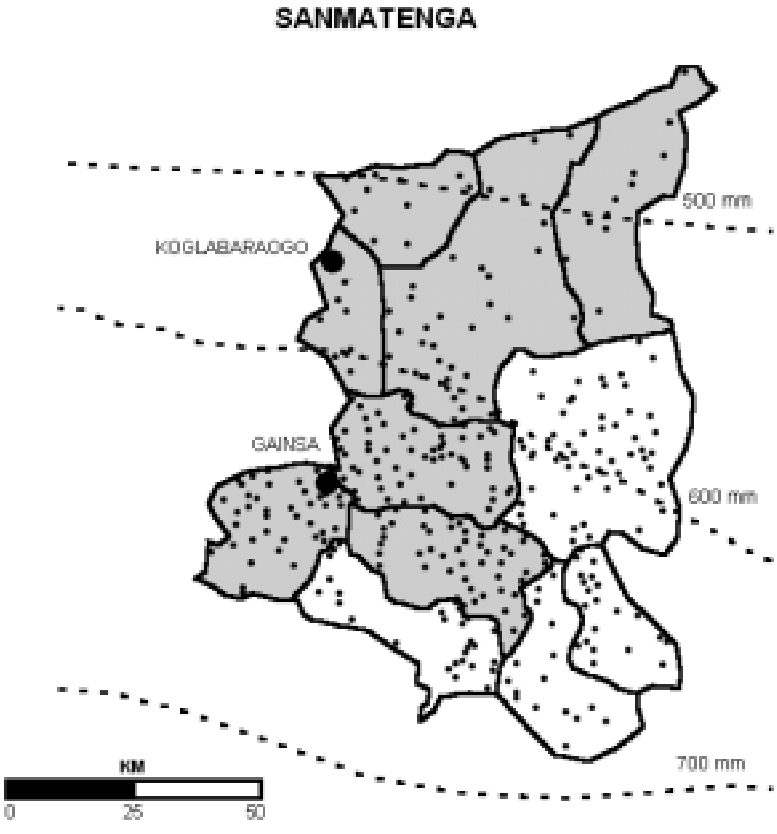

Figure 5.1: The test villages and the other villages in Sanmatenga province

The aim of the action-research was to formulate a participatory extension approach, which covered individual farm management as well as communal natural resource management. A sub-objective of the action-research was to see whether the SHARES model was useful for the formulation and/or execution of the extension programme. It depended on the interest and the judgement of the PEDI staff whether SHARES would be used or not.

5.2.2 The match of the empirical material, theoretical framework and research method

The empirical material
At the time of the field research, I was not yet acquainted with the latest communication theories and I decided to use a broad research approach. The general objective was to analyse the utility of SHARES for the PEDI agricultural extension programme. This covered a wide range of activities: extension activities to support individual farmers and communal natural resource management; the development and use of computer models; the reflections and activities of the farmers, the PEDI extension staff, the scientists at the Antenne Sahélienne, and the project owners (the donor and the Ministry of Planning and Economy). On the one hand, I observed various field trials and meetings, executed interviews and had informal chats. All this was recorded in a research diary. On the other hand, I collected all kinds of remnants, written narratives and secondary literature about the PEDI history, other NRM projects, government policies and extension activities with respect to NRM as well as the Antenne Sahélienne and other agronomic modelling projects in Burkina Faso.

The research concentrated on the relevance of the model for the extension staff *and* the farmers. It was not clear whether the general problem of the limited use of models originated from the lack of convergence between the model and the model users (the extension staff) or the model and the ultimate target group (the farmers). Earlier research suggested that computer models could enhance farmer learning, if only the scientist, in the quality of model-designer-cum-learning-facilitator, had an open mind for the farmer's perspective (Lansing, 1991; Lansing & Peterson, 2003; Gonzalez, 2000; 2002). In practice, it is too expensive to employ a model-designer-cum-learning-facilitator for every locality, social group and learning issue. Therefore, most models are designed for a broad area or social group. Furthermore, in West African countries the predominantly illiterate farmers can only benefit from models if extension services are capable and willing to handle the models on their account. Does this approach work? To answer this question, it is crucial to study the use of model by extension systems.

The theoretical framework
When my contract with the PEDI project expired, I returned to the Netherlands to (a) search a theoretical framework that covered the issue of the study and enabled a better understanding of the learning process; (b) further elaborate the research questions; and (c) select a research method to systematically organise and interpret the gamut of empirical data. This was a laborious process, which involved a continuous iteration between the empirical material and social-psychological theories, between lived-through experiences and argumentation, between details and the overall picture of the process.

At first sight, ANT adequately covered and explained the main elements of the field case. The empirical material revealed that both, biophysical and social aspects influence people's livelihood and learning: (a) biophysical and social aspects influence a farmer's livelihood and learning and (b) computer models and interpersonal communication influence the PEDI staff learning. It also suggested that actor-networks related to the PEDI staff (e.g., farmers, donors, model designers) had different power resources and exerted different kinds of influence on the staff learning. ANT highlights the influence of *the human and non-human entities* on interaction and the emergence of knowledge and action. Furthermore, ANT analyses the *mutual interference between actor-networks and their projects*.

However, ANT's definition of knowledge and agency is problematic. According to ANT, knowledge and agency are emerging properties of the interaction process. However, this study analyses the added value of computer models for learning, with the intention to intervene to improve the use of computer models. This means, that we attribute agency to people: people can make a difference (to some degree). To pay due attention to the perception, reasoning and agency of human actors, I opted for an eclectic approach, combining theoretical concepts of ANT, the actor-oriented approach and the planned action theory and I elaborated the theoretical framework of the learning actor-network (Chapter 4).

The research method
The research principles of ANT and the actor-oriented approach seemed to fit with the study. Because the study focussed on a single micro-process, the principles of symmetry and heterogeneity were less relevant. However, when reading about the principles of reflexive research, everything seemed to fit. Like ANT and the actor-oriented approach, reflexive research considers processes of interaction in their ideological-political context and focuses on issues that are of critical interest to the research subjects. In addition, reflexive research draws attention to some other aspects that are important to this study: a systemic treatment of the empirical material; a theoretical framework apt to analyse the deep structure of the empirical material; the impact of the ideological-political background of the researcher; and the struggle and continuous iteration that make up the interpretive act.

The match of the empirical material and the theoretical framework led to the following research question: "Can SHARES enhance learning for natural resource management?" Three sub-questions were defined. In the next sections, I organise the empirical material in accordance with these questions.

5.2.3 Research question (a): What is the match of interest between the model and the potential users?

Field research on staff interests
The first part of the research question consists of the assessment of the initial interest of potential users in the computer model. To answer this part of the research question, I distinguish two research lines. The first line consists of a general study of the life-world of the staff complemented by an in-depth study of their interest in the SHARES model. The general study covers 3 years of work at the PEDI project: observant participation in the corridors of the project, at meetings, during joint field visits and informal social gatherings. A retrospective reading of project documents and personal activity reports of the various colleagues complements this experience. The in-depth study consists of participant observation of the presentation of SHARES and the unfolding action-research by the PEDI project. The author worked as an advisor for the Communication, Planning and Gender section and in this quality she participated in the PEDI action-research.

The donor perspective influenced the considerations of the PEDI staff and their learning needs. To get a comprehensive picture, I consulted secondary literature on policy making in Burkina Faso by the government as well as the main donor agencies, and reviewed the notes on my personal discussions with donor representatives during fieldwork. This information made up chapter 3: the local context of this research.

Field research on farmer interests

The second part of the research question consists of a study of the life-world of farmers and their concerns about to natural resource management. Did SHARES cover the issues that farmers perceived as relevant and 'at stake'?

In each of the two villages that participated in the PEDI action-research, 32 individual interviews were held to get an idea of the household composition, the agricultural production and marketing, and the off-farm activities of the farmers (Van Paassen, 2000). Furthermore, farmers were asked to present their farm achievements and disappointments for photo-sessions. This triggered hilarious reactions, pleasant, teasing and enjoyable joint touring in the outskirts of the villages and very informative surprises.

The farmer discussions on resource management followed the RAAKS method (Rapid Appraisal of Agricultural Knowledge System, as defined by Engel & Salomon (1997; 2002)). This method was used to identify the farmers' views on collective natural resource management, the perceived issues at stake, the involved actor-networks and the interaction amongst these actor-networks. The farmers also indicated the type of solutions they envisaged.

Aim of this part of the study is to assess whether the model was of interest to the staff and or the farmers (Figure 5.2).

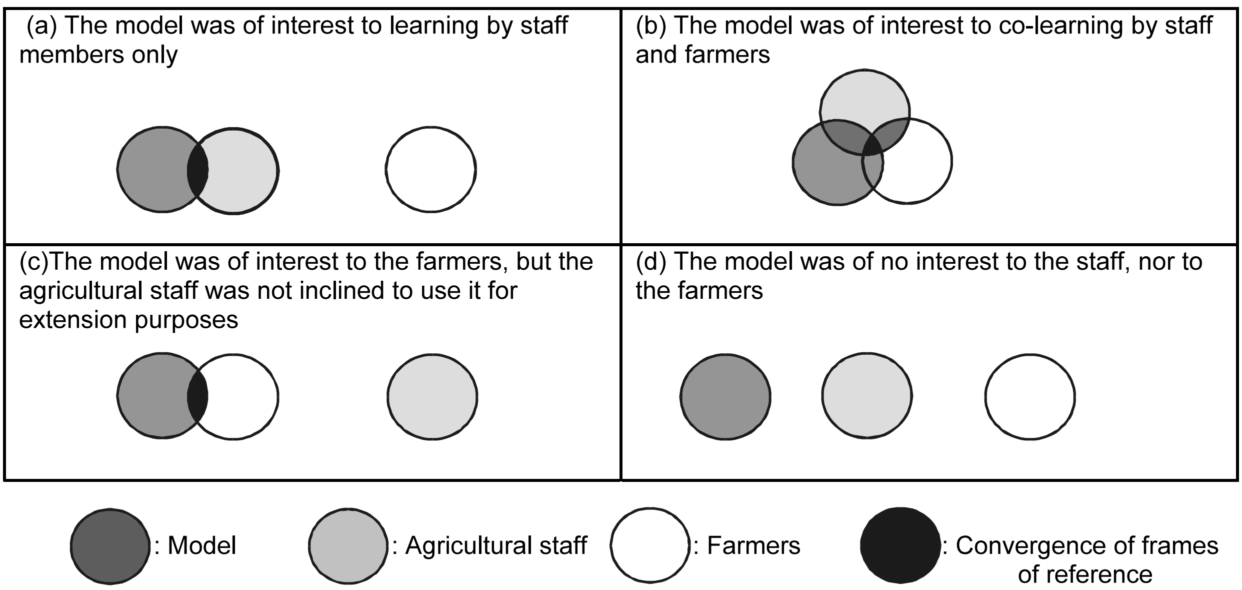

Figure 5.2: Possible situations of convergence of perspectives and interests of actor groups

Interpretation

The field data reveal a process of convergence and distantiation of perspectives and interests between the SHARES model, the agricultural staff and the farmers. The framework of the 'learning actor-network' helps to understand the life-world of the various actor-networks and the interaction process. Secondary material supplies additional information and further colours the picture.

5.2.4 Research question (b): How does model use affect the learning process of the users?

Field research

The agricultural staff wanted to trigger co-learning. They tried it in various ways and, amongst others, considered the possibilities of SHARES. They came up with an idea how to use SHARES for co-learning of staff and farmers. The possibilities of SHARES were explored and visuals were designed to make the SHARES results accessible to the illiterate farmers. The staff members tested the utility of the visuals for extension. During these sessions, the interaction between staff and farmers was carefully observed. An interpreter was employed from outside the project, to literally translate the discussions evoked by the SHARES visuals. These field observations were noted down. Part of the observations were recorded in the minutes and subsequently discussed in joint staff meetings. The other part of the field observations were recorded in a research diary, and checked via informal chats and confidential interviews with staff members.

Interpretation

Chapters 7, 8 and 9 present the study of the learning process. With the help of the learning actor-network framework, the chapters describe and analyse the process of probing by the staff, the use of SHARES and the subsequent learning. This is done for the case of two villages: Gainsa and Koglabaraogo. This part of the study concentrates on the agricultural extension staff. Field observations provide some indication of the interests and the insights gained on the side of the farmers. However, detailed data on the perspective of the farmers are lacking. The researcher was widely known as a PEDI employee; hence, it was impossible to execute trustworthy personal interviews with farmers. Even the employment of an outside interviewer would have raised suspicion.

5.2.5 Research question (c): Can computer models enhance learning for coherence and correspondence?

Field research

Social reality is an ongoing process rather than a state of affairs. An evaluation of an outcome is a time-related judgement. The research question determines the moments that are most opportune to assess the outcome. For learning processes, it is recommended to assess the change of mind right after the interaction, and the change of action after a lapse of time.

This study limits itself to the assessment of the change of mind of the staff members. To assess this change of mind, I use (a) conversations, meetings and activity reports of staff members *before* the PEDI action-research; (b) minutes and diary notes made *during* the PEDI action-research; and (c) project evaluation and formulation documents, and personal interviews *after* the finalisation of the PEDI action-research. Just after the completion of the PEDI action-research, in January 2001, the researcher returned to the Netherlands to start the theoretical part of this study. Other staff members remained at the project to write various PEDI evaluation reports. In February 2002, the researcher returned to Burkina Faso to study these reports and further discuss issues with individual staff members. By that time, everybody had left PEDI and felt freer to disclose personal ideas on the PEDI action-research and SHARES. Except one, all former agricultural staff members currently work outside the PEDI zone. They might use the SHARES experience in their new job, but it is hard to evaluate this aspect. The remaining staff member started a consultancy for the execution of project-related activities. However, at the time of the writing of this thesis, PEDI has been transformed into PDL (Projet du Développement Local) and is still in its consultation and start-up phase (PDL/S, 2001). Only few agricultural PDL activities are running, hence it would be unwise to draw conclusions concerning the 'change of action'.

Interpretation
Chapter 10 gives an assessment of the outcome of the research and draws conclusions. This chapter tries to answer the research questions. The model designers wanted to know whether model use could enhance learning for natural resource management. In line with my background and my commitment to the development practice, I have put this question in a broader perspective. This thesis is written from the perspective that:

- Development co-operation efforts in Sanmatenga province should be directed at human equity, empowerment of the poor, and the improvement of the living conditions while not seriously endangering the natural resource base.
- In Africa, as elsewhere, scientists are busy developing agronomic computer models because it enables them to integrate disciplinary knowledge, improve their understanding of complex issues, and to produce more locally and target group specific knowledge. This is a positive phenomenon. However there is a danger of uncritical use of these models so it is important to become sensitive on how these models can be used for learning.

These considerations led to the final research question, to be answered in chapter 10: Can model use enhance learning for correspondence *and* coherence?

5.3 The application of the principles of reflexive research

5.3.1 Systematics and techniques in research procedures

The experience of the fieldwork guided the theoretical study. What theory was best fit to analyse and interpret the case, producing conclusions that were relevant for the research subjects as well as the academic world? After the choice of the theoretical framework, the empirical material was systemised in concordance with the framework. Secondary material gave information on the political-ideological context, narrative sources gave insights in the research subjects' political-ideological considerations, and remnants and participatory observation gave information about the current behaviour of actor groups (Table 5.1).

5.3.2 Awareness of the interpretive act

The interpretation of the case study demanded a continuous dialogue between the research subjects and the academic world. The visit to Burkina Faso in 2002 and later e-mail contact enabled me to continue the debate with former project colleagues. The debate with the model designers continued as well. There is also a continuous internal dialogue: I intermittently shift between the role of 'the researched' and 'the researcher'.

5.3.3 Awareness of the political-ideological character of, and issues in research

Critical Theory stresses the importance of the political-ideological character of research: the creation of knowledge is inherently connected with the operation of power and norms in social interaction. The social context influences the inquiry and the learning processes of the research subject as well as the researchers.

To understand the learning process of the research subjects, the study focuses on the context, the actual behaviour as well as the research subjects' own interpretation. To know the political-ideological context, secondary material was studied and interpreted (Chapters 2 and 3). Participatory observation and informal chats supplied the necessary information about the actual behaviour and the espoused theories of the research subjects. This empirical material will be interpreted with the use of the 'learning actor-network' framework.

Section 5.2.5 describes the background of the researcher and how this determines the focus of the research. Ideological convictions and commitment to development co-operation heightened my interest in 'learning for correspondence and coherence'.

5.3.4 Awareness of the problem of relevance and authority

This study sprouts from a concern by its research subjects. It starts with critical events and issues defined by the research subjects. The SHARES designers were interested in two issues: "How to improve the use of MGLP models within the practice of agriculture in Africa? Can agronomic MGLP models induce extension workers and farmers to take more notice of the technical potential, economic productivity and ecological sustainability?" The staff of the PEDI agricultural programme, at their turn, struggled with the question: "How to achieve farmer learning?" The research question "Can computer models enhance learning for natural resource management?" combines these concerns.

Apart from its practical relevance, the study aims at an improved scientific understanding of socio-technical learning processes. The objective of the study is to provide empirical material and theoretical concepts to inspire β- and γ scientists to join the debate on model-enhanced learning for NRM.

The authority of a study depends on the prudent, systematic treatment of empirical data and the choice of a theory, best fit to analyse the deep structure of the empirical material. After the scrutiny of various social theories, it appeared that no existing theory really covered the issues of the study and provided sufficient analytical tools to interpret the learning process of the people studied. I therefore opted for an eclectic approach and constructed the 'learning actor-network' framework. This framework pays due attention to the interaction between human and non-human entities. It does not just observe interaction but attributes agency to the people in actor-networks and identifies external and intermediate variables determining the reasoning and action of the people concerned.

Relevance and authority are relative concepts and depend on the actor-networks that the researcher is associated with. This study intends to inspire β- and γ scientists, model designers, users and others to join the debate on model-enhanced learning for NRM. While writing the thesis, I try to be explicit about the research choices, to allow the reader to judge the relevance and plausibility of the research results. It is up to the reader, to finally judge the relevance and authority of this study.

Table 5.1: Overview of the empirical material schematised in concordance with the 'learning actor-network' framework

	Model	**Donor**	**Agricultural staff**	**Farmers**
Remnants/ Participatory Observation	• The SHARES model	• Participation in various reflection seminars on the project reformulation;	• Four years of collaboration: joint participation in field visits and staff meetings • PEDI action-research to reformulate the extension programme	• Four years with regular field visits • Participation in the execution of various PEDI studies • A study on the effect of ploughs on the farm practices and labour division (Tapsoba, 2000) • A study on the use of 'SHARES technologies' in the village Sidogo (Van Hoeve, 2000) • 64 farmer interviews • Observing participation in the PEDI action-research to rephrase the extension programme
Oral narrative sources	• Personal interviews and informal discussion with scientists who played a key role in the development of SHARES	• Personal conversation with donor representatives	• Four years of meetings, informal talks in the corridors and at social gatherings • Personal interviews	• RAAKS sessions to identify interests in communal natural resource management • Photo sessions to identify local agricultural achievements and disappointments
Written narrative sources	• Annual reports and student reports of the Antenne Sahélienne programme. • Working paper former PhD candidate (Nederlof, 1998) • Book on Agricultural land use in Sahelian Villages (Stroosnijder & van Rheenen, 2001)	• Various donor and government policy papers. • Policy agreement of the 11 main donors of Burkina Faso, who harmonised their rural intervention approaches (2000).	• Project formulation and evaluation reports, individual activity reports, and external evaluation reports • PhD thesis Zanen (1996)	• Indirect information sources: • PEDI farmer participation and effect studies executed by external consultants (Agba, 1999a; 1999b; SAEC, 1999) or other PEDI employees (Barning & Dambré, 1994) • Various unpublished village studies executed by PEDI staff members and fieldworkers.
Secondary material	• Scientific articles and books about land use models (See Chapter 2)	• Scientific articles and books about the evolution of rural development policies in Burkina Faso (See Chapters 2 and 3)	• Scientific articles and books about rural development activities in Burkina Faso, with special reference to the PEDI project (See Chapter 3)	• Scientific articles and books about the evolution of farmer livelihoods in Sanmatenga province (See Chapter 3)

6 The match of interests between model and potential users

6.1 Introduction

Actor-networks influence each other's learning processes. The receptiveness for outside influence depends on the perceived similarities and differences in knowledge and interests, and the exerted power of control. A computer model is a material part of the actor-network of model designers; it represents the beliefs and interests (vision and goals) of the model designers. Through their model, model designers intend to influence the reasoning of the user. The latter's eagerness to use the computer model depends on:

The perceived match of knowledge
- The convergence of belief;
- The contextualisation: the capacity of the model (a) to make the users move from the complex reality to abstract reasoning, and (b) to enable the user to explore and move forwards.

The perceived match of norms, values and emotions
- The convergence of norms, values and interests
- The ease-of-use (the match between the complexity of the model and the computer skills of the envisaged user) and the fun-of-use (the ambience when handling the model and the availability of support);

The perceived control on the learning process
- The room for manoeuvre: the possibility to adapt the model and/or interpret the results to needs of the user.

This chapter analyses the fit between the SHARES model and its potential users. It elaborates upon the elements relevant for the use of a computer model. Initially, I concentrated on the match of beliefs and interests, the ease-of use and room of manoeuvre of the SHARES model, but I soon discovered that the ambiance and personal interaction played a crucial role. Section 6.2 discusses the relation between the Antenne Sahélienne and the PEDI staff. The staff became energised by the activities of the Antenne Sahélienne and feelings of trust and enthusiasm, rather than the cognitive challenge, motivated staff members to use the SHARES model. Section 6.3 gives an account of the SHARES introduction and the first SHARES trials. The match between the knowledge and key interests of the model and those of the staff members is discussed. PEDI staff members asked questions to be answered with the SHARES model. Originally, the questions just served to illustrate the nature and the capabilities of SHARES. At the same time, the questions represented the perspectives of the PEDI staff and the trials provided the material to analyse the match of perspectives between SHARES and staff. In Section 6.4, we match the perspectives of SHARES and the local stakeholders. An analysis was made to identify key concerns of the local population: issues they were capable and willing to act upon. These issues were confronted with the answers SHARES might be able to provide. Did SHARES have an added value? Could SHARES enhance farmer learning?

In short, this chapter describes the match of interest between SHARES and the staff, and between SHARES and the local stakeholders. These activities coincided with the PEDI action-research, which will be described in the chapters 7, 8 and 9. To avoid confusion between this study and the PEDI action-research all elements are visualised by the time line in Figure 6.1.

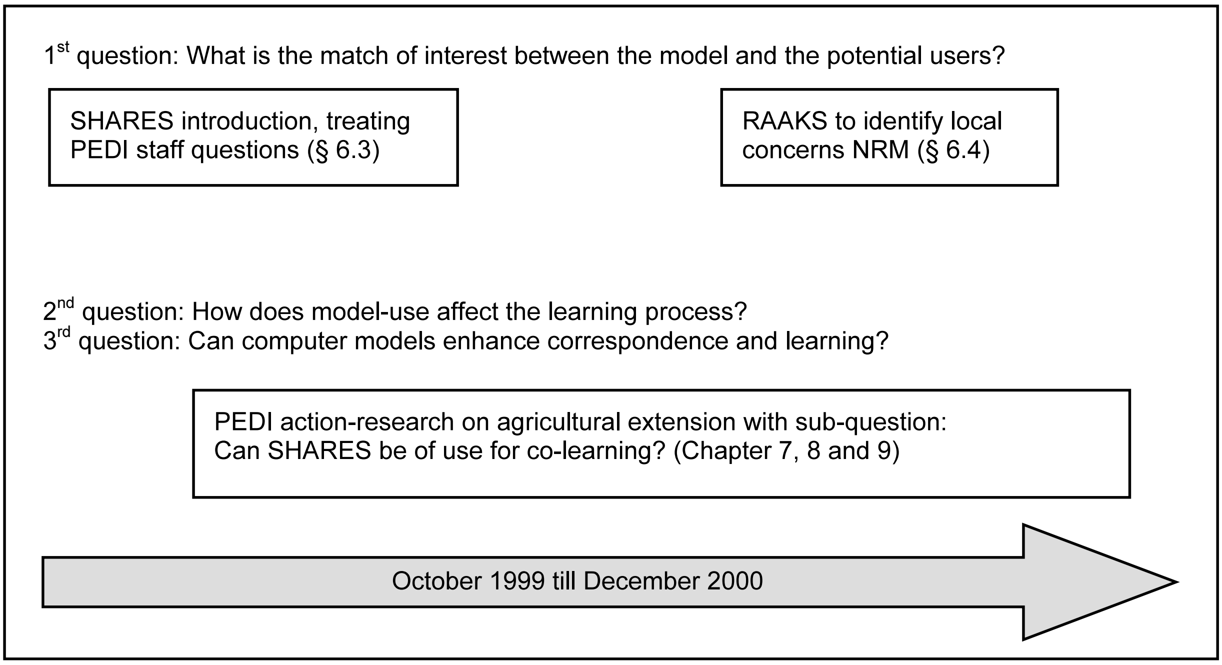

Figure 6.1: Components of this study and their sequence

6.2 The feeling of interdependence between model designers and envisaged users

6.2.1 The Antenne Sahélienne

In 1992, Wageningen University formulated a research programme to develop an integrated perspective on agro-sylvo-pastoral land use in Sahelian villages. After eight years of research by disciplinary as well as interdisciplinary groups it was deemed appropriate to integrate the knowledge into a computer model and to make a 'holistic' land use analysis. At the time, the culture and the organisation of most national and international research institutes were characterised by a strong alliance to disciplines, and multidisciplinary modelling was a challenge. The Antenne Sahélienne developed SHARES: an MGLP model for land use analysis (See Figure 6.2). The purpose of SHARES was to answer questions related to (a) the increase of welfare (defined as income and self-sufficiency) and (b) the degradation of the environment (defined as soil-loss and nitrogen-loss). The results of the research project were published in Stroosnijder & van Rheenen (2001). To fully participate in the international scientific debate on modelling and land use, all contributing scientists, the Dutch as well as the Burkinabé, published in English[49].

During the development of the model, the scientists wondered whether SHARES could provide useful information for village natural resource management discussions. SHARES was a village level model and this matched nicely with the government proclaimed Gestion du Terroir Villageois (GTV) approach. SHARES provided scientific knowledge and could enrich the stakeholder knowledge. The Antenne Sahélienne contacted the PEDI staff and asked them to test the utility of the SHARES model for extension purposes.

[49] In francophone West Africa most scientists (including those of the National Agricultural Research Institute - INERA and the French institute ORSTROM) publish in English to join the international scientific debate.

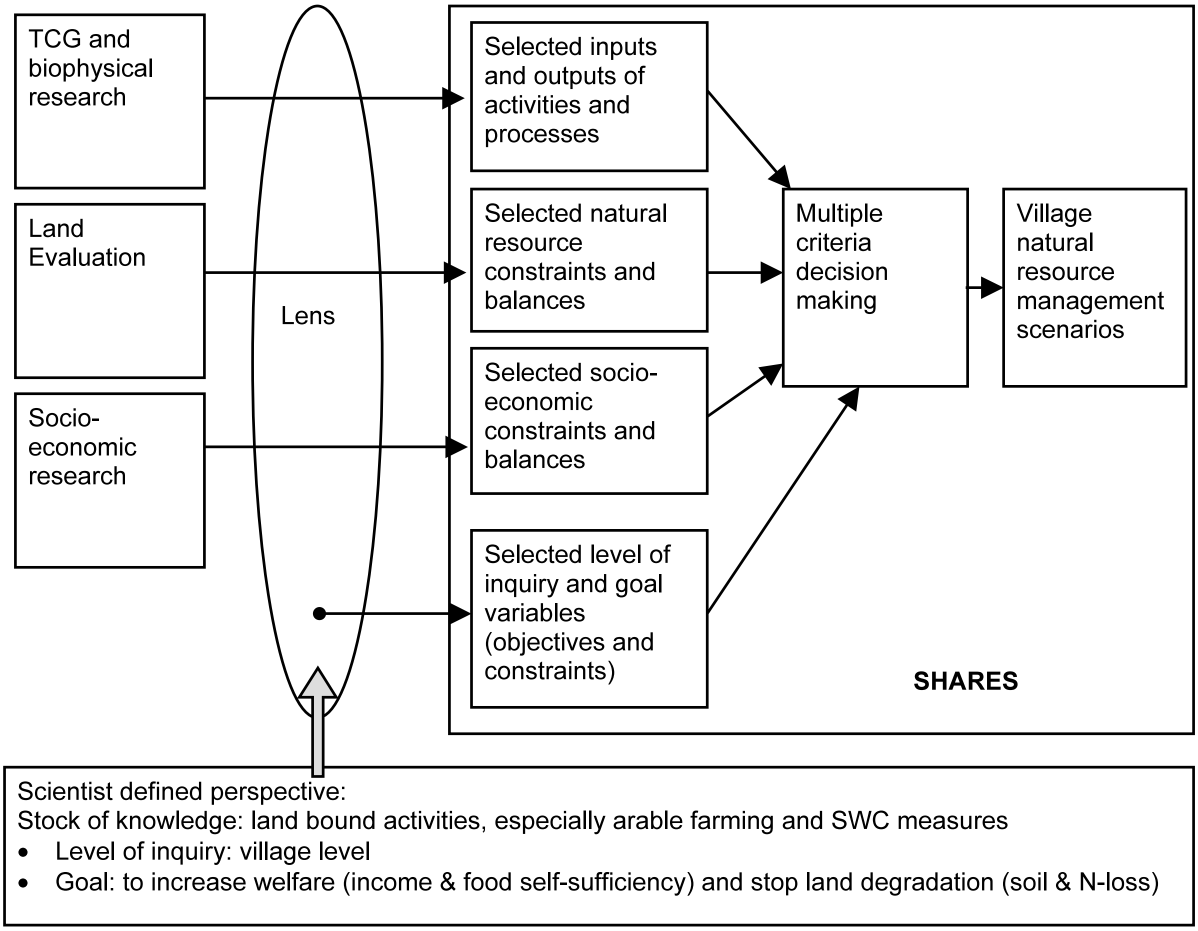

Figure 6.2: The MGLP methodology in SHARES

6.2.2 PEDI staff members

The Antenne Sahélienne was no stranger to PEDI staff members: they had previously been involved in joint research activities. The PEDI staff was interested in new knowledge. The abundant criticism on traditional agricultural extension had made them somewhat insecure and eager to learn about appropriate and effective agricultural techniques and extension methods. Exchanges with scientists and research programmes were perceived as useful and interesting. On the side of the agricultural staff, there was a feeling of dependency and trust towards the scientific world.

The PEDI staff was also intrigued by computers. The annual computer courses were well attended and everybody longed for an internet connection. “Computers are the future” and computer literacy improved your employment opportunities. Everybody used computers for administrative tasks and report writing, but there was little experience with computer-enhanced learning. When being in need for information, PEDI staff organised a workshop or hired consultants, but studying available information on CD-roms and experimenting with software (or researching literature for that matter) was rare[50].

[50] In 1997, PEDI received a CD-rom with valuable agronomic information on the province of Sanmatenga: it consisted of soil maps, a description of the vegetation, erosion probability maps, actual and potential land use maps and a crop yield model. PEDI had ordered and paid for the CD-rom, but nobody took the time to study the findings and to draw conclusions for the agricultural programme. Finally, in 2000, a consultant was hired to interpret this information and draw conclusions on the fertiliser subsidy programme.

6.2.3 Mutual commitment

The PEDI staff members felt honoured when being approached by the Antenne but doubted whether to involve themselves because time was precious. To justify their involvement it was crucial that SHARES was relevant to their current concerns. They invited the Antenne to present SHARES and to demonstrate its capabilities. The first presentation of SHARES highlighted the following issues:

1st presentation of SHARES

- *SHARES integrates different kinds of scientific knowledge. The purpose of SHARES is to provide a comprehensive view of the agricultural potential of village areas in the Zoundweogo and Sanmatenga provinces. SHARES could help PEDI to assist farmers to make informed decisions.*
- *SHARES distinguishes four or five different actor groups. SHARES applied an emic categorisation approach: village members were asked to classify each other according to their natural resource use.*
- *SHARES consists of various components: there were village input files (soil quality and quantity, human resources, climate conditions) and activity and process files (soil and water conservation measures, fertilisation measures, mechanisation, various crops, vegetation growth, animal grazing schemes, livestock growth, milk and meat production, etc.). For various combinations of constraints and objectives, SHARES generates optimum land use alternatives. The output files show an optimised land use situation and the resulting herd size, agricultural production, money revenues, soil loss and nitrogen loss.*
- *Table 6.1 gives an idea of the arable farm practices included in the SHARES model.*
- *Two examples of SHARES-runs. The farmers were free to choose the technologies T0 up to T7. Both examples refer to a specific PEDI village in an average rainy year. The runs showed production data, when the village opted for (a) maximum grain production (Max Cer), or (b) minimisation of erosion (Min Erosion) under the condition of a 50% grain self-sufficiency (food need is 190 kg cereal per adult per year). The results showed the tension between the production objective and sustainability, but also the structural food deficit (Table 6.2). Land was short in supply and even in an average rainy year most farmers did not produce enough cereals. Cereal prices varied between 70 to 82 FCFA per kg; hence, the money revenue was also insufficient to cover the household food needs. Apparently, villages in the South of Sanmatenga, where land was in short supply, had no economic potential. Scientists raised the question, whether it was worthwhile for a project to invest in these areas.*

Table 6.1 Arable farm activities as used in the SHARES model

Activity code	Crop residues	Soil conservation measures	Fallow practice	Manure application	Nitrogen fertiliser application	Mechanisation
T0	taken **from** the field	-	Yes	-	-	-
T1	left **on** the field	-	Yes	-	-	-
T2	left **on** the field	Mulching	Yes	-	-	-
T3	left **on** the field	Stone rows	Yes	-	-	-
T4	left **on** the field	Mulching + stone rows	Yes	-	-	-
T5	left **on** the field	Vegetation bunds	Yes	-	-	-
T6[1)]	left **on** the field	Stone rows	No	2,000 kg manure per ha	-	Animal traction
T7[1)]	left **on** the field	Stone rows	No	1,000 kg manure per ha	15-20 kg N per ha[2)]	Animal traction

1: T0 to T5 were extensive farm practices. T6 was a labour intensive farm practice (transport manure, compost production, application compost/manure) and T7 was the input intensive farm practice (T6 and applying fertiliser). Model designers considered T0 - T5 as current practices and T6and T7 as future options.

2: The exact quantity of N depends on selected crop and soil type.

Adapted from Kiepe *et al.* (2001: 237-254)

Table 6.2: Two examples of SHARES results for a village in Sanmatenga province

	Actor group A	Actor group B	Actor group C	Actor group D	Village
Ressources:					
Population	462	850	400	100	1812
Land (ha)	143	219	151	34	547
SHARES run : Max Cer					
Net Revenue (FCFA)	4,357,531	8,792,944	6,216,916	1,995,511	21,362,902
Cereals (kg)	45,091	132,664	100,548	32,386	310,689
Meat (kg)	3,071	4,475	2,724	816	11,033
Milk (kg)	7,825	9,212	3,944	1,184	22,165
Erosion 1000 kg ha^{-1}	149	319	238	70	776
N-loss	-17	384	280	107	754
Revenue per capita (FCFA)	9,432	10,345	15,542	19,955	11,790
(€)	14.4	15.8	23.7	30.5	18.0
Cereals per capita (kg)	98	156	251	324	171
SHARES run: Min Erosion					
Net Revenue (FCFA)	3,639,045	8,036,399	2,092,871	1,728,057	15,496,372
Cereals (kg)	37,672	129,423	34,841	21,562	223,498
Meat (kg)	2,742	3,894	1,067	826	8,531
Milk (kg)	6,067	6,200	1,218	698	14,183
Erosion 1000 kg ha^{-1}	73	275	70	46	464
N-loss	6	416	123	69	614
Revenue per capita (FCFA)	7,877	9,455	5,232	17,281	8,552
(€)	12.0	14.4	8.0	26.4	13.1
Cereals per capita (kg)	82	152	87	216	123

Note: 655 Francs FCA ≈ 1Euro

The presentation by one of the SHARES designers took an afternoon. All staff members tried to understand the presented data and they posed questions. In the end, staff members had some understanding of what SHARES was about but they could not yet assess its relevance. The PEDI staff was asked to come forward with the kind of questions they would like to see addressed. These could then be treated with the model and this would demonstrate the relevance of SHARES for the PEDI concerns. In addition, two chapters of the SHARES book were translated in French to enable staff members to study the logic of model.

After the presentation, the staff members felt uncertain about the 'SHARES-affair'. It was hard to define the demanded questions. Finally, they confessed that the English language and the multitude of formulas and data posed a problem. Was it not possible to involve an intermediary who was fluent in French and had the necessary computer skills? This intermediary could slowly introduce them into the world of SHARES.

The model designers did not envisage a close involvement with PEDI. Their main concern was to publish the scientific research results in time rather than to get involved with the daily chores of a development project (Newman *et al*., 1994). The practical use of SHARES constituted a separate object of research: a social scientist should match the SHARES knowledge to the learning needs of the agricultural staff and farmers. The envisaged researcher worked at PEDI and was therefore in an excellent position to assess the relevance of the SHARES knowledge for PEDI. The model designers did not consider it their task to spend time and money on the training of PEDI staff members to promote the use of SHARES.

The study of SHARES was a sub-question of the PEDI action-research on extension. To assess the relevance of SHARES it was necessary to prepare SHARES for the natural resource management analysis in the two selected test villages. The Antenne Sahélienne engaged a soil scientist to map the village soil resources and to develop the natural resource input files. They also hired an interview team to execute the categorisation of the villagers. In this way, the Antenne took the lead in the research process but they carefully implicated the PEDI staff. This was a lucky move: the PEDI staff appreciated the emic classification method of SHARES. Inspired by the PLAR approach in Mali, the PEDI R&D section had tested similar methods for specific agricultural domains such as soil fertility and herd management (§ 3.3.4). These tests were valued as successful and the PEDI R&D section thought about generalising and extending these approaches. The SHARES classification seemed the general categorisation method they had been looking for. The method enabled villagers to form relatively homogeneous farmer exchange groups. In consultation with the Antenne, some minor adjustments were made and all staff members were eager to join the field tests.

The categorisation

The ultimate aim was to enhance farmer learning for natural resource management. The point of departure was the farmers' perspective. This required an emic categorisation approach. In the two test villages, the field tests consisted of the following activities:

- An introductory village meeting to present the research objectives and the research team and to ask for the collaboration of the villagers;
- Interviewers wandered around in the village and asked key informants to draw social maps of the village to identify all active farmers;
- In each ward, interviewers invited two men and two women to classify 30, randomly drawn, ward members according to their use and management of natural resources. After

the classification, they were asked to explain the criteria they had used during this classification

- In a public meeting, all selection criteria were presented and the villagers were asked to prioritise the criteria. About five criteria were selected. Men and women were separated in two discussion groups. With the use of the criteria, each group defined four or five natural resource user categories. The groups exchanged their work and they elaborated a final description of the user categories (For details of the selection criteria and final results refer to Section 7.2, notably the Tables 7.1 and 7.2);
- In ward meetings all farmers were asked to choose the category, they felt they belonged to. To get a complete overview, the meeting also classified absent ward members.
- The interviewers executed in-depth interviews with eight representatives of each user category to get detailed information about their household situation and livelihood strategy.

The categorisation served as the kick-off of the PEDI action-research on extension. At first, staff members felt pressed by the presence and enthusiasm of the Antenne and its consultants. They were forced to leave routine tasks and administrative matters and to give priority to field research. Soon after, they became energised themselves: the learning challenge, the exchange of ideas and joint fieldwork were welcome diversions from ordinary work. The action-research attained full swing and the staff developed a soft spot for the Antenne. They were enthusiast and willing to try SHARES.

At the start of this process, I preferred not to act as the advocate of SHARES, in order to be able to study the Antenne-PEDI interaction and the true interest of Burkinabé staff in agronomic models. As one of the senior staff members, any advocacy of SHARES on my side was likely to influence the reaction of my PEDI colleagues. However, it soon became clear that there was no other way for studying the process than by simultaneously facilitating the probing process. The enthusiasm and commitment of the staff members that emerged during the categorisation process convinced me that my colleagues were open to try SHARES if we could keep the momentum that had started with the categorisation. As the PEDI staff lacked the knowledge to handle the SHARES model and the Antenne was not in the position to train them, I had to play multiple roles. Apart from being PEDI extension advisor, I facilitated the collaboration between the Antenne and PEDI and acquired the necessary SHARES skills.

6.2.4 Discussion

The PEDI staff was interested in new knowledge and skills for a mixture of reasons (ranging from true professional needs of their day-to-day project work to opportunistic motives such as CV improvement) but found it hard to judge the relevance of SHARES to their problems and to integrate it into their (tight) schedule of project work.

The Antenne Sahélienne wanted to test the practical relevance of its computer model but their scientific culture and organisation did not allow a close involvement with the PEDI extension system. Furthermore, the scientists concerned held the view that the research should focus on the relevance of the SHARES knowledge for the users. The underlying hypothesis was that the relevance of a model, automatically leads to its adoption and use.

This perspective somewhat overlooks the affective and meta-cognitive regulation aspects of the model, the social and organisational environment and the interaction process. In practice, potential model users not only value the cognitive relevance of a model but they also consider affective aspects such as the match of values and priorities and the ease-of-use. Furthermore, they assess the meta-cognitive regulation aspects: to what degree the model controls the learning process and/or leaves room for manoeuvre. All these aspects refer to intrinsic properties of a model. Apart of the intrinsic model properties, model use also depends on external variables, such as the ambience during the first contact, the availability of support when handling the computer and when interpreting results (Pijpers e*t al*., 2001; McCown, 2002b), and the enthusiasm and energy that emerges from joint action (Wielinga, 2001).

Looking back at the process of first acquaintance, one can conclude that staff members found it difficult to grasp the logic of the SHARES model. Their willingness to test SHARES did not emanate from its perceived relevance, but rather from a feeling of interdependence combined to the enthusiasm and trust evoked by the joint fieldwork during the categorisation. The interests of the Antenne and PEDI differed, but the categorisation proved to be a win-win activity that triggered positive feelings about future collaboration. My decision to act as an intermediary between PEDI and the Antenne, and to acquire the computer skills was crucial. This removed the last (practical) barrier for a test of the SHARES model.

6.3 The match of perspectives between SHARES and the agricultural staff

The PEDI action-research started and there was a willingness to test if SHARES could fit in. The SHARES designers organised sessions to demonstrate the model's capabilities and relevance for the PEDI programme. They invited PEDI staff members to come forward with questions and concerns they thought SHARES could explore. I assisted the model designers to answer the questions using SHARES. This allowed me to acquire the necessary computer skills while demonstrating the potential use of the model.

In this section, the first encounter between SHARES and PEDI staff is presented. The staff questions and the SHARES answers are put into context and the convergence of perspectives, goals and key interests are assessed.

6.3.1 The match of perspectives in the domain of arable farming

The questions
The agronomist was the first to forward his questions:

1. *What is the economic profitability of the application of different doses of fertiliser on the sorghum production? Condition: no soil-loss.*
    a. *NPK, 25 kg ha^{-1}*
    b. *Urea, 25 kg ha^{-1}*
    c. *NPK, 25 kg ha^{-1} + 25 kg ha^{-1} of urea*
    d. *NPK, 50 kg ha^{-1}*
    e. *NPK, 50 kg ha^{-1} + 50 kg ha^{-1} of urea*
2. *What is the profitability, if a sorghum field is treated with manure and different doses of fertiliser:*
    a. *Only 2,000 kg of manure ha^{-1};*
    b. *Applying 2,000 kg of manure ha^{-1} and 25 kg ha^{-1}NPK;*
    c. *Applying 2,000 kg of manure ha^{-1} and 25 kg ha^{-1} of urea*

3. What is the production of cowpea and peanut, when applying 100 kg ha^{-1} of NPK?

The agronomist asked questions about the economic profitability of various fertilisation practices. The focus of the questions was on *technologies* rather than on management or institutional aspects. This is exemplary for the disciplinary reductionist perspective of the staff members. All agricultural staff members were farmers' sons and regularly referred to the farm practices at their place of origin. Because most of the staff members originated from southern regions[51], they had difficulties in understanding the farm strategies in Sanmatenga province. In practice, the staff questions demonstrated more affinity with their professional and home background than with the Sanmatenga farmer reality.

Secondly, there is a pronounced interest in the *economic profitability* of technologies. At the time of the research, the staff members were primarily interested in the economic profitability because they felt that this was the main evaluation criterion for future farm activities. Right form the start of the programme, PEDI had concentrated on land degradation and food self-sufficiency and the project only intervened under the condition that farmers applied SWC measures[52]. PEDI assumed that farmers, after gaining food self-sufficiency, would opt for commercial farming by using an input-intensive mixed farming strategy (See Table 6.3).

PEDI agricultural activities, such as R&D, extension and the subsidy programme followed this logical framework (PEDI, 1996a; PEDI, 1998). Staff members fully adhered to these programme priorities and activities[53]. According to their vision, many Sanmatenga farmers still focussed on food-self sufficiency, but once shown the way, successful dynamic farmers would increasingly apply an economic rationality.

The convergence of perspective of SHARES and the agronomist

The PEDI staff and SHARES had similar development visions: in general, they assumed that the only way out of the vicious circle of natural resource degradation was farm intensification, financed by the sales of agricultural produce (Stroosnijder & van Rheenen, 2001, prologue). National agricultural statistics indicated that farmers predominantly used fertilisers for commercial crops (MARA, 1996a; 1996b). The experience of PEDI also showed that Sanmatenga farmers were ambiguous about the purchase of inorganic fertiliser (Tapsoba, 2000). The agricultural staff assumed that fertiliser use was economically profitable and on-farm tests would convince dynamic farmers to start input intensive farming. They engaged several students and consultants to study the details (Beneder, 1998; Agba, 1998; Van den Elshout, 2001; Van den Elshout *et al*., 2001); hence, it was no surprise that the agronomist also asked SHARES to explore the profitability of fertilisers.

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[51] Southern and westerns regions of Burkina Faso were characterised by a higher average rainfall, higher agricultural potential and more commercial farming.

[52] PEDI III requested a village or ward land rehabilitation plan, before discussing any other development activity. During the subsequent IVth phase, the construction of stone rows and the application of rock phosphate (or Burkina Phosphate - BP) were also of prime importance. Farmers were not entitled to farm equipment subsidies, if they didn't apply stone rows and BP. The size of the village development fund also depended on the number of farmers participating in the stone row and BP programme.

[53] Like most agricultural staff members, the researcher was recruited in 1996, at the start of the project phase. At that time, the policy document of PEDI IV had been approved but it still lacked a detailed operational plan. Staff members subscribed the policy intentions and enthusiastically discussed and elaborated the operational plans.

Table 6.3: The objectives and activities of the agricultural programme of PEDI

<table>
<tr><td colspan="2">Global objective PEDI IV:
To revive Sanmatenga province by increasing the agricultural and non-agricultural production to:
• feed the increasing population;
• increase the monetary revenue;
• improve the living conditions.

Priorities of agricultural programme</td></tr>
<tr><td colspan="2">1. To achieve food self-sufficiency</td></tr>
<tr><td>Domains:</td><td>Activities to be promoted:</td></tr>
<tr><td>• Erosion control, Soil and Water Conservation (SWC) measures</td><td>• Construction of stone rows, vegetation bunds and small dikes.</td></tr>
<tr><td>• Fertilisation</td><td>• Mulch, use of livestock dung, production of compost. Application of rock phosphate and other fertilisers.</td></tr>
<tr><td colspan="2">2. To improve the monetary farm revenue</td></tr>
<tr><td>• Animal nutrition</td><td>• Collection and storage of hay, cultivation of fodder crops, use of crop residues, purchase of cotton cake and the application of nutritional regimes.</td></tr>
<tr><td>• Livestock management</td><td>• Livestock fattening and milk production, management of the herd composition, grazing management.</td></tr>
<tr><td>• Livestock health</td><td>• Prevention and treatment of livestock illness.</td></tr>
<tr><td>• Multipurpose trees/herbs</td><td>• Plantation of wind breaks, edible trees and nitrogen fixing herbs, management of the communal areas.</td></tr>
<tr><td>• Commercial crops</td><td>• Cultivation of cowpea, peanut, sesame, etc.</td></tr>
<tr><td>• Mechanisation</td><td>• Use of ploughs for land preparation and weeding, use of donkey carts for the transport of cow dung and compost.</td></tr>
<tr><td>• Arable farm practices</td><td>• Land preparation, treatment of seeds, crop maintenance, intensive use of fertiliser, use of improved seeds.</td></tr>
<tr><td colspan="2">3. To develop the agricultural market chain

• Research and Development for intensive commercial farm production
• Market studies and the promotion of profitable market trade</td></tr>
</table>

Source: PEDI (1996a), Plan d'opérations 4e phase 1996-2000, page 54-55.

A comparison of the objectives and activities of the PEDI staff and SHARES suggest that:

- They both focussed on technical-economic, rather than political-ideological and institutional issues;
- For both, the purpose was to attain ecological sustainability, regional food self-sufficiency and economic profitability;
- To reach these objectives they both considered improved and intensive farm practices such as manure/compost, fertilisers, draught power and the use of by-products (e.g., crop residues and manure).

The overall development vision of PEDI staff members more or less matched with the vision of SHARES. However, there was some difference in focus. The PEDI agronomist perceived fertilisation to be a key concern: PEDI farmers widely used SWC measures but they were less enthusiastic about the promoted fertilisation measures. The agronomist struggled with the issue of fertilisation, but SHARES contained only three fertilisation practices. The focus of SHARES was a logical consequence of the SHARES development process: scientists spend much effort on the formulation and validation of current agricultural practices (e.g., SWC measures) and had little time for the articulation of potential future agricultural practices such as the use of fertilisers. As a result, SHARES included six SWC practices against three fertilisation practices. This limited the explorative character of SHARES: it concentrated on current management options, while the PEDI staff was primarily interested in future options.

The answers

The interests of the agronomist and SHARES did not coincide and it was hard to answer the questions that were posed. By that time, I had more or less mastered the SHARES model and together with the SHARES designer the second SHARES presentation was prepared. Some creative assistance was received from a consultant, familiar with the PEDI agricultural section and agronomic models. He proposed to answer the agronomic questions with the use of simulation models and simultaneously explain the difference between simulation models and MGLP models. The presentation ended with a demonstration of the strong points of SHARES.

2^nd^ presentation: The capacity of SHARES to answer the questions about arable farming

SHARES includes three levels of fertilisation (Table 6.1). For each level of fertilisation, SHARES provides yield forecasts for a wide range of crop-soil-weather combinations. These forecasts give a rough indication of the profitability of fertiliser use in Sanmatenga province. To explore the exact profitability of various fertilisation practices, staff members are advised to use simulation models. Staff members received a short introduction on the logic of crop growth models and how these models generate the answers to the agronomic questions (Refer to Chapter 2, Figure 2.1).

SHARES is a village level MGLP model. The MGLP methodology works with input-output coefficients generated by a TCG or a simulation model. MGLP models generate scenarios for management decisions. To prevent the model from becoming too complex and too difficult to handle, scenarios contain a limited number of details: model designers have to select the details they consider important. The SHARES model only contains a selection of the information generated by crop growth models. Unfortunately, SHARES contained too few details on fertilisation to explore the issue raised by the PEDI agronomists.

To show the strong points of SHARES, we presented two imaginary management questions:

1. ***Question**: A Sanmatenga village wants to attain food self-sufficiency (= 190 kg cereal per village member) with some additional monetary revenue. What is the production potential of (a) an extensive farm strategy versus (b) an input-intensive farm strategy?*
   ***Answer**: Farmers will not attain their food self-sufficiency if they opt for an extensive farm strategy (the farm techniques T0 up to T5 (T0-T5). If including the input-intensive farm technique T7, they are able to produce 190 kg grain plus 1885 FCFA per household member.*

2. ***Question:** The previous case assumed that households traded cereals and other agricultural produce within their village. The allocation of agricultural activities to available land resources was optimised at village level: some farmers produced the food for their neighbouring households. Now we assume that households do not want to trade cereals, but they insist on producing their own food. Again, all farmers hope to reach food self-sufficiency plus some additional revenue. What is the production potential?*
   ***Answer:** The allocation of agricultural activities is now optimised at household level. This severely limits the production potential. Farmers cannot attain food self-sufficiency*

if they do not apply input-intensive farm strategies. Even when they apply intensive farm strategies, they just attain food self-sufficiency but no monetary revenue.

The staff members showed great interest in the crop growth models. These models seemed to provide specific answers to their questions. As far as SHARES was concerned: the results bewildered them. What to believe of the predicted food deficits? In an average year, the majority of the farmers still experienced severe food shortages. Were these predictions realistic or did SHARES underestimate the potential? The discussions with the farmers would have to demonstrate the validity of the SHARES scenarios.

6.3.2 The match of perspectives in the domain of livestock farming

The questions

The third and last presentation dealt with the livestock questions. The PEDI livestock officer forwarded the following questions:

1. *Could you quantify the livestock production (in terms of meat production or revenues) of:*
   a. Extensive livestock production: putting livestock out to pasture.
   b. Semi-extensive livestock production: cutting and conservation of hay, the use of crop residues and the purchase of agro-industrial by-products such as cotton cake.
   c. Grassland improvement: rotational grazing and the application of SWC measures.

2. What is the effect (in terms of extra meat or milk), when you intensify livestock production, putting livestock in stables, using supplementary feed, and cultivating fodder crops.

These questions, like those of the agronomists, show an interest in technologies. These questions have their origins in the ambiguous role of PEDI in livestock farming.

Since 1982, PEDI intervened in Sanmatenga province, a transitional zone between the Sahel (pastoralism) and the Soudan (arable farming with some sedentary livestock). From a technical perspective, the Soudano-Sahel makes best use of its natural resources when it opts for mixed farming. From a social perspective, it is important that both, the Mossi majority and the Peulh minority attain a decent livelihood. Nowadays, Mossi own a considerable amount of livestock but they primarily identify themselves as arable farmers. The Peulh identify themselves as livestock herders. To respect the social organisation, it is desirable to develop both farming systems, while encouraging mutual exchange of by-products amongst arable farms and livestock herder (Slingerland, 2000).

PEDI policy documents did not want to choose between mixed farming or two interdependent farming systems: “Despite the massive experience in Burkina Faso and neighbouring countries, we do not yet know the ‘solution’ for agro-silvo-pastoral farming in the Soudano-Sahelian zone. Besides, there is no single solution. Therefore, the intensification programme only consists of general guidelines. The programme does not want to impose solutions but intends to follow the requests and priorities of the beneficiaries” (free translation of PEDI, 1996a: 52). The ambiguous PEDI objective “to follow the requests of the beneficiaries” ignored the divisive interests in livestock of Mossi and Peulh. In practice, the progressive involvement of Mossi in mixed farming endangered the livelihood base of the Peulh pastoralists (§ 3.1.4).

The PEDI livestock officer had regular contacts with the Peulh minority but for reasons of accessibility and convenience, she mainly tried to stimulate the Mossi majority to take up mixed farming. This was both an encouraging and a frustrating affair. At the time of the action-research, she had just finalised some successful tests on livestock fattening, but it was hard to raise Mossi interest for fodder crops and grassland improvement.

When being asked to formulate questions for SHARES, the livestock officer seized the opportunity. Information on the productivity of intensive livestock farming might trigger the interest of the farmers. She inquired about the added value of various livestock techniques, but also explicitly referred to mixed farming. This shows a technical perspective geared towards the Mossi land use system and ignores the broader land management issues that might have interested the Peulh.

The convergence of perspective of SHARES and the livestock officer

Before matching the frames of reference of the livestock officer and SHARES, the livestock related aspects included in the SHARES model are discussed. What was the SHARES perspective on livestock farming?

The SHARES input files distinguished three animal feed resources: the herbaceous layer (forage), woody species (browse) and crop residues (fodder). Scientists had made an inventory of the feed production of the herbaceous and woody layer for 3 types of bush land, three grazing regimes (wet season grazing, only dry season grazing, all season grazing) and three rainfall situations (a dry, an average and a wet year). The production of crop residues was directly related to the crop harvest. The animal-feed resources were classified into nine roughage quality classes, which differed in energy intake level, digestible organic matter content, and nitrogen content. The classification also considered the selective grazing of livestock (Slingerland & Savadogo, 2001a). Cotton cake, an agro-industrial by-product that can be fed to supplement animals, was added as the 10th feed quality class.

Other activity files contained ‘feed ratio-livestock production’ coefficients, obtained from a TCG (Chapter 2 and Hengsdijk *et al.,* 1996; Hengsdijk and Bakker, 1996; Hengsdijk, 1997). The coefficients were validated through comparison with Sanmatenga field studies (Slingerland & Savadogo, 2001b). These activity files distinguished two types of livestock (cattle and small stock), three production objectives (milk, meat and traction) and diet qualities. In theory, diet qualities were expressed as multipliers of the animal maintenance requirements and ranged from 1.05 (extensive farming) up to 1.75 (intensive farming). SHARES designers were primarily interested in land-bound activities and only included extensive livestock activities (diet quality 1.05 and 1.10) and no livestock fattening or milk production activities (which required diet qualities of 1.50 or 1.75).

Comparing the frame of reference of the livestock officer and SHARES reveals that:

- They both focussed on technical and economic farm management issues, rather than political-ideological and institutional aspects;
- The livestock officer explicitly focused on the development of intensive livestock farming. She explores the possibilities of keeping livestock under 0-grazing[54], intensive feed production as well as pasture management. SHARES paid little attention to these issues. SHARES contained the option of cotton cake but it ignored livestock fattening, feed production and grassland improvement. The SHARES designers concentrated on

[54] A system whereby livestock is kept in stables and fed, rather than left to roam for forage.

land use and land-bound activities so livestock fattening under 0-grazing was left out. This can be explained by the original SHARES objective: a summary of past research into existing practices aimed to identify new research topics.

The answer

In theory, it was possible to use a TCG and/or expert knowledge to adapt SHARES and include all relevant livestock activities. In our case, the SHARES designers were busy wrapping up the Antenne programme and the time was not available to adapt the model. The presentation demonstrated the multiple goal nature of SHARES and the kind of production questions the existing version was able to handle:

- the trade-off between cereal production (sorghum, millet, maize) and the production of leguminous crops (cowpea and groundnut). These leguminous crops fetched a higher market price. The beans were used to prepare protein rich snacks and the leaves served as nutritious fodder.
- the productivity and profitability of the use of cotton cake.

3rd presentation: the trade-off between cereal production and livestock farming

SHARES concentrates on land-bound activities and only contains extensive livestock activities. Hence, it is impossible to answer all the questions, but the following SHARES-runs give some idea of the profitability of livestock production (Table 6.4):

Table 6.4: SHARES generated trade-off between village cereal- and livestock production

	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
Constraints		Vcer = 97 tons	Vcer = 97 tons VliveC=0	Vcer = 85 tons	Vcer = 85 tons VliveC=0	Vcer = 75 tons	Vcer = 75 tons VliveC=0	Vcer = 65 tons	Vcer = 55 tons
Farm Objective	Max Vcer 1000 FCFA	Max VliveR 1000 FCFA	Max VliveR 1000 FCFA	Max VliveR 1000 FCFA	Max VliveR 1000 FCFA	Max VliveR 1000 FCFA	Max VliveR 1000 FCFA	Max VliveR 1000 FCFA	Max VliveR 1000 FCFA
Vrev	7744	11930	11856	15127	15094	16286	16248	16608	16283
VceR	7180	7180	7180	6364	6364	5626	5626	4806	4377
VlegR	564	564	564	3287	3287	4459	4459	5288	5268
VliveR		4185	4111	5475	5442	6201	6162	6513	6637
VmilkR		3895	2750	4155	3641	4721	4123	4526	4440
VmeatR		1926	1360	2055	1800	2335	2039	2238	2197
VliveC		-1636	0	-734	0	-855	0	-251	0
Kg cereal	96657	96657	96657	85000	85000	85000	75000	65000	59594
kg meat		6955	4911	7419	6501	8429	7362	8082	7929
kg milk		22781	16087	24299	21294	27610	24113	26472	25969

Vrev: Village net farm revenue
VceR: Village net cereal revenue
VlegR: Village net leguminous crops revenue
VliveR: Village net livestock revenue
VmilkR: Village milk revenue
VmeatR : Village meat revenue
VliveC: Village livestock costs (= purchase of cotton cake)

- *For the village in question, SHARES first generated the maximum cereal production using extensive farm techniques T0-T5 (Table 6.1). The maximum village cereal production (Vcer) was 96,657 kg of cereals, worth 7,180,000 FCFA. The option included* *some cowpea- and groundnut production, but no livestock activities. The net agricultural revenue was 7,744,000 FCFA (11,823 Euro).*

- *The second run maximised the livestock net revenue (VliveR), under the condition that the Vcer remained at the maximum of 96,657 kg. SHARES recommended buying cotton cake (1,636,000 FCFA) to produce milk and meat. The net agricultural revenue increased to 11,930,000 FCFA (18,214 Euro).*
- *The third run stopped the purchase of cotton cake. Expenses decreased with 1,636,000 FCFA, and this led to a decrease of the livestock gross revenue of 1,145,000 FCFA: The net livestock revenue only decreased with 74,000 FCFA. The cost-benefit ratio of the purchase of cotton cake was 0.96.*
- *The fourth run included fodder production: the cereal production was diminished to 85 tons, to allow for an increase of the cowpea and groundnut area. The decrease of cereal area led to a decrease of the cereal revenue of 816,000 FCFA. This was largely compensated by an increase in cowpea and groundnut revenue (2,723,000 FCFA) and livestock revenue (1,290,000 FCFA). The availability of fodder led to a higher milk and meat production, while simultaneously allowing lower cotton cake expenditures. In sum: the limitation of the cereal production led to a higher livestock production and higher net agricultural revenues (Table 6.4).*
- *The fifth run skipped the purchase of cotton cake. The omission of cotton cake (734,000 FCFA) resulted in a decrease of the livestock revenue of 767,000 FCFA. The net agricultural revenue decreased slightly with 33,000 FCFA. The cost-benefit ratio of the purchase of cotton cake remained 0.96.*
- *This procedure was continued: the minimum required village cereal production was reduced to respectively75, 000 kg, 65,000 kg and 55.000 kg. At 65,000 kg of cereal, the cereal production was as profitable as the cowpea/groundnut production; the marginal production value (MPV) of a hectare cereal was equal to the MPV of a hectare cowpea. The village had reached its maximum obtainable net agricultural revenue of 16,608,000 FCFA or 25,356 Euro (Figure 6.3).*

An adult needs about 190 kg of cereals per year. The village had 1812 inhabitants, and needed about 344,280 kg of cereals (worth 24,099,600 FCFA or 36,793 Euro) to cover its food needs. Figure 6.4 demonstrates the trade-off between own cereal production and cereal accessibility: lower cereal production leads to a higher agricultural revenue and cereal purchasing power. The village was able to cover 67% of its food needs.

The presentation demonstrated the trade-off between cereal production and mixed farming (more leguminous crops and livestock production). The cultivation of leguminous crops, such as cowpea and groundnut (a) improved the soil quality; (b) produced nutritious beans, which fetched relative high market prices; and (c) produced nutritious fodder for the animals. Under these circumstances it was not recommended to use cotton cake: the cost-benefit ratio was only 0.96.

The PEDI staff members understood the type of questions SHARES could handle and found it a worthwhile analytic tool. However, they remarked that farmers reasoned differently: farmers used cowpea and groundnut for intercropping. They would probably insist on growing their own cereals.

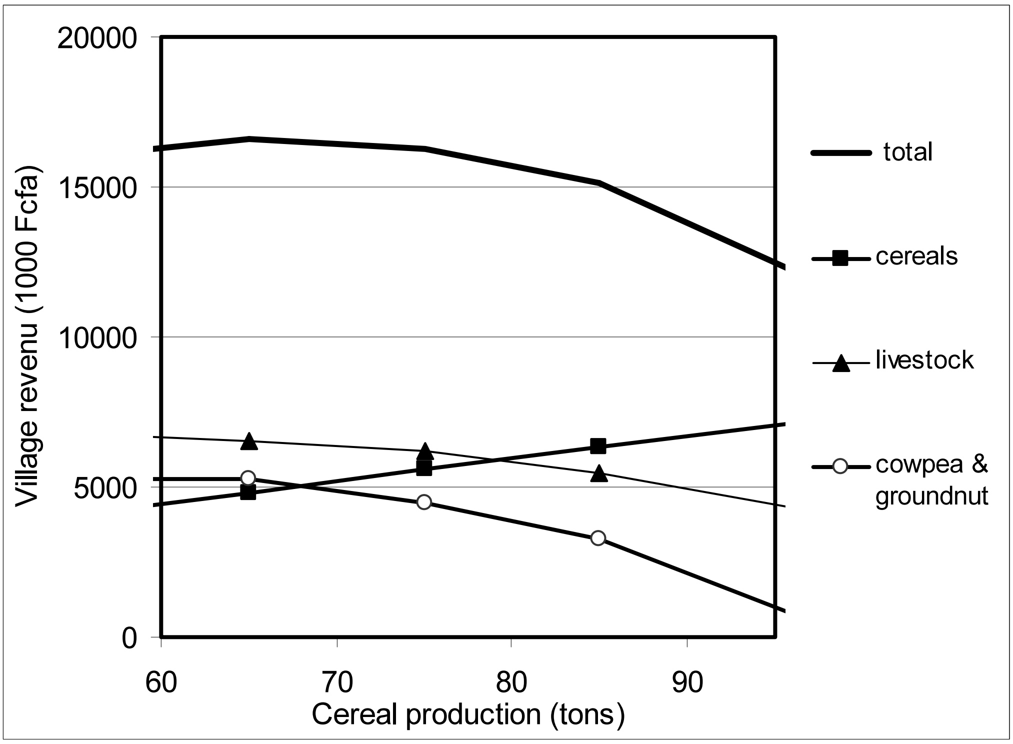


Figure 6.3: SHARES generated trade-off between village cereal- and livestock production

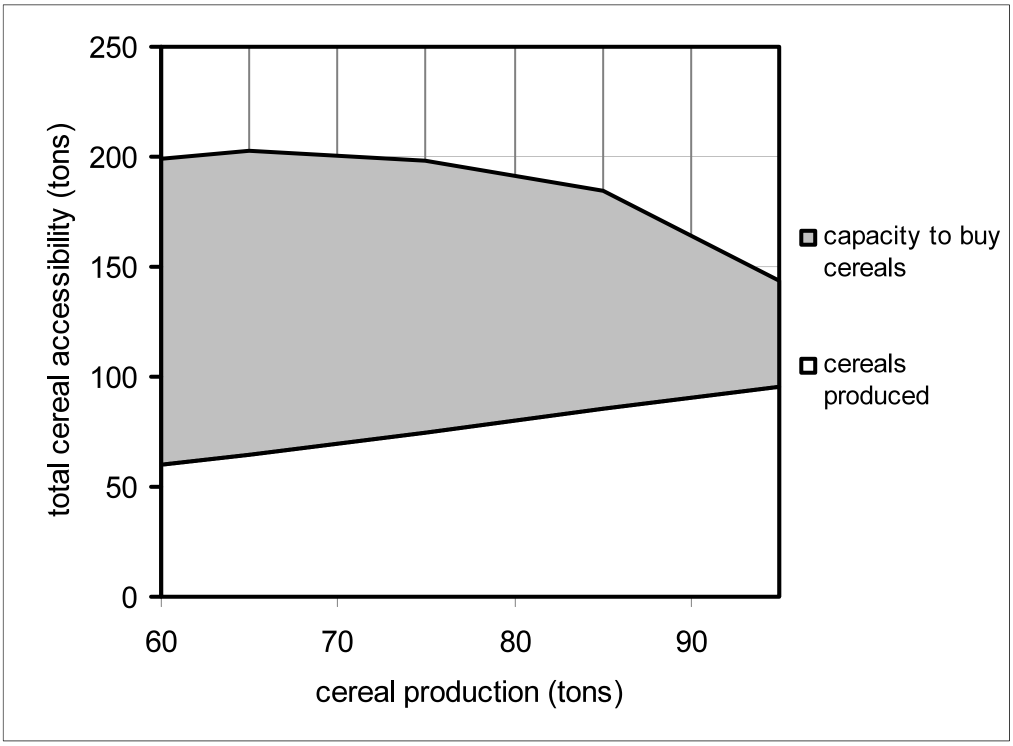


Figure 6.4: Cereal accessibility related to cereal self-sufficiency

6.3.3 The match of perspectives in the domain of agro-forestry

The question
The team leader of the Agro-Sylvo-Pastoral (ASP) section formulated the last question:

Could SHARES demonstrate the added value of various tree-species for: (a) soil fertility and arable farming, (b) fodder production and livestock farming, and (c) wood production?

The ASP team leader was a forester but did not fancy wood plantations in Sanmatenga: "the soil layer is too shallow for woodlot production". Local farmers themselves also displayed little interest in commercial woodlots. Some villages had bad experiences with project and government promoted village woodlots. The northern part of Sanmatenga province was sparsely populated and still contained considerable natural wood reserves. The government promoted woodlots and the uses of wood-stoves but these practices were not popular. Programme impact studies suggested that local people did not perceive severe wood problems. In some areas, the local population allowed seasonal migrants from North Burkina to cut the wood in their neighbourhood. They sold part of the wood to passing truck drivers. Another common phenomenon was the queue of donkey carts belonging to wood traders going in and out of Kaya town. Many townsmen owned a donkey cart and a woodcutting permit. They sent young family members on wood collection trips and sold the wood at their compounds. Local farmers were not involved in commercial wood activities: they detested woodcutting jobs and lacked the capital and contacts to participate in the profitable wood trade.

Farmers showed no interest in commercial woodlots, but highly appreciated trees as windbreaks, soil improvers etc. To assist farmers in their search for utilitarian trees, the PEDI officer asked SHARES to elaborate upon the utility of various tree species.

The convergence of perspective of SHARES and the forester
SHARES included two wood activities: wood production of the natural vegetation as well as wood plantations. All production activities were derived from the TCG (Hengsdijk *et al.,* 1996: 82-86) and validated through comparison with literature and experimental data of wood production and natural vegetation in Burkina (Slingerland & Wiersum, 2001). For the natural vegetation the TCG provided production coefficients, based on Breman and Kessler (1995), for six soil types and three rainfall regimes. Similar procedures were applied to calculate the production coefficients for wood plantations. To achieve the calculated wood production phosphate should be applied. For plantations, it was assumed that 75% of the production could serve as construction wood. The remaining 25% was used as firewood (Slingerland & Wiersum. 2001: 282-283).

A comparison of the interest and activities of the PEDI staff and SHARES reveal a high convergence:

- Both, PEDI and SHARES, consider technical-economic aspects rather than the social structure and interaction;
- Neither PEDI nor the SHARES designers demonstrated a deep interest in woodlots. PEDI staff members concentrated on utilitarian trees (soil improvement, wind breaks, fodder, medicine, firewood). SHARES included wood production from the natural vegetation and plantations, but the designers considered Zoundweogo province, rather than Sanmatenga province, as a potential regional wood producer.

Neither the PEDI staff nor the SHARES designer considered wood plantations as a major land use option for Sanmatenga. The PEDI forester only formulated questions about wood production, because he was invited to. According to him, wood plantations were no issue, but it was always handy to know more about utilitarian tree species.

The answer
SHARES worked with woody layer units (m^3 ha^{-1}) rather than individual trees, hence, it was difficult to use SHARES to assess the utility of specific tree species. This was the third time that SHARES lacked the specific details that were of concern to the potential users. The SHARES designers underlined the limited value of computer models. Computers would never be able to answer all imaginable questions; computer models were no decision support devices, but rather discussion facilitation tools. SHARES was a venue for interaction between scientists and practitioners. The third presentation explained how wood was included in the SHARES model and advised the PEDI staff to look for complementary information at international agro-forestry research institutes.

4th presentation: the feasibility of wood production
- *The SHARES model does not contain the sought-for information. However, the SHARES designers may help the PEDI staff to contact scientists and to obtain relevant literature. The positive thing of the SHARES exercise was the increased interaction amongst scientists and practitioners.*
- *The SHARES model distinguishes two kinds of wood: timber wood and firewood. Timber wood comes from plantations or woodlots. About 25% of the wood produced at plantations cannot be used for construction and is sold as firewood. Firewood comes from plantations and the natural vegetation at the rangelands. SHARES includes wood production estimates for plantations and rangeland, and pays attention to the soil type and rainfall regimes.*

Does SHARES recommend farmers to invest in wood plantations? According to SHARES, commercial wood plantations are very lucrative, but there are several points to consider:
- *Most farmers have limited access to land. Only a few farmers have enough land to consider woodlots.*
- *Sahelian villages have to choose between conflicting objectives, namely food self-sufficiency and growing crops or wood for sale.*

For three Sanmatenga villages SHARES explored the production potential for the year 2010. All farmers could apply input-intensive farm techniques (up to T7). During normal or wet agricultural seasons, only one land-rich village surpassed the food self-sufficiency level and could actually sell wood. In the other two villages, wood production was not possible if they wanted to meet their food requirements. In a dry year, none of the villages could attain food self-sufficiency and nobody could consider wood production.

Conclusion: only farmers with sufficient land in villages with sufficient space can afford wood production.

The wood issue was fascinating: both PEDI staff and the SHARES designers followed the current farm practices and prioritised food production:
- The PEDI forester reasoned that the humus layer was too shallow for wood plantations. He followed the current practice: wood came from the non-cultivated bush area; the hills

and slopes with their shallow soils. He did not consider the possibility to explore the trade-off between wood plantation and food production in the valleys.

- For the SHARES designer, the problem might have been that SHARES included a high timber price of 10.000 FCFA m^3 (wood price at the Ouagadougou market). SHARES allocated large areas to wood production. This did not seem realistic because only few farmers were interested in agro-forestry. In his presentation, the SHARES designer therefore underlined the importance of food production. The SHARES scenario might have been more realistic and open for discussion when including a more realistic wood price. In the North of Sanmatenga, a cartload of wood (about m^3) fetched 1.500 to 2.000 FCFA; in the regional centre Kaya 7.000 FCFA. The South was heavily populated and lacked substantial wood reserves.

6.3.4 Discussion

Through the questions, the relevance of SHARES for the PEDI staff is assessed: (a) What was the level of convergence of vision and goals? (b) What was the convergence of the level of inquiry and key interests? And, (c) was there some room for manoeuvre to interpret model results in such a way that they enable staff members to explore their key concerns and move forwards?

The convergence of vision and goals

SHARES is part and parcel of the Wageningen land use planning tradition (Chapter 2). It is an MGLP model that aims (a) to increase the welfare of the people (interpreted as income and self-sufficiency) and (b) to avoid degradation of the environment for future generations (interpreted as soil loss and nitrogen loss).

Looking at the questions of the PEDI staff members, the prevalence of a technical and economic perspective can de discerned. It was assumed that many farmers still applied a food self-sufficiency strategy but would gradually adopt more commercial farm strategies if shown the right way. As explained in Section 3.3.3, staff members were at the crossroads of two extension approaches. They wanted farmers to experiment to find their own solutions but also promoted certain agricultural techniques. The staff members recognised the disadvantages of the T&V extension approach and experimented with participatory methods, but they remained locked in their technical and economic perspective (Chambers, 1997; Bawden, 2000). Through training and professional careers, they had internalised this perspective. At times, they perceived a discord between their assumptions and actual farmer behaviour (e.g., they rejected SHARES' recommendations for cowpea production). However, they could not formulate a coherent farmer perspective and they kept to their technical-economic reasoning.

Both, the PEDI staff and SHARES looked for '*technical-economic* solutions that fit the *local context*'. The staff members acknowledged the diversity of the farmer population and highly appreciated the SHARES' emic categorisation method. Both, staff members and SHARES interpreted 'the local context' as 'a specific resource availability': to earn a good living, farmers should consider their resource availability and look for the best technical-economic options. This view ignores the ideological-political dimension: a different context not only implies differences in resource availability but also differences in perspectives, goals, etc.

The convergence of the area of inquiry (level and boundary) and key concerns

Wageningen scientists are known for their land-oriented MGLP models. They first concentrated on regional and farm-level MGLP models, but the West-African 'Gestion du

Terroir Villageois' policy inspired them to develop village level MGLP models for Mali and Burkina Faso (Chapter 2). The level of inquiry was the village level and SHARES focussed on land-related activities and concerns.

The SHARES model elaborated a village perspective to support village level decision-making. It attributed, implicitly, much authority to the village leaders. The practice was different. Village leaders had limited authority. Most management decisions resorted to the households and individual farmers. In 1982, PEDI had started with watershed management and village planning, but soon learned to focus on the individual puugsoba and beolgsoba.

PEDI policy papers reasoned from the perspective of the household and/or farmer, but it proved difficult to monitor developments at these levels. Household and farmer livelihoods encompass remittances, off-farm activities, extensive and intensive farm activities. Most people are illiterate and only a few keep accounts of their income and expenditure. Income and expenditure surveys are expensive and difficult to execute; they demand frequent interviews and touch sensitive issues such as livestock wealth and remittances.

In practice, PEDI focussed on economic activities of the local population: farming, petty trade and handicrafts. PEDI organised several round table meetings between farmers and traders, it offered some technical training for handicrafts but concentrated on farming activities. Because it was difficult to monitor farm income and expenditure, staff members worked with general indicators such as the productivity per hectare, productivity per animal and productivity of invested capital (benefit/cost ratio). As a result, the questions of the staff members did not refer to a specific level of inquiry. They understood the village-level reasoning of SHARES and, where possible, worked with 'self-sufficiency rates'.

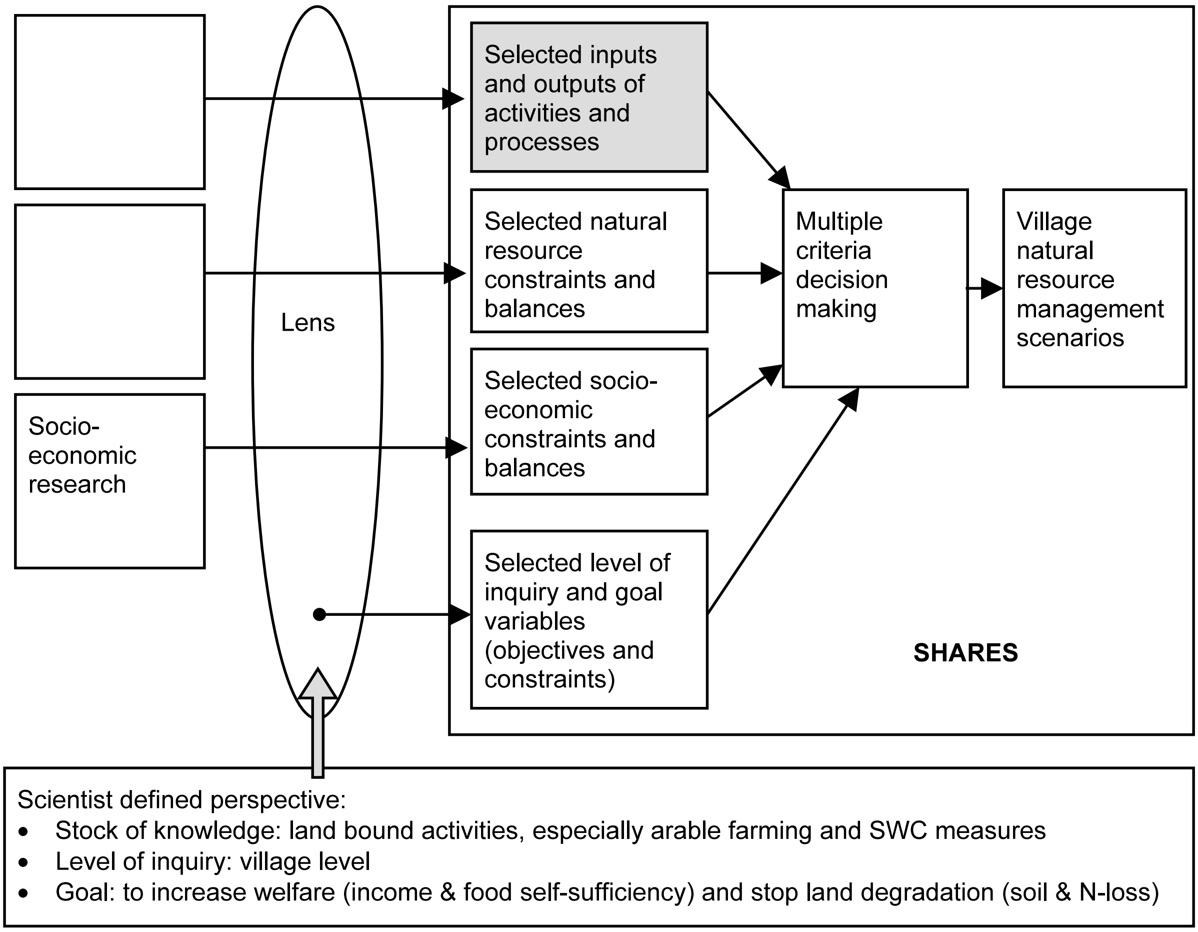
The PEDI staff had some key-concerns: they felt insecure about some of the promoted agricultural techniques. Low adoption rates cast doubt on the appropriateness of these techniques in the Sanmatenga context. When being invited to forward questions, staff members seized the opportunity. They asked SHARES to analyse the added value of various combinations of inorganic fertiliser, intensive livestock farming and agro-forestry.

SHARES could not answer the specific questions because it did not cover the necessary fertilisation, livestock practices and nutritional trees. The SHARES model is a product of interdisciplinary scientific collaboration; the main challenge was to develop a holistic model for land-use analysis. Through its emphasis on current agricultural practices, SHARES was not very useful for exploring the potential of future options. It was not developed to answer the specific questions of the staff. The computer model provided some interesting insights, but did not cover the key concerns of PEDI staff (Figure 6.5).

The room for manoeuvre

A computer model as such is a fixed product: a frozen version of the designer's knowledge, perceived interests and solutions. The match of the frames of reference of the model and the user is a delicate affair: the model designer needs to understand and closely describe the life-world of the user. This is difficult, almost impossible: often, scientists do not a priori know the users and, furthermore, key concerns may change in time. To overcome discrepancies, it is essential to create flexibility and room for manoeuvre.

SHARES covered several aspects of village level natural resource management, but did not focus on specific questions. When being confronted with the PEDI questions, the designers acknowledged the limited value of the current SHARES model. SHARES contained a selection of elements, activities and processes. It generated interesting insights but was not able to explore the specific concerns of practitioners. PEDI staff members found it hard to perceive the relevance of SHARES. To bridge the gap between the model and its users flexibility and creativity were needed.



Note: the area of friction is marked in grey

Figure 6.5: Friction between the staff perspective and the items included in SHARES

The SHARES designers had different ideas about how to attain flexibility and room for manoeuvre. Some scientists saw the SHARES model as a finished product. Like all tools, the SHARES model had limited capabilities and should be used in combination with other analytic tools: "One of the advantages of using the SHARES model is that people with disciplinary backgrounds interact. Even when the SHARES tool in itself does not directly come up with answers, the act of discussing and seeking advice of others, will eventually lead to answers". The SHARES land use approach stood for a model-enhanced interaction between scientists and practitioners. For other scientists, the SHARES model was not a finished product. They underlined the provisional and temporary character of the model and the importance to concentrate on the MGLP methodology. So far, SHARES represented the interests and knowledge of scientists. To improve its usefulness one should redefine the modelling perspective (the lens), and adapt the subsequent input - output files. The model developers should either consult the envisaged beneficiaries and integrate their vision, level of inquiry and key interests; or, direct users such as PEDI staff members should be trained on how to adjust the computer model for upcoming questions.

In our case, the Antenne Sahélienne programme closed down. Time and resources to adapt the SHARES model were not available. There was no other option than to encourage PEDI members to use the present version of SHARES for land use discussions and to look for complementary information from other scientists and practitioners.

6.4 The match of perspectives between SHARES and the population

The PEDI staff was approached to test whether SHARES was of use for themselves and/or for the population. The previous sections described the probing of SHARES by staff members. This section discusses the relevance of SHARES for the population. Would SHARES be able to contribute insights to their understanding of natural resource management? Would it be able to facilitate the discussion between the farmers and the staff?

6.4.1 Farmer discussions to identify key concerns

SHARES focused on village natural resource management. Stakeholder discussions in two selected villages were held to identify the perspectives and interests of the population. Former PEDI experiences with village level SWC measures indicated the importance of the institutional aspects; hence, the researcher applied an adapted version of the RAAKS method (Engel & Salomon, 1997). Extension workers contacted the traditional village leaders, the village government representative (Réprésentant Administrative Villageois or RAV), the Village Development Committee (VDC) and the identified user categories (§ 6.2). Each of them analysed the use, conservation and management of various natural resources: the arable fields, livestock, pasture, water points and wood. The discussions covered the following aspects:

- A historical analysis of the context (evolution of natural resources, user practices and social organisation);
- An analysis of natural resource use and conservation measures;
- An analysis of the present management: the actors and their tasks;
- An analysis of the communication and decision making about natural resource management;
- An identification of needs, constraints and opportunities for change;
- An actor potential analysis: an assessment of the potential and willingness of various actors to effect change.

After the group discussions, there was a plenary meeting to exchange views and to identify key concerns. Key concerns were issues upon which they were capable and willing to act. The group discussions revealed the following perspectives and interests on natural resource management:

Arable fields

Land degradation was a point of concern. PEDI was known as the ‘stone row project’. In the intervention villages, most men constructed stone rows. Women, who lacked the labour resources to construct stone rows, used vegetation bunds (Van Hoeve, 2000). At the time of the research, the people knew various SWC measures and wanted to explore new issues. They expected agricultural extension workers to provide technical knowledge as well as other kinds of support.

In Gainsa, the farmer groups wanted to experiment with intensive farm techniques. They asked information about the fertilisation of zaï[55], high yielding varieties, treatment of weeds and the regeneration of useful herbs and trees. They also requested project support for large-scale anti-erosion measures to protect the valley fields. In Koglabaraogo, farmers asked extension workers to provide information about vegetation bunds and windbreaks, chemical fertilisers, composting in the rainy season[56], harvest preservation, and mechanical weeding.

In both villages, the people were satisfied with the land tenure system. The guiding principle for land tenure was to provide everybody with a means of subsistence (§ 3.1.3). In Koglabaraogo, the family head took care of the land allocation. In Gainsa, land was in short supply and the head of family discussed land matters with various family members. Here, immigrants only obtained tenure grants for 2 to 3 years.

Livestock & pasture

In both villages, farmer groups wanted to improve their livestock management and looked for technical advice. The Gainsa farmers posed very general questions: "How to breed livestock for meat production?" The farmers in Koglabaraogo posed questions that were more specific: "What are appropriate feed ratios for livestock fattening? How to prevent and treat illnesses? How to improve the breed?"

The Gainsa farmers were satisfied with their pasture management. Since long, arable farmers and pastoralists coped with land scarcity and they both respected the management rules they agreed upon. Gainsa had no pasture area. The canton chief of Mané, in consultation with the Mossi Naaba (village chiefs), the Tengsoba (land chiefs) and the Peulh Joore chief, had delineated two livestock corridors. The Gainsa small stock browsed the hills and cattle left the village territory to graze elsewhere. The corridors were essential: arable farmers abstained from cultivating in the corridors and herders prevented passing livestock from entering the fields. In case of occasional field damage, the RAV, in consultation with the traditional village chief, proposed compensation and usually matters were settled amiably. In case opposing parties refused to comply, agricultural officers were called to make a report and the prefect would settle the matter.

In Koglabaraogo the situation was different: the village had pasture in abundance and attracted many herds. Pasture management had always been liberal: there were no assigned pastures or livestock corridors; all non-cultivated land was available for pasture. Like in Gainsa, there were rules to compensate for occasional field damage. Still, Koglabaraogo struggled with continuous conflict and field damage in the moist, fertile valley areas: after the first rains, arable farmers started cultivation, while livestock herders refused to leave these green areas.

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[55] Zaï are small holes dug in the ground. In the rainy season run-off collects in these holes where fertiliser/manure is applied and the seeds are placed. Zaï preparation is labour intensive but it enables an efficient use of water and fertiliser. It is advised to construct zaï in the dry season.

[56] The compost pits posed a problem: farmers did not manage to meet the compost water requirements during the dry season. The transport of water was strenuous and many pits remained empty. To solve the water problem and to make composting also accessible to women, PEDI experimented with compost trays. Furthermore, innovative farmers had started composting during the rainy season. They produced compost one year before the actual use. This causes nutrient losses but it seemed a viable alternative to 'composting' without water in the dry season.

This conflict emerged from a structural change in land use patterns: Various scientists note an expansion of arable farming into richer, but difficult to work and sometimes waterlogged, valley-bottoms, which were previously grazing areas[57]. Changes in land use patterns demand a reconsideration of management rules and, formally, the prefect is expected to pronounce himself. However, government administrators lack the resources to enforce compliance and they rule through political alliance and leverage (Lund, 1999). In this case, neither party contacted the prefect. Apparently, there was a power balance: neither the Mossi nor the Peulh were sure about their case and preferred to avoid public humiliation. In private, Mossi referred to the power leverage of the Peulh. Like all Mossi, the relatively wealthy judiciary have considerable cattle herds entrusted to the Peulh and they maintain informal but mutually beneficial relationships (§ 3.1.4). Prefects were 'known' to be considerate for Peulh. The local prefect seemed somewhat exceptional: a nearby radio station warned passing pastoralists for the prefect because he was strict about the compensation of field damage. This is probably also the reason why the Koglabaraogo Peulh did not take the case of the infringement on grazing land to court. Another possible reason was their internal division: some long-settled Peulh families cherished their relationship with the Mossi, while others preferred action. These factions searched for different solutions.

Waterholes

Waterholes were a point of concern for both villages. In earlier times, all water users contributed to the maintenance of waterholes: everybody did his part in the digging. However, traditional waterholes had a limited capacity and the villages invited PEDI to excavate existing waterholes. Bulldozers deepened the holes. No further digging was required and traditional water management rules became outdated. A legal vacuum emerged. PEDI provided most of the resources, interfering with the responsibilities and authorities of customary leaders. Initially, PEDI ignored the political impact of its activities. In the 1980s, most development projects concentrated on SWC measures and the construction of infrastructure. It was only in the 1990s that they explicitly invited villagers, customary leaders and government officers to formulate new management rules. From 1996 onwards, PEDI installed VDCs and borehole committees to ensure the planning, management and maintenance of village infrastructure. Unfortunately, the project overlooked waterhole management. In Gainsa, water became an open access resource. Villagers had ambiguous feelings about this situation: "it might be good to levy a user fee to save money for future reparations". Koglabaraogo had a history of water conflicts and the waterhole improvement heightened tensions.

Koglabaraogo had much pasture but little water. The effective use of the pasture was limited by the availability of water and cattle herds walked long distances to drink. The Peulh used to dig small wells to overcome this problem. Conflicts started, when a project decided to drill a borehole next to the Peulh camp. In principle, boreholes provide water for human consumption but the position of the borehole was tempting. The Peulh first assumed to be the exclusive users but soon they shared the water with nearby Mossi. This sharing was troublesome: Mossi accused Peulh of generously spilling water in favour of their livestock whereas the Peulh accused Mossi of denying access. Someone finally destroyed the borehole.

It was within this atmosphere, that the village discussed the envisaged waterhole improvement. The Peulh were not consulted. When the villagers contributed to pay for the

[57] This trend may be attributed to population growth induced land scarcity and/or the increased agricultural value of valley-bottoms. Poor rainfall leads to a lowering of water tables and less frequent flooding (Batterbury, 1998).

obligatory local contribution, the Peulh decided to pay a small fee. The deepened waterhole did not provide for all cattle herds and access remained restricted to small stock, washing and brick making. There were no user rules. The brick making soon damaged the impermeable clayey layer. When, during a meeting, the PEDI extension worker inquired about the waterhole, the majority of the village population responded with discontent. This event encouraged the village leaders to take action: they invited the Mossi heads of household for a public meeting. Together, they decided to install a water levy to pay for a guard. These decisions met with opposition. Women, in the person of a recognised VDC member, and other regular water users (envisaged levy payers!) complained about their exclusion. Pastoralists still opposed the idea that cattle herds were denied access and they refused 'to make peace'.

Wood

Water was a sensitive issue but wood was also a problem. In both villages, farmers were aware of deforestation and they protected tree seedlings in their private fields. In both villages, they resented the government forestry policy for the common areas. In former times the land chief discouraged excessive woodcutting: once in a while he checked the amounts of wood in stock and excessive wood reserves were sold to pay for public feasts. In 1983, at the time of a major drought, the revolutionary government broke with the past: they proclaimed reforestation campaigns and reinforced the regulatory role of the Forestry Department. To reach out to the local level, the Forestry Department asked villages to appoint village foresters. These foresters could issue wood cutting permits and they were supposed to patrol against excessive woodcutting. Village foresters served as 'the government's eye'. Their position was delicate as most villagers perceived it as an intrusion on the village organisation, the traditional authorities and values. Villagers did not understand why they had to make a request and pay the government to cut trees in their own village territory. Some village forestry posts remained vacant. The situation grew worse when villagers learned that outsiders easily obtained permits to cut wood in their village. Nobody understood the government forestry policy: village foresters closed their eyes and wood became an open access resource (§3.2.2). Koglabaraogo inhabitants expressed their discontent but they experienced no severe wood shortage. Gainsa inhabitants endured real fuel-wood shortages: trees disappeared from private fields and the Tengsoba summoned wood thieves. Construction wood was hardly available.

6.4.2 The farmer perspective placed within its context

The villagers considered technical issues as well as ideological-political issues. At the ideological-political level, they experienced conflicts both between Mossi and Peulh and between the village community and the national government. There were opposing ideologies and interests. The willingness of villagers to attack and solve natural resource problems depended on the way they perceived their chances with the authorities.

In Burkina Faso, the organisational and normative structures for natural resource management are many, and often they are ambiguous: colonisation, modernisation and natural resource concerns engendered a split in the legal system between state law and the customary regulation of social life and natural resource management[58]. This dichotomy gave way to ambiguity and contradiction, both in terms of which institution was authorised to

[58] In customary law, the binding of norms is assured by reciprocal interest in bilateral agreement among free agents, while in state law the binding of norms is ensured by a central authority's imposition and sanctioning (Lund, 1997).

intervene in a conflict, and which principle should be applied (Lund, 1997). The prevalence of state law or customary law varied per natural resource issue depending on the stakes and the involvement of government.

State law prevailed in the domain of forestry. Wood on common lands was declared state property and the forestry department issued wood permits. Villagers rebelled against the imposed ‘illogical’ state law, and wood became an open access resource (Nederlof & Dangbégnon, 1998). Local people perceived problems but did not act until they experienced a real crisis. In the case of a wood crisis, as in Gainsa, people turned to the customary chiefs.

Customary law remained influential in the domain of land tenure and water management. In 1984, the national government codified land rights (§ 2.3.2), but lacked the means to enforce them. At the time of the research, the local population still respected the traditional rules and the deliberations of the Mossi and Peulh chiefs at canton level (Breusers, pers. comm.). Village leaders interpreted these rules to arrange village matters. In the domain of water, customary law accorded priority to people and small stock. In case of water shortage, large cattle herds were denied access and were moved to other waterholes. The other case, the multi-functional use of bottom-valleys, was a recent phenomena surrounded by a legal vacuum. Both the Mossi and the Peulh could start litigation on this issue but they perceived the ruling of the prefect as incalculable. They kept a low profile and probably awaited the Mossi-Peulh deliberations at the canton level.

Though the villagers considered technical as well as ideological-political aspects of natural resource management they primarily used the project for technical information and physical support. The villagers estimated that they had little authority to tackle management problems and they did not seek PEDI’s assistance in these matters. There was one exception: the gender issue. Maybe encouraged by the presence of PEDI officers, women insisted on their participation in village decisions. Apart from this issue, villagers rather reconciled themselves to the undesirable situation than to try to effect change, because they feared public humiliation.

Little notice was given to the announcement that the existing Village Development Committees would soon be transformed into legally recognised CVGT. To implement the national ‘Gestion du Terroir Villageois’ policy (described in § 3.2.4), the government had just passed the act on the competencies of the CVGT: “The CVGT has the authority to grant or withdraw village land use rights. It is their duty to make a natural resource management and development plan. Among other things, they are responsible for the maintenance of village infrastructure, village forests, the pasture areas and the fauna and all other natural resources”[59]. The local population had little affinity with ministerial acts and awaited local government officers and customary chiefs to express themselves.

6.4.3 Matching perspectives: Could SHARES help to explore their key concerns?

SHARES contained technical and economical information. For several objectives, the model calculated optimum natural resource use alternatives: it recommended specific land use practices and calculated the expected production, income, nitrogen-loss and soil-loss. SHARES could also demonstrate trade-offs of conflicting interests between male and female farmers, arable farmers and pastoralists; a village perspective and the national government

[59] Summary translation of the articles 46 and 139 of the RAF 1997.

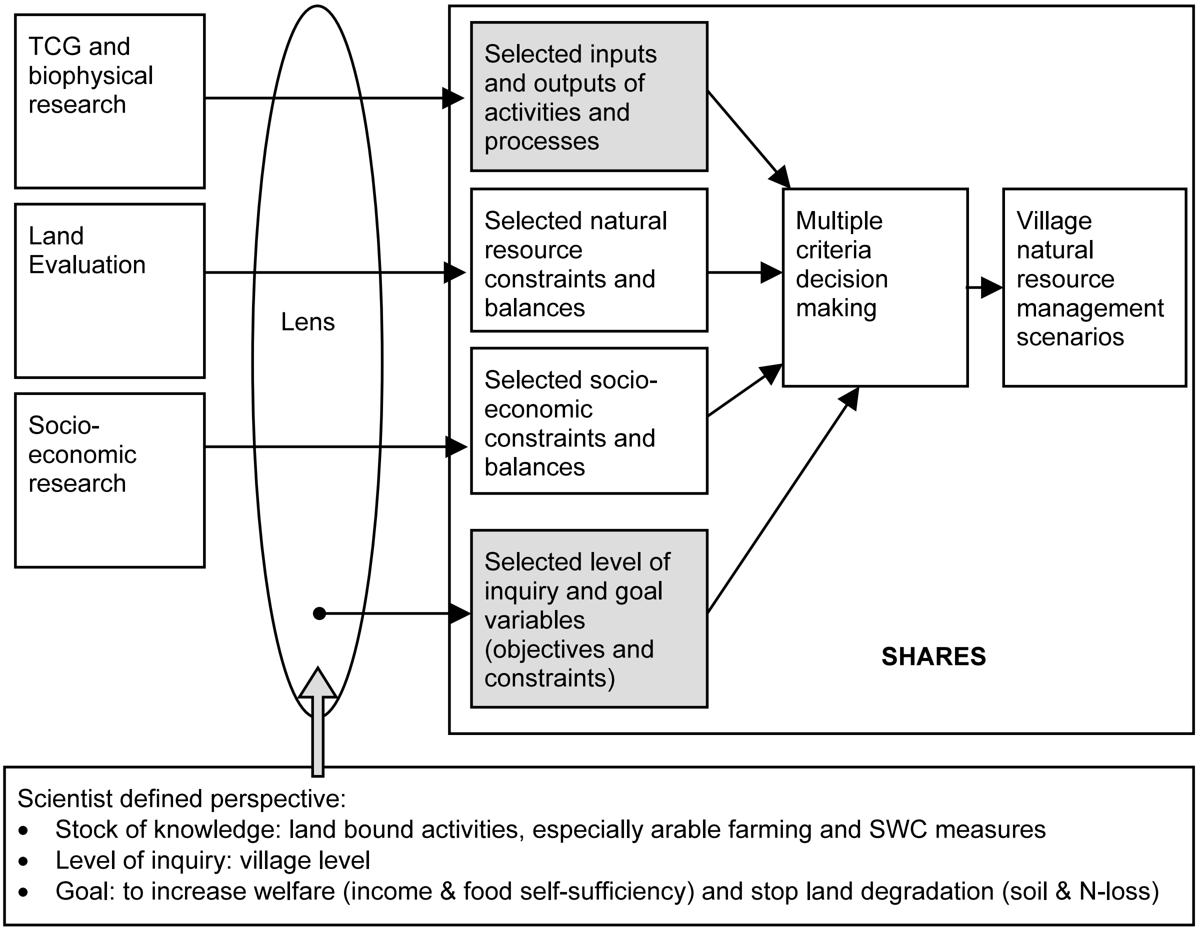
perspective. However, one should keep in mind that the SHARES model focussed on the ecological, productive and financial consequences. The MGLP methodology is quantitative in character and is unable to analyse the historical, ideological and political aspects of natural resource management. Therefore, it is unable to deal with the social consequences of the proposed agronomic solutions.

When comparing the SHARES perspective with those of the local stakeholders, the latter seem to have a broader scope: local people consider the technical-productive as well as the ideological-political aspects of natural resource management. However, villagers thought they had no authority to intervene at the ideological-political level. Despite the proclaimed CVGT regulations, they expected government officials and/or customary chiefs to bring verdicts. Meanwhile, villagers occupied themselves with the issues they thought they could properly perform: the technical management of farming. Here we find a match: the MGLP methodology focuses on the technical aspects of farming. Unfortunately, the current version of SHARES does not fit the farmer perspective. The first problem concerns the level of inquiry: SHARES focuses on the village level, but villagers explore issues at farm level. The second problem concerns the activities and processes included in the model: SHARES does not cover the activities of interest to the farmer.

To be exhaustive, the usefulness of SHARES for the problems that surpassed the authority of the local stakeholders is also assessed. Could SHARES be of use for decision makers: the customary chiefs and/or government officers? Could SHARES help to explore waterhole problems, land use conflicts and the wood cutting policies?

The conflict over waterholes and valleys were rooted in a history of competing livelihoods. Since long, Mossi and Peulh competed for the same natural resources. In principle, the MGLP methodology gives no insight into the historical ideological-political aspects, but helps to analyse technical-economic trade-offs of the competing livelihood systems. To do so, it is essential to have a perspective that includes the competing livelihood systems (Bawden *et al.*, 1984; Wilson & Morren, 1990) and covers the village area as well as the transhumant grazing areas outside the village. Such a model could demonstrate the trade-offs of varying levels of access to waterholes and valleys. With the current version of SHARES this is not possible.

The various wood management problems find their cause in ideological differences and organisational problems. Villagers are willing to consider immigrants' livelihood needs, but they primarily reason from a farm, family or village perspective. This perspective may conflict with the government perspective. In 1991, the Burkina Faso government modified the land tenure laws (RAF-91). From that moment, government recognised local management as the most appropriate and feasible option for the state as well as the farmers (Lund, 1997). However, the Forestry Department remained responsible for the distribution of wood cutting permits. The Department seemed willing to consider the local wood needs and availability, but lacked the resources to monitor them. For these cases MGLP modelling is of little use.



Note: the areas of friction are marked grey

Figure 6.6: Friction between the farmer perspective and the items included in SHARES.

6.4.4 Discussion

The discussions with the villagers convey a broad perspective on natural resource management. In line with the 'learning actor-network' framework (Figure 4.3) the following issues are analysed:

- Their belief/vision and level of inquiry;
- Their interests and concerns (issues at stake);
- Their perceived self-efficacy: the concerns that local villagers thought they were able to control;
- Their apprehension of the context: past events and envisioned challenges.

Section 6.4.1 describes the espoused belief, interest and perceived self-efficacy of the local population. Section 6.4.2 puts the espoused theories in a broader context. This shows the vision, the level of inquiry, the issues at stake and key concerns.

To assess the utility of the MGLP methodology and the SHARES model for local stakeholders, the vision, the level of inquiry and the key concerns are compared. It was not necessary to assess the room of manoeuvre: the predominantly illiterate population would not use the model directly. A comparison of the SHARES perspective with those of the local population suggests that:

- The villagers were concerned about the material well being of their household and the productivity of their farm. The level of inquiry was the household and/or farm. Farmers were familiar with various SWC techniques and now wanted to explore the possibilities of rainy season composting, fertilisers and livestock fattening. They did not inquire about the economic feasibility of these techniques, but seemed interested to know the production effects. The MGLP methodology handles this kind of information. Unfortunately, the SHARES model lacked these specific techniques.

- The villagers also considered about the political-ideological and organisational issues, but did not perceive them as their key concerns. They estimated that they lacked the authority to regulate these controversial issues. The MGLP methodology is of limited use for the exploration of the political-ideological and organisational issues. The methodology can demonstrate trade-offs between competing ecological and economic interests, but then the level of inquiry (scale and model boundary) should match with the perspective and livelihood system of the stakeholders. In principle, the MGLP methodology could assist customary chiefs and prefects with the allocation of pasture and water resources. However, the existing SHARES model did not cover water resources and pastoral areas outside the village territory, hence it could not demonstrate trade-offs between Mossi and Peulh interests.

6.5 Conclusion

The purpose of this chapter was to assess the relevance of the MGLP methodology and the SHARES model for the potential users: the PEDI staff and/or local natural resource users. A computer model is an artefact. Compared to people, models have little power of persuasion or control. Potential users easily decide to leave computer models in their drawer. Effective use of a computer model depends on its ability to help users to learn and move forward. There should be a minimum level of convergence of knowledge, norms and values, level of inquiry and room for manoeuvre.

In practice, the user often contacts a consultant in search for a computer model and complementary training. In our case, the model designers introduced SHARES and they had some influence on the acceptance of the model. The commitment and cooperation of the model designers inspired PEDI staff members to seriously consider the use of SHARES. They appreciated the emic categorisation method and the technical-economic orientation of the MGLP methodology. It was only after further study that they discovered that the specific SHARES model did not cover their key-concerns. After the analysis of the staff perspective, the MGLP methodology and SHARES were matched with the farmer view. Farmer discussions revealed a broad perspective: they considered ideological-political as well as technical natural resource management issues. Villagers did not perceive themselves to be capable to handle ideological-political issues and, like the PEDI staff, they primarily focussed on technical-productivity related issues. The MGLP methodology could have been useful, but the current SHARES model provided no insight in their key-concerns. This is in line with other recent findings, suggesting that computer models are not straightforward answering machines. Models are discussion facilitation or learning tools rather than decision support tools (Walker, 2002). SHARES contained some interesting information and PEDI staff could try to use the SHARES model for discussion and dialogue. The question remained: in what kind of discussion could SHARES be useful?

Photo ii: Farmers discussing the natural resource maps

Photo iii: Staff member presenting the intensification matrix

7 How to trigger co-learning?

7.1 Introduction

Parallel to this study into the use of SHARES, the PEDI staff started an action-research on agricultural extension. After intensive consultation, the main donors and the government harmonized their intervention approaches and decided to give priority to liberalisation and decentralisation. For agriculture, this meant that the government and the projects would withdraw from extension programmes and transfer these responsibilities to farmer organisations (§ 3.2.5). The envisaged farmer organisations would employ farmers and expert advisors to execute research and extension activities. Large-scale donor commitment triggered a sense of urgency: PEDI headed towards a new project phase (2001-2005) and needed a new extension approach with capacity building as a guiding principle. PEDI opted for the farmer learning approach: to improve the problem-solving capacity of the farmers and to strengthen their organisational and extension skills. PEDI staff used various participatory tools that focussed on specific problems and/or domains. It was time to integrate the various tools into a comprehensive approach and to test it for different geographical areas and beneficiaries. In the process, the PEDI staff first concentrated on farmer-led problem diagnosis and planning. The question was how to facilitate farmer learning.

PEDI needed two test villages: one in the South and one in the North as land use patterns differed significantly. The South was more densely populated and received relatively more rainfall (§3.1.6). The staff selected test villages that represented the extremes: Gainsa was densely populated (121 habitants km^2) whereas Koglabaraogo was relatively empty (19 habitants km^2). Both villages were R&D villages[60]. The farmers in these villages already executed on-farm tests and had regular discussions with R&D officers.

The purpose of the action-research was to elaborate an integrated 'farmer learning methodology'. The PEDI staff wanted to work from the farmer perspective: they saw it as their task to respond to the farmers' priorities, to provide information and to design tools for learning and experimentation. The staff explicitly focussed on the learning process of the farmers. However, the facilitation of learning requires co-learning. Facilitators go through their own learning process, which subsequently influences farmer learning.

Co-learning encompasses the following processes[61]:

Learning for coherence: to reduce ambiguity

(a): Farmers and extension officers attain understanding of their own and each others' perspectives;

(b): Farmers and extension officers 'reframe': they formulate a new broad objective to address the interests of both parties;

(c): Farmers and extension workers monitor and regulate the negotiation and learning process and they adjust objectives/desired developments to their capabilities;

Learning for correspondence: to reduce uncertainty

(d): Farmers and extension officers activate knowledge and engage in joint fact-finding to obtain a comprehensive view on the relationship between action and outcome. This

[60] The agricultural Research and Development (R&D) section collaborated with 10 of the 62 PEDI intervention villages. The farmers in these R&D villages choose the items they wanted to test.

[61] Co-learning is often referred to as integrative or inclusive learning.

enables them to better discriminate between possible actions and to improve the correspondence of their behaviour with the dynamics of the outside world.

In our case, the PEDI staff concentrated on learning for correspondence (d). They were aware of their directive role (c), which they wanted to change via learning-by-doing. Points (a) and (b) remained tacit theories-in-use (Argyris, 1976; 1992; Argyris & Schön, 1996; Schön & Rein, 1994). The PEDI staff thought that their engagement with farmers would automatically lead to convergence of perspectives, objectives and joint learning.

This chapter describes the PEDI action-research: the various ways in which PEDI staff tried to facilitate farmer learning. Section 7.2 gives an account of the emic categorisation. During the categorisation, local people identified criteria determining natural resource use and management. Section 7.3 describes the process that took place, when staff members encouraged villagers to express themselves on their problems and the envisaged solutions. The farmers used the exercise to negotiate support rather than to learn. Gradually, PEDI staff took more control of the process and structured farmer reflection (Section 7.4). This approach produced clear insights but the staff still did not understand farmer reasoning. Finally, they decided to use SHARES to exchange views on farm strategies (Section 7.5).

7.2 Farmer exchange groups

Extension should be demand driven, exploiting diversity and specificity. The first question was how to cover the heterogeneous farmer population in a way that respected diversity and specificity. Individual counselling was too costly and the only way out was the formation of farmer groups.

In the rural areas of Sanmatenga, there are strict communication rules: in public, customary leaders express themselves via spokesmen, men are free to speak and women and youngsters are supposed to listen. In village meetings, the Communication & Planning Section usually asked people to discuss matters in subgroups of village leaders, men, women, young men and young women. The question was whether to form extension groups based on these social criteria or to follow the OPA format (§3.2.5), which assembled farmers with similar farm specialisations and farm practices. The SHARES categorisation was a promising compromise: people were asked to categorise themselves according to their natural resource use and the results showed a clear relation between natural resource use and the social status.

The PEDI staff decided to use the SHARES categorisation method to form farmer discussion groups (§ 6.2.3). In every ward, some people were invited to classify ward members according to their natural resource use. After the completion of the exercise, they were asked to identify the selection criteria they had used[62]. Later on, PEDI organised village meetings to prioritise the identified criteria. With the use of these criteria, the villagers described the farmer categories existing within their village. The results revealed a Mossi dominated

[62] The criteria identified in the densely populated village Gainsa were: Access to equipment, agricultural practices, access to draught power, working on puugo or beolga, age, disability, non-agricultural resources, financial position, the quantity harvested, soil quality, preparedness to try techniques, counting on beneficial weather conditions, Peulh/Mossi, size of the field plots, man-woman. In the relatively empty village Koglabaraogo, the people identified criteria such as: access to equipment, agricultural practices, access to labour,working on puuga or beolga, eagerness to work, man/woman, other resources, age, specialisation in arable farming or livestock farming, control over distribution of labour,ability to work, soil quality, financial resources.

perspective (Table 7.1 and 7.2). Both villages based their classification on arable farm practices and arable farm resources. They ignored criteria related to livestock and off-farm revenue[63].

Table 7.1: Description of the natural resource use categories in Gainsa (8-2-2000)

Description of the category / Selection criteria	Category A: wealthy men	Category B: Men	Category C: young men	Category D: female farmers
	20 male puugsoba and 4 beolgsoba	*21 male puugsoba and 3 beolgsoba (amongst them 3 Pullo)*	*18 male puugsoba and 21 beolgsoba (amongst them 3 Pullo)*	*30 female puugsoba and 104 beolgsoba*
Access to equipment	Plough, cart, small tools	Plough, cart and small tools	Small tools such as the hoe	Small tools such as the hoe
Agricultural practices	Manure, compost pit, fertiliser, stone rows, vegetal bunds, wind hedges, ploughing, improved seed, zaï, mulch, using stable	Manure, compost pit, fertiliser, stone rows, vegetal bunds, wind hedges, ploughing, improved seed, zaï, mulch, using stable	Manure, stone rows, mulch and zaï	Manure, stone rows, mulch and zaï
Available work force	A lot: about 10 persons	Satisfactory: about 6 persons	Few: about 3 adults	About 2 persons
Soil fertility	The fields received sufficient fertiliser and conservation measures. Fields in the valley, sandy or clay	Some fertiliser is added, but the soil quality is not very good	A lot of gravel and empty patches	Low soil quality: sandy, gravel and empty patches
Other revenues	Livestock: cattle, goats, sheep, chicken Other: livestock trade to Ivory Coast and horticulture	Livestock: cattle, goats and sheep Other: gold mining	Livestock: goats, sheep and chicken (for Pullo cattle) Other: handicrafts and gold mining	Livestock: Sheep, pigs and chicken Other: handicrafts, beer brewing, preparing peanut cake and threshing rice
Access draught animals	Cattle and donkey	Donkey	No draught power	No draught power

In Gainsa, the population identified four user categories: wealthy men, men, young men and women. The Mossi and the Peulh did not constitute separate categories. Due to land shortage, Peulh herders had left the village in search for pasture. The remaining villagers, Mossi *and* Peulh, concentrated on arable farming. During the categorisation, a Peulh extension worker explicitly invited the Peulh to speak out but they did not insist on a separate category. In public, they preferred to keep a low profile. Koglabaraogo had land in abundance and could accommodate Mossi arable farmers as well as Peulh herders. Here, the Peulh insisted on a separate category. The local population defined the following farmer categories: well

[63] Individual interviews revealed that about 80% of the elder Mossi farmers (male and female) received remittances from migrant household members. Young men who had just started their household received only small gifts from family members. There are few Peulh labour migrants. Remittances are only discussed in private but they constitute an important livelihood resource.

endowed Mossi men, less endowed Mossi young men, Mossi women and Peulh men. Peulh women were not involved in agriculture.

Table 7.2: Description of the natural resource use categories in Koglabaraogo (25-3-2000)

Description of the category / Selection criteria	Category A: men	Category B: young men	Category C: female farmers	Category D: pastoralists
	Mossi: 26 male puugsoba	*Mossi: 15 male puugsoba and 21 male beolgsoba*	*Mossi: 29 female puugsoba and 116 female beolgsoba*	*Peulh: 9 male puugsoba, 1 male beolgsoba, 1 female puugsoba and 2 female beolgsoba*
Access to equipment	Plough, cart, small tools, draught animals, compost pit	Plough, cart, draught animals, compost pit	Small tools: hoe and pickaxe	
Agricultural practices	Manure, compost, chemical fertiliser, stone rows, vegetal bunds, wind hedges, zaï, mulching, cultivation in lines, ploughing, treatment of seeds and cultures, improved seed, enclosure of animals, improved feed and care of animals	Manure, stone rows, zaï, ploughing, broadcast sowing, mulching, improved seed and improved care for animals	Zaï, mulching, broadcast sowing, treatment of cultures	Broadcast sowing, manure
Available workforce	8-10 persons	5 persons	2-3 persons	2-3 persons
Soil quality	Valley, slope with sandy topsoil, slope with loamy topsoil.	Slope with sandy topsoil, slope with loamy topsoil	Gravel soil, bare stony soil, slope with sandy topsoil, soil with loamy topsoil, valley	Slope with sandy topsoil
Specialisation in arable farming or livestock	Arable farming and rearing cattle, sheep and goats	Arable farming, rearing small stock	Arable farming, rearing small stock	Rearing cattle and small stock, with some arable farming
Possible time management, depending on marital status	Male head of household (puugsoba)	Puugsoba and beolgsoba	Puugsoba and beolgsoba	Male head of household

7.3 To create space for people to speak up

After the categorisation, the farmers could start with their diagnosis and the identification of learning needs. The idea of the PEDI staff was to use PRA tools to activate farmer knowledge. PRA maps, calendars and flow diagrams would help the farmers to organise and integrate knowledge and to recognise problems and opportunities. The selected PRA tools focused explicitly on natural resource management[64]. The staff intended to flexibly use these PRA tools. It was essential to follow farmer reasoning and to identify the farmer's problems. To ensure openness and flexibility, the PEDI staff opted for a step-by-step approach. After each exercise, there would be an evaluation of the activities executed and a brainstorm about the appropriate follow-up.

The farmer diagnosis started with a village natural resource map. After the completion of the map, the farmers were invited to divide the village in separate zones. No mention was made about the criteria to use for the zoning. The idea was to impel farmers to reason from their own perspective. After the zoning, the staff asked each farmer category to look at the zones and to identify the individual and communal problems encountered in these zones.

With ease, the villagers drew village natural resource maps (Figure 7.1). They were used to PRA maps and with some guiding questions they swiftly identified village borders, water points, small rivers, soil types and farm practices. The problems started with the zoning. Farmers exclaimed: "We have no clue about where you are heading at". In both test villages, there was an impasse. Finally, a staff member explained that they should delineate according to land use. After this remark, both villages zoned their village according to the soil type. They explained their choice: "The soil type determines the land use".

In the next meeting, the members of each category discussed the individual and collective problems of the identified zones. Apparently farmers considered their former experiences with PEDI (e.g. the kind of support they had received, the issues PEDI was concerned about) because they identified all kinds of problems related to land degradation: deforestation, the occurrence of Striga[65], severe water erosion in the valleys, impoverished soils, difficult germination of the crops, frequent droughts, crusty soil surfaces and diminishing water infiltration. When it came to the discussion of the solutions, it was clear that farmers needed little information: they knew the solutions but they lacked the investments, so they asked PEDI to provide the necessary material support.

The exercise did not achieve its objective: there was no identification of new learning needs. PEDI was known as 'the stone row project' and the farmers assumed that the project would surely support SWC activities. They considered their immediate interests and the advantages they could gain from a direct encounter with staff members. They took the opportunity to negotiate extra material support for SWC rather than to engage in a new, time consuming and uncertain learning processes. The staff members evaluated the outcome and decided to take more control and to guide future reflections.

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[64] General background information was already available: a PEDI intervention used to start with PRA sessions to gain insight in the population composition, the socio-political history, local institutions, infrastructure, income generating activities and former development interventions.

[65] Striga is a witch weed threatening cereals throughout sub-Sahara Africa. Striga flourishes in cultures on impoverished soils.

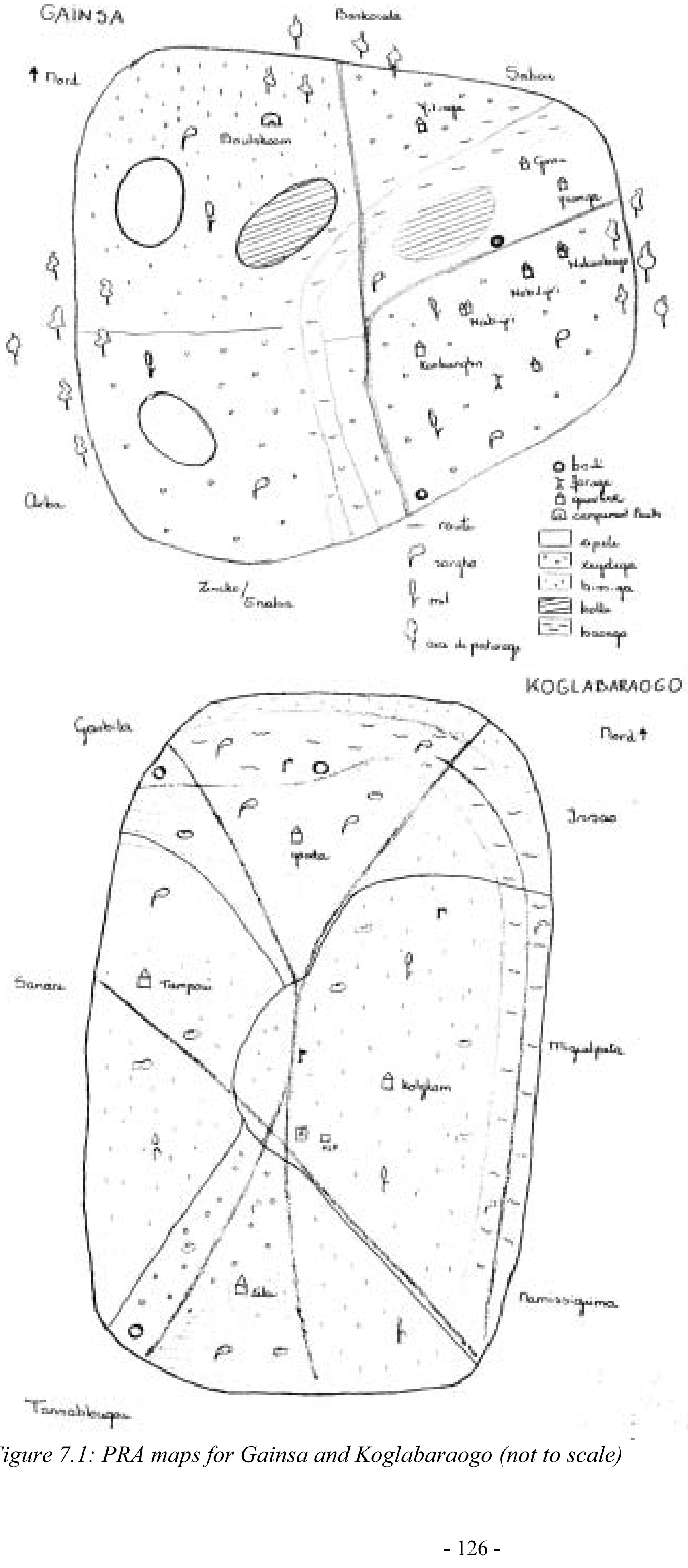

Figure 7.1: PRA maps for Gainsa and Koglabaraogo (not to scale)

7.4 The farm intensification matrix

The R&D agronomist proposed a structured approach. For the Farmer Innovation Project he coordinated the exchange and experimenting amongst twenty farmer innovators (§3.3.4). The farmer innovators had elaborated matrices of farm intensification (Tables 7.3 and 7.4). These matrices enabled them to position their existing farm practices and to monitor farm development. The R&D officer suggested to use these matrices for extension purposes: (a) to present farmers a broad array of common and future farm practices, (b) to ask farmer categories to position themselves and to give the reasons behind their present farm practices, (c) to make a strengths-weaknesses analysis and identify necessary improvements.

During the fieldwork, the agronomist and the livestock officer presented the intensification matrices as developed by the farmer innovators. With each farmer category they reflected upon various farm practices, common practices as well as unknown techniques. All practices were examined and people pronounced themselves: whether they applied a technique and why (not). While looking at the intensification matrices, the farmers listed their strengths and weaknesses and forwarded desired improvements. They proudly listed the applied techniques and they attributed non-application to poverty, intra-household distribution and institutional deficiencies. Furthermore, they showed their interest in new techniques (e.g. broad hoes to construct zaï, rainy season composting). The desired improvements consisted of learning needs as well as hoped-for material support.

Table 7.3: The intensification matrix of arable farming as elaborated by the farmer innovators

	Soil & Water Conservation (SWC)	Land preparation	Organic fertilisers	Chemical fertilisers	Seed	Cultivation	Natural Resource Management
Intensification	fallow, without SWC measures	no land preparation	no application of organic fertilizer	fallow periods	non-selected local seed	thinning	protection of tree seedlings
	stone rows	Animal draught for ploughing	mulching	rotation of crops	selected local seed	more than one weeding periods	reforestation
	vegetal bunds	Zaï construction	use of manure	phosphate	improved seed	chemical seed protection	planting wind breaks
	vegetate small dams and gullies	Harrow	use compost from compost pit	NPK		chemical crop protection	
		Animal draugt for ploughing and weeding	use compost from small compost tray	urea		timely harvest (before the spread of pests)	
						harvest conservation	

Joint scrutiny of the learning needs of each farmer category revealed that most techniques were known in the village. Some innovative farmers agreed to inform the others. Farmers underlined their need for investment and material support. For instance, women complained that they participated in extension but somehow were ‘forgotten’ when it came to the distribution of improved seeds and other materials. They were skilled negotiators and went further; they stressed the importance of credit. Credit systems have the potential to empower the disadvantaged; it enables them to overcome traditional rules of accessibility. This seemed to be the case for the women. They noted: “Our husbands never allow us to use manure from the household coral but they can not deny us to use the manure of livestock that we personally acquire on credit.”

Farmers perceived extension primarily as a venue for material support. These expectations stemmed from earlier experiences with the agricultural extension service. For farmers there was not much to learn, but the contact with extension officers facilitated access to credit and other material support. Extension officers often mediated between farmers and various subsidy and credit systems. Many farmers subscribed to extension because they perceived participation as a good opportunity to obtain farm credit and material support.

Table 7.4: The intensification matrix of livestock farming as elaborated by the farmer innovators

	Habitat and accessory	Food production	Animal feed	Feed preparation	Animal health	Breeding	Additional activities
Intensification	livestock sleeps outside	protection of pasture	forage and browse		vaccination of cows	improved sheep breeds	small stock fattening: animal selection, feeding, health, marketing
	livestock sleeps in crawl	to plant wind breaks	straw	to chop up straw	vaccination of small stock	improved cattle breeds	cattle fattening: animal selection, feeding, health, marketing
	livestock sleeps in hangar	tree planting	hay of bambara groundnut	to enrich straw with salt	vaccination of poultry	improved pig breeds	milk production: animal selection, feeding and health
	small stock fold	to sow forage	hay and pods of cowpea	to enrich straw with urea	internal parasitic control cows		yoghurt production
	cowshed and hay barn	to cultivate fodder	hay of groundnut		parasitic control small stock once / twice a year		cheese production
	hay barn		local bran (from cereals)		internal parasitic control poultry		
	drink trough		bran cubes		tick treatment		
	food trough		cotton cake		traditional pharmacopoeia		
			cotton grains		modern medicines		
			lick stone				
			to water up to thrice a day				

The fieldwork demonstrated the difficulty for PEDI staff to break trough the traditional relations with their farmers and find new entries for learning. PEDI was seen as a project that promoted certain agricultural techniques and that provided generous material support.

Farmers were used to negotiate a certain support and did not expect much from a joint learning process. The PEDI staff could work with the action lists but acknowledged that they still had no clue about how to support farmer learning systematically. The detailed exercise gave neither insight in the farm situation, or in the farmer knowledge or his livelihood strategy. Staff members recognised their need for reflexive learning.

7.5 To prepare SHARES for farm strategy discussions

How to attain more understanding of the farmer perspective? During PEDI IV, the staff initiated various studies to gain more insight in the situation and the behaviour of the farmers. There were regional market studies (Agba, 1998; Beneder, 1998; Loozekoot & Nana, 1998); a factor analysis of farmer participation in the PEDI programme (Agba, 1999a; 1999b); an action-research on small stock fattening (Elskamp *et al.*, 1999); a farm practice and household labour study (Tapsoba, 2000) and an analysis of fertiliser use (Van den Elshout, 2001). Most of these studies were quantitative in nature: they identified certain correlations but lacked a thorough understanding of the reasons behind the observed phenomena. The studies revealed that the staff assumptions on farmer behaviour did not always apply, but gave no insight in the farmer reasoning.

PRA sessions were meant to explore farmer perspectives and livelihoods, but it was difficult to make sense of the diagrams and visuals without a clear analytical framework (Guijt & van Veldhuizen, 1998; Guèye, 1999). The PRA sessions undertaken by PEDI lacked a unifying analytical framework and critical facilitators (Lavigne, 2003). The sessions did not systematically elucidate the biophysical, social and institutional context and gave no insight in the farmer frame of reference or the envisaged farm development. PRA was used in an instrumental manner, as an intrinsically technical, action-oriented instrument that decision makers use to solve problems (Cornwall, 2000; Leeuwis, 2000). The PRA executed by PEDI remained patchy, superficial and did not touch on the underlying beliefs, norms and values and power relations. It concentrated on learning for correspondence, while ignoring the learning for coherence. This was a waste of time, because learning for coherence is a requisite for co-learning.

The PEDI staff struggled with ambiguity, the lack of convergence between their own and the farmers' development perspectives. During a brainstorm session, a staff member wondered whether SHARES could help to trigger a debate on farmer livelihood strategies and the envisaged farm development. To match and integrate scientific and farmer knowledge, it was necessary (a) to present the scientific logic in a clear and concrete way and (b) to ask farmers to react upon the scientific reasoning and to clarify their own way of thinking. It was decided to use SHARES for this purpose.

For the staff, the basic question was: "To what extent do farmers in Sanmatenga province intend to remain subsistence farmers and to what extend are they tempted to adopt a commercial rationality?" With 'commercial rationality' they meant:

- A tendency to invest money to improve production (fertiliser, cotton cake etc.);
- A tendency to opt for a maximisation of farm revenue at the expense of food self-sufficiency;
- A certain specialisation in cash crops (groundnut, cowpea etc.) and/or commercial livestock farming (e.g. the farmers produces leguminous crops at the expense of food crops);

- A tendency to produce more than the quantity needed to satisfy the basic needs (the basic need coverage was assumed to correspond to 100 % food self-sufficiency + 50% to cover non-food expenses).

To use SHARES, it was necessary to translate the staff question into the 'SHARES language'. To characterise different farm strategies, they needed the SHARES expressions as presented in Table 7.5. This enabled them to present farm strategies such as 'Max Cer, T0-T5': a farmer aiming at food production and only applying SWC measures, using an extensive way of farming (no application of manure and no purchase of fertiliser or animal feed).

Table 7.5: The SHARES expressions selected by PEDI staff to characterise farm strategies

Farm goals	
Max Cer	Farmers aim at food production and the satisfaction of the basic household needs. Max Cer means that priority is given to cereal production. At the second iteration, all remaining resources are used to maximise the revenue.
Max Rev	Farmers aim at revenue maximisation Max Rev leads to a maximisation of the cash crop area and livestock production (milk and meat).
Farm constraints: the technology levels[1)]	
T0-T5	A farmer applies SWC measures (T0-T5) but does not use manure/compost (T6) or fertiliser (T7). He does not buy feed supplements such as cotton cake. The farm situation is characterised as: Extensive arable farming combined with extensive livestock farming.
T0-T6	A farmer applies SWC measures (T0-T5) and manure/compost (T6). It takes much labour to produce, transport and apply manure and compost. He does not invest money in farming: he buys no fertiliser (T7) or cotton cake. The farm situation is characterised as: Labour intensive arable farming combined with extensive livestock farming.
T0-T7	A farmer applies SWC measures (T0-T5), manure/compost (T6) and N fertiliser (T7). He does not buy animal feed. It takes much labour to produce, transport and apply manure and compost and it needs money to buy fertiliser. The farm situation is characterised as: Labour and input intensive arable farming combined with extensive livestock farming.
T0-T5^{+}	A farmer applies SWC measures (T0-T5) and buys animal feed in the form of cotton cake ($^{+}$). He does not use manure/compost (T6) or fertiliser (T7). The farm situation is characterised as: Extensive arable farming combined with input intensive livestock farming.
T0-T6^{+}	A farmer applies SWC measures (T0-T5) and manure/compost (T6) and he buys cotton cake ($^{+}$). He does not buy N fertiliser (T7). The farm situation is characterised as: Labour intensive arable farming combined with input intensive livestock farming .
T0-T7^{+}	A farmer applies SWC measures (T0-T5), manure/compost (T6), N fertiliser (T7) and cotton cake ($^{+}$). It takes much labour to produce, transport and apply manure and compost and it needs money to buy fertiliser and cotton cake. The farm situation is characterised as: Labour and input intensive arable farming combined with input intensive livestock farming.

1: A farm technology level refers to a range of farm practices available to the farmer. For instance, technology level T0-T5 means that a farmer is free to choose from a selection of cultures (sorghum, millet, maize, cowpea, groundnut) and arable farm practices T0 up to T5 (for a detailed description of these arable farm practices: see Table 6.1) The addition '+' means that the farmer considers intensive livestock farming, buying cotton cake.

Preparing SHARES for application

SHARES was useful to develop concrete examples of scientific reasoning about farming in a specific area. SHARES was science-based and produced village specific farm scenarios. It generated optimum farm situations for various combinations of farm objectives and farm technology levels. These SHARES runs provided concrete examples, which the staff could present and discuss with the farmers.

To use SHARES for farmer discussions, it was necessary to prepare the model for use in the test villages Gainsa and Koglabaraogo. Village input files with information about the farmer categories had to be made:

- The availability of land for arable farming (soil quality and area);
- The availability and relative access to pasture[66];
- The availability of farm labour;
- The number of dependants.

The Antenne Sahélienne hired a soil scientist to elaborate the soil maps of the two test villages (Figure 7.2). Meanwhile, the farmers categorised themselves (refer to § 6.2.3 and § 7.2). An interview team collected the data on the farmers' access to natural resources. The question was: how to integrate the information in the SHARES model? What was the most appropriate unit of analysis?

SHARES focussed on village and household categories, and used the concept of the household as defined by Luning: "a group of persons, who are in general linked by blood ties or marriage, usually living together in the same compound, producing together and having the right on the meal prepared in the same kitchen, whose budgetary authority relies (at least theoretically) on one of the inhabitants, called the household chief" (Luning, 1989, translated by Nederlof, 1998: 20). Mooré has no word for household chief: Mossi refer to the zaksoba (compound chief) or puugsoba (chief of the collective fields, of which the food is shared). The puugsoba were the household chiefs, but most puugsoba also had the status of zaksoba. Because it was sometimes difficult to distinguish between puugsoba and beolgsoba, interviewers rather worked with zaksoba: compounds and compound chiefs were easily distinguished. This meant that in practice SHARES worked with zaka (male headed compounds) and female-headed households (Nederlof, 1998). This delineation was troublesome:

- Sometimes a compound accommodated several households and male puugsoba, e.g., when married sons lived together at the compound of their elderly or deceased father. In this case, puugsoba were linked by blood ties but they managed their own household: they had their own puugo and prepared separate meals.
- The household as such did not really 'produce together': everybody worked at the puugo (household fields), but the young men and women also cultivated their individual beolga.
- At a certain age, elderly women received the title of puugsoba and were exempted from the work at the household fields. This did not mean that they really started their own independent household; if necessary, they were cared for by their relatives [67].

In consultation with PEDI, the Antenne Sahélienne changed their approach. The PEDI agricultural programme worked with individual farmers rather than farm households and it was decided to work with farmer categories. During the categorisation exercise (§6.2.3), farmers were invited to categorise themselves on an individual base.

[66] Non-cultivated land and fallow land were used for pasture. Pasture was not distributed but a collective resource. In such cases MGLP models may allocate all pasture to one farmer category. To get acceptable farm options, we ensured a minimum access to pasture for each farmer category.

[67] There were no independent widows, as people practiced levirate: a widow married her husband's brother or an elder son of a co-wife. In this way elderly women were taken care of.

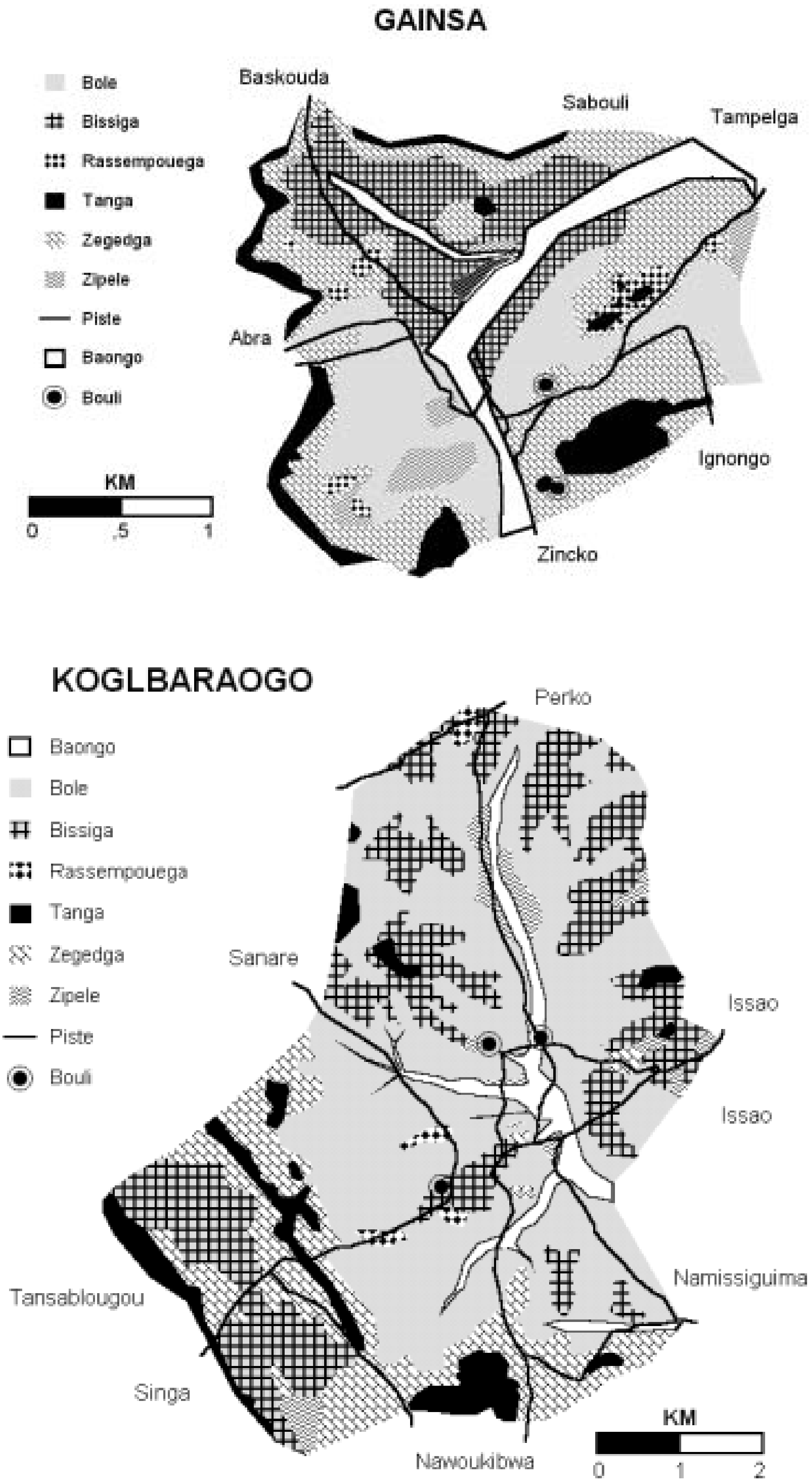

Figure 7.2: Soil maps for Gainsa and Koglabaraogo (Van den Elshout, 2000)

Now the question was posed, whether all farmers, puugsoba and beolgsoba should be included, in the SHARES analysis. There were two considerations:

- The PEDI agricultural programme focussed on individual puugsoba and beolgsoba. In former days, the agricultural programme concentrated on male puugsoba but now PEDI staff insisted on the inclusion of the beolgsoba: “Female farmers are ‘forgotten’ and PEDI should improve its outreach.” “Adolescent sons are more dynamic and innovative than their elder fathers. Furthermore, they often manage the farm on behalf of their father.”
- Beolgsoba posed a problem for the SHARES model: beolgsoba owned very few resources (Table 3.5) and the SHARES model could crash. SHARES needed resources to allocate.

It was decided to include male puugsoba and female puugsoba/beolgsoba[68]. Female puugsoba/beolgsoba had slightly more access to resources than male beolgsoba (Tapsoba, 2000). Male beolgsoba would be invited to analyse their father’s (and their own future) situation. The socio-economic survey covered eight representatives of each category. The integration of the soil map and the socio-economic survey provided the SHARES input data as presented in the Tables 7.6, 7.7, and 7.8.

Table 7.6: Access to land in Gainsa (121 inhabitants/km) and Koglabaraogo (19.1 inhabitants/km)

		Category A	Category D	Category C	Category D	Area arable fields	Total area	% Arable field
Gainsa		Wealthy Men 20 puugsoba	Men 21 puugsoba	Young men 18 puugsoba	Women 134 women			
Hill	*Tanga*[1)]	5.2	0	14.2	4.7	24.1	60	35%
Plateau	*Rassempouega*						14	0%
Slope	*Zegdega, Kougri*	26.7	11.5	12.2	9.0	59.4	84	71%
Sand	*Bissiga*	42.5	37.8	26.8	88.4	195.5	201	97%
Clay	*Bollé*	27.5	18.9	8.3	27.9	82.6	86	96%
Valley	*Baongo*	20.1	20.7	9.8	19.9	70.5	72	98%
Bush	*Zipele, Kossogo*	10.5		1.0	2.6	14.1	30	47%
Total		**133 ha**	**89 ha**	**72 ha**	**153 ha**	**446 ha**	**556 ha**	**80%**
Koglabaraogo		Men 26 puugsoba	Young men 15 puugsoba	Women 83 women	Pastoralists 9 puugsoba			
Hill	*Tanga*						157	0%
Plateau	*Rassempouega*						56	0%
Slope	*Zegdega, Kougri*						332	0%
Sand	*Bissiga*	145.5	56.1	169.1	5.3	376.0	941	40%
Clay	*Bollé*	56.2	28.6	52.4		137.2	1645	8%
Valley	*Baongo*	25.6	13.8	23.9		63.3	249	25%
Bush	*Zipele, Kossogo*	4.4		3.0		7.4	431	2%
Total		**232 ha**	**99 ha**	**248 ha**	**5 ha**	**584 ha**	**3811 ha**	**15%**

1: soil name in the local language Mooré

68 It was difficult to draw a clear distinction between female puugsoba and beolgsoba because all women practiced agriculture and catered for some children. The health situation, and not the formal status, determined the elder women’s activities and household situation.

Table 7.7: Livestock property in Gainsa and Koglabaraogo

	Category A	Category B	Category C	Category D	Total
Gainsa	Wealthy men (20)	Men (21)	Young men (18)	Women (134)	
Number of cows	172	108	74	0	354 head
TLU cows	129	81	56	0	265 TLU
Number small stock	385	308	365	300	1358 head
TLU small stock	39	31	37	30	136 TLU
Total TLU[1)]	**167 TLU**	**1128 TLU**	**92 TLU**	**30 TLU**	**401 TLU**
Koglabaraogo	Men (26)	Young men (21)	Women (83)	Pastoralists (9)	
Number of cows	387	135	0	266	789 head
TLU cattle	291	101	0	200	591 TLU
Number small stock	556	179	168	532	1435 head
TLU small stock	56	18	17	53	144 TLU
Total TLU	**346 TLU**	**119 TLU**	**17 TLU**	**253 TLU**	**735 TLU**

1: In West Africa the official conversion rate of a cow is 0.75 Tropical Livestock Unit (TLU), a sheep 0.1 TLU and a goat 0.08 TLU. SHARES only distinguished cows (0.75 TLU) and small stock (0.1 TLU).

Table 7.8: Availability farm labour in Gainsa (670 inhabitants) and Koglabaraogo (729 inhabitants)

	Category A	Category B	Category C	Category D	Total
Gainsa	Wealthy men (20)	Men (21)	Young men (18)	Women (134)	
labour	213.1	161.6	106.7	101.7	**493.0 MEV[1)]**
Koglabaraogo	Men (26)	Young men (21)	Women (83)	Pastoralists (9)	
labour	209.9	110.4	39.6	17.5	**377.4 MEV**

1: MEV = Man Power Equivalent. The FAO norm was used: 0-9 year = 0 MEV, 10-15 years = 0.5 MEV, 16-64 years = 1 MEV, 65^{+}year = 0.5 MEV

Access to land

The match of the village soil maps and the survey questions on farmer land use provided the data on the quality and quantity of arable land, available to each farmer category (Table 7.6).

Livestock ownership and access to pasture

Survey data on livestock property were extrapolated to farmer category level (Table 7.7) to estimate the relative use of the pasture area. Some caution was needed with respect to these livestock data. Nobody, the Mossi nor the Peulh, were very open about their wealth and livestock numbers. We assumed that everybody systematically underestimated their livestock numbers in the same way and we used the data to approximate *relative* livestock ownership and pasture use. When running through the livestock data, we decided to use all data except those forwarded by the pastoralists. The Koglabaraogo pastoralists claimed to have only five head of cattle each, while a well-endowed Mossi registered 13 head of cattle. The pastoralists had strained relations with the Mossi and clearly refused to forward realistic data. For that matter we consulted livestock data of other studies (Barning & Dambré, 1994; Zaal, 1998; Slingerland, 2000) and included an average livestock herd of 38 head of cattle.

Availability of labour
Table 7.8 shows the farm labour availability. For the male puugsoba, we calculated the MEV from the household data; we deducted the MEV available to women and extrapolated the results to category level. To estimate the MEV available to women, we used the household labour study of Tapsoba (2000). This study covered 20 households in the North and 20 households in the South of Sanmatenga province and revealed that in 1998-1999:

- In the South, women had access to about 20 % of the household labour (18.5% for small households, up till 12 household members and 21% for larger households, with more than 12 household members;
- In the North, women had access to approximately 10% of the household labour (7% in larger households and 12% in small households).

The MEV used by women, were deducted from the MEV of the male puugsoba.

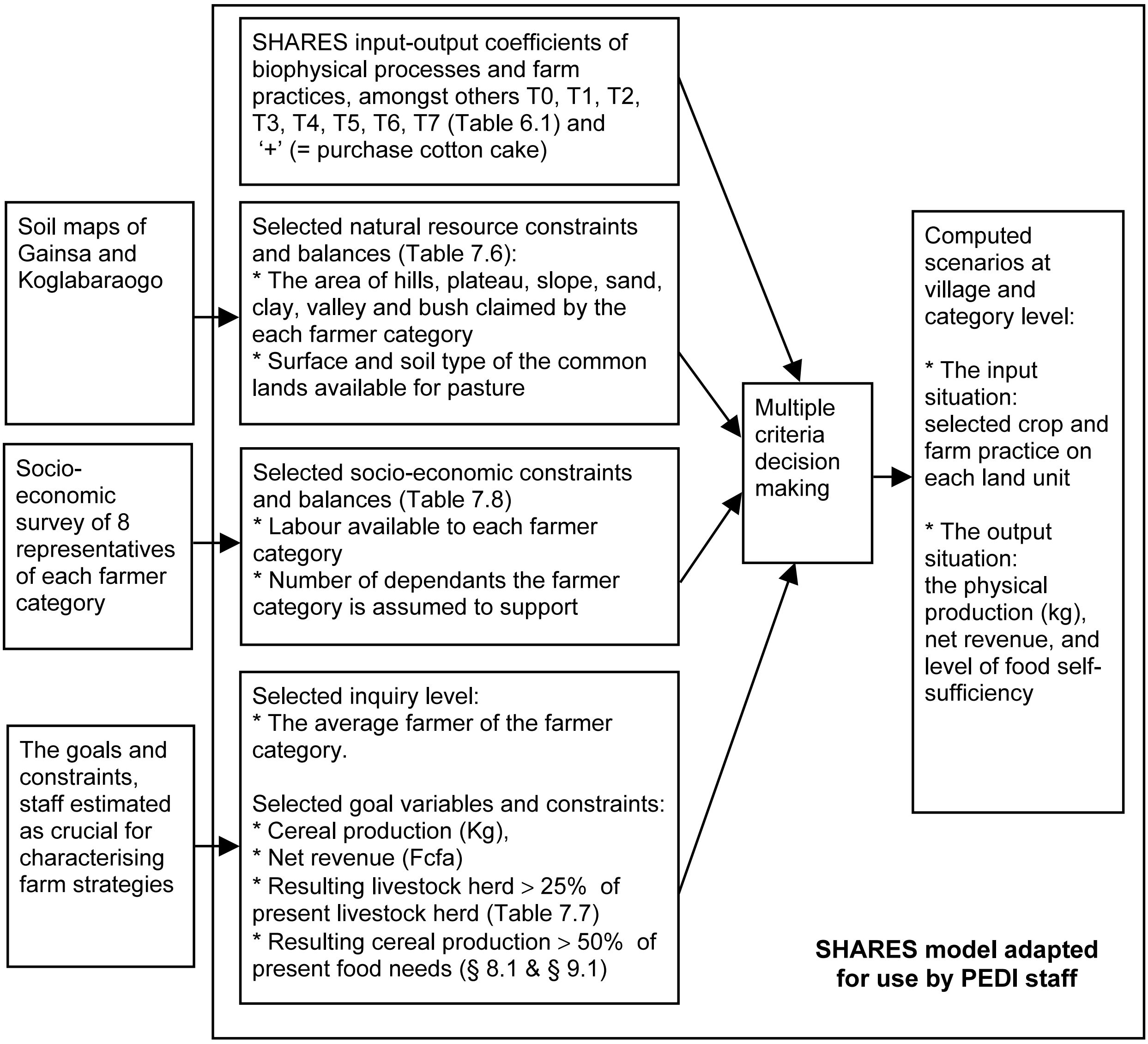

Figure 7.3: The adapted SHARES model, ready to be used for the farm strategy analysis

The data were included in the SHARES input files, the model was run and it seemed to generate plausible farm options (Figure 7.1). It was time to run the model for the various farmer categories and to match the SHARES runs with farm reality. Originally, SHARES focussed on the village and category level, but to analyse farm strategies it was necessary to get down to the farm level. To attain the desired level of inquiry, the staff divided the SHARES' category results through the number of farmers involved and worked with 'the farm options of an average farmer of the farmer category'.

7.6 Conclusion

This chapter described the attempts of the PEDI staff to trigger a co-learning process. The first idea was to use participatory rapid appraisal techniques to activate and organise farmer knowledge. This would then be the starting point for the facilitation of farmer learning. The fieldwork showed staff members that it was difficult to leave the beaten tracks: farmers mentioned theories, problems and solutions they esteemed appropriate to forward to PEDI staff members. Furthermore, they seized the opportunity to negotiate the support that they thought PEDI was prepared to offer and that they were eager to receive.

For the next project phase, the PEDI adage was capacity building. The aim was to improve the problem-solving capacity of the farmers and to strengthen their organisational skills. Staff members could not contend themselves with the role of providing support, and brainstormed on how to guide the farmer reflections and trigger real learning. Was it an idea to present a gamut of farm practices, to ask farmers to make strength-weakness-analyses and to identify desired improvements? Desired improvements would indicate the farmer learning points! The idea was tested and some progress was made: farmers critically analysed their present farm behaviour and explained how knowledge, biophysical circumstances, household responsibilities and resource distribution as well as institutions determined their present farm practices. However, when it came to the formulation of the desired development, they again concentrated on the need for material support. Farmers did not expect PEDI to facilitate learning. They acted strategically rather than communicatively.

PEDI staff members felt they still lacked an understanding of the perspectives of the farmers and the issues at stake. They were unable to relate the farmers reasoning and interests with their own thinking, to formulate new joint learning objectives. Apparently, it was important to organise an explicit exchange of perspectives between staff and the farmers. They remembered that the SHARES model produced concrete examples of scientific thinking with respect to farm development. It was clear to them that farmers reasoned differently than SHARES, hence it might be beneficial to present SHARES examples and to ask farmers to spout criticism. This would trigger an exchange of perspectives. Staff members esteemed that SHARES could be of use and they prepared the model to generate farm options for the test villages.

8 Model enhanced learning in Gainsa: to eke out a living

The previous chapter described the attempts of the PEDI staff to trigger co-learning. Through these experiences, they realised that both the farmers and they themselves remained locked in their own life-world and easily lapsed into strategic action. To attain communicative learning, it was necessary to understand each other's situation and the mental models that underpin the behaviour. To exchange views, staff members decided to use SHARES to demonstrate the logic of their professional thinking and to ask farmers to spout criticism.

In this chapter, we describe the staff learning process with respect to Gainsa. Through SHARES, staff gained local and category specific knowledge about the farm situation. This enabled them to better understand the reasoning and behaviour of the farmers. Section 8.1 gives the characteristics of the farmer categories and the farm options generated by SHARES. To assess the plausibility of the SHARES options and to prepare the farmer discussions, staff members compared the SHARES results with other information about farm behaviour (Section 8.2). Section 8.3 describes the dialogue with the Gainsa farmers: farmers were invited to comment on the SHARES results and to discuss farm strategies. At the end of this exercise, staff members and farmers reflected upon the co-learning process and the added value of the SHARES exercise (Section 8.4).

8.1 SHARES generated options for natural resource management

This section provides the characteristics of the four Gainsa farmer categories, as revealed by the socio-economic survey. Part of this information had been included in SHARES (§7.5) to generate farm options for the different farmer categories. Staff members studied the SHARES runs and gained insight in structural relations between the biophysical aspects and the farm production.

8.1.1 Gainsa, category A: "Wealthy men"

The category covered 20 male puugsoba and 4 male beolgsoba. The latter were adult sons, married and with some children, but who had not yet started their own household. In most cases, their father (the formal puugsoba) was an elderly man and the daily farm management was taken care of by the sons. As for SHARES, we concentrated on the average puugsoba. The average puugsoba served as the virtual farmer, a representative of category A. The characteristics of the average puugsoba are shown in Box 8.1.

The survey data on the category A's access to arable land, pasture and labour were included in the SHARES model. The question was whether to include extra information about local farm practices. To approximate the local practice of cereal-leguminous intercropping, SHARES already included the condition that the cowpea area ranged between $1/10^{th}$ and $1/3^{rd}$ of the cereal area. The researcher tried to add a local livestock practice: farmers first invested in small stock and thereafter, if possible, in cattle. This condition was difficult to include and finally abandoned. The trial triggered a discussion about the aim of the exercise: should we adapt the model to mimic the current farm practices and explore small improvements, or concentrate on the broad outlines and explore possibilities that went beyond the current farm

Box 8.1: Characteristics of the wealthy male farmers, Category A in Gainsa

Arable farming
On average, the puugsoba took care of 13.6 household members, of whom 7.4 were agriculturally active. During the rainy season, the family usually stays at the fields and children offer a helping hand, but it is only at the age of 11-13 years that they are really counted upon. In category A, the average puugsoba was responsible for the daily management of about 6.6 hectares: sandy soils (36%), valleys (22%), slopes (19%) and clay soils (14%). The relative importance[1)] of the crops was white sorghum (100), millet (94), cowpea (65), groundnut (50), maize (37), sesame (31) and roselle (31).

Livestock farming
The average farmer owned 6.5 head of cattle, 1.6 donkeys, 8.4 sheep, 9.1 goats and about 20 chicken and/or guinea fowls.

Income and expenditure
It remains difficult to obtain reliable data on the income and expenditure through a once-time survey. The agricultural season of 1997 marked a period of hunger, but the subsequent season of 1998 had been relatively good. Apparently, the good harvest of 1998 could not make up for the food deficit: in 1999, 40% of the farmers reported buying additional food. Everybody had sold livestock to pay for food, medicines and/or ceremonies. Household needs rather than economic opportunities determined livestock sales. Nobody sold cereals but farmers indicated they sold 70-80% of the cultivated groundnut and cowpea. About half of the farmers received remittances from migrated household members.

1: Farmers find it hard to quantify the cropped area. To get an idea of the relative importance of crops, we therefore asked the respondents to classify the cultivated crops. The presented figures are the weighted priorities. We indexed the most important crop at 100.

practice. SHARES was a tactical model and covered a time span of about 5 years [69]. It was not designed to generate short-term, operational recommendations and we should concentrate on the broad visions and strategies. It was decided not to further refine SHARES and only include two additional conditions. The first condition was about the food production: so as not to divert too much from the actual situation, staff included the condition that Gainsa farmers produced at least 50% of their present cereal needs. The second condition addressed the use of the common lands. If left unchecked, SHARES could allocate all grazing area to one single farmer category. To ensure a reasonable access to pasture, staff included the condition that all Gainsa farmers maintained at least 25% of their current livestock herd.

After the inclusion of these conditions, staff used SHARES to generate farm options for *normal rainy year*. For each farmer category, we executed several SHARES runs. For every run, we formulated an objective function and a technology level. The objective function varied between Max Cer (maximising cereal production) and Max Rev (maximising revenue). The farm technology levels varied between T0-T5, T0-T6, T0-T7 and T0-T7^{+} [70]. For each farmer category, we executed scenarios such as 'Max Cer, T0-T5' (= Maximise cereal production, while only using technologies T0 up to T5) and SHARES made a run to find an optimum natural resource use situation (a so-called farm option). Table 8.1 displays the results of the runs executed for the farmer category A.

[69] Strategic land use models cover a time span of 15-20 years and explore more profound strategy changes. Tactical models concentrate on middle-term management and cover a period of 5-10 years.
[70] For a detailed explanation of the farm technology levels T0-T6, T0-T7, T0-T7^{+} refer to Table 7.5.

Table 8.1: SHARES farm options for category A, wealthy male farmers in Gainsa

Max Cer, using the farm constraints[1)]:	% Fields for cereals	% Fields for leguminous crops[2]	Inputs: manure, N-fertiliser and cotton cake[3]	Cattle	Small stock	Food self-sufficiency	Net revenue per capita (FCFA)	Purchasing power related to food needs[4]
T0-T5	27 %	3 %		1.0	6.0	52 %	13,693	88 %
T0-T6	24 %	15 %	20 loads manure	1.9	12.2	91 %	21,771	140 %
T0-T7	26 %	12 %	0 loads manure 18,270 FCFA	2.0	11.2	119 %	21,500	138 %
Max Rev, using the farm constraints:								
T0-T5	12 %	56 %		1.0	6.0	24 %	22,017	141 %
T0-T6	18 %	32 %	22 loads manure	2.0	11.8	66 %	27,333	175 %
T0-T7	20 %	18 %	5 loads manure 14,639 FCFA	2.0	11.2	95 %	25,925	166 %
T0-T7[+]	35 %	17 %	0 loads manure 24,000 FCFA 31,000 FCFA	2.5	14.6	95 %	30,906	198 %

Notes: 1: For a detailed description of T0-T5, T0-T6 etc. refer to the Tables 6.1 and 7.5.
2: Leguminous crops fix nitrogen. The most common ones are the cash crops cowpea and groundnut.
3: The column gives the number of cartloads manure and the costs of the purchased fertiliser and/or cotton cake respectively.
4: 100% purchasing power means a 100% coverage of the household food requirement of 190 kg per capita of cereals à 82 FCFA= 15,500 FCFA (or 23.66 Euro).

When studying the results, one should be aware that SHARES aimed at sustainable agriculture: to maintain and improve the soil quality SHARES combined extensive arable farming with obligatory fallow periods; and livestock farming could not surpass the carrying capacity. One year of T0 required 5 years of fallow; T1 required 4 years of fallow; T2 and T3 required 3 years of fallow; and T4 required 2 years of fallow. T6 and T7 replenished the soil nutrients and did not need a fallow period. SHARES used the concept of the carrying capacity as formulated by Breman[71]: sedentary livestock farming required 10 to 20 hectares per head of cattle. These conditions, intrinsic to SHARES, explain why the model recommended category A farmers to cultivate only 30% to 52% of their arable fields and to raise only 19% to 52% of their current livestock herd.

SHARES provided the following insights:

- Farmers who opted for extensive production techniques (T0-T5) and food self-sufficiency had a hard time to make ends meet. In a normal rainy season, they attained a food accessibility rate of 88% of their household food needs. To attain basic needs sufficiency (to provide for food, soap, salt, clothes and school fees) a farmer should at least attain a purchasing power equal to 150% of the food requirement (1.5* 190 kg * 82 FCFA= 23,370 FCFA or € 35.70 per household member). To attain basic needs sufficiency, category A farmers had no alternative than to opt for intensive arable farming coupled with a revenue-oriented farm strategy (Max Rev, T0-T7).

[71] Nomadic livestock farming required 14 hectares (normal year) up to 42 hectares (dry year) per head of cattle, sedentary livestock farming 10 to 20 hectares and transhumance 3,5 to 8 hectares respectively (Breman & de Ridder, 1991; Diarra & Breman, 1997; Breman & Sissoko, 1998).

- According to SHARES, village pasture only sufficed to feed 19-52% of category A's livestock herd. The cattle that grazed outside the village territory were beyond the scope of SHARES.

8.1.2 Gainsa, category B: "Men"

This category covered 21 male puugsoba and 3 male beolgsoba. The socio-economic survey of the puugsoba provided the characteristics as presented in Box 8.2.

Box 8.2: Characteristics of male farmers, Category B in Gainsa

Arable farming
The average puugsoba supported a household with 14.4 members, of whom 7.9 were agriculturally active. On average, the farmer managed 4.2 hectares: sandy soils (43%), valley (32%), slopes 12% and clay soils (13%). Compared to category A, a category B farmer had less land but relatively good soils: they cultivated more sandy soils and valleys, and less slopes and clay soils. The relative importance of the crops was white sorghum (100), millet (94), cowpea (65), groundnut (50), maize (37), sesame (31) and roselle (31).

Livestock farming
The average farmer owned 3.7 head of cattle, 1.1 donkey, 7.0 sheep, 5.7 goats and 7.0 chicken or guinea fowls.

Income and expenditure
Category B sold livestock, cowpea, groundnut, sesame and roselle to meet household expenditures. In 1999, half of the farmers even sold cereals to meet urgent cash needs. About 85% of the farmers received remittances from migrated relatives.

For category B, SHARES generated the farm options as presented in Table 8.2. According to SHARES, category B farmers could not cover their basic household needs (150% food requirement) except when opting for revenue maximisation coupled with input intensive farming (T0-T6^{+} or T0-T7^{+}). The village territory covered 30% up to 60% of the grazing needs of the farmers' current livestock herd; part of the herd was bound to pasture elsewhere.

Table 8.2: SHARES farm options for category B, male farmers in Gainsa

Max Cer, using constraints:	% Fields for cereals	% Fields for leguminous crops	Inputs (cartload or FCFA)	Cattle	Small stock	Food self-sufficiency	Net revenue per capita (FCFA)	Purchasing power related to food needs
T0-T5	26 %	2 %		1.0	6.0	55 %	9,737	62 %
T0-T6	29 %	18 %	13 loads manure	1.2	7.3	69 %	15,398	99 %
T0-T7	29 %	14 %	13,500 FCFA	1.3	7.7	88 %	15,897	102 %
Max Rev, using constraints:								
T0-T5	10 %	60 %		0.7	4.2	15 %	15,822	102 %
T0-T6	19 %	39 %	13 loads manure	1.4	8.3	50 %	20,699	133 %
T0-T7	21 %	19 %	3 loads manure 10,339 FCFA	1.3	7.8	71 %	19,338	124 %
T0-T7^{+}	40 %	24 %	11 loads manure 18,500 FCFA 25,500 FCFA	1.9	11.1	113 %	33,841	217 %

8.1.3 Gainsa, category C: "Young men"

The category covered 18 male puugsoba and 21 male beolgsoba. The socio-economic survey revealed the characteristics for the average puugsoba of category C as presented in Box 8.3.

Box 8.3: Characteristics of young male farmers, Category C in Gainsa

Arable farming
An average puugsoba supported a household of 11.0 members, of whom 7.6 were agriculturally active. They managed 4.0 hectares: sandy soils (47%), valley (23%), slopes (9%), clay soils (13%) and plateau (23%). Compared to category A and B, the fields were of lower quality and contained of a large portion of plateau. The relative importance of the crops was white sorghum (100), millet (96), red sorghum[1)] (67), cowpea (63), groundnut (40), maize (37), sesame (29) and roselle (29).

Livestock farming
The average farmer owned 0.8 head of cattle, 1.4 donkey, 8.2 sheep and 8.0 chicken or guinea fowls.

Income and expenditure
Category C sold 50-80% of their cash crops (cowpea, groundnut, sesame and roselle). Like category B, half of the farmers of category C sold cereals to meet urgent cash needs. About 80% of the farmers received remittances from migrated relatives.

1: Red sorghum was used for the beer brewing. Beer was brewed for ceremonies and sold at market days.

The potential situation of the puugsoba of category C (Table 8.3) was more promising than the situation of category B (Table 8.2). A category C puugsoba had fewer resources (less land, lower soil quality and less livestock), but he also supported a smaller household. SHARES recommended the farmers to increase their present livestock herd with about 30%. With all but one farm strategy (notably 'Max Cer, T0-T5), category C farmers surpassed basic needs coverage.

Table 8.3: SHARES farm options for category C, young male farmers in Gainsa

Max Cer, using constraints:	% fields for cereals	% fields for leguminous crops	Inputs (cartload or FCFA)	Cattle	Small stock	Food self-sufficiency	Net revenue per capita (FCFA)	Purchasing power related to food needs
T0-T5	27 %	7 %		0.7	4.0	50 %	13,684	88 %
T0-T6	28 %	17 %	15 loads manure	1.3	7.6	61 %	23,104	148 %
T0-T7	30 %	52 %	9 loads manure 9,549 FCFA	1.3	7.6	73 %	24,807	159 %
Max Rev, using constraints:								
T0-T5	12 %	35 %		1.0	5.7	28 %	20,710	130 %
T0-T6	21 %	35 %	9 loads manure	1.4	7.6	45 %	25,383	163 %
T0-T7	22 %	29 %	4 loads manure 13,614 FCFA	1.4	7.6	60 %	24,113	155 %
T0-T7$^+$	35 %	35 %	4 loads manure 18,213 FCFA 0 FCFA	1.4	7.6	108 %	27,993	180 %

8.1.4 Gainsa, category D: "Female farmers"

Category D consisted of 134 female farmers. 104 women presented themselves as beolgsoba and 30 women as puugsoba. At their adolescence, women already cultivate small plots of groundnut, but they attain the status of farmer (beolgsoba) when they give birth and need to provide for their siblings. At a later stage, they acquire the status of puugsoba. The change of status depends on the age, the situation of the husband and co-wives, the age of the siblings and their personal health. In practice, it was difficult to distinguish between the farm situation of a beolgsoba and a puugsoba, and the socio-economic survey covered both.

Box 8.4: Characteristics of the Mossi female farmers, Category D in Gainsa

Arable farming

An average puugsoba had access to 1.1 hectare, while a beolgsoba had access to about 0.8 hectare. They had different fields, most of them on sandy soils, bottom valleys and clay soils. Married women not only worked on the family fields (puugo), but they also had the responsibility to cultivate food crops at their individual fields (beolgo). During the dry season co-wives took turns to provide the household with one meal each day. However, if you compared their cropping plans with those of the male farmers, female farmers gave more priority to cash crops. For puugsoba, the relative importance of crops was: white sorghum (100), groundnut (69), peas (66), roselle (43), red sorghum (41), maize (38), cowpea (32). For beolgsoba commercial crops were even more important: white sorghum (100), groundnut (88), peas (78), millet (56), red sorghum (45), cowpea (45), and maize (38).

Livestock farming

In general, women have no cattle. They reported to own about 1.9 head of sheep and 1.0 goat.

Income and expenditure

In 1999, all the women bought extra cereals to meet their food requirements. Through the sales of small stock, beer and petty trade women were able to buy complementary food and other daily necessities. All women reported to receive remittances from migrated relatives.

In the rural areas, polygamy was common practice and co-wives shared their household food production responsibilities. It was difficult to determine a single woman's food production responsibility. Because all women, even the elderly, took care of one or more small children, the staff included the criteria that every woman at least catered for 1.5 household members.

Table 8.4: SHARES farm options for category D, female farmers in Gainsa[1)]

Max Cer, using constraints:	% Fields for cereals	% Fields for leguminous crops	Inputs (cartload or FCFA)	Cattle	Small stock	Food self-sufficiency	Net revenue per capita (FCFA)	Purchasing power related to food needs
T0-T5	1 %	5 %		0	0.6	11 %	4,357	28 %
T0-T6	9 %	9 %	1 load manure	0	0.7	42 %	8,924	57 %
T0-T7	27 %	0 %	-	0	0.5	39 %	7,209	46 %
Max Rev, using constraints:								
T0-T5	1 %	5 %		0	0.6	11 %	4,357	28 %
T0-T6	9 %	9 %	2 loads manure	0	1.8	35 %	13,768	88 %
T0-T7	0 %	55 %	-	0	1.5	0 %	15,524	100 %
T0-T7^{+}	0 %	55 %	0 loads manure 0 FCFA 683 FCFA	0	1.5	0 %	15,069	97 %

1: We assume that each female farmer supports 1.5 household members.

Table 8.4 shows the SHARES options for the Gainsa women. The fallow requirements led to very small cultivated areas (For T0-T5, only 6% of the cultivated area). Apparently, women's resources were too small and SHARES had problems in allocating them. The SHARES runs were not deemed realistic: the fallow requirements were too restrictive. The PEDI staff decided to soften the fallow requirement and to calculate new farm alternatives (Table 8.5).

Table 8.5: Alternative farm options for category D, female farmers in Gainsa[1)]

Max Cer, using constraints:	% Fields for cereals	% Fields for leguminous crops	Inputs (cartload or FCFA)	Cattle	Small stock	Food self-sufficiency	Net revenue per capita (FCFA)	Purchasing power related to food needs
T0-T5	67 %	18 %		0	0.6	132 %	24,961	160 %
Max Rev, using constraints:								
T0-T5	37 %	37 %		0	0.6	75 %	29,016	186 %
T0-T6	37 %	37 %	3 loads manure	0	1.8	75 %	40,248	258 %

Note 1: We assume that each female farmer supports 1.5 household members.

Table 8.5 suggests that women found themselves in a more favourable position than the men, be it category A, B, or C. Staff members took notice of these results, but realised that the results were based on the assumption that women only supported 1,5 household members; this might have been an underestimation.

8.1.5 First insights gained through the SHARES analysis

The SHARES results revealed the following structural tendencies:

- For the technology level T0-T5, a shift from food-oriented production to revenue-oriented production led to a decrease of the cereal area in favour of an increase of the leguminous crop area. In this case, the farm production value increased considerably.
- When applying technology level T0-T6 or T0-T7, a shift from food-oriented production to revenue-oriented production required less drastic changes in the cropping plan. The availability of fertiliser improved the productivity of the cereal crops relative to that of the leguminous crops. Whether the farmer opted for food production or revenue maximisation, SHARES recommended a cultivation plan with a substantial cereal area (millet, sorghum and maize). When switching from food production to revenue maximisation, the increase of the production value was noticeable, but smaller than in the case of technology level T0-T5.
- A shift from the technology level T0-T6 to T0-T7 had a minor effect on the production results. Labour intensive arable farming (T0-T6) and input intensive arable farming (T0-T7) were almost equally productive.
- In contrast to the SHARES livestock example of Chapter 6, Gainsa farmers augmented their revenue considerably when purchasing cotton cake (shift from T0-T7 to T0-T7^{+}). This effect was caused by the extreme land scarcity.

When looking at the overall farm potential, staff members discerned the structural poverty and they were struck silent. The net farm revenue per capita could not surpass 40,248 FCFA (€ 61.45) per year. Staff felt confused and embarrassed. To attain basic needs coverage a Gainsa puugsoba needed high farm investments in labour or money. For Category A and category B, this was not enough: they needed revenue-oriented farm strategies just to make ends meet. Gainsa farmers had little opportunity to surpass the basic needs level, to produce something extra to make life easy. For women, in theory, the situation seemed more relaxed but in practice they shared the concerns of their husband. Land scarcity forced farmers to exert all efforts to eke out a living. Despite their hard work, agriculture did not provide prosperity. It appeared that the assumptions of the PEDI programme had been too optimistic. Farmers survived thanks to their off-farm activities and the remittances of transmigrated relatives.

The SHARES runs enabled PEDI staff:
- To gain insight in the agricultural potential of a specific village and farmer category;
- To understand the structural relations between the biophysical properties, farm strategies and output within a specific context.

8.2 The preliminary match of SHARES options and current farm behaviour by PEDI staff

SHARES was used to generate tailor-made scenarios. The idea was to use SHARES to generate an array of possible farm strategies for the farmer categories in the two test villages, to present the SHARES options to the farmers and to ask their opinion. Did SHARES generate realistic production levels and strategy choices; what were current farm strategies and what were challenging future options?

To prepare the farmer discussions, the staff looked for data on actual farm practices. This information would help them:
- To select plausible SHARES scenarios to be presented to the farmers (current and potential future farm options);
- To move beyond theories that farmers espoused to please PEDI staff;
- To identify discrepancies between the espoused farm theories and the theories-in-use (actual farm strategies). Knowledge about the theories-in-use would help the farmers and the staff to define realistic future farm options.

To gain insight in the actual farm practices, the staff studied the results of the farmer positioning exercise (§ 7.4). This provided the data presented in the Tables 8.6 and 8.7.

Scrutiny of the arable farm practices in Table 8.6 gives the following insights:
- There was a widespread application of SWC measures. All men used fields treated with stone rows. Women were not able to mobilise the required labour for the construction of stone rows but some of them received treated fields from their husbands while others planted Andropogon (vegetation bunds). The recently introduced zaï was already common practice.
- Apart from category B, most farmers applied fallow and rotation schemes. Category B farmers supported large households and were short of land; hence they had little opportunity to practice fallow and/or crop rotation.
- When looking at the fertilisation practices, almost all category A farmers applied mulching, used Burkina rock Phosphate (BP), manure and compost. The majority of these farmers participated in the PEDI agricultural investment scheme, which encouraged them to apply BP, manure and compost. Category B applied some BP but concentrated more on the direct application of manure. Only few Category C and D farmers (young men and

women) participated in the PEDI programme[72] and they had a limited access to BP and compost. As an alternative, young men applied manure, burned the crop residues on their fields and bought additional NPK. Female farmers only had few resources and they just spread the crop residues to protect the soil. Some women received compost, BP or manure from their husbands.

Table 8.6: Arable farm practices as applied in 1999, Gainsa

Average resource situation[1)]	Category A Wealthy men	Category B Men	Category C Young men	Category D Women
Labour availability (MEV)	7.4	4.9	6.8	0.5
Land availability (hectare)	6.6	4.2	4.0	1.1
Available MEV/hectare	1.1	1.2	1.7	0.5
Number of farm practices applied[2)]				
Stone rows, vegetation bunds	10	10	10	8
Zaï	9	8	6	9
Fallow	10	0	9	6
Rotation of crops	10	3	10	8
Leaving crop residues on field	0	1	1	6
Burning crop residues on field	0	0	8	4
Mulching	10	5	0	3
Use of manure	9	10	9	2
Use of compost	9	5	1	4
Burkina Phosphate	9	7	5	3
Urea or NPK fertiliser	3	2	9	0
Improved seed	9	6	9	0

1: Results from the socio-economic survey
2: Results from the farmer positioning exercise.

According to Tapsoba (2000), in the southern villages, about 32% of the cultivated area was treated with manure, 13% with BP and 7% with NPK. Farmers did not apply the recommended doses but applied small doses fertiliser on patches of soil with low fertility. Farmers preferred NPK to BP: BP had a long-term effect while NPK led to short term, visible improvements. Women mixed some NPK with the crop seed to accelerate the germination.

The study of the livestock practices in Table 8.7 revealed the following tendencies:

- Most of the wealthy farmers had stables to stall livestock and to conserve straw and hay. They fed crop residues as well as industrial by-products and applied health control. More than half of them fattened cattle and/or small stock for sale.
- Category B farmers had fewer resources to invest: fewer farmers constructed stables and purchased industrial by-products, vaccines and parasitic treatments. A small number of farmers were involved in livestock fattening.
- The young men showed relatively more interest in intensive livestock keeping. They owned few cattle but were heavily engaged in small stock fattening and paid much care to feed production and health control.

[72] Most puugsoba of this category lacked the resources to pay the required 'own contribution'. In the PEDI programme beolgsoba were second order beneficiaries: beolgsoba could only benefit from PEDI subsidies if the related puugsoba already applied stone rows and BP (at least one hectare).

- Women had few animals and they were less occupied with feed production and health control. Nevertheless, some of them had started small stock fattening.

Table 8.7: Livestock farm practices as applied in 1999, Gainsa

Average resource situation[1)]	Category A Wealthy men	Category B Men	Category C Young men	Category D Women
Number of cattle	6.5	3.7	0.8	0
Number of small stock	17.5	12.7	10.8	2.0
Applied farm practices[2)]				
Use of pods & chaff harvest	10	10	10	2
To mow and conserve grass	9	7	10	1
To conserve hay on a hangar	9	10	10	2
To conserve hay in a stable	7	2	9	3
To apply salt or urea on hay	1	5	10	0
Use of industrial by-products (cotton cake)	10	3	9	0
Internal parasitic control	10	4	10	0
Vaccination	10	7	10	0
Cattle fattening	5	2	1	0
Small stock fattening	5	3	9	3
Milk production	0	0	0	0

1: Results from the socio-economic survey
2: Results from the farmer positioning exercise.

How did these farm practices fit in with the SHARES farm strategies? The applied farm practices suggested the following farm orientations: wealthy men applied T0-T6$^+$; men applied T0-T6; young men applied T0-T6$^+$; and the women applied T0-T5. To trigger farmers discussions on actual and envisaged future farm strategies, staff members decided to present the SHARES options 'Max Cer, T0-T5', 'Max Cer, T0-T6', 'Max Rev, T0-T6' and 'Max Rev, T0-T7^{+}' (For a clarification of this notation refer to § 7.5 and Table 7.5).

8.3 The staff-farmer dialogue: The consequences of land scarcity

8.3.1 The presentation and questions of the PEDI staff

The SHARES options were visualised with symbols the farmers were familiar with. Initially, the visuals portrayed the farm resources, the farm practices and the resulting farm revenues. During the preparation of the field session, it was noted that farmers were primarily concerned about food security. So it was more practical to express production in terms of food self-sufficiency rates rather than farm revenue: a full granary would mean 100% food self-sufficiency. Figure 8.1 gives an example of the pictures, presented to the farmers.

During the presentation of the SHARES options, it was explained that the pictures represented the view of the PEDI staff. Data of the village resources had been integrated in a computer model and this science-based model developed various farm scenarios. The scenarios represented the logic of the staff members. Was this logic realistic or not? In concrete terms, farmers were asked:

1. Were the computer-generated options realistic? If not, why not?
2. Was there a picture that more or less reflected their current farm strategy?

3. Was there a picture, a farm strategy that could serve as a future challenge? Which farm options were desirable:
   - to increase the cash crop area to augment their food purchasing capacity?
   - to increase the labour input (e.g. to cultivate larger areas or using more labour intensive farm techniques such as compost production)?
   - to invest money? If yes, what inputs would they prefer to buy?
   - to augment the production level beyond the basic needs level?
   - to monitor prices at various markets to sell their farm produce in the best market at the best time?

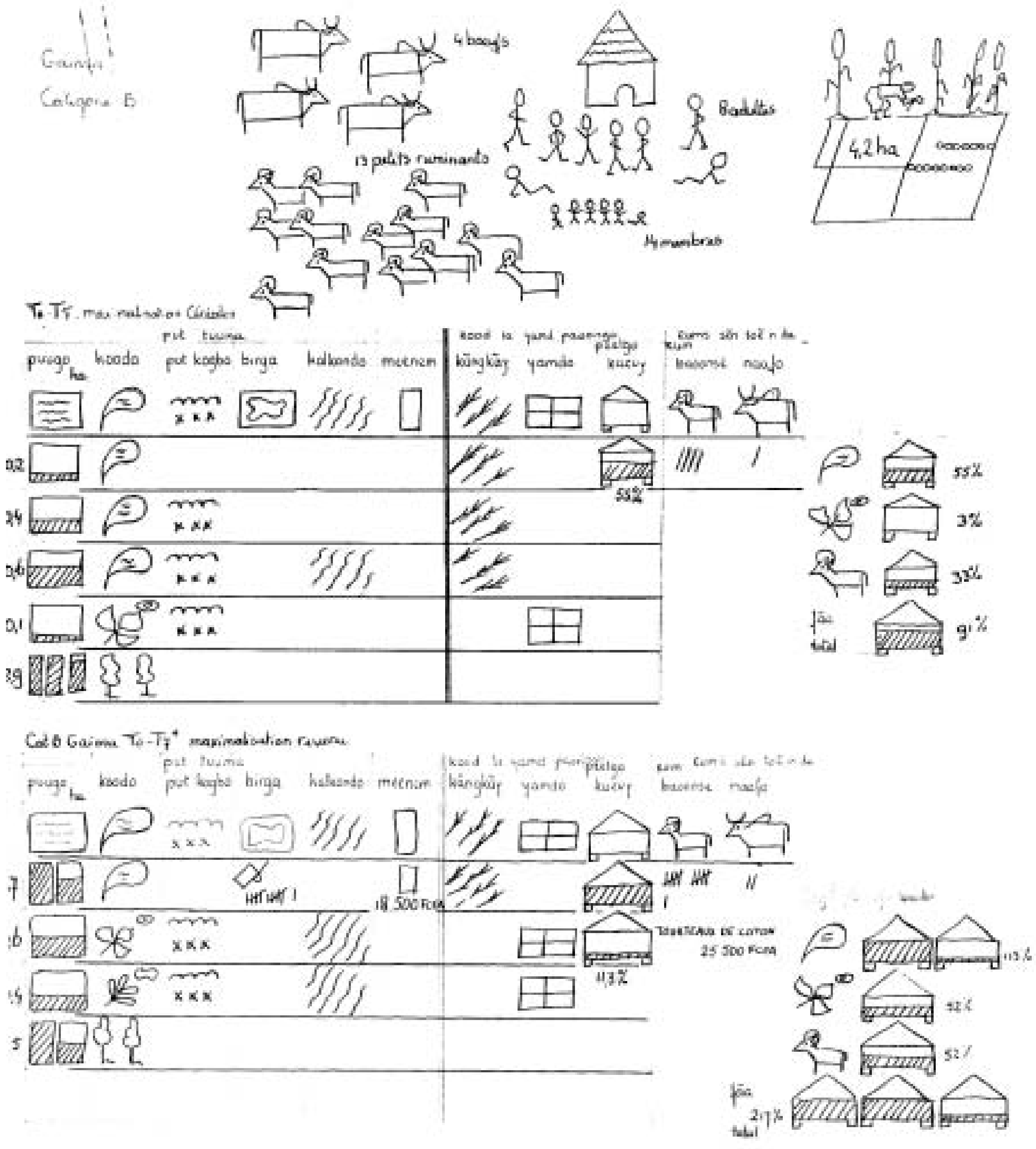

Figure 8.1: Pictures of the presentation of Category B in Gainsa: household resources; results Max Cer, T0-T5; and Max Rev, T0-T7 +

8.3.2 The debate between PEDI staff and the male farmers

The farmers easily recognised the symbols and understood the SHARES pictures. When everything seemed clear, staff asked for comments. The male farmers (Category A, B and C) reacted as follows:

Plausibility of the SHARES scenarios

The presented scenarios pleasantly surprised the farmers. SHARES provided challenging future farm options! Most adolescent, aspiring farmers (Category C) choose for 'Max Rev, T0-7^{+}'. They wanted to earn money. Large numbers of the young men migrated to work in West Burkina or Ivory Coast, and those who remained at home focussed on cash crop production.

Older farmers felt responsible for their household. They prioritised household food self-sufficiency and were selective with their investments. They aimed at 'Max Cer, T0-T6^{+}'. Category A farmers managed to implement this farm strategy, but most category B farmers lacked the means to invest money and just applied 'Max Cer, T0-T6' (Box 8.5).

Box 8.5: An example: The appreciation of the SHARES options by category B, Gainsa

To assess the plausibility of the SHARES runs, 8 farmers provided information on their current farm practices: they applied each 20, 15, 10, 15, 9, 9, 7 and 7 cart loads of manure. The compost pits did not function; they just transported manure to their fields. They had contracts with the Peulh, which allowed them to collect manure at the corral. They did not invest money in agriculture but preferred to invest in livestock fattening. In conclusion, one could say that they aimed at 'Max Cer, T0-T6^{+}'.

The 'Max Cer, T0-T6' option recommended 1.2 ha cereals, 0.4 ha cowpea, 0.3 ha groundnut and 2.3 ha fallow. For comparison, a farmer described his present farm situation: 2 ha cereals, 0.3 ha groundnut and 4 ha fallow. He owned more land than assumed by SHARES, but the proportion cereals/leguminous crops/fallow corresponded with the SHARES example.

Option 'max rev, T0-T7^{+}' was an eye-opener. They had always contented themselves with basic needs coverage. Could PEDI help them to arrive at that production level?

Food production versus revenue maximisation

Older farmers concentrated on the household food situation, which was delicate and deserved first priority. In good rainy seasons, they produced small cereal reserves to complement the food deficit of the bad rainy seasons. They cultivated small quantities of leguminous crops. They preferred cowpea to groundnut: it was an intercrop, it improved the soil fertility and it produced food as well as quality fodder. The farmers questioned the commercial value of cowpea: it is difficult to conserve and it fetched a low price at the local market. You could try to sell the harvest at the regional market in Kaya to fetch a better price, but then local traders would seek revenge.

Younger farmers were ambitious. They acknowledged the conservation and trade difficulties of cowpea but estimated that PEDI could help them to overcome these problems. They had limited household responsibilities: they worked at the puugo to provide food for the household, but at their own plots, they aimed at revenue maximisation.

Labour investment to increase farm production

Labour was scarce during the agricultural season. If possible, labour migrants temporarily returned home to offer a helping hand. The rainfall pattern and labour availability determined the arable farm production. Farmers always tried to cultivate the biggest area possible. Before the rainy season, they constructed zaï. After the first rains, they started ploughing, fertilising and sowing. Even when time lacked to plough and fertilise, farmers at least sowed the area. Farmers felt they exploited their labour resource as much as possible. Ceremonies and village festivities were scheduled during the dry season. During the agricultural season, only elderly people attended the market days while the others concentrated on the agricultural work. The main problem was the physical weakness of the labour force: during the agricultural season most granaries were empty and people experienced food shortages, felt weak and easily fell ill.

Capital investment to increase farm production
Most farmers had no money reserve. If money was available, they invested in livestock. Farmers considered livestock fattening as more profitable than arable farming. Unstable rainfall made arable farming a risky affair. Rather than buying fertiliser, farmers would buy quality lambs, appropriate for fattening. At this moment, most of them selected one or two sheep from their herd for fattening purposes. Of course, animals could die, but the risk was relatively small.

To increase farm production beyond basic needs coverage
Most farmers struggled to cover the basic needs of their household and felt it was inopportune to think about extra production beyond the basic needs level.

Price awareness
Farmers closely monitored price differences. If the situation allowed, they would sell at the most opportune time: they planned sheep fattening to benefit from the high prices around Tabaski. Sheep fattening served to cover the anticipated cash needs, to buy clothes etc. Non-fattened livestock was sold when the owner needed cash to cover unforeseen expenditures (illnesses, ceremonies and food shortage). The farmers preferred not to sell more than strictly necessary, to limit expenditure. The cash needs determined what item was sold: a quantity of cowpea or groundnut, one or more chicken, a goat, a sheep or a cow. Farmers regularly sold small quantities; hence, it was more important to maintain good relations with traders at nearby markets, than to comb out all markets to fetch a good price.

8.3.3 The debate between PEDI staff and the female farmers
The situation of the women differed slightly: they had limited access to labour and combined domestic and productive responsibilities. Staff members presented the calculated farm options of Table 8.5 and asked the women to position themselves and to comment on the SHARES options. The women reacted as follows:

The plausibility of the SHARES scenarios
Four women volunteered to describe their farm situation (Table 8.8). Their access to land exceeded the average of 1.1 ha for puugsoba and 0.8 ha for a beolgsoba. Cowpea was only used as an intercrop for sorghum or millet. Women applied no fallow; about 75% of the cultivated area was used for cereals and 25% for cowpea and groundnut. The women used labour intensive farm techniques: part of the area was treated with zaï and they applied manure in the zaï holes. Unfortunately, this year the rainfall was low and parts of the cultivated area had no harvest. The zaï provided some relief: the plants in the zaï received enough water to ripen and to produce grains. Nevertheless, the harvest was small and did not suffice to feed the 4-6 persons they were supposed to support.

Table 8.8: Some descriptions of women's farm situation in Gainsa, 2000[1)]

Access to land (ha)	Sorghum & millet (ha)	Cowpea intercropped (ha)	Groundnut (ha)	Fallow (ha)	Zaï	Manure (cartloads)	Number of people to support
Puugsoba							
1.5	1.25	0.25	0.25	0	Yes	3	5
1.5	1.25	0.25	0.25	0	Yes	7	5-6
Beolgsoba							
1.0	0.75	0.2	0.25	0	Yes	2	4
1.0	1.0	0.2	-	0	Yes	3	4

1: The farmers found it difficult to estimate plot surfaces. The data are indicative only.

The delicate food situation forced the women to concentrate on food production. They did not sell food but used the revenue from off-farm activities such as gold mining, beer brewing and groundnut cakes to buy additional cereals. There was no money to invest in livestock fattening. In the SHARES language, we could say that the women aimed at 'Max Cer, T0-T6^{+}', but actually applied 'Max Cer, T0-T6'. This option was not included in the SHARES presentation. Staff had assumed that they either opted for 'Max Cer, T0-T5' (older women, who just took care for their own food) or 'Max Rev, T0-T6' (younger women who need income to support their children).

Food production versus revenue maximisation
All arable farm activities were geared to food production, be it cereals, cowpea or groundnut.

Labour investment to increase production
The male puugsoba managed the household labour resources: from 9 a.m. to 2 p.m. all beolgsoba worked at the puugo. It was only after 2 p.m. that female beolgsoba cultivated their personal plots. If possible, children offered a helping hand. After finishing the household cereal fields, a husband sometimes offered his wives to plough part of their fields.

Capital investment to increase production
Women were good at livestock fattening, but they often lacked the money to start fattening activities. The money they earned with gold mining, beer brewing, etc. was used to buy extra food to cover the household needs.

Price awareness
Women did not sell agricultural produce, but they had a keen intelligence for their purchases: just after the harvest, when the prices were low, they bought extra stocks of cereals to mitigate anticipated food deficits.

8.4 Computer model enhanced learning

The staff members appreciated the SHARES discussions. The SHARES scenarios confronted them with the precarious situation of the Gainsa farmers. They now understood that land was in short supply and farmers had to mobilise all means to attain food security. When they considered this context, the farmer reasoning sounded very logical. Gainsa farmers had no other choice than to carefully exploit resources to eke out a living. Only ambitious young men dared to opt for 'Max Rev, T0-T7^{+}'.

Table 8.9: The farm strategies identified in Gainsa, 2000

	Wealthy men	Men	Young men	Women
Observed behaviour (Table 8.6 & 8.7)	T0-T6+	T0-T6	T0-T7+	T0-T6
Current farm strategy (theories-in-use)	Max Cer, T0-T6$^+$	Max Cer, T0-T6	Max Rev, T0-T7$^+$	Max Cer, T0-T6
Envisaged future farm strategy	Max Cer, T0-T6$^+$	Max Cer, T0-T6$^+$	Max Rev, T0-T7$^+$	Max Cer, T0-T6$^+$

When the staff presented the production figures of 'Max Rev, T0-T7$^+$' for a normal rainy year, they felt uneasy: they showed a rosy picture while Gainsa farmers experienced hard times. The agricultural season had been bad. In 2000, rainfall displayed a high spatial variability. The agricultural extension officer estimated that Gainsa farmers harvested 200 kg sorghum per ha while Koglabaraogo farmers harvested up to 800 kg per ha. For the case of Gainsa, it would have been more appropriate to show the SHARES options for a dry year and to explore farm risks[73].

In the end, the PEDI staff drew their conclusions:

- The staff was truly surprised by the general poverty of the farmers in Gainsa. Even the most dynamic farmers had problems to make ends meet. The remittances of transmigrated relatives were of crucial importance for their survival. Apparently, extension officers had relatively more contact with the more prosperous farmers in the land-endowed villages than with farmers struck by poverty. As farmers felt ashamed to display their poverty, the staff members were easily carried away by the ambitions of development project.
- Through SHARES, staff acquired site and category specific knowledge of the biophysical situation of farmers. Furthermore, they gained insight in the agricultural potential and the structural relations between the biophysical properties and the farm production within a specific context. Before, they extrapolated parts of knowledge (certain assumptions, theories and solutions acquired through agronomic research, farmer system research, other experiences) from other areas to formulate recommendations for *the* Sanmatenga farmer. Contradicting field experiences were perceived as accidental and not representative, and were dismissed. The staff members trusted science and they could not ignore the SHARES analyses. It confused them and created a momentum for reflexive and transformative learning; it provided new insights, which better fitted the statements and behaviour of the farmers. Through SHARES, the staff realised that the PEDI development objectives were too ambitious. Poverty was more widespread and structural than they had assumed. Farmers struggled with land scarcity and local trade monopolies minimised farm profits. The staff now recognised the necessity of risk avoiding, and coping farm strategies.
- SHARES convinced the staff that extension should recognise and work from diversity. They identified a clear difference between the 20 innovative farmers who readily applied fertiliser and the Gainsa farmers who refused to purchase fertiliser. Through their participation in the Farmer Innovation Project (§ 3.3.3), the staff members envisaged an extension system in which innovative farmers served as role models for the Sanmatenga farmers. However, the SHARES discussions cast doubt on the applied selection procedure. PEDI staff used to select the most progressive farmers. Now, it seemed more appropriate to pursue an area and category specific approach and to ask the farmer categories to identify farmers whom they valued as innovative and who served as role models. It was essential that innovative farmers were socially integrated: persons who

[73] For a dry year, SHARES estimated the production at 65% of the production in a normal year. For a wet year, the production level was estimated at 135% of the production in a normal year.

lived in familiar farm situations and with whom farmers liked to share experiences (Reij & Waters-Bayer, 2001).
- The SHARES runs provided very concrete, site and farmer category specific information. This information was easily visualised (Figure 8.1) and triggered illuminating discussions on farm strategies.

The farmers, on their turn, gave the following feedback:
- They welcomed the discussion: so far, no other institution had ever triggered a debate on strategic issues. Strategic thinking had remained tacit.
- They realised that PEDI challenged them to develop their agricultural practices; they understood the advantages they could gain if they applied the SHARES options. However, they lacked the necessary reserves to involve themselves in risky enterprises and to carry through drastic changes. They asked credit for small experiments, to slowly develop their farm[74].
- They were surprised that nowadays they communicated with machines.

[74] In the eyes of the farmers, credit was the opportunity to increase capital and to transfer risks to the credit institution. Former experiences with (project financed) credit institutions had taught farmers that it was possible to transfer or share risks: in case of adversity (bad harvest or livestock mortality) farmers stopped the repayment and asked credit institutions to be lenient.

Photo iv: Weeding of the beolga

Photo v: Threshing millet in front of granaries

Photo vi: Woman with her fattened sheep

Photo vii: Catlle looking for pasture

9 Model enhanced learning in Koglabaraogo: the moral economy

The previous chapter described the learning processes with respect to the densely populated village Gainsa. In this chapter the learning with respect to Koglabaraogo, a village were land is abundant, is analysed.

The characteristics of the farmer categories and the SHARES generated farm options are presented (Section 9.1). To prepare the farmer discussions, the staff studied the current farm behaviour in Koglabaraogo as compared to the farmer behaviour in Gainsa (Section 9.2). After these preparations, the staff invited the farmers to comment on the SHARES options and to reflect upon their possible farm strategies (Section 9.3). Finally, the learning process and the added value of SHARES were evaluated (Section 9.4).

9.1 The SHARES options for Natural Resource Management

As for Gainsa, the Antenne Sahélienne executed a land evaluation and socio-economic survey for the land-rich village Koglabaraogo. This section presents the characteristics of the farmer categories and the farm options as generated by SHARES.

9.1.1 Koglabaraogo, category A: "Mossi men"

Category A consisted of 21 puugsoba and 6 beolgsoba. The socio-economic survey (§7.5) gave the characteristics as presented in Box 9.1.

Box 9.1: Characteristics of Mossi men, category A in Koglabaraogo

Arable farming
The average puugsoba supported a household with 16.7 members, of whom 8.9 were assumed to be agriculturally active. On average, the farmer managed 8.9 hectares: sandy soils (63%), clay soils (24% and valley (11%). The relative importance of crops was as follows: white sorghum (100), millet (93), maize (67) groundnut (49), cowpea (30) and tobacco (21).

Livestock farming
The average puugsoba owned 12.7 head of cattle, 2.2 donkeys, 9.2 sheep, 12.2 goats and 34 chicken or guinea fowls.

Income and expenditure
The farmers did not sell cereals, but they sold part of their cash crops such as groundnut, cowpea and tobacco. In 1999, they also sold livestock to buy additional food, for ceremonies and illnesses. About 83% of the puugsoba received remittances of migrated relatives.

The natural resource data were incorporated in the SHARES model. Like for Gainsa, we incorporated the condition that farmers produced 50% of their cereal consumption. An exemption was made for the pastoralists. To assure a reasonable access to pasture, the condition was included that each category should be able to pasture 50% of their current livestock herd within the village. After these preparations, SHARES was used to generate the farm options for a virtual farmer in category A. Again we explored the farm potential for a *normal rainy year.* Table 9.1 shows the SHARES results.

Table 9.1: SHARES farm options for category A: male Mossi farmers in Koglabaraogo

Max Cer, using constraints:	% Fields for cereals	% Fields for leguminous crops	Inputs: manure, N-fertiliser and cotton cake	Cattle	Small stock	Food self-sufficiency	Net revenue per capita (FCFA)	Purchasing power related to food needs
T0-T5	29 %	3 %		3.7	5.4	78 %	15,921	102 %
T0-T6	83 %	8 %	91 loads	17.6	15.5	371 %	72,952	468 %
T0-T7	83 %	8 %	9 loads 75,549 FCFA	20.5	10.4	462 %	106,782	685 %
Max Rev, using constraints:								
T0-T5	10 %	2 %		10.5	5.3	25 %	53,828	345 %
T0-T6	69 %	22 %	101 loads	20.0	10.4	309 %	100,774	647 %
T0-T7	80 %	12 %	14 loads 69,561 FCFA	21.2	10.4	431 %	108,006	694 %
T0-T7^{+}	79 %	20 %	13 loads 69,936 FCFA 0 FCFA	21.1	10.4	462 %	107,056	687 %

The table shows that a farmer who opted for 'Max Cer, T0-T5' just attained food self-sufficiency. However, if he opted for revenue maximisation or intensive arable farming, farm production quickly surpassed the basic needs level. More than half of the farm revenue derived from livestock farming. The Koglabaraogo pasture area produced more feed than the food needs of the existing livestock herd. SHARES recommended the farmers to enlarge their livestock herd.

9.1.2 Koglabaraogo, category B: "Mossi young men"

The category consisted of 15 puugsoba and 21 beolgsoba. The average puugsoba had the characteristics as in Box 9.2.

Box 9.2: Characteristics of Mossi young men, category B in Koglabaraogo

Arable farming
The average puugsoba supported a household with 16.6 members, of whom 8.0 were agriculturally active. He managed 6.6 hectares: sandy soils (57%), clay soils (29%) and valley (14%). The relative importance of crops was as follows: white sorghum (100), maize (85), millet (50), cowpea (40), groundnut (20) and tobacco (21).

Livestock farming
The average puugsoba owned 4.0 head of cattle, 1.3 donkeys, 2.1 sheep, 4.9 goats and 29 chicken or guinea fowls.

Income and expenditure
In 1999 everybody bought additional food. Farmers sold cash crops and livestock to pay for the food and medical expenses. Only 29% reported to receive remittances of migrated relatives.

Category A, and category B farmers supported an equal number of household members, but category B farmers had less land and livestock resources. This category consisted of the poorer Mossi puugsoba. Their resource situation more or less resembled the situation of the category A farmers in Gainsa. The main difference was the access to pasture. This appeared to be crucial as it enabled SHARES to generate lucrative farm options. Pasture availability allowed for a considerable livestock herd and an increased availability of manure. SHARES recommended category B in Koglabaraogo to double or triple their present livestock property and to apply intensive arable farm practices. Except for the option 'Max Cer, T0-T5', farmers easily covered the basic household needs.

Table 9.2: SHARES farm options for category B, young male Mossi farmers in Koglabaraogo

Max Cer, using constraints:	% Fields for cereals	% Fields for leguminous crops	Inputs: manure, N-fertiliser and cotton cake	Cattle	Small stock	Food self-sufficiency	Net revenue per capita (FCFA)	Purchasing power related to food needs
T0-T5	26 %	3 %		1.3	2.4	51 %	9,251	74 %
T0-T6	59 %	20 %	45 loads	5.5	18.1	202 %	42,745	321 %
T0-T7	79 %	8 %	0 loads 52,879 FCFA	6.5	4.7	335 %	50,587	380 %
Max Rev, using constraints:								
T0-T5	11 %	3 %		4.6	2.0	21 %	30,285	194 %
T0-T6	46 %	33 %	39 loads	10.6	3.3	166 %	58,792	422 %
T0-T7	71 %	15 %	43 loads 44,975 FCFA	11.7	3.3	291 %	67,522	538 %
T0-T7^{+}	71 %	16 %	43 loads 44,718 FCFA 0 FCFA	11.7	3.3	291 %	67,522	533 %

9.1.3 Koglabaraogo, category C: "Mossi women"

Category C consisted of 29 female puugsoba and 116 female beolgsoba. All of them were Mossi women. Peulh women were not engaged in farm activities. They processed milk from the family herd. The socio-economic survey provided the characteristics as presented in Box 9.3.

Box 9.3: Characteristics of female farmers, category C in Koglabaraogo

Arable farming

An average puugsoba had access to 1.9 hectare, while a beolgsoba had access to 1.7 hectares. 68% of the cultivated area was located on sandy soils, 21% on clays soils and 10% on valleys. Like in Gainsa, the puugsoba concentrated a bit more on food crops than the beolgsoba. For puugsoba the relative importance of the crops was: white sorghum (100), peas (82), groundnut (66), roselle (47), cowpea (44). For beolgsoba the relative importance was: white sorghum (100), peas (90), groundnut (70), okra (70) and cowpea (53).

Livestock farming

None of the women owned cattle. The average puugsoba owned 1.7 sheep and 0.7 goats, while the average beolgsoba just owned 1 head of sheep. This meant that Koglabaraogo women owned less livestock than their Gainsa counterparts.

Income and expenditure

In 1999, 90% of the female puugsoba and 50% of the female beolgsoba bought additional food. Half of the puugsoba sold 15-30% of their cash crops, while all beolgsoba sold at least 50% of their cash crops (especially peas and groundnut). 88% of the puugsoba received remittances from migrated relatives against 50% of the beolgsoba.

For the sake of comparison with Gainsa, it was assumed that a woman supported 1.5 household members. Table 9.3 gives the SHARES generated farm options for the women.

Like in Gainsa, SHARES applied excessive fallow requirements and the recommendations did not seem realistic.

Table 9.3: SHARES farm options for category C, female Mossi farmers in Koglabaraogo[1)]

Max Cer, using constraints:	% Fields for cereals	% Fields for leguminous crops	Inputs: manure, N-fertiliser and cotton cake	Cattle	Small stock	Food self-sufficiency	Net revenue per capita (FCFA)	Purchasing power related to food needs
T0-T5	24 %	7 %		0	0.1	87 %	13,222	87 %
T0-T6	27 %	0 %		0	0.1	92 %	13,634	92 %
T0-T7	27 %	0 %		0	0.1	92 %	13,634	92 %
Max Rev, using constraints:								
T0-T5	24 %	20 %		0	1.8	73 %	19,535	125 %
T0-T6	24 %	3 %	0	0	1.8	77 %	19,606	126 %
T0-T7	24 %	3 %	0	0	1.8	77 %	19,606	126 %
T0-T7^{+}	24 %	3 %	0	0	1.8	77 %	19,618	126 %

1: We assume that each female farmer supports 1.5 household members.

After softening the fallow requirements, we calculated alternative farm options as presented in Table 9.4. These were the options presented to the women.

Table 9.4: Alternative farm options for category D, female farmers in Koglabaraogo[1)]

Max Cer, using constraints:	% Fields for cereals	% Fields for leguminous crops	Inputs: manure, N-fertiliser and cotton cake	Cattle	Small stock	Food self-sufficiency	Net revenue per capita (FCFA)	Purchasing power related to food needs
T0-T5	67 %	18 %		0	0.7	204 %	38.576	268 %
Max Rev, using constraints:								
T0-T5	41 %	41 %		0	1.8	106 %	41,245	268 %
T0-T6	41 %	41 %	7 loads	0	1.8	106 %	57,829	403 %

1: It was assumed that each female farmer supported 1.5 household members.

As in Gainsa, the Koglabaraogo women seemed more prosperous than the men did. However, the farmer discussions in Gainsa had taught the staff that women supported more household members, than the assumed 1.5 (§ 8.3.2). Together with their husbands, they supported about 4 to 5 household members. For the case of Koglabaraogo, this meant that the purchasing power of the women ranged between 160% (T0-T5) and 242% (T0-T6) and was slightly less than those of their spouses.

9.1.4 Koglabaraogo, category D: "Peulh livestock farmers"

The category consisted of Peulh pastoralists: nine heads of household and one young man. The survey provided the characteristics as presented in Box 9.4.

As explained in Section 7.4, we did not trust the livestock property data forwarded by the Peulh. Through the examination of other literature, we estimated the livestock wealth at 38 head of cattle. This estimated livestock wealth was used to determine the relative access of Peulh pastoralists to the village pasture (§7.5). For the Peulh, we abandoned the 50% cereal

Box 9.4: Characteristics of Peulh livestock farmers, category D in Koglabaraogo

Arable farming
An average Peulh farmer supported a household of 5.5 members, of whom 2.5 were agriculturally active. They had access to 0.8 hectare of sandy terrain. They cultivated millet, sorghum and some maize for own consumption.

Livestock farming
The pastoralists recorded an average livestock property of 5 head of cattle, 3.0 sheep, 12.5 goats and 18 chicken and/or guinea fowl.

Income and expenditure
All Peulh farmers bought additional food. They sold milk and livestock to pay for the cereals and other necessities. None of the Peulh received remittances from relatives.

self-sufficiency requirement but we maintained the livestock pasture requirement: 50% of their livestock herd should graze within the village territory. For the Peulh SHARES generated the farm options as presented in table 9.5. SHARES considered Peulh farmers to be prosperous. With 20 to 22 head of cattle, they produced about nine times their household food requirement.

Table 9.5: SHARES farm options for category D, male Peulh farmers in Koglabaraogo

Max Cer, using constraints:	% Fields for cereals	% Fields for leguminous crops	Inputs: manure, N-fertiliser and cotton cake	Cattle	Small stock	Food self-sufficiency	Net revenue per capita (FCFA)	Purchasing power related to food needs
T0-T5	33 %	0 %		22.3	14.4	12 %	138,946	892 %
T0-T6	83 %	17 %	6 loads	19.7	28,9	58 %	144,101	925 %
T0-T7	83 %	17 %	6 loads 0 FCFA	19.7	28.9	73 %	144,549	928 %
Max Rev, using constraints:								
T0-T5	0 %	100 %		22.0	14.4	0 %	139,633	896 %
T0-T6	83 %	17 %	6 loads	19.7	28.9	58 %	144,101	925 %
T0-T7	83 %	17 %	6 loads 0 FCFA	19.7	28.9	73 %	144,549	928 %
T0-T7$^+$	83 %	17 %	6 loads	19.7	28.9	73 %	144,549	928 %

9.1.5 First insights gained through the SHARES analysis

Staff compared the SHARES runs of the male farmers in Gainsa with those of Koglabaraogo and identified the following similarities and differences:

- With 'Max Cer, T0-T5', nobody attained basic needs coverage (=150% household food requirement). However, with revenue-oriented farm objectives and/or more intensive farm practices Koglabaraogo farmers quickly surpassed the basic needs level while Gainsa farmers just managed to make ends meet.
- In both villages, there was a negative trade-off between food production and revenue maximisation. With T0-T5, the fallow requirement was high and food production had a considerable negative effect on the farm revenue. This effect was less pronounced for the technology level T0-T6. When applying manure, the productivity of the cereal crops approached the productivity of the leguminous cash crops. With T0-T7, food production and revenue maximisation were equally lucrative.

- In Koglabaraogo, a shift from T0-T6 to T0-T7 had a positive effect on the farm revenue. This had not been the case in Gainsa. In Gainsa, farm production attained its optimum at the technology level T0-T6. In Koglabaraogo, the optimum technology level was T0-T7. The only explanation possible is labour availability. T0-T6 demands a considerable amount of labour for the transport of manure and composting; hence, it was difficult to treat large surfaces. In villages where land is abundant, labour is the limiting factor. Labour availability limits the application of manure and compost. The application of fertiliser (T7) demands less labour. T0-T7 enabled Koglabaraogo farmers to increase the cultivated area and farm revenue.
- In contrast to Gainsa, Koglabaraogo farmers did not benefit from the purchase of cotton cake. Pasture was abundant and farmers did not need to buy feed.

SHARES was not suitable to explore the farm options of the women. SHARES could not handle low levels of resources. PEDI staff therefore calculated alternative farm options to be presented to the women.

SHARES focused on arable farming and gave little information about the farming possibilities of the pastoralists. SHARES estimated Peulh farmers as well off. Pastoralists spend little time on arable farming but allocated all resources to livestock farming, a lucrative farm activity.

9.2 The preliminary match of SHARES results and current farm behaviour by PEDI staff

To prepare the farmer discussions, the staff members studied the results of the farmer positioning exercise (§ 7.4) as presented in Table 9.6 and 9.7.

In Koglabaraogo, male Mossi farmers applied SWC measures such as stone rows and vegetation bunds. They showed little interest in the laborious zaï technique. Land was readily available. To maintain soil quality the farmers applied fallow, crop rotation, the burning of crop residues and mulching. The farmers had a large livestock herd and manure was readily available. Most farmers participated in the PEDI programme and applied the PEDI promoted BP. In 1999, nobody invested in NPK.

The women hardly practised SWC measures. Women used the fields allocated to them for about three years, a time too short to practice fallow. To maintain soil quality, they treated their fields with crop residues and household waste.

The Peulh men concentrated on livestock farming. They practised arable farming but in a very extensive way: they applied no SWC measures and spend little time on land preparation and weeding. Crop residues were left on the ground. They made contracts with Mossi farmers: the Mossi where allowed to collect the manure from the Peulh cattle on the condition that they deposited part of it in the Peulh fields.

Compared to Gainsa, Koglabaraogo farmers applied more extensive arable farm techniques: fewer farmers applied SWC measures, only a small minority opted for zaï and they hardly purchased NPK. They just used the available crop residues and manure. Farmers in the North received less rain, but they had more land to their disposal. They used larger areas and good quality soils (Table 7.6). This enabled them to attain satisfactory production levels, even with extensive farm techniques. Farm labourers in the North worked more hours and cultivated larger areas than their counterparts in the South (§ 3.1.6). The northern farmers maximised the production per labourer, while the southern farmers maximised the production per hectare. The first complained about labour shortage, while they latter about land shortage.

Table 9.6: Arable farm practices as applied in 1999, Gainsa and Koglabaraogo

Average resource situation[1)]	Gainsa				Koglabaraogo			
	Cat. A.	Cat. B	Cat. C	Cat. D	Cat. A	Cat. B	Cat. C	Cat. D
Labour availability (MEV)	7.4	4.9	6.8	0.5	8.4	7.4	0.2	1.7
Land availability (hectare)	6.6	4.2	4.0	1.1	8.9	6.6	1.7	0.6
Available MEV/hectare	1.0	1.8	1.7	0.5	0.9	1.1	0.1	2.8
Number of farmers applying the agricultural practices[2)]								
Stone rows, vegetation bunds	10	10	10	8	8	9	1	0
Zaï	9	8	6	9	2	3	1	0
Fallow	10	0	9	6	10	10	3	0
Rotation of crops	10	3	10	8	8	10	1	5
Leaving crop residues on field	0	1	1	6	4	6	6	9
Burning crop residues on field	0	0	8	4	8	7	6	0
Mulching	10	5	0	3	10	10	2	9
Use of manure/household waste	9	10	9	2	10	9	10	9
Use of compost	9	5	1	4	8	9	1	0
Burkina Phosphate	9	7	5	3	8	9	1	0
Urea or NPK	3	2	9	0	0	0	0	0
Improved seed	9	6	9	0	6	3	0	0

1: Results from the socio-economic survey (§ 7.5)
2: Results from the farmer positioning exercise (§ 7.4). From each category 10 farmers were asked to position themselves. The only exception was Category D in Koglabaraogo: the whole category of 9 pastoralists was interviewed.

Table 9.6 gives the number of people that applied a certain farm practice. These data give little information about the intensity of the practice. Table 9.6 suggests a widespread application of manure and/or compost, but farmers only treated small areas with manure and compost: In the North about 7% of the fields was treated and in the South this was 32% (Tapsoba, 2000).

When looking at the livestock farm practices (Table 9.7), there is a clear difference between the Peulh and the Mossi. Peulh farmers were pastoralists: they practiced transhumance and put little effort in the conservation and purchase of animal food. Peulh were knowledgeable about in animal health; they applied traditional medicines but also participated in vaccination campaigns. In contrast to the Mossi, the Peulh sold milk to pay for their daily expenses.

The Mossi entrusted their cattle to Peulh herders, their small stock browsed around the village, and many kept some animals at home for fattening purposes. Men *and* women undertook livestock fattening. This activity demanded intensive care: all farmers fed crop residues and many of them cut grass, conserved hay, purchased cotton cake and participated in vaccinations.

Table 9.7: Livestock farm practices as applied in 1999, Gainsa and Koglabaraogo

Average resource situation	Gainsa				Koglabaraogo			
	Cat. A.	Cat. B	Cat. C	Cat. D	Cat. A	Cat. B	Cat. C	Cat. D
# Cattle herd	6.5	3.7	0.8	0	12.7	4	0	38[1)]
# Small stock	17.5	12.7	10.8	2.0	21.4	7.0	0.9	15.5
Number of farmers applying the agricultural practices[2]								
Use of pods & chaff of harvest	10	10	10	2	10	10	10	3
To mow and conserve grass	9	7	10	1	7	8	9	1
To conserve hay on a hangar	9	10	10	2	9	10	10	3
To conserve hay in a barn	7	2	9	3	2	1	0	0
To apply salt or urea on hay	1	5	10	0	3	7	10	0
To use industrial by-products	10	3	9	0	9	7	8	1
Internal parasitic control	10	4	10	0	9	8	10	6
Vaccination	10	7	10	0	10	8	10	9
Cattle fattening	5	2	1	0	3	8	0	0
Small stock fattening	5	3	9	3	8	10	10	0
Milk production	0	0	0	0	0	0	0	9

1: Cattle ownership by the Peulh was estimated by the PEDI staff, as the survey results seemed far too low.
2: Results from the farmer positioning exercise (§ 7.4). From each category 10 farmers were asked to position themselves. The only exception was Category D in Koglabaraogo: the whole category of nine pastoralists was interviewed.

In Koglabaraogo, livestock fattening was a common practice and everybody paid much attention to the feed quality. In Gainsa, livestock practices differed greatly amongst the categories: wealthy men invested in barns and cattle fattening while the others concentrated on small stock fattening; young men put relatively more effort in the production of animal feed and; women kept some small stock but hardly invested in animal feed and vaccination.

To prepare the farmer discussions, the PEDI staff members matched the current farm behaviour with the SHARES technology levels. They classified the farm behaviour of the Mossi men and Mossi young men as T0-T6^{+}. The women and the pastoralists posed a problem, because they combined extensive arable farm techniques (T0-T2) with the application of manure. Staff members were tempted to add the SHARES technique T6, but this implied the application of manure, stone rows and animal traction. Neither the Mossi women nor the pastoralists applied stone rows and animal traction. Finally, it was decided to abandon T6. The farm practices of the women were classified as T0-T2^{+}, while the activities of the pastoralists were classified as T0-T2.

9.3 The staff-farmer dialogue: the importance of norms and values

The staff presented visuals of the SHARES options to the farmers, checked their comprehension and asked for their appreciation. Were the SHARES options realistic and/or inspiring? What were their current farm strategies and what were their ambitions? In the next sections the results of the dialogue of the PEDI staff members with the Mossi men, the Mossi women and the Peulh men are presented.

9.3.1 The debate between PEDI staff and the Mossi male farmers

The plausibility of the SHARES scenarios

The PEDI staff presented the SHARES options 'Max Cer, T0-T5', 'Max Cer, T0-T6', 'Max Rev, T0-T6' and 'Max Rev, T0-T7' of the Tables 9.1 and 9.2. Like the Gainsa farmers, the Koglabaraogo farmers were pleasantly surprised by the farm potential described by SHARES. The high production potential of livestock farming comforted them. They kept livestock as a form of capital reserve but SHARES showed that, in case of need, livestock activities could provide for all household needs.

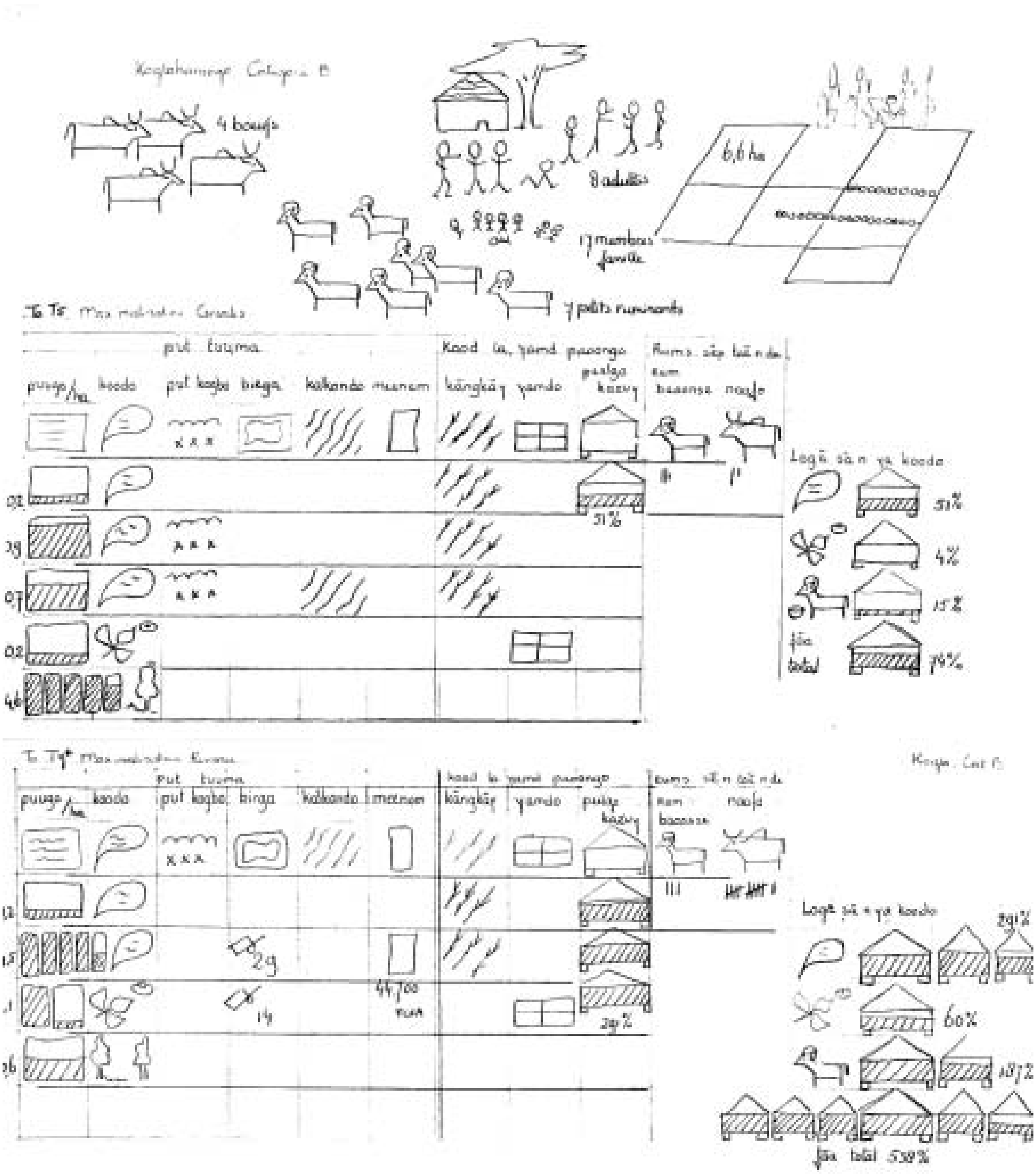

Figure 9.1: Pictures of the presentation of Category B in Koglabaraogo: household resources; results Max Cer, T0-T5; and Max Rev, T0-T7 [+]

According to the farmers, SHARES overestimated the cultivated area of category A: instead of 8.9 ha they rather cultivated 4 to 6 hectares. The estimate of 6.6 hectares category B was more realistic. The farmers aimed at technology level T0-T7^{+}. In 1999, they had not applied fertiliser because at the start of the season the weather conditions had not been promising. In 2000, the weather developed favourably and several farmers had applied NPK. They used fertiliser to complement the manure gifts. The main concern of the farmers was labour availability: they applied manure but they were not able to transport the recommended 90-100 loads (T0-T6, category A) or the 45 loads (T0-T6, category B). The category A farmers owned carts and managed to transport 20-45 loads of manure. Category B contented themselves with 15-20 loads of manure. To economise on labour for manure transport, half of the farmers purchased one or two 50 kg bags of NPK. They invested less in fertiliser than the quantity recommended by T0-T7, but the quantity applied improved the production sufficiently. They did not reach the SHARES predicted 300% cereal self-sufficiency, but this year the weather had been good and the granaries were filled: they were able to cover the household food needs of the next 2 years.

Table 9.8: Some descriptions of farm strategies of Mossi men in Koglabaraogo, 2000

Category A access to land (ha)	Sorghum & millet (ha)	Cowpea intercropped (ha)	Groundnut (ha)	Fallow (ha)	Manure (cartloads)	NPK[1)] (kg)	Estimated food self-sufficiency (%)
5.75	2.5	0.5	0.75	2	25	100	200
3.75	2.0	0.25	-	1.5	42	-	200
4.75	2.5	0.25	-	2	20	50	200
Category B access to land							
6.5	2.5	0.5	0.5	3	14	-	150
5.5	2.5	1.0	-	2	13	50	200

1: INERA recommended farmers to apply 75 kg NPK and 50 kg urea per ha. The innovative farmers of the PEDI programme opted for 50 kg NPK per ha. In 2000, 50 kg NPK cost 11,750 FCFA.

Food production versus revenue maximisation

Category A farmers had small areas with cash crops, while younger Category B farmers easily cultivated 0.5 to1.0 hectare of cash crops (Table 9.8). The younger farmers were tempted to follow the SHARES option 'Max rev' and they considered the increase of livestock fattening as well as the expansion of the cowpea area. They had doubts about the profitability of cowpea production. Firstly, cowpea was hard to conserve. Secondly, local traders sometimes refused to buy cowpea.

All category A farmers were puugsoba and they stressed the importance of food production. They complained about the behaviour of young men: even when the household food situation was not yet secured, youngsters longed for money to buy pretty clothes. From the point of view of the puugsoba food self-sufficiency was crucial and deserved first priority. Of course, in case of urgency, you could sell livestock to buy food, but this felt differently. Farmers fattened some livestock to earn money to cover the basic household needs, but it was important to establish a livestock herd, a capital reserve to guarantee the future of the household. One should not waste money on luxury goods.

Labour investment to increase farm production
Koglabaraogo farmers had participated in a study tour to Gainsa and they considered the Gainsa farmers as the champions of farming. They had been impressed by the dynamism of these farmers: the barns, the zaï, the cutting of hay, etc. “Gainsa farmers are the real role models of the PEDI recommended mixed farming.” Koglabaraogo farmers tried these techniques, but the results were unsatisfactory. For instance, the zaï did not produce. They did not carefully apply the PEDI instructions and they perceived themselves as ‘lazy farmers’.

The PEDI staff contested the ‘laziness’ and explained that, in contrast to Gainsa, Koglabaraogo farmers struggled with a labour shortage. The labour to land ratio was relatively low (Table 9.6) and the agricultural labourers worked hard. Staff members emphasised the results from the Tapsoba study (2000): in Koglabaraogo agricultural labourers spend about 25% more hours on farm activities than the labourers in the South of Sanmatenga (§ 3.1.6). The farmers admitted: they were at the limit of their capabilities. Labour shortage forced them to concentrate on labour saving techniques such as buying ploughs and donkey carts, and if necessary to substitute labour by inputs. The category A farmers owned the necessary implements, they applied large quantities of manure and they obtained good production results. The first priority of Category B farmers was the purchase of a plough and/or donkey cart. If there was no time available to treat the fields with manure, they bought some fertiliser to obtain the required production. To economise on labour, the farmers spend little time on the cutting and conservation of hay and rather bought cotton cake to supplement the animal diet.

Capital investment to increase farm production
The Category B farmers had clear investment plans: the purchase of ploughs and donkey carts. Their second priority was the acquisition of draught power. As soon as the requirements for arable farming were met, they would invest in livestock fattening (third priority). One head of cattle could fetch up to 150.000 FCFA (€ 229); an amount of money you would never earn with arable farming. The fourth priority was the purchase of fertiliser *not* to commercialise their farming but to economise on the transport of manure.

The category A farmers were in the situation aspired by Category B: they owned ploughs, donkey carts and draught animals; they fattened cattle and small stock to earn some extra cash; and they bought 50-100 kg NPK to ease the agricultural work of their household members. The category A farmers emphasised that they invested their farm surpluses in livestock. They would not increase their livestock fattening activity, but rather enlarge their livestock herd, the capital reserve for the future.

To increase farm production beyond basic needs coverage
The category A farmers emphasised the responsibility to ensure the long-term well being of the household. They detested farmers who exploited economic opportunities at the detriment of the household food situation. “Your granaries should be full. A prudent farmer anticipates on a bad agricultural season and fills his granaries to cover the food needs for at least two years. It is a social disgrace, when you sell agricultural produce to buy luxuries and in the end you are not able to provide for your family. Your lifestyle should be modest, to be able to pay for the ceremonial expenses and to slowly build up a herd.” The farmers were pleasantly surprised, when SHARES demonstrated that extensive livestock production could cover 160% of their household food needs: “Apparently, it is not necessary to worry about the survival of the family”.

The category B farmers shared the concern for the family food situation, but they were also eager to take advantage of economic opportunities. The SHARES presentation comforted them: it showed the economic potential of livestock farming. According to SHARES, livestock production generated enough income to cover 175% of the household food need. They were not used to selling the surplus of their livestock production and had never imagined the economic potential of livestock farming. According to SHARES, livestock production provided sufficient security to allow farmers to invest in risky, but profitable, arable farming or other commercial activities.

Price awareness
In principle, the farmers in category A produced to satisfy the basic household needs and to build up a capital reserve. They only sold agricultural produce, when in need of cash. The periodicity and magnitude of the household needs determined the type of sale: part of the harvest, chicken, small stock or cattle. Everything was sold at the local market.

The category B farmers planned their money earning activities and tried to take advantage of lucrative prices. They cultivated relatively large areas with cowpea and groundnut. Cowpea was sold in small quantities, to cover small cash needs. Farmers stored part of the cowpea harvest for home consumption. Groundnut was the real cash crop: farmers sold groundnut when the prices were favourable. They also fattened two to four head of livestock. They planned the fattening period to be able to sell around Tabaski. Non-fattened animals were only sold in case of emergency and dire cash needs: "You never sell an animal just to fetch a good price. If you have no clear idea about a proper investment, you easily waste the money you have earned."

The farms in Koglabaraogo had an economic potential, which remained untapped. Rather than exploiting their economic opportunities, the farmers adhered to the prevailing rules for production and exchange. There were clear social norms to produce your own food; to earn some cash to cover basic household needs and ceremonial expenses; and to build a capital reserve and a social network to guarantee the future of the household. The category A farmers upheld the subsistence ethic. The farmers in category B (mostly youngsters) aspired a more luxury lifestyle. They intended to make small changes and allowed themselves some room of manoeuvre with respect to the prevailing subsistence ethic.

9.3.2 The debate between PEDI staff and the Mossi female farmers

The plausibility of the SHARES scenarios
The women had great difficulty to estimate their production areas so it was difficult to confront the SHARES runs with their farm reality. They estimated that half of the area was covered with cereals and the other half with leguminous crops. They had no access to manure and used straw and household waste to improve soil fertility. When looking at the SHARES visuals, they thought that their current farm practices more or less resembled 'Max Rev, T0-T5'. Despite the good weather conditions, they did not produce the quantities presented in the SHARES visual (268% food self-sufficiency). They harvested just enough food to cover the food needs for one year. These remarks corresponded with the statements of the women in Gainsa: a woman supported 2 to 2.5 household members instead of the assumed 1.5 household members. If this was taken into account the food self-sufficiency level dropped to 134%, implying that the women just attained basic needs coverage.

Food production versus revenue maximisation
The women stressed the importance of food production, but admitted that they also cultivated a considerable area of cash crops. To earn some extra money, they engaged in petty trade and the fattening of small stock. These activities did not compete with food production.

Labour investment to increase farm production
The women exploited their own labour as much as possible. Because most of them also worked at the puugo, they had little time left to cultivate their individual plots. The women were not able to mobilise the labour necessary to construct SWC measures and they had no access to ploughs; hence they concentrated on mulching and the application of household waste. They expressed their interest in compost trays[75], to compost small quantities of manure, crop residues and household waste. During the agricultural season, the women were fully occupied with arable farming and their household chores, but in the dry season, they generated some extra income with livestock fattening and petty trade.

Capital investment to increase farm production
If money was available, the women bought cereals, cowpea and groundnut just after the harvest, when the prices were low. Later, they could sell the products at a higher price, process it for sale (e.g., beer, groundnut oil or cake) or use it to feed the family. Second priority was livestock fattening. Each year, all women purchased a sheep to fatten and to sell at Tabaski. They cut some grass and bought cotton cake to supplement the animal diet. The third priority was the household security: to accumulate livestock wealth. Most beolgsoba had a sheep and the puugsoba owned two or three small stock to ensure the future of their household. They emphasised that they would never invest money in arable farming: the activity was too risky.

To increase farm production beyond basic needs coverage
In a good rainy year, they just managed to make ends meet. The women had to provide cereals for one meal, each day. Their husbands provided for the other meal. If their food stock did not suffice, they minimised the portions and expected their husbands to increase their contribution. Given the circumstances, it was inappropriate to talk about production beyond basic needs level.

Price awareness
Right after the harvest, when the prices were low, women bought cereals and cash crops. They speculated with a part of the stock they purchased. The fattened sheep were sold at Tabaski. Because of their domestic responsibilities, women were not very mobile and they sold their produce at nearby markets.

Summarising one could say that women had few resources and struggled to make ends meet. They were responsible for the provision of cereals and the sauce ingredients and often bought their own clothing. To fulfil their obligations, they cultivated cereals as well as cash crops. If they had the opportunity, they invested and speculated with petty trade and livestock fattening. They would not invest money in arable farming, because they perceived it as too risky.

[75] A compost pit measured 14.4m^3. This volume was much too big for the women, hence PEDI introduced compost trays measuring 3m^3. This enabled them to treat 0.8 hectare.

9.3.3 The debate between the PEDI staff and the Peulh pastoralists

For pastoralists, the main activity was livestock rearing and it was not considered appropriate to present various options for arable farming. Other studies such as Zaal (1998) indicate that pastoralists aspire big herds and only sell milk and meat to cover daily living expenses. In Koglabaraogo, the Peulh had small cereal fields to complement the milk diet of their families. PEDI staff assumed that pastoralists aimed at food self-sufficiency and the growth of their herd. They spend little or no money on agricultural inputs. The staff, therefore, presented the SHARES option 'Max Cer, T0-T6'[76]. This option resembled the actual farm practices, but also visualised the economic value of the non-sold livestock production.

The plausibility of the SHARES runs

For the pastoralists, the plausibility of the SHARES runs depended on realism of the predicted livestock herd. For the Peulh, staff relaxed the condition of the 50% cereal self-sufficiency and the pastoralists were free to allocate their labour resources to livestock farming. According to SHARES, land and labour availability sufficed to keep 20 head of cattle and 29 goats/sheep. Was the predicted livestock herd realistic? Staff confronted the Peulh farmers with their underreported livestock wealth: "How should we interpret the interview results: an average pastoralist has 5 head of cattle, while an average Category A farmer owns 12.7 head of cattle? From other studies, we estimated that a Koglabaraogo pastoralist owns about 38 head of cattle. What is, according to you, a plausible estimation of the pastoralist livestock herd? We ask you to consider the herd in the vicinity of Koglabaraogo as well as those grazing at the pastures of Djibou[77]." The Peulh received the SHARES data, the staff assumptions and the questioning with mixed feelings: it touched upon the pastoralist pride but also on their need for secrecy. While considering the reported livestock wealth of Category A, the pastoralists acknowledged that each of them owned about 15 to 20 head of cattle. In public, it was impossible to obtain more reliable livestock data and staff accepted the answer.

According to the Peulh, they consumed their arable farm production. They also consumed part of the milk and sold another part to cover daily expenses. If possible, they kept the meat: they preferred to increase their herd and only slaughter animals when in need of cash. The SHARES run 'Max Cer, T0-T6' (Table 9.5) gave a plausible production estimate: Peulh farmers cultivated 83% of their land (0.8 hectare) with cereals and 17% with cowpea and groundnut. It was not uncommon that Mossi farmers assisted with 5-6 cartloads of manure. According to SHARES, the milk production largely sufficed to cover the daily household needs. The pastoralists did not need to sell livestock, but could easily live from the cereal and milk production.

Food production versus revenue maximisation

Peulh farmers aimed at food production and not at the maximisation of the revenue. While moving around, they sold their milk in nearby villages but most pastures were at great

[76] Max Cer means that priority is given to cereal production. At the second iteration, all remaining resources are used to maximise the revenue. Max Rev leads to a maximisation of the cash crop area and livestock production (milk and meat). Cereal production and livestock farming do not compete, so the farm objective 'Max Cer' more or less covered the Peulh farm strategy.

[77] The Peulh families in Koglabaraogo had relatives in and around Djibou, a northern pastoral area with an important livestock market. Pastoralists pose a conceptual problem for SHARES. SHARES is a land based model and has great difficulty to cope with livestock moving in and out of the village borders: in the model land is a finite and fixed resource. Whatever livestock was herded in Djibou should not be (fully) included in the production in Koglabaraogo, yet the animals were available to the families if they needed them.

distance from the consumer markets. The pastoralists had a modest lifestyle: they sold agricultural produce to cover the basic needs and took pride in the growth of their herd.

Labour investment to increase production
Peulh farmers identified themselves as herdsmen. They practised transhumance and put much effort in the care of the animals, especially of the ones selected to give birth and to produce milk. They preferred to live of transhumance rather than to work in the fields. Like SHARES, they estimated that it was more profitable to concentrate on livestock rearing.

Capital investment to increase production
The Peulh farmers invested small amounts of money in vaccination, control of parasites and the construction of wells. Apart from this, all money was invested in the purchase of animals.

To increase farm production beyond basic needs coverage
The farmers adhered to a modest lifestyle, to minimise livestock sales and to increase their herd.

Price awareness
The farmers sold milk and animals when they needed cash and hardly looked for marketing opportunities.

9.4 Computer model enhanced learning

The SHARES exercise in Koglabaraogo enabled the staff members:

a. To gain insight in the relation between labour scarcity and farm strategies, and the need to seriously consider the labour requirements of the farm techniques they promoted.
b. To better understand the reasoning of the farmers, the mental model that underpinned their actions, especially the significance of norms and values for farm strategies and farming behaviour.

Labour scarcity
For Koglabaraogo, SHARES generated higher farm revenues for 'T0-T7' than for 'T0-T6'. This had not been the case in Gainsa. Here T0-T7 and T0-T6 produced almost equal revenues. The only explanation possible was labour scarcity.

So far, PEDI extension officers had paid little attention to the issue of labour shortage. Staff members were aware of the relatively low labour/land ratio, but had no idea to what degree labour actually limited farm production. They indiscriminately informed everybody about all possible farm techniques, whether labour demanding or labour saving. Every year, PEDI organised farmer study tours and encouraged farmers to test all the techniques they considered beneficial. In this way, Koglabaraogo farmers had started to apply the labour intensive zaï technique.

The SHARES analysis pointed to the limiting effect of labour. During the farmer discussions the staff learned that the situation was even worse than predicted by SHARES. For instance, in reality farmers only applied half of the amount of manure that SHARES recommended, simply because they lacked the necessary labour. The farmers' prime concern was labour scarcity: they looked for labour saving techniques and prioritised the purchase of ploughs and donkey carts.

SHARES had underestimated the labour problem. This might be due to the problem of obtaining reliable data on labour productivity (the data collection is extremely laborious). Another explanation is the ignorance of the overall health conditions: during the agricultural season, people are weak and easily fall ill. This aspect had not been included in the SHARES model. Nonetheless, through the discussions the PEDI staff was alerted to the seriousness of the labour problem and the need to concentrate on labour saving farm strategies.

The moral economy
Koglabaraogo was a village with abundant land and hence a reasonable agricultural potential[78]. In such a village, the PEDI staff expected farmers to easily ensure their food requirements and to apply an economic rationality. After the confrontation with the poor prospects for Gainsa village, the staff welcomed the favourable results for Koglabaraogo and felt relieved: at least in part of the intervention zone, the ambitious PEDI objectives seemed appropriate.

The staff members remembered the farmer rationality that dominated their youth, but assumed that farmers had passed through a similar development as they themselves had gone through. In their mind, rural development was synonymous with commercialisation and globalisation. They took it for granted that, as soon as minimum food needs were secured, the rural economy would gradually integrate into the larger economic system.

The farmer discussions confronted staff with a different perspective. Farmer thinking had evolved differently. Experiences taught them to put no unconditional trust in institutions such as markets, government structures and scientific knowledge: they did not always prove to be appropriate and beneficial. In contrast to the staff members, they did not perceive economic rules and state law as generally applicable and for them money did not serve as a common denominator for exchange. They simultaneously used different rationalities.

Koglabaraogo farmers stressed the importance of norms and values for their farm strategy. They adhered to a subsistence ethic, which called upon members of the *moral economy*[79] to live modestly and to share what is needed for subsistence (Scott, 1976). Production and exchange should serve to build up social relations, as these were the best guarantee for social security of the individual and the long-term survival of the larger social unit, to which he or she belonged.

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[78] Note that we are still talking about relative poverty. According to SHARES, the highest farm revenue per capita was 108,000 FCFA (€ 164,90) per year for a Mossi household and 144,549 FCFA (€ 220.69) per year for a Peulh household.
[79] Shipton (1989) and Mazzucato & Niemeijer (2000) use the concept of ‘cultural economy’. They state that rationality is embedded. It is locally and historically situated and therefore they treat social institutions as key factors determining the organisation of economic activity. This leads them to call the ‘local economy’ a ‘cultural economy’. I take this argument one step further. Institutions refer to the structural properties of actor-networks. In this thesis, we distinguish three intermediate variables to which people orient themselves: the stock of knowledge, the stock of norms and values and the stock of resources. The farmer discussions in Koglabaraogo confirmed the view of Platteau (1992) that it is not the context as such, but the ruling system of norms and values that determines the degree of legitimacy and acceptability of particular arrangements in the eyes of its participants. The concept ‘moral economy’ is more precise and has more analytical power than the concept ‘cultural economy’.

Subsistence farming meant production for direct use. To ensure the satisfaction of different needs, farmers engaged in various activities for production and exchange. The farmers had a *repetoire of options* and did not confine themselves to the economic rationality aimed at profit maximisation but they simultaneously used several lines of social organisation, modes of thinking, modes of legitimisation and modes of exchange (Vel, 1994). In other words, they engaged themselves in various actor-networks, each with its own rules of interpretation, norms and values, and power resources. Farmers applied a different rationality for food-related activities, income generating activities, material wealth and social capital related activities[80]. For instance, farmers were more inclined to spend money on fertiliser for cash crops than on food crops.

Farmers had a gamut of options but through time they developed certain preferences. They obtained certain resources through specific actor-networks. This explains why Koglabaraogo farmers insisted on food production rather than on the purchase of food and why they perceive it as a disgrace to sell cattle to buy food. Each actor network had its own morality and attributed different exchange values to the resources. SHARES used local market prices as a common denominator, but farmers had no single standard in which exchange values could be expressed and they did not freely exchange resources between actor-networks. They only applied the economic rationality, market prices, the purchase of inputs, cost-benefit analyses etc. for explicit cash earning activities. Depending on their access to resources, social responsibilities, personal needs and ambitions, farmers allocated resources to the various actor-networks. For example, they allocated land and labour to food production and cash crops; they selected animals for fattening and sale, but the sale of non-fattened livestock was an emergency measure. Farmers did not maximise food production and/or farm revenue. They delicately balanced their involvement in actor-networks to optimise (what they considered to be) their well-being.[81]

In Koglabaraogo, staff members learned about the prevalence of the norms and values. When talking with the Gainsa farmers, staff members recognised the poor biophysical conditions but they did not yet perceive a profound difference in perception and logic. In Koglabaraogo, it became evident that farmers reasoned differently than staff members had assumed. Despite their economic potential, most farmers insisted on the continuation of their modest lifestyle and the need to guarantee the future of the household. The Antenne-PEDI household study already hinted at the importance of the collective well-being of the household in the north of Sanmatenga (Table 3.5): the male puugsoba firmly controlled the land and labour resources and beolgsoba had little opportunity to pursue their personal tasks and interests. Despite the relative wealth of their husbands, Koglabaraogo women struggled to fulfil their household responsibilities. Their livestock wealth was similar to, or even less than, that of their counterparts in Gainsa.

Mossi as well as Peulh adhered to the moral economy. Both ethnic groups had a high agricultural potential they could exploit, but they preferred a modest lifestyle to ensure the

[80] Social capital: the social resources (networks, social relations, affiliations, associations, norms, trust and disposition to work for the common good) upon which people can draw to secure their livelihood (Gottret & White, 2001).

[81] Various scientists (Geertz 1963; Vel, 1994) pointed at the prevalence of the moral economy in societies, where the deceased were believed to live on in the world of spirits and to determine the well-being of the living. Zanen (1996:102) notes that the Mossi belief discerns a world of the bush and the spirits (*kinkirsi*) and a world of the village and the living. The living are incarnations of the *kinkirsi* from the bush and after death the spirits leave the body to transform again into *kinkirsi. Kinkirsi* accompany the living and they can be consulted. Sometimes they bring fortune, sometimes misfortune.

future of their household. Young men seemed eager to increase their involvement in commercial activities, but this does not yet prove a change of norms: most youngsters changed their priorities as soon as they took up household responsibilities.

Staff members learned that farmers did not farm as recommended by the SHARES scenarios: they never concentrated on one or two farm objectives, but simultaneously considered multiple objectives and activities. SHARES demonstrated a high commercial potential and therewith promoted an economic farm rationality. Farmers took notice of their ‘commercial potential’, but those in control (the male puugsoba) preferred a modest lifestyle and multiple goal farming. Through various iterations, MGLP models are able to explore multiple goal farming, but SHARES did not cover all the objectives and activities that were valued by the farmers. Nevertheless, SHARES had fulfilled its purpose: it enabled staff to present their farm logic and to elicit the reactions and comments of the farmers.

The farmers appreciated the discussions, hoped that the staff better understood their situation and would soon deliver the necessary support. They were impatient and feared a break in extension activities during the PEDI reformulation phase.

Photo viii: Goats at the compound

10 Conclusive summary and recommendations

This chapter presents the conclusions of the research and makes recommendations for MGLP enhanced learning. Section 10.1 shortly dwells on the origin of the research question. It highlights the problems that scientists experience when they design models for operational use. Section 10.2 describes the need for and the construction of a new theoretical framework. This framework should connect β- and γ-sciences and help to gain a joint understanding of complex issues such as modelling for NRM. Section 10.3 summarises the field research and provides the answers to the research questions. In section 10.4, the reader finds some additional insights about computer-based learning that emerged during the research process. These insights lead to the recommendations for MGLP enhanced learning (10.5). Finally, in Section 10.6, the relevance of this study for β-γ professionals, scientists as well as extension workers is discussed.

10.1 The origin of the research

Since the 1970s, Wageningen University is known for its WMS based on the 'systems thinking' of the late C.T. de Wit. It all started when De Wit expressed biophysical processes in mathematical equations, which resulted in simulation models. Computer technology allowed scientists to gain insight in the multi-level interaction of various biophysical processes and to identify knowledge gaps. Modelling enhanced interdisciplinary collaboration, systems research and scientific understanding.

From 1980 onwards, the emphasis shifted to the practical application of the results. Agro-ecological zonation, quantitative land evaluation and yield prediction required exploratory data that were impossible to obtain using conventional methods (Bouman *et al.,* 1996). The idea of using MGLP models for land use analysis (De Wit *et al*., 1988), improved the practical relevance of modelling, because it matched biophysical and technical potentials with assumed societal demands. An MGLP model was called a 'decision support device'. The aim was to assist users (policy makers, agronomic researchers, extension workers and farmers) to make well-informed decisions. MGLP modelling meant a new challenge; it stimulated biophysical, technical and economic scientists to collaborate and develop a more holistic perspective on contemporary land use problems (WRR, 1992; Penning de Vries *et al*., 1995; Van Rheenen, 1995; Rossing *et al.,* 1997a; 1997b; Van Ittersum *et al*., 1998; Schipper *et al.,* 2000; Bessembinder *et al*., 2000; Kruseman & Bade, 1998; Kruseman, 2000; Roetter *et al*., 2000).

At this moment, land use modelling is at a crossroads (Newman *et al.,* 1999; Stroosnijder, 2000; Walker & Zhu, 2000; McCown, 2002a). Modelling had a clear impact on agricultural science, but the models are hardly used by policy makers and farmers. Several reasons have been forwarded to explain the limited use. Some are of a technical nature (Hilhorst & Manders, 1995; Walker & Zhu 2000) but the most fundamental ones are rooted in the observation that MGLP modelling was based on the positivist epistemology: scientists deal with 'facts' which are as they are and which can be known objectively. MGLP is referred to as the 'facts-alternatives-choice' methodology: scientific facts, employed in rigorous modelling, determine the 'correct' choices and decisions for people to take. "Modelling scientists do not understand that the outcomes of their modelling can be rejected because they are not as satisfactory as the 'non-scientific' practices previously used" (David, 2001: 460). One question keeps recurring: "Why are so many models built and so few used."

The answer to this question can only be understood by applying a constructivist epistemology. This epistemology recognises that all knowledge, scientific knowledge as well as local stakeholder knowledge, is socially constructed. These 'constructions' evolve selectively; they are historically and culturally embedded, and continuously recreated through experimentation and communication (Knorr-Cetina, 1981; Latour, 1987). All sciences are constructive rather than descriptive: "the products of science are contextually specific constructions, which bear the mark of their situational contingency and interest structure" (Knorr-Cetina, 1984: 227).

Constructivism is not the opposite of realism. It may be that a causal explanation is valid, but we should accept the hermeneutic or interpretive notion of social reality. Interpreting subjects orient their behaviour to the outside world to be able to survive. Their knowledge is partial: some phenomena are identified, discussed and empirically tested. It is important to recognise that knowledge is never context-free and that actors need to integrate their knowledge, both to get a better understanding of the outside world and to improve their performance.

When analysing MGLP modelling from a constructivist perspective, the following observations can be made:

a) MGLP modelling is not neutral, but target-oriented. The envisaged targets are predefined (i.e., assumed by the scientists) and the required combinations of agricultural practices and inputs are quantified (Van Ittersum & Rabbinge, 1997).
b) To identify optimal solutions, MGLP models explore the biophysical and technical boundaries and match them with predefined objectives. MGLP models focus on agro-ecological properties, the so-called 'hard system', and consider human actors as 'soft systems', which can be engineered (Veldkamp & Fresco, 1997; Leeuwis, 1999b).
c) MGLP models work on the basis of an old Wageningen adage: 'our aim is to develop the best technical means for given human needs'.

The target-orientation and biophysical character of MGLP models imply that the methodology is only useful to explore certain issues from a certain perspective and that the solution will be sought within a range of predefined alternatives. Considering that all human actors have a specific perspective, interests and efficacy, it is likely that the envisaged target and the solutions proposed by the scientists diverge in one way or another from those of the policy makers and the farmers. To provide relevant advice, model designers are obliged to actively search for the perspectives and the issues at stake of the envisaged users. Brinkman was one of the first to urge model designers to draft simple land management plans and to modify them after discussion with the local community: "A plan based on imperfect information but having the agreement and consensus of the people and the government is better than a 'perfect' plan prepared without people" (Brinkman, 1994: 20). He made a plea to replace the concept of land use planning by that of 'land use negotiation'. Up till now, model designers struggle with the integration of the user perspective. So far, only few models have had an impact on decision-making. They are often rejected (Newman *et al.*, 1999) or trigger discussion on the perspective and the assumptions (Van Ittersum *et al.,* 1998).

Can computer-based models enhance learning? So far, there has been little end-user research to explore the effectiveness of MGLP models as learning tools. This kind of research is delicate. It more or less evaluates the utility of land use modelling, an activity in which much funding, scientific work and reputations have been invested in. Model designers have to make themselves vulnerable to be able to let outsiders critically look at the ins and outs of their enterprise: often they would have to train the outsider/user in the semantics and the logic of the model only to be criticised as a reward. The Antenne Sahélienne pursued this challenge and assisted the PEDI project in scrutinising their own work. This rare opportunity allowed me to pose the central question of this study: Can computer-based land use models enhance learning for natural resource management? And if so, under what conditions?

10.2 A new theoretical framework: The learning actor-network

The study applied a hermeneutic research approach. The subject of the study was the relation between computer models, the intended users c.q. stakeholders and natural resource management. This calls for a theoretical framework capable of analysing the internal dynamics and interaction of material *and* human entities[82].

Initially, the actor-network theory (ANT) (Callon, 1987; Law, 1987; 1992; 1994) seemed useful: it studied the interaction and continuous reshaping of 'collectifs', ordered networks of human *and* non-human entities. However, the fact that ANT did not attribute agency to people became a problem. I decided to take an eclectic approach and I have adapted the theoretical framework to what I have called 'the learning actor-network'. This framework enabled me to analyse the issue of computer model enhanced learning for natural resource management. I consider this as a useful guide for beta-gamma professionals.

10.2.1 The fusion of the actor-network theory and the actor-oriented approach

ANT draws on structuralism and post-structuralism (Law, 1994) and defines agency as a product of cultural and material structure. According to ANT, people and objects as such do not act (Law, 1994). The process in which sets of relations between projects[83], interests, goals and naturally occurring entities are proposed and brought into being is called 'translation' (Law, 1992). In the course of translation, different forms of knowledge and action emerge as 'necessary points of passage' (Callon, 1987).

In contrast, the actor-oriented approach (Long 1992; Long & Van der Ploeg, 1989; 1994; 1995) attributes agency to human actors. This theory is inspired by post-modern ideas. Post-modernists emphasise plurality, ambivalence, open-endedness, indeterminacy and contingency. The society is fragmented and multiple; there are different actor-networks, life-worlds and rationalities, and actors have the possibility to choose. The actor-oriented approach takes the view that individual actors have agency even under the most extreme forms of coercion (Long, 1992).

[82] This study focuses on 'model-enhanced learning' and necessarily deals with the characteristics of computer-models as fixed artifacts. It concerns a specific type of computer-based learning. Other studies focus on 'modeling enhanced learning': model designers work along with the stakeholders; they model the knowledge forwarded by the stakeholders to gain insights in the (possible) consequences of the stakeholder logic and action (Lynam *et al.,* 2002). Here modeling is part and parcel of the integrated learning process. In this study, the modeling part is executed and final; hence the question is whether an existing model is of use to stakeholder learning.

[83] We use the term 'project' rather than activity, because the word project reminds us of the verb 'to project' and refers to actual as well as envisaged activities (Van der Ploeg, 1999: 19).

Giddens (1984) was one of the first to problematise the issue of agency and structure. Social systems provide meaning and order: they structure the conduct of knowledgeable actors. Structure is not only the medium, but also the outcome of the conduct it recursively organises. In their interaction, and by using rules of interpretation, normative rules and power resources, actors produce and reproduce the 'structural properties': signification, legitimation and domination (see Figure 4.1).

There is a variety of rules and resources that actor-networks and individual actors can create or draw upon. Each specific compilation of knowledge, norms and resources conveys certain structural properties or mode of order. The creation or the use of a specific body of knowledge is inherently connected to the operation of norms and power in social interaction. The mode of order is no stable entity. There is room for manoeuvre and people continuously choose and actively negotiate rules of interpretation, normative rules and resources (Leeuwis, 1993: 105).

To study model-enhanced learning, I needed a theoretical framework that focuses on issues such as interaction, mode of order, agency and rationality. It was essential that the theory did justice to the influence of structure as well as to human agency. I therefore applied an eclectic approach and worked from the assumptions that:

- Actor-networks consist of ordered networks of human and/or non-human entities;
- Actor-networks differ in size, are nested, interlocked and distantiated. Each network, time and locality has its own specific mode of order and agency.
- Network structure (formalised, material embodied or tacit knowledge, norms and power relations) shape human thinking and behaviour, determining the room for manoeuvre and agency of individual actors. Structure and agency are continuously changing, recursively organising one another.

10.2.2 The integration of the theory of planned action

To come to grips with the phenomena of action and learning at the individual level, I integrated elements of the 'theory of reasoned action' (Ajzen and Fishbein, 1980) and the subsequent 'theory of planned action' (Ajzen & Madden, 1986; Ajzen, 1988). Based on these theories, socio-psychologists identify three intermediate variables that account for the relations between external variables and any kind of behaviour that is under an individual's volitional control: (a) beliefs about the outcome of actions; (b) subjective norms about what one is supposed to do; and (c) perceived self-efficacy. The three intermediate variables are constructs, which are interdependent and inseparable. Together they constitute the frame of reference people draw upon.

People develop a frame of reference in accordance with their context. The question remains which external variables influence a person's construction of belief, norms and notion of self-efficacy and subsequent action. To be able to answer this question aspects of the actor-network are needed as it emphasises the importance of one's own actor-network and projects, other actor-networks and their projects, and the resources available to implement projects and to mobilise actor-networks. The amalgam of the above theories led to the framework of 'the learning actor-network' (Figure 4.3). Individual actors as well as actor-networks have structural properties (their frame of reference) and a certain agency (the capability to make a difference and change the sequence of events); they deal with the environment on the basis of learning and inventing what works.

10.2.3 Learning for coherence and correspondence

Concepts on the process of learning were also added to the framework. Learning starts with a problem; some kind of gap; a difference; a disparity between the way things are and the way one wants them to be (Smith, 1988: 1491; Weick, 1995: 88; Argyris & Schön, 1996). Learning or active sense making aims at the reduction of ambiguity and uncertainty.

Learning to reduce the ambiguity of interpretation means learning for coherence. At an individual level, actors feel most comfortable when there is a certain coherence between their perception, frame of reference and action. At the social level, individual actors participate in various actor-networks, with which they share the knowledge, values and actions. Individual actors as well as actor-networks interact: they opt for communicative or strategic learning. They converge or distantiate to get a univocal frame of reference to guide future activities. Convergence or communicative learning, demands (a) reflexive learning, which means the increased awareness of one's own and other people's historical position, and the discovery of tacit theories, assumptions, norms and values that shape the behaviour (Delanty, 1997; Groot & Maarleveld, 2000); and (b) transformative learning, which means that people no longer take their own frame of reference and interests for granted.

Learning to reduce uncertainty is linked to learning for correspondence. The idea behind it is that our incremental body of knowledge and subsequent behaviour should increasingly correspond with the dynamics of the outside world. Learning for correspondence is often instrumental learning because it helps us to attain a desired situation.

Integrative, inclusive or co-learning requires a (partly) shared frame of reference and/or a joint exploration of the outside world. Co-learning for natural resource management is action oriented; co-learning processes consist of learning for coherence and learning for correspondence.

Models are fixed products and they represent the knowledge, the values and the preferred action of the model designers. Models can be seen as part of the model designers network, but also as an independent actor-network. A model as such is normative: it has fixed knowledge and values and promotes certain actions. Models may provide users with interesting knowledge and activities, which help them to attain their desired situation. However, models are inflexible: they lack the capability to incorporate the users' perspective and can only promote the predefined solutions and actions. Users have no other option than to go along or to reject the model's point of view.

10.3 The synthesis and conclusions of the research

10.3.1 Research question (a): What is the match of interest between the model and the potential users?

MGLP models explore land use options. In fact, they aim at improved understanding and action of people within the dynamics of the outside world: in other words, they aim at correspondence. Literature on the operational use of models (§ 4.2) suggests that models are used for learning, if there is a match of beliefs (type of knowledge, level of inquiry and model boundary), values (what is deemed important), key interests (issues at stake that the user feels he is able to control). Imperfect matches can be (partially) overcome by the flexibility and room for manoeuvre built into the model and by favourable working conditions such as the availability of support or the work ambiance.

In other words, the literature suggests (a) that models aim at learning for correspondence and (b) that a (partial) convergence of the frames of reference of the model and the user is a prerequisite for model use. Models are fixed artefacts. They cannot reframe to adjust to its user, nor do they have much power to influence the user to adjust his frame of reference. From the start, there should be a certain area of common interest.

The first part of the research question is about the match of interests and the capabilities incorporated in the SHARES model and those of the potential beneficiaries. The SHARES model, the questions posed by the PEDI extension staff[84] and the discussions with the local population revealed the perspective and interests of the different parties. The study of secondary material (Chapter 2 and 3) and participatory observation allowed me to put the various observations and findings in their context.

The local population identified a wide range of issues: conflicts about the use of valley areas and waterholes, mismanagement of forestry resources and the technical innovation of farming. However, they felt they were not authorised to deal with valley, waterhole and forestry problems (perceived self-efficacy), hence their learning interests centred on technical farm improvements.

The PEDI staff members primarily reasoned from their professional, technical perspective. They were acquainted with the Mossi-Peulh conflicts and with organisational and authority problems relating to common resources, but they did not want to intervene. The Gestion du Terroir Villageois approach, proclaimed in 1986, had not yet been implemented. In February 2000, the government ratified the legal status of village natural resource committees (CVGT) but it still had not informed the local authorities. Until that moment, it was deemed inappropriate to discuss institutional aspects of village natural resource management so the staff concentrated on technical aspects.

The MGLP methodology as such can explore all kinds of technical farm issues, but the SHARES model did not include all elements that were of interest to its users. SHARES was a village level model, which explored the land use situations of different farmer categories. SHARES concentrated on the understanding of present land use practices and included only a few innovative practices. The PEDI staff and the farmers focussed on the individual farm level and they wanted to explore innovative farm practices. The frames of references of the farmers and the PEDI staff hardly matched with those of SHARES (Table 10.1). There was only a limited opportunity to use SHARES for learning for correspondence.

[84] The fieldwork was executed at PEDI, an integrated rural development project in Sanmatenga province. The project had an interest in agriculture and natural resource management. For a detailed description refer to §3.3

Table 10.1: The knowledge, interests and capabilities of the MGLP methodology, the SHARES model and the intended beneficiaries

MGLP methodology	
Belief/rules of interpretation	Technical, biophysical and economic elements and relations. Level of inquiry: a geographically fixed area.
Learning interest	Exploration of outer boundaries of the technical and biophysical potential. Identification of technical and resource allocation opportunities. No political, ideological or organisational pursuits.
Support for computer-based learning for NRM	MGLP models are not user-friendly for non-specialists
SHARES model	
Belief/rules of interpretation	Land bound biophysical processes and *applied* agricultural practices, especially SWC measures. Level of inquiry: Village level and aggregate levels of farmers of specific categories.
Learning interest	Outer boundary of the technical and physical potential. The effect on levels of intensification of arable farming on welfare (revenue, production & food self-sufficiency) and land degradation (soil loss & N-loss)
Support for computer-based learning for NRM	SHARES was not user-friendly. Limited support offered by Antenne Sahélienne, but daily support by interested project consultant/husband
PEDI Staff	
Belief/rules of interpretation	Techniques, the productivity and profitability of agricultural practices. Level of inquiry: per hectare and, if possible, also per farmer or household.
Learning interest	Techniques, the productivity and profitability of *promising* agricultural practices, notably fertiliser application and intensive livestock farming Tacit: farmer situation and rationality
Self-efficacy computer-based learning for NRM	Capable to handle MGLP models if sufficient training is provided. Limited priority given to model use.
Village population	
Belief/rules of interpretation	Ideological, organisational and political issues as well as technical farm issues. Level of inquiry: Farmer livelihood, household food self-sufficiency.
Learning interest	Techniques and the productivity of promising agricultural practices, notably fertiliser application, rainy-season composting, zaï, harvest preservation, livestock fattening and breed improvement.
Self-efficacy computer-based learning for NRM	Farmers are predominantly illiterate and will always need an intermediary to handle and interpret computer models.

10.3.2 Research question (b): How does model use affect the learning process of the users?

Learning for natural resource management requires a continuous iteration between instrumental, communicative and strategic learning. Stakeholders, consciously or unconsciously, seek coherence and correspondence.

Learning for correspondence

During the first acquaintance with SHARES, the PEDI staff members primarily reasoned from their professional and technical perspective. Like SHARES, they looked for technical and economical farm improvements. Nevertheless, it seemed not helpful to use SHARES, because the model included only a few new techniques. At first, SHARES did not fit the learning needs of the staff.

The contingency of learning
Learning bears the mark of situational contingency. The staff members were primarily interested in the technical and economic details of agriculture, but the project work forced them to also consider the communication aspects. The approaching project reformulation and the donor's insistence on bottom-up approaches triggered a sense of urgency: after all the years of reflection on, and testing of participatory tools, the PEDI staff finally had to come up with a comprehensive approach. An unfortunate CNRM test was the immediate cause for the PEDI action-research: the staff realised that they had to join forces and work on a univocal extension approach. The main question was: how to start co-learning? How could farmers be stimulated to make their own analysis of the farm situation and identify learning needs? At first, SHARES did not seem useful because it offered specific analyses and solutions and did not really stimulate users to make their own analysis. The staff put more trust in PRA tools and started with natural resource mapping.

Bottlenecks for co-learning
The PRA sessions lacked a guiding framework and farmers did not know what they were heading for. The staff had explained that the aim of the discussion was 'to attain improved natural resource management', but there were various ways to achieve this goal. The farmers recalled PEDI's interest in SWC measures and demanded material support for SWC. They did not consider or feel like learning for technological or institutional change. Nevertheless, PEDI staff wanted to test farmer learning. They restarted the action-research and increased their control on the diagnostic process.

This time, the staff opted for a very structured framework (farm intensification matrixes coupled with a farm strengths-weaknesses analysis) and they urged farmers to identify material support *and* learning needs. Now, learning needs did come up but farmers still underlined the importance of material support. Apparently, they preferred the short-term gains to the uncertain joint learning processes.

A new insight: the requisite of learning for coherence
The staff members saw farmer learning as a new professional challenge. They now possessed a list of task-related learning needs, but they sensed that they still had no clue about the farmer reasoning. Farmers behaved differently than expected. The staff felt they were committed to the farmers, but in one way or another, they worked from a different perspective. To assist farmers with their development and to properly assess the desirability of farming options, they needed more understanding of the farmer's life-world and farming strategies. In fact, they recognised that joint learning for correspondence (task-related learning) required a convergence of perspectives and, for that matter, learning for coherence. The only way out was to problematise the very issue of perspectives and envisaged strategies.

SHARES as a tool to trigger reflexive learning
SHARES was a clear and consistent representation of economic and technical reasoning. When handling the model, it occurred to the staff that SHARES was straightforward in its reasoning and sometimes proposed farm options that they knew were unacceptable to the farmers. This gave them the idea to use SHARES to trigger the necessary debate on farm development perspectives.

For the sake of the debate, the staff decided to put their case in black-and-white: they presented and defended the economic and technical SHARES perspective. In this perspective, farm strategies ranged from 'extensive farming, aimed at food self-sufficiency' to 'intensive farming, aimed at revenue maximisation'. With the help of the SHARES model, the staff developed concrete examples of farm strategies for each farmer category. In this way, it was most likely that the farmers would identify themselves with the described situation, would feel confronted and challenged to respond. They would defend their own farm behaviour and, where necessary, refute the model's logic. The staff encouraged farmers to be critical and they added some questions to stimulate the discussion. It was crucial that the staff decided to be explicit about their own perspective and that they made real efforts to understand the local population.

Shares enhanced learning of the PEDI staff

The SHARES presentation triggered reflexive learning. Firstly, the SHARES runs demonstrated very low farm potential for the Gainsa farmers: even when applying input and labour intensive farm techniques, the farms produced just enough to cover the basic household needs. There were no development opportunities. Through SHARES, staff members improved their knowledge of the outside world, notably the biophysical situation and the agricultural possibilities of farmers in Gainsa. The staff had not searched for this kind of information, but the information about the structural poverty surprised them and triggered learning. They engaged in reflexive learning: they recognised the problems of the farmers and learned about the coping and risk avoiding farm rationality. Secondly, in Koglabaraogo, the SHARES examples triggered a debate on perspectives. Farmers pointed at the importance of norms and values and how these determined farm rationality. In sum, SHARES enabled the staff to learn more about (a) the biophysical context and (b) the norms and values of the farmers and how they influenced their behaviour (Figure 10.1).

The reflexive learning gave way to transformative learning. The staff members no longer took their frame of reference for granted. In Gainsa, they started considering farm risks and the capacity of the farmers to cope with adversity. In Koglabaraogo, they took notice of the norms and values of the different categories of farmers. In general, they considered category specific debates on perspectives and farm strategies a requisite for agricultural extension. For the next phase of PEDI, it was recommended that extension officers used the SHARES pictures to trigger a debate on perspective and strategies. Extension should start with this kind of reflection to enable the extension officers to better understand and support the farmers. Agricultural extension activities should start with (a) an emic farmer categorisation; (b) a reflection on farm strategies; (c) a discussion on farmer organisation; and (d) the identification of task-related learning needs (Sandwidi, 2001: 30).

In 2001, PEDI IV ended. The formulation and take-off of the next phase took another year. During my visit in February 2002, field workers prepared themselves for the first village meetings. In 2002, the villages elaborated Village Development Plans, applied for funds, mobilised their own contribution and started with the first activities. These concerned especially agricultural credit and village infrastructure. Albeit, it was not possible to fully assess the effect of learning on the new agricultural extension activities, the study did provide some important insights.

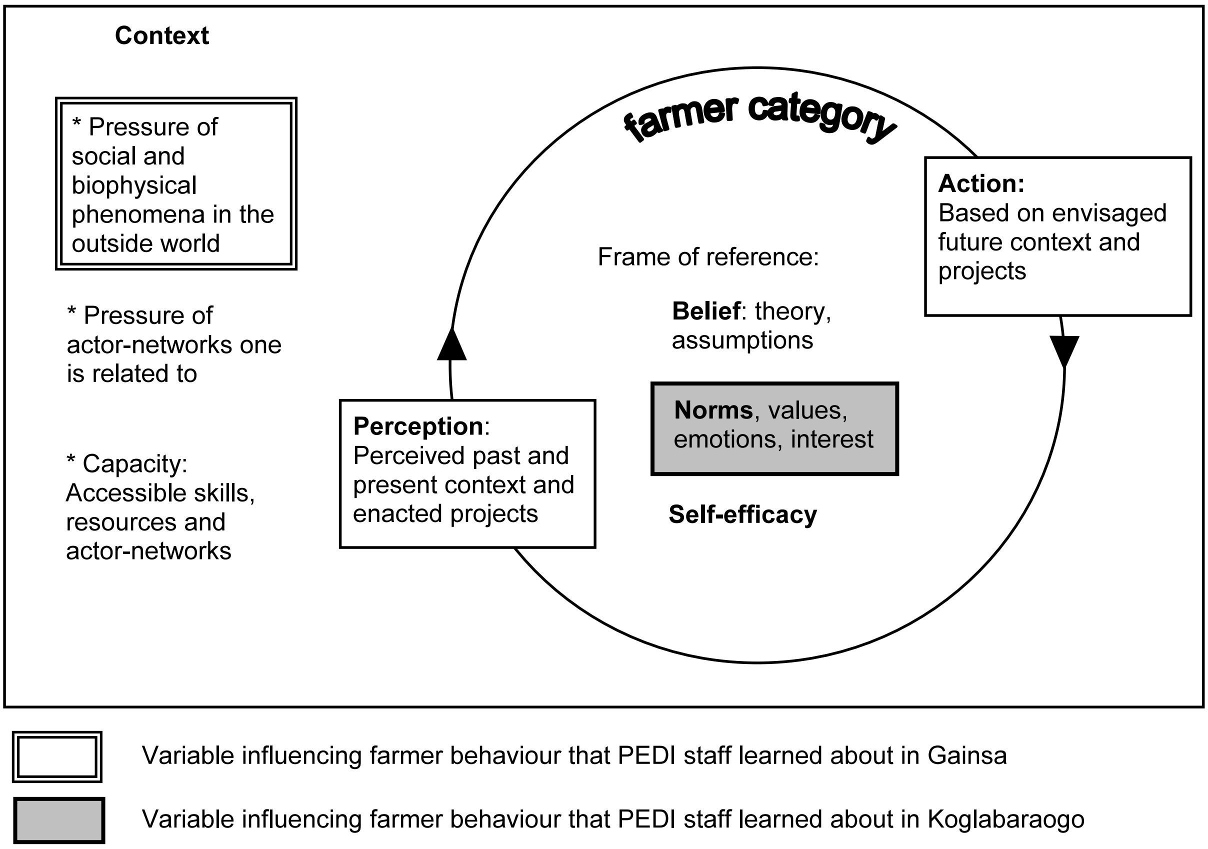

Figure 10.1: SHARES model enhanced reflexive learning

SHARES enhanced learning of the local stakeholders

The research focussed on the learning of the PEDI staff, but what about the learning of the farmers? As a staff member, it was difficult for me to get a clear picture of the feelings of the farmers. The only possible way was to carefully observe and interpret the utterances and non-verbal reactions of the farmers during and after the joint field sessions. I got the impression that the SHARES model had less impact on the farmers than it had on the staff.

In Gainsa, the farmers exclaimed that the SHARES pictures gave hope: in the long run, intensive farming provided enough food to cover their household food needs. Nevertheless, they had to cope with short-term fluctuations of the weather and because they had few reserves these fluctuations highly influenced their farming strategies. The SHARES option 'Max Cer, T0-T6' was informative, it showed the potential of their present farm strategy, but it did not trigger learning for correspondence. SHARES triggered learning for coherence in the sense that farmers became more aware of the differences in perspectives between them and the staff, and they recognised the need to be more explicit in their communication with the staff members.

In Koglabaraogo, again, SHARES did not trigger much learning for correspondence. It rather confirmed their knowledge: if in need of labour, one could easily exchange labour intensive compost production for the purchase of fertiliser. The production per hectare of both options was almost equal. Young aspiring farmers were impressed by the SHARES pictures and asked whether they could keep them for further reflection. However, the elder farmers were bothered by the ambitions of their younger colleagues/relatives. There seemed to be a generation gap. This led to heightened emotions rather than learning.

10.3.3 Research question (c): Can computer models enhance learning for coherence and correspondence?

Coherence

The results of the study suggest that MGLP models can enhance learning for coherence. Learning for coherence involves the recognition of the perspectives, problems and interests of the people involved. It is essential that users are encouraged to take a critical look at the perspective of the model and compare it to their own points of view. MGLP models are called ‘strategic models’. They are target-oriented and it is relatively easy to trace the rationality and priorities incorporated in these models. Through a discussion of perspectives, underlying theories, assumptions, norms and values, and the perceived capabilities, actor-networks gain more understanding of each others problems and interests. MAS models go a bit further than MGLP models in the sense that modellers can include information about actors (their positions, norms and values, access to resources and interests) and actor-based processes (reasoning, communication, negotiation, NRM activities, See section §2.5.2). Both type of models can be used for discussions on perspectives.

Increased understanding of an actor’s position and problems may also stem from new understanding of a social or biophysical phenomenon that strongly influences the livelihood of the actor. For the case of Gainsa, SHARES provided new insights on the biophysical situation and the farm possibilities, something that was previously not understood by the extension staff. SHARES showed that the low agricultural potential endangered the livelihood of most Gainsa farmers irrespective of the project recommendations or technical support. Here the MGLP generated estimates of the farm potential and the structural poverty were an eye-opener.

Correspondence

To assess the learning for correspondence, it is necessary to iterate between the perspectives of the researched (the model designers, the PEDI staff and the farmers) and the researcher. All of them have a different idea about ‘the desired situation’ and will have different views on the question whether the use of SHARES helped to attain the desired situation.

The model designers wondered whether the model could help the local population to attain a reasonable agricultural production, while not endangering the soil quality. For the current case study, the answer seems negative: the PEDI staff and the farmers were interested in sustainable agricultural production but they needed detailed information about compost and fertiliser applications while the SHARES had a strong bias towards known SWC measures. An MGLP model with detailed information on fertiliser application would have been more useful.

The PEDI agricultural staff aimed at a decent livelihood for the farmers, while not endangering the ecological capacity for future generations. As described above, SHARES did not help to attain the desired situation. However, they did discover that it was impossible to support farmers to attain a decent livelihood without a minimum convergence of perspectives. Learning for coherence was a prerequisite for future, joint learning for correspondence.

The farmers in Gainsa as well as in Koglabaraogo aimed at a certain level of food self-sufficiency. To ensure food production they applied fallow, SWC measures and compost and experimented with fertilisers. The new challenge was livestock fattening. SHARES could not help to improve fertiliser application nor livestock fattening.

As a researcher, I took a somewhat distanced position and tried to get an overall view. Nowadays, it becomes increasingly apparent that most problems have both a biophysical and technical, as well as an ideological and political dimension. This calls for a 'beta-gamma' approach. From this perspective, the aim of natural resource management in Sanmatenga province should be: human equity and improved human livelihood, while not endangering the ecological capacity for future generations. While interpreting secondary material on the historical context and the narrative accounts of the local stakeholders, it appears that technical changes may provide improvements but a substantial part of the problems are of an ideological, institutional and organisational nature. The main strength of MGLP models is biophysical and technical analysis. This study revealed that MGLP models can be used to clarify strategic thinking and ideological perspectives, but they are not useful to the analysis of organisational and political issues. For this kind of analysis, MAS-based models may be of help (§ 2.5) and the first combined MGLP-MAS models already emerged (Berger, 2001). However, one should keep in mind that model design is very data, expertise and time consuming, and it might well be that other more simple and cost-effective tools trigger a similar learning effect.

10.4 Emerging insights

10.4.1 SHARES enhanced learning in Sanmatenga province

SHARES had an added value for learning for natural resource management, though SHARES could have been more useful if the designers had involved the stakeholders right from the beginning. SHARES was designed in a time, when it started to dawn that purely science-based models were not intrinsically valuable for operational use. For future model design, the SHARES experience provides the following insights:

The boundary problem: land oriented or livelihood oriented?

SHARES designers were land-oriented and focussed on land-bound activities while collective action for natural resource management depends on the purpose, interpretation and interests of the stakeholders. Dangbégnon (1998: 247) notes: "People act when they perceive an ecological crisis as a problem: when it makes sense to them or seriously affects their livelihoods". To be relevant, to increase consciousness and to trigger action, SHARES needs to link natural resource activities with farmer livelihoods. For example, SHARES should also include issues such as petty trade, livestock fattening and remittances.

The pressure of outside phenomena on the farmer livelihood strategies

The debate with the farmers revealed the impact of price fluctuations, weather risks and poor health on farm strategies. SHARES worked with fixed prices, while farmers heavily speculated on seasonal price differences. In Gainsa, farmers underlined the importance of weather risks: they stressed that they rather invested in livestock because they perceived arable farming as too risky. In Koglabaraogo where land was abundant, SHARES suggested labour intensive farm strategies, while in reality most farmers focussed on the effective use of scarce labour. SHARES underestimated the labour issue. It is difficult for researchers to measure daily labour use and they tend to overlook the health effects of food deficiency and hunger. The returns on labour are extremely low and hardly improve under intensification (Van den Elshout, 2002). Preliminary discussions with the farmers would have made model designers more attentive and considerate about the issues crucial to the farmers.

Ambiguous objectives

There was a lack of clarity on the purpose of SHARES. During the development, the aspirations of the designers changed and increased. Initially, SHARES was seen as a means to increase scientific collaboration and understanding. In the end, the wish emerged to see whether SHARES could be beneficial for agricultural extension. However, no effort was made to include the extension and/or farmer learning needs in the model. SHARES aimed at increased understanding of the present farm reality and the model merely included present farm practices. Extension workers and farmers, on their side, wanted to explore the potential of new, innovative farm practices and for them the model should have included more innovative farm practices. Present practices are essential to validate the model: to see whether the model generates realistic, plausible farm situations. These runs can serve as a baseline to which new farm practices are compared. Model designers need stakeholder research (Engel & Salomon, 1997; 2002) to identify and include farm practices that farmers and extension staff want to test.

Complex models are hard to use by non-specialists

Most staff members did not have the skills nor the training or the time to handle the SHARES model. SHARES was used because one of the staff members, the author, made SHARES the subject of her PhD research. I made an effort to understand the model and needed regular assistance from the designers and others. The preparation and use of SHARES took considerable time and effort. The weekends had to be used to understand the model because it was difficult to combine learning to operate the model with the PEDI project routines and priorities. After the action-research, it was clear that it took too much time to adapt SHARES to cover (a) some of the learning issues identified and (b) other 'typical' villages in the PEDI intervention zone. It was decided just to use the pictures of the Gainsa and Koglabaraogo farmers to trigger the debate in the other PEDI villages. Computer models are too complex and time consuming to be combined with the ordinary duties of the project staff. Specialists, who can devote their time to the subject, are needed.

The importance of the pressure of related actor-networks on staff learning

The ultimate role of agricultural extension and the use of the SHARES pictures depend on the interests and priorities of the national government and the donors. During the reformulation period, it was decided that all future project activities were 'on demand': villagers now have to prepare requests for funding and to pay a substantial own contribution. In line with this philosophy, agricultural extension has to apply a bottom-up approach. The donor priorities rather than the professional background and the personal fascination with computer models oriented staff learning.

The importance of farmer beliefs about the outcome and their notion of self-efficacy

As was shown in Chapter 7, farmers gave priority to material support. Little mention was made of the need for agricultural extension, nor of the need to resolve conflicts and institutional problems with respect to natural resource management. The farmers felt that they had no authority to tackle CNRM issues and they shied away from lengthy, cumbersome and uncertain learning and negotiation processes. These first experiences show that, in Sanmatenga province, agricultural extension and CNRM cannot succeed without the initiative and commitment from outsiders, e.g., the government and projects. Stakeholder analyses are needed to show outsiders whether or not to initiate/facilitate multi-actor learning processes.

10.4.2 The strong and weak points of MGLP models

Computer technology enlarges the bounded human rationality. It enables us to perceive invisible and abstract aspects, to improve our understanding of complex phenomena, and to experiment. The use of computer models depends on the learning need, the capacity of the users to handle computer models and the cost-effectiveness of the computer model. MGLP models are just one of a gamut of learning tools and they have their specific strengths and weaknesses.

Integrating knowledge to generate site and category specific analyses

MGLP models integrate various types of biophysical knowledge: knowledge about plant growth, soil dynamics, SWC measures, animal growth, animal feed, etc. MGLP models enable the integration of knowledge to obtain more site and farmer-category specific information. This is essential in an area like Sanmatenga province, where most farmers are illiterate and keep few records. The MGLP methodology provides detailed knowledge about the farm situation of various types of farmers and may be less expensive than extensive farming system research. The methodology enables agricultural professionals to avoid inappropriate generalisations and to become more specific in their reasoning and recommendations.

Triggering learning for coherence

MGLP models are called strategic: they are explicit about their perspective, objective and preferred solutions. This makes these kinds of models suitable for the exchange of perspectives. They easily trigger debates on underlying assumptions and preferred goals. At present, co-learning is often blocked by the difficulty of agricultural professionals to put their scientific methods and values in perspective (Chambers, 1997; Bawden, 2000). This study shows that MGLP models can help professionals to overcome biases. MGLP models are useful for learning for coherence under the condition that the professionals sincerely look for the farmer perspective.

Limited accuracy and validity

One of the advantages attributed to computer models, is the level of detail and accuracy. However, the validity of the model is determined by the quality of the data included. MGLP models are known to be data demanding and it is often not possible to obtain all the necessary information. Especially in the African context where it is difficult to get reliable data, designers have to work with guesstimates. This limits the validity of the model. Model outcomes provide more detailed knowledge than most simple learning tools, but their accuracy and validity should not be overestimated.

Ambitious, ambiguous modelling is troublesome

The development of MGLP models is data, expertise and time-consuming (Newman *et al*., 1999; Walker & Zhu, 2000; Stroosnijder, 2000). This in itself is a problem: the more resources become mobilised for a modelling project, the more difficult it will be for the initiating organisation to stay at a distance and leave (part of) the model development dynamics to others (stakeholders, users, beneficiaries). The more people and organisations become involved, the more ambitious and ambiguous the project becomes: the more difficult it will be to critically assess the objectives and added value of the project (Cox, 1996). Many failures of modelling efforts can be attributed to vague and muddled objectives.

The danger of distortion

Model use needs prudence because the danger of distortion is substantial. Modelling may foster a 'solution seeking a problem', rather than a 'problem seeking a solution' approach (Walker & Zhu, 2000). When the stakes are high, there is a danger of distorting the learning process: instead of considering all kinds of biophysical, human and institutional issues, stakeholders tend to focus on the issues incorporated in the model.

In modern society, science is still seen as a primary source for decision-making. Scientists often present model outcomes as unambiguous and conclusive. To prevent distortion of learning, it is essential to be explicit about the limitations of the model, the underlying perspective and its focus. It is advantageous, when model users are able to adapt the model to suit their own learning: to include elements, activities, problems and solutions that they and their co-learners judge relevant (to improve coherence).

MGLP models focus on trade-offs of interests rather than relational aspects

MGLP models explore outer boundaries of the agricultural potential and trade-offs between various stakeholder interests. In other words, MGLP demonstrate the ecological and economic interests and inherent conflicts of NRM. MGLP models look for a single best solution or equilibrium of interests, but it is not always possible to determine a single best solution via multiple-objective model (Munasinghe & Lutz, 1993). Different stakeholders perceive environmental problems in a different way and use different criteria for assessing the desirability of a given intervention. It is very difficult to include all assessment criteria of all stakeholders in one MGLP model and to find an optimum solution. For CNRM it is more important to clarify the values and opinions of the stakeholders, to pinpoint the sources of disagreement, to assess the influence and power of the stakeholders and to jointly develop compromise solutions. CNRM needs to focus on conflicts between stakeholders rather than the trade-offs between objectives (Grimble & Wellard, 1997). MGLP models may trigger discussions in interest and values, but they do not cover all aspects of NRM conflicts and are of limited use for CNMR.

10.5 Recommendations: A niche for MGLP models

The cost-effectiveness of computer modelling is an important issue because of the substantial resources devoted to this activity. The need to allocate scarce research resources to the development of technologies with the highest pay-off is obvious. This implies that it is necessary to think as broadly as possible about how we can best use MGLP methodology to achieve increasingly urgent goals associated with improved agricultural production and long-term sustainability in resource use (Cox, 1996).

10.5.1 Linking agronomic research with the farmer reality

MGLP models are powerful tools to trigger discussion between agricultural professionals and farmers. In a country such as Burkina Faso, MGLP models are too complex and time-consuming to be used by extension staff. They may be useful for the national agricultural research institutes. Instead of using MGLP models to recommend certain farm practices, they may use MGLP modelling to exchange perspectives with farmers, to refine their knowledge of divergent farm strategies and to orient their research programmes and look for more appropriate farm technologies.

10.5.2 Linking extension systems to the farm reality

Extension workers are not in the position to handle MGLP models but case studies (for example done by a research institute) based on MGLP might be useful to them. The site and group specific MGLP information assist extension workers (a) to attain more detailed knowledge about the biophysical production possibilities within a specific village, and (b) to initiate discussions on farm strategies. This latter enables them to initiate co-learning processes.

The study suggests that MGLP models that stay close to the existing farm practices are of interest to farmers though they do not provide them with surprisingly new insights. If properly designed, MGLP models approach the farmer reality but it is difficult to excel vis-à-vis the knowledge that farmers already have about their own life-world. It is likely that MGLP models indicate development directions that farmers have already sensed and anticipated on. A potential value of those MGLP models, however, is the demonstration of aspects, which are difficult to observe such as the loss of soil nutrients, the overall farm productivity, etc.

The main value of MGLP models is that they trigger discussion on fundamental issues: assumptions and livelihood strategies. In daily life, farmers focus on operational issues and add-on innovations (NRLO, 1997; Rossing *et al.,* 1997b, Hamilton, 1998), but at times one should consider the long-term perspective and strategic developments. MGLP models that include innovative practices may trigger a debate on strategic issues: the assumed future situation, norms, values and envisaged livelihood strategies. To facilitate discussion on long-term perspectives, it is essential for MGLP models to include all those aspects that farmers value as important. Then, MGLP scenarios with more drastic innovations may induce farmers to (slowly) change track.

10.5.3 Limited relevance for Communal Natural Resource Management

MGLP models have specific strengths: they demonstrate the biophysical and technical possibilities of given societal demands and trigger discussion on development objectives. MGLP runs induce discussion on desirable farm strategies. Furthermore, MGLP models display trade-offs between stakeholder interests, and are useful to analyse and discuss political issues of access to natural resources. However, MGLP models are not very useful to analyse relational, organisational and political processes.

MGLP models can enhance learning, but the problem of computer models is that they are data, expertise and time consuming. Multi-actor learning are uncertain, event-driven processes; one cannot predict who is going to learn and when. To facilitate learning for CNRM, it is essential to select and adapt tools and methods in line with newly emerging learning needs. In contrast to scientific learning, multi-stakeholder learning processes need flexibility and momentum. To attain dynamism, it is recommended that learning tools are simple and cost-effective (Walker & Zhu, 2000). There is little chance that an existing model entirely fits an emerging learning need and as computer models are costly to make and difficult to adapt, facilitators for CNRM should rather opt for other simple and cheap learning tools.

10.6 The relevance of the research

For my conclusions, I look back to the original question about computer model enhanced learning for NRM. This question has a practical and a theoretical side. In the academic world, there is an increasing recognition that learning for NRM encompasses more than instrumental learning for a more productive and ecologically sustainable agriculture. Agro-ecological problems emerge from human action and interaction vis-à-vis the natural environment and solving them requires changes in technologies *and/or* in human (inter) action. Learning for NRM requires facilitation and learning tools that pay due attention to biophysical and social processes. In spite of these insights, most agronomic models are still designed by beta-scientists who focus on improved understanding of, and technical intervention in the biophysical world. This is due to the following reasons:

- In contrast to human processes, biophysical processes can be explained by causal relations, expressed in mathematical equations and integrated in computer models. Modelling enhanced scientific understanding of biophysical processes and technical possibilities.
- Many beta-scientists still adhere to the positivist epistemology and assume that society changes in accordance to the (science demonstrated) technical possibilities. In their perspective, models are useful tools to transfer scientific knowledge to practitioners.
- Very few social scientists use modelling to improve their understanding. Modelling focuses the attention on specific aspects, while social scientists prefer studying human behaviour within their complex reality to avoid overlooking emerging and unexpected phenomena.
- Social sciences consider their explanatory role more important than their prescriptive or problem-solving role (Van Aken, 2002). Practitioners can draw on academic theories and literature to understand their challenges (Easterby-Smith *et al.* 2001). Understanding makes solutions trivial; hence, they are not interested in prescriptive, decision support models.

This has led to a paralysing dichotomy: model designers promote multidisciplinary, but biophysically oriented models, while social scientists continuously stress the limitations of computer models and the learning distortions caused by these models.

Computer technology has pervaded modern society and we cannot imagine working without the possibility of experimenting and using computer models. Whether social scientists start modelling or not, agricultural practitioners use modelling for learning as do learning organisations. It is therefore essential that social scientists study these processes and provide explanatory theories. We need beta-gamma professionals, scientists *and* practitioners, to capture the benefits of computer models for specific learning situations. To do so, they need a theoretical framework and practical knowledge about model-enhanced learning.

The empirical explorations of this study provide some practical knowledge. Firstly, the case study shows the relevance of the match of perspectives, the learning for coherence. Interdependent actor-networks need to (partly) share beliefs and norms and have to match competences to arrive at joint learning for correspondence. The SHARES model was of little interest to the beneficiaries because of the misfit of the frames of reference. Secondly, it demonstrated how difficult it is to initiate co-learning. Unstructured and uncritical application of participatory techniques may lead to short term bargaining and power play rather than co-learning. To initiate co-learning, one needs to explicitly work on the understanding of each other's context, perspectives and interests. The last part of the case study revealed the utility of MGLP models for reflexive learning; it easily triggers debate between agricultural professionals and farmers on assumptions and farm strategies, and it helps professionals to better understand and support farmer learning. MGLP modelling is no panacea for all learning for NRM, but it may help agricultural professionals in Burkina Faso to better perform a crucial role: enhancing co-learning.

I hope the theoretical framework elaborated in this study is of use for beta-gamma professionals. Beta-gamma professionals aim at co-learning; they engage in interaction of multiple actors in order to collectively construct shared meaning and more effective (joint) action. To better understand and handle learning processes, they need a theoretical framework that pays due attention to: (a) the interplay of context-variables and intermediate variables that shape learning and action; and (b) two essential components of learning: the learning for coherence and the learning for correspondence. The theory of the 'learning actor-network' offers beta-gamma professionals analytical tools necessary to interpret the learning processes they are involved in.

Summary

Land use modelling is at crossroads: it has encouraged much scientific collaboration and understanding, but the models are hardly used by policy makers and farmers. The recurrent question is: “Why are so many models built and so few used?” Apparently, there is a gap between model designers and the intended beneficiaries, and this gap cannot be bridged by latest handbook on modelling methods. There is a need to critically examine this gap. This study presents a theoretical framework to better understand crucial aspects of model design and model-use. This can help Beta and Gamma professionals to improve their understanding of, and intervention in socio-technical learning processes. With this framework, the use of a Multiple Goal Linear Programme (MGLP) model by agricultural extension in Sanmatenga province, Burkina Faso is analysed. The framework enables us to assess the practical relevance of MGLP models for co-learning on Natural Resource Management (NRM).

Chapter 1 introduces the research topic. It starts with the evolution of agriculture and development concerns. There was a strong emphasis on land evaluation and technical economic oriented land use planning. Computer technology enlarged the scope of land use analysis: MGLP models enabled the confrontation of biophysical and technical potentials with various societal objectives and priorities. In the 1980s, the expectations were high: it was thought that computer models could help to solve contemporary problems. In the 1990s, however, it became clear that land use modelling did enhance scientific understanding and multidisciplinary collaboration but it had a limited functionality for agricultural policy making and extension. The question whether models could be used outside their scientific (‘laboratory’) environment became evident.

At that moment, the author worked as a communication advisor at PEDI, an integrated rural development project in Sanmatenga province, Burkina Faso. The research programme of the Wageningen University in Burkina Faso, the Antenne Sahelienne, had developed the MGLP model, SHARES, to explore village land use options. As there were various contacts between the Antenne and PEDI, both professionally and personally, PEDI seemed an obvious test case for the SHARES model. The Antenne asked me whether I could test the usefulness of this model for agricultural extension in Sanmatenga.

Chapters 2 and 3 describe the context of the study. Chapter 2 gives and overview of the history of computer based modelling for NRM. It focuses on the Wageningen modelling school of C.T. de Wit and explores the potential of MGLP land use models for scientific understanding, policy making, agricultural research and extension.

In the Sudano-Sahel, agronomic modelling advanced scientific understanding of NRM but it also experienced several setbacks. Apart from inherent methodological deficiencies, model designers had a hard time to get reliable data and local scientists with the necessary computer programming skills remain extremely rare. These experiences called for modesty but also for a thorough analysis: was the lack of application of models merely a technical issue or were there other issues at stake. A proper, contextual analysis of the added value of modelling for local learning about NRM was needed.

Chapter 3 portrays the local context of the study: Sanmatenga province in Burkina Faso. It describes the livelihood of the farmers, the national policies and the development interventions that have a bearing on NRM. This was the context of PEDI, a project with a pronounced interest in agricultural development and natural resource management. PEDI

more or less followed the government proclaimed policies and intervention strategies with respect to NRM. In the 1990s, the agricultural staff experimented with participatory tools, yet they had no consistent, comprehensive extension approach. The prospect of a new project phase and the donor's insistence on bottom-up strategies created a sense of urgency. The PEDI staff launched an action-research on farmer learning. This provided the opportunity to test whether the SHARES model was of use for learning about NRM.

Chapter 4 investigates the appropriateness of various socio-psychological theories for explaining socio-technical learning processes. It describes the search for an appropriate theory: the match of the empirical material with a theoretical framework, capable of analysing model enhanced learning. The theory should deal with:

(a) The influence of human *and* non-human entities on interaction and learning processes;
(b) The mutual interference of actor-networks and their projects;
(c) The need for a consistent, shared frame of reference with respect to the desired situation (need for *coherence*) before exploring what action is best fit to attain the desired situation (need for *correspondence*).

Furthermore, the study was undertaken with the aim to formulate recommendations about MGLP modelling and appropriate model use. It was therefore essential not to use a theory with a distanced bird's-eye perspective, but to choose a theory that worked from the actor (network) perspective and that attributed agency to an actor (-network).

At first, the actor-network theory (ANT) seemed appropriate. It studies the interaction and continuous reshaping of ordered networks of human and non-human material. Unfortunately, ANT's notion of agency is problematic: ANT does not attribute agency to individual actors. In line with Giddens' reasoning (1984), I assume that actor-networks have structural properties: a mode of order and a frame of reference that consists of rules of interpretation (beliefs), normative rules (norms and values) and power resources (capabilities, material resources, notion of self-efficacy). In their action, individual actors draw upon their frame of reference but they also have some room of manoeuvre: they actively choose and negotiate certain rules of interpretation, normative rules and resources. The actor-oriented approach and the theory of planned action provided the necessary actor-oriented perspective and concepts such as *context*-related external variables and *actor*-related variables for learning. To better understand and intervene in model-enhanced learning, I amalgamated aspects of ANT, the actor-oriented approach and the theory of planned action, and constructed the theoretical framework called 'the learning actor (-network)'.

Chapter 5 discloses the research method. This study does not apply strict research methodologies but applies the principles of reflexive research. Giddens defined reflexivity as a continuous monitoring of one's own practices in interaction with others and the world of nature. Reflexive research, therefore, not only urges for a systematic treatment of the empirical material, but it also points to the influence of the ideological-political background of the researcher, the need for awareness of the interpretive act, and the relatively of the authority and the relevance of the study. The researcher should be aware that he himself, the people studied and the readers of the study have their own ideas and interpretation of the world. He should be explicit about his own bias, position and role. The ultimate relevance and authority of a research depends on the fit and explanatory power of the theoretical framework to the empirical material, the people studied and the intended readers.

This study is a product of a continuous iteration between the empirical material and existing socio-psychological theories; lived-through experiences and concerns of the people studied, and scientific argumentation; details and the overall process, and the outcome of learning. It aims at improving scientific understanding of model-enhanced learning as well as the practical use of MGLP models for learning for NRM.

Chapters 6, 7, 8 and 9 present the field case. The empirical material is organised in a way to answer the three sub-questions of the research: (a) Can the model trigger learning for correspondence? Is there a match of interest between the model and the potential users; (b) How does model-use affect the learning process of the users; and (c) Can model use lead to co-learning, which consists of learning for coherence *and* correspondence?

Chapter 6 focuses on question (a). Computer models are supposed to enhance learning for correspondence. To engage in joint learning for correspondence, the model and the user need to have a common frame of reference and common interests. The study investigates the knowledge, the level of inquiry and the learning interest on NRM of the SHARES model, the PEDI staff and the local population. It matches the learning interest of the staff and the local population with the capabilities of SHARES and concludes that there is no overlap between the frames of reference. This means that there was little opportunity that SHARES would help its envisaged beneficiaries with learning for correspondence.

Chapters 7, 8 and 9 describe the action-research and the learning process of the PEDI staff members. They provide the empirical material to answer questions (b) and (c). Chapter 7 describes the contingency of learning. In line with the donor requirements, the PEDI staff decided to further test and elaborate a consistent participatory extension approach. Staff members undertook an action-research and used various Participatory Rural Appraisal (PRA) methods to trigger farmer learning. The trials revealed that local farmers were not very interested in trying, uncertain processes of learning about NRM but rather negotiated direct material support. When forced to, farmers forwarded practical learning issues. While evaluating the PRA trials, the staff realised that they usually focussed on learning for correspondence, but they would only be able to appropriately support farmer learning if they better understood the reasoning and interests of the farmers. They discovered the concept co-learning: inclusive learning requires learning for coherence *and* correspondence. Explicit action was required to start learning for coherence. Because the SHARES model represented a straightforward technical-economic perspective on farming, the staff members decided that they would use the model to illustrate their professional perspective and encourage farmers to comment upon and criticise this perspective. In this way, they would learn each other's perspective and identify common goals.

Chapter 8 depicts how SHARES generated farming options for various categories of farmers in Gainsa, a village with a serious shortage of land. SHARES provided site-specific information and showed the staff the severe biophysical limitations. For the first time, they realised the low development potential and the structural poverty of the Gainsa farmers. Staff members had always worked with general assumptions and recommendations supposing that, in the end, 'things would improve'. They worked with the more dynamic farmers and had ambitious development goals; hence, they had never allowed themselves to seriously consider signals of extreme poverty. SHARES confronted them with this situation and staff surprisingly quickly understood the reasoning and behaviour of the Gainsa farmers.

Chapter 9 is about the SHARES enhanced learning in Koglabaraogo where land is abundant. Koglabaraogo farmers owned more land than their southern counterparts and had a considerable agricultural potential. SHARES showed that farmers could easily improve their farm revenue if they opted for a more commercial farm strategy: buying more inputs and timely selling of their products at appropriate markets. In Koglabaraogo, the presentation of the SHARES scenarios triggered much discussion on values and socially acceptable livelihood strategies. Through the confrontation between the SHARES logic and the villagers, the staff discovered the strong influence of morality on farmer reasoning and action. In this process, the open attitude of the PEDI staff members was of critical importance for the learning: they did not use SHARES in a normative way, but to discover and become more knowledgeable about the farmers' perspectives.

Chapter 10 draws the conclusions and presents some recommendations. The field case showed that learning is contingent and depends on the mutual interference of projects and interests of various actor-networks. Models are inflexible and normative: they represent certain knowledge, interests and preferred solutions. If the frame of reference of the model coincides with those of the intended users, a model can be used to enhance learning for correspondence: to improve the knowledge of one's environment and actions that lead to the desired situation. However, the chances are high that the frames of reference and learning interests do not match, especially when the model has been designed without proper consultation of the intended users. In this case, a model can still be useful to put new items on the agenda: a model may raise the awareness about a new (hidden or abstract; hence unperceived) issue. Similarly, it is possible to use the model as a representation of a certain perspective to initiate an exchange of perspectives.

Since long, agricultural research institutes and extension services concentrated on learning for correspondence, but nowadays the need for learning for coherence becomes evident. Co-learning requires both kinds of learning. MGLP models are strategic models, which can provide site and social group specific information and focus on a certain range of development strategies. These two characteristics make them useful for learning by agricultural professionals: they provide information about the biophysical situation of local farmers and encourage a debate on development strategies. In this way, MGLP models assist professionals to better learn the farmer reality and to start joint learning processes.

MGLP models have a limited relevance for learning for communal NRM. Communal NRM involves multi-stakeholder learning about ideological, organisational, institutional and technical aspects. MGLP models have a difficulty in covering multiple stakeholder perspectives and diverging interests and values: it makes them complex and difficult to handle. Furthermore, MGLP models only cover the technical and economic aspects of NRM issues. Other models such as Multi-Agent System models seem more promising in this respect. However, computer models (including MAS) remain expensive, time- and expertise consuming learning devices, which are difficult to handle and hard to adapt to emerging learning needs. Multi-stakeholder learning is characterised by uncertainty and complexity and needs simple flexible, cost-effective learning tools.

In sum, this study offers a new theoretical framework to understand socio-technical learning processes such as model-enhanced learning for NRM. This framework pays attention to biophysical and social aspects and enables Beta and Gamma professionals to better understand and intervene in learning processes. The field case about MGLP model enhanced learning in Sanmatenga province, Burkina Faso, provided some practical insights in the use of MGLP and co-learning processes, and led to the recommendation to use MGLP models for reflexive learning by agricultural professionals.

Résumé

La modélisation informatique de la gestion du terroir est à la croisée des chemins : elle a renforcé la collaboration et la compréhension des scientifiques, mais les modèles ne sont guère utilisés ni par les décideurs politiques ni par les paysans. La question récurrente est la suivante : « Pourquoi tant de modèles sont développés et si peu utilisés ? » Apparemment il y a un fossé entre ceux qui les conçoivent et les bénéficiaires potentiels. Un fossé qu'on n'arrive pas combler, même à l'aide des manuels les plus récents sur les méthodes de modélisation.

La présente étude offre un cadre théorique permettant de mieux comprendre les aspects fondamentaux de la modélisation et l'apprentissage par moyen de modèles informatiques. Elle aidera les professionnels Bêta et Gamma à mieux comprendre les processus de l'apprentissage socio-technique afin d'adapter leurs interventions. A l'aide de ce cadre théorique, nous exécutons une analyse d'un modèle Multiple Goal Linear Programme (MGLP) par un service de vulgarisation agricole dans la province de Sanmatenga, au Burkina Faso. Ce cadre nous permet de déterminer la pertinence des modèles MGLP pour l'apprentissage conjoint de la gestion des ressources naturelles (GRN).

Le chapitre 1 introduit le sujet de la recherche. Il présente l'évolution des débats scientifiques et politiques par rapport à l'agriculture et au développement. Un accent particulier a été mis sur l'évaluation des terres et la planification technique et économique. La technologie informatique a élargi le champ de l'analyse de la gestion du terroir : les modèles MGLP ont permis la confrontation des potentiels biophysiques et techniques avec les différents objectifs sociaux. Dans les années 1980, ces possibilités ont soulevé de grands espoirs : les modèles informatiques étaient supposés résoudre tous les problèmes contemporains dans le domaine de la GRN. Néanmoins, à partir des années 1990, il devenait de plus en plus clair que la modélisation de la gestion de terroir augmentait la compréhension et la collaboration des scientifiques mais son utilité pour les hommes politiques et les vulgarisateurs agricoles restait limitée. Il restait alors à savoir comment les modèles pourraient être mieux utilisés hors du milieu scientifique.

A cette période, l'auteur travaillait comme conseillère en communication au PEDI, un projet de développement rural intégré dans la province de Sanmatenga, au Burkina Faso. Au même moment, le programme de recherche de l'Université de Wageningen au Burkina Faso, l'Antenne Sahélienne, avait développé un modèle MGLP, dit SHARES, afin d'explorer les options de gestion des terroirs villageois. Il existait une collaboration entre le Projet PEDI et l'Antenne Sahélienne, ce qui a permis de tester l'utilité du modèle SHARES. C'est alors que l'Antenne me demanda d'évaluer l'utilité de SHARES pour la vulgarisation agricole au Sanmatenga.

Les chapitres 2 et 3 décrivent le contexte de la recherche. Le chapitre 2 retrace l'historique de la modélisation informatique de GRN, notamment celle de l'école de modélisation de C.T. de Wit à Wageningen. Le chapitre explore la valeur théorique des modèles MGLP pour la compréhension scientifique, de même qu'à l'intention des décideurs politiques, de la recherche et de la vulgarisation agricole. Dans la zone Soudano-Sahélienne, la modélisation agricole se trouve confrontée à de nombreux problèmes. Outre les insuffisances inhérentes à la méthodologie MGLP, il est difficile de rassembler des données fiables. Par ailleurs, peu de chercheurs maîtrisent la programmation des modèles informatiques. Les résultats de la modélisation nous incitent à plus de modestie et à un examen plus minutieux des expériences.

La non-utilisation des modèles est-elle juste un problème technique ou y a-t-il d'autres contraintes? Pour répondre à cette préoccupation, une analyse contextuelle de l'utilité de la modélisation pour l'apprentissage de la GRN est nécessaire.

Le chapitre 3 décrit le contexte local de la recherche : les modes de vie des paysans de Sanmatenga, les politiques nationales et les actions de développement dans le domaine de GRN. C'est l'environnement de PEDI, un projet axé sur les actions d'intensification de la production agricole et la gestion des ressources naturelles. PEDI mettait en œuvre, dans la mesure du possible, les politiques et les démarches d'intervention, proclamées par le gouvernement. Dans les années 1990, les agents du projet ont expérimenté des méthodes et des outils participatifs, mais il manquait une vision claire et consistante en matière de vulgarisation agricole. Les progrès réalisés dans les processus de la décentralisation et le changement de l'approche de la nouvelle phase du projet ont engendré un sens d'urgence. Les agents du projet ont alors initié une recherche-action sur la démarche de l'apprentissage conjoint en milieu paysan. Ceci a permis de tester la valeur de SHARES dans le domaine de la GRN.

Le chapitre 4 explore le potentiel de diverses théories socio-psychologiques pour l'explication des processus d'apprentissage socio-technique. Il fallait un cadre théorique approprié pouvant correspondre au matériel empirique et permettre une analyse des processus d'apprentissage facilités par les modèles informatiques. Ce cadre théorique devait prendre en compte :

- l'influence des entités humaines et non-humaines sur les processus de l'interaction et l'apprentissage ;
- l'interférence mutuelle des réseaux d'acteurs et de leurs projets ;
- la nécessité d'un cadre de référence commun (*la cohérence* des visions de la situation désirée) afin d'explorer les options d'action les plus aptes à atteindre la situation désirée (*la correspondance* entre les actions et l'environnement).

Outre les objectifs théoriques, il y avait des objectifs pratiques : formuler des recommandations sur la modélisation et l'utilisation des modèles MGLP. C'est pourquoi il était essentiel de ne pas utiliser une perspective distante (l'œil de l'oiseau), mais d'opter pour la perspective des acteurs.

En premier lieu, la théorie des réseaux (Law, 1987; 1992; 1994; Callon, 1987) semblait être propice. Cette théorie étudie l'interaction et la transformation continuelle des réseaux de matériaux humains et non humains. Malheureusement, la notion d'*agence* (la capacité d'agir et de faire la différence) de la théorie des réseaux est problématique : la théorie n'attribue pas d'agence aux acteurs individuels. En accord avec la pensée de Giddens (1984), je suppose que les réseaux ont des propriétés structurales : un *cadre de référence* et un mode d'organisation, avec des *règles d'interprétation* (la connaissance), *des règles normatives* (les normes et valeurs) et *des ressources de pouvoir* (les capacités, les ressources matérielles, la notion d'efficacité). Dans leur action, les individus sont guidés par leur cadre de référence mais ils ont un espace de manœuvre : ils choisissent activement et négocient certaines règles d'interprétation, des règles normatives et des ressources. L'approche par le biais des acteurs (Long, 1992; Long & van de Ploeg, 1989; 1994; 1995) et la théorie de l'action planifiée (Ajzen & Madden, 1986; Ajzen, 1988) procurent une perspective ciblée aux acteurs ainsi que des variables d'apprentissage externes (du contexte) et intermédiaires (du réseau d'acteurs). Pour mieux comprendre et intervenir sur les processus d'apprentissage facilités par des modèles, j'ai combiné des éléments de la théorie des réseaux, de l'approche par les acteurs et de la théorie de l’action planifiée, pour construire un nouveau cadre théorique : ‘le réseau d’acteurs apprenant’ (Figure 4.3).

Le chapitre 5 explicite la méthodologie suivie. L’étude n’applique pas de méthodologie stricte mais adhère aux principes de la recherche réflexive. Giddens définissait la ‘réflexivité’ comme « un suivi-évaluation permanent de ses propres actions vis-à-vis de la dynamique des autres personnes et de la nature ». Quant à la recherche réflexive, elle attire l’attention non seulement sur le traitement systématique du matériel empirique mais aussi sur l’influence de la position idéologique et politique du chercheur, la nécessité d’être conscient de l’acte d’interprétation, la relativité de l’autorité et la pertinence de l’étude. Le chercheur doit être conscient que lui-même, les personnes étudiées, de même que les lecteurs, tous ont leurs idées et interprétations des événements. Il est essentiel d’être explicite sur ses propres biais, ses positions et son rôle. La pertinence et l’autorité de la recherche dépendent de la correspondance des intérêts et de la puissance explicative de la théorie pour les personnes étudiées ainsi que les lecteurs ciblés.

L’étude est le produit d’une itération permanente entre le matériel empirique et les théories socio-psychologiques ; entre les soucis des personnes étudiées et l’argumentation scientifique ; entre les détails, le processus global et les résultats de l’apprentissage. Mon engagement dans les actions de développement de PEDI a influencé le but et l’acte de l’interprétation, puisque je voudrais à la fois bien comprendre le processus de l’apprentissage facilité par les modèles informatiques ainsi que l’utilisation pratique des modèles MGLP dans le cadre de la GRN.

Les chapitres 6, 7, 8 et 9 présentent l’étude de cas. Le matériel empirique est structuré d’une telle façon qu’il nous permet de répondre aux trois sous-questions : (a) Le modèle est-il capable de déclencher un processus d’apprentissage ? Y-a-t-il un chevauchement des intérêts du modèle avec ceux des bénéficiaires ?; (b) Quel est l’effet de l’utilisation du modèle sur le processus de l’apprentissage ? (c) L’utilisation des modèles informatiques peut-elle engendrer des processus d’apprentissage, aboutissant à plus de cohérence et de correspondance?

Le chapitre 6 est axé sur la sous-question (a). Les modèles informatiques sont supposés faciliter l’apprentissage pour la correspondance. Afin de s’engager dans un apprentissage conjoint, le modèle et l’utilisateur ont besoin d’un cadre de référence et d’intérêts communs. L’étude analyse la connaissance, le niveau de l’exploration et l’intérêt de l’apprentissage par rapport à la GRN avec le modèle SHARES, de la part des agents du projet PEDI et de la part de la population locale. Il y a ensuite une confrontation des intérêts de l’apprentissage du personnel et de la population locale avec les capacités du modèle SHARES. L’étude permet de conclure qu’il n’y a pas de chevauchement des cadres de référence et des intérêts. Les chances que SHARES aide les bénéficiaires avec l’apprentissage pour la correspondance sont très limitées.

Les chapitres 7, 8 et 9 décrivent la recherche-action et le processus de l’apprentissage des agents du PEDI. Ces chapitres présentent et analysent les matériaux empiriques afin de répondre aux sous-questions (b) et (c). Le chapitre 7 examine le concours de circonstances qui détermine l’émergence ou non de l’apprentissage. En conformité avec les conditions des bailleurs de fonds, les responsables du PEDI ont décidé de reformuler l’approche de vulgarisation agricole et de lancer une recherche-action. Avec l’aide des outils de la Méthode Accélérée de Recherche Participante (MARP), ils ont tenté de déclencher un processus d’analyse et de l’apprentissage au niveau paysan. Les essais ont montré que les paysans préféraient des supports matériels aux processus durs et incertains comme celui d'un apprentissage conjoint. Néanmoins, à la demande du projet, les paysans ont exprimé leur intérêt par rapport à l'apprentissage. C'est pendant l'évaluation des tests, que les agents se sont rendu compte qu'ils ne pourront pas soutenir l'apprentissage des paysans sans bien connaître la logique et le raisonnement de ces derniers. Ils se sont rendus compte que jusque là, ils se concentraient sur l'*apprentissage pour la correspondance* mais il manquait une vision commune et cohérente. Il fallait alors un échange de perspectives. Le modèle SHARES représentait une perspective techno-économique ; une perspective professionnelle avec laquelle les agents du projet se sentaient à l'aise. Puis, ils se sont décidés à utiliser SHARES pour illustrer leur perspective en encourageant les paysans à la critiquer. Ainsi, chacun apprendrait la perspective de l'autre et ils pourraient cerner les objectifs communs.

Le chapitre 8 expose la manière dont SHARES a fait émerger les options de gestion pour les différentes catégories de paysans du village Gainsa. Gainsa est un village caractérisé par un manque sérieux de terre. SHARES a procuré des informations spécifiques pour Gainsa et révélé des limites biophysiques importantes. Pour la première fois, le personnel du projet s'est trouvé confronté à un potentiel de développement très faible et à une pauvreté structurelle au niveau des paysans. Les agents avaient toujours travaillé avec des suppositions et des recommandations générales, en espérant qu'à terme 'les affaires s'amélioreraient'. Ils collaboraient avec les paysans les plus dynamiques et qui avaient des objectifs de développement ambitieux. SHARES les a dissuadés et rapidement ils se sont connectés à la réalité et au raisonnement des paysans.

Le chapitre 9 examine le processus de l'apprentissage déclenché par SHARES dans le village de Koglabaraogo où les terres sont plus abondantes. Ici, les paysans occupaient plus de terre que leurs confrères de Gainsa au Sud et ils ont un certain potentiel agricole. SHARES a montré que les paysans pouvaient facilement améliorer leurs revenus agricoles s'ils optaient pour une stratégie commerciale : acheter plus d'intrants et vendre sa production en temps opportun et aux marchés appropriés. A Koglabaraogo, la présentation des scénarios de SHARES a enclenché beaucoup de discussions sur des normes et valeurs, et les stratégies de vie socialement acceptables. A travers la comparaison des logiques, les agents du projet ont compris que la moralité avait une influence forte sur le raisonnement et le comportement paysans. Ce qui était crucial dans le processus de l'apprentissage, c'était l'attitude ouverte des agents : pour ce qui est du modèle SHARES, ils ne l'ont pas utilisé d'une façon normative, mais plutôt pour découvrir et s'imprégner des perspectives paysannes.

Le chapitre 10 tire les conclusions de l'étude et présente les recommandations. L'étude de cas a montré que l'apprentissage est un processus incertain. Tout dépend des interférences mutuelles des projets et des intérêts des différents réseaux d'acteurs. Un modèle en tant que tel est inflexible et normatif : il représente une certaine connaissance, des intérêts et des solutions privilégiées. Si le cadre de référence du modèle coïncide avec ceux des bénéficiaires prévus, le modèle peut être employé pour l'apprentissage pour la correspondance : il peut améliorer la connaissance de la dynamique de l'environnement ainsi que la connaissance des actions les plus efficaces pour aboutir à la situation désirée. Néanmoins, les fortes chances que les cadres de référence et les centres d'intérêt ne coïncident pas, surtout quand le modèle est développé sans participation des bénéficiaires. Cependant, un tel modèle peut être utile pour mettre de nouveaux points à l'ordre du jour : un modèle est capable d'illustrer des aspects cruciaux mais invisibles et/ou abstraits, donc inaperçus. L'étude a aussi montré qu'il est possible d'utiliser un tel modèle pour l'illustration de certaines perspectives dans le but d'initier des échanges.

Depuis longtemps les instituts de recherche agricole et les services de vulgarisation s'occupent de l'apprentissage pour la correspondance, mais de nos jours il est de plus en plus reconnu qu'il manque une vision cohérente du développement, ancrée dans la réalité et dans la logique paysanne. L'apprentissage conjoint vise une meilleure correspondance et cohérence. Les modèles MGLP sont des modèles stratégiques, qui procurent des informations spécifiques par rapport au lieu et à la catégorie des paysans. Ils proposent une certaine série de stratégies de développement. Ce sont ces deux caractéristiques qui les rendent utiles pour l'apprentissage des professionnels agricoles : ils fournissent des informations détaillées de la situation biophysique des paysans et ils soulèvent souvent des débats sur les stratégies de développement. Ainsi, les modèles MGLP pourraient aider les professionnels à mieux connaître la réalité des paysans et à démarrer un processus d'apprentissage conjoint.

Les modèles MGLP ont une pertinence limitée pour la Gestion du Terroir Villageois (GTV). La GTV englobe un apprentissage de multiples (réseaux d') acteurs avec tous les aspects idéologiques, organisationnels, institutionnels et/ou techniques. Les modèles MGLP ne peuvent guère couvrir toutes les perspectives et les intérêts divergents de tous les acteurs : cela les rendrait complexes et difficiles à manipuler. En plus, la méthodologie MGLP se concentre sur les aspects techniques et économiques. Les autres types de modèles, comme Multi-Agent System (MAS), couvrent des aspects psychologiques et sociaux, donc semblent plus puissants pour l'analyse des aspects organisationnels et institutionnels. Cependant, tous les modèles informatiques restent des outils d'apprentissage assez chers et inflexibles : le développement et la manipulation consomment beaucoup de temps et d'expertise, et l'adaptation rapide aux besoins naissants est problématique. L'apprentissage pour la GTV est un phénomène complexe et incertain, et exige l'emploi d'outils simples, flexibles et peu coûteux.

Somme toute, cette étude offre un nouveau cadre théorique pour l'analyse des processus de l'apprentissage socio-technique comme l'apprentissage de GRN facilité par les modèles informatiques. Cette théorie attire l'attention sur les aspects biophysiques et sociaux, et permet aux professionnels Bêta et Gamma de mieux comprendre les processus de l'apprentissage afin de mieux adapter leurs interventions. L'étude de cas de SHARES au Sanmatenga, au Burkina Faso, a fourni quelques idées pratiques en ce qui concerne l'emploi de MGLP pour l'apprentissage conjoint. Elle a abouti à des recommandations sur l'emploi des modèles MGLP pour l'apprentissage réflexif des professionnels agricoles.

Samenvatting

Het modelleren van landgebruik staat op een kruispunt: modelleren heeft tot meer wetenschappelijke samenwerking en kennis geleid maar tot nu toe worden de modellen nog weinig door planners en/of boeren gebruikt. De vraag waarom er zoveel modellen ontwikkeld en zo weinig gebruikt worden dringt zich op. Blijkbaar bestaat er een kloof tussen modelontwikkelaars en modelgebruikers. Iets wat niet zomaar met een nieuw handboek voor modelleren overbrugd kan worden. Deze studie presenteert een theoretisch kader dat het mogelijk maakt om meer inzicht te krijgen in socio-technische leerprocessen. De studie veronderstelt dat computermodellen niet gebruikt worden om panklare oplossingen te genereren maar om leerprocessen te ondersteunen. Het theoretisch kader stelt Bèta- en Gamma-professionals in staat om deze leerprocessen te analyseren en adequaat te interveniëren. Vervolgens wordt de bruikbaarheid van een Multiple Goal Linear Programme (MGLP) model voor de landbouwvoorlichting in de provincie Sanmatenga in Burkina Faso geanalyseerd. De theorie wordt gebruikt om de relevantie van MGLP-modellen te bepalen voor interactief leren over het beheer van natuurlijke hulpbronnen.

Hoofdstuk 1 introduceert het onderwerp. Het schetst de evolutie van de landbouw en de gedachten over ontwikkeling die daarbij een rol speelden. Lange tijd lag de nadruk op landevaluatie en de planning van landgebruik. Men zocht naar de technisch-economisch meest optimale gebruiksmogelijkheden. In de jaren zeventig was de computercapaciteit zo ver dat het planningsperspectief verbreed kon worden: MGLP-modellen tasten de grens af van de fysische en technische mogelijkheden en confronteerden deze met verschillende sociale en politieke doelstellingen. In de jaren tachtig waren de verwachtingen hoog gespannen: men ging er van uit met computermodellen de hedendaagse landbouw- en milieuproblemen te kunnen oplossen. In de jaren negentig werd echter duidelijk dat computermodellen en systeemdenken weliswaar het wetenschappelijk onderzoek en de interdisciplinaire samenwerking sterk bevorderden, maar dat de modellen voor de landbouwbeleidsmakers en voorlichtingsdiensten slechts van beperkt belang bleven. De vraag rees ‘of’ en ‘hoe’ landgebruikmodellen buiten het wetenschappelijk ‘laboratorium’ van nut zou kunnen zijn.

Op het moment dat deze vraag speelde werkte de auteur als adviseur communicatie en planning bij PEDI, een geïntegreerd ruraal ontwikkelingsproject in de provincie Sanmatenga, Burkina Faso. Het onderzoeksprogramma ‘Antenne Sahélienne’ van de Wageningen Universiteit in Burkina Faso had het MGLP-model SHARES (SHAred RESources) ontwikkeld: een model om op dorpsniveau de landgebruikmogelijkheden te verkennen. Er waren verschillende contacten tussen PEDI en de Antenne en dit schiep de mogelijk om PEDI het SHARES model te laten testen: de Antenne vroeg mij of ik de bruikbaarheid en de toegevoegde waarde van SHARES voor de landbouwvoorlichting kon onderzoeken.

De hoofdstukken 2 en 3 beschrijven de context van de studie. Hoofdstuk 2 geeft een overzicht van de ontwikkeling van landgebruikmodellen en concentreert zich op de Wageningse School van C.T. de Wit. Het inventariseert de mogelijkheden en het gebruik van MGLP-modellen voor wetenschappelijk onderzoek, beleidsformulering, praktijkgericht onderzoek en de landbouwvoorlichting. In de Sudano-Sahel verschaften agronomische modellen meer inzicht in de dynamiek en exploitatie van natuurlijke hulpbronnen. Toch kampten modelontwikkelaars hier met diverse problemen: het was moeilijk om aan de benodigde betrouwbare data te komen en lokale onderzoekers misten de vaardigheid om zelf computermodellen te maken, aan te passen en te gebruiken. Deze ervaringen noopten tot bescheidenheid en de vraag rees of men hier alleen te maken had met een technisch manco of dat het probleem diepgaander en complexer was. Dit vroeg om een contextgevoelige analyse van de toegevoegde waarde van MGLP-modellen.

Hoofdstuk 3 geeft een schets van de lokale omgeving: de provincie Sanmatenga in Burkina Faso. Het beschrijft de bestaanwijze van de rurale bevolking, het nationale beleid en de lokale ontwikkelingsinterventies met betrekking tot het gebruik van natuurlijke hulpbronnen. Dit was de context waarin PEDI functioneerde. Het was een project met een grote belangstelling voor landbouwontwikkeling en een duurzaam beheer van de natuurlijke hulpbronnen. PEDI had zijn specifieke activiteiten, maar volgde in grote lijnen het door de overheid vastgestelde landbouw- en milieubeleid en de daarmee samenhangende ontwikkelingsstrategieën. In de jaren negentig experimenteerde PEDI met diverse participatieve methoden maar het had nog geen consistente en uitgebalanceerde voorlichtingsstrategie. Het donorbesluit om in de volgende projectfase (2001-2005) decentralisatie en bottom-up planning centraal te stellen, creëerde de druk om de voorlichtingsstrategie centraal te stellen. De PEDI-staf lanceerde een actie-onderzoek over boerenleren. Dit gaf de mogelijkheid om te testen of SHARES nuttig was voor leren over het beheer van natuurlijke hulpbronnen.

In hoofdstuk 4 wordt onderzocht welke sociaal-psychologische theorie het meest geschikt is om modelondersteunde leerprocessen te analyseren. De theorie moest recht doen aan het empirisch materiaal en de variabelen leveren die nodig waren voor een analyse van het leerproces. De leertheorie moest aandacht schenken aan:

- de invloed van menselijke en niet-menselijke entiteiten op interactie en leerprocessen;
- de wederzijdse beïnvloeding van actor-netwerken en hun projecten;
- de noodzaak om eerst (samen) een consistent en eenduidige idee over de gewenste situatie te vormen *(de coherentie van visies)* alvorens te gaan kijken welke actie het meest geschikt is om die gewenste situatie te bereiken *(de correspondentie van de actie met de dynamiek van betreffende omgeving).*

Behalve de theoretische doelstelling, was er ook een praktische doelstelling: aanbevelingen formuleren over het gebruik van MGLP-modellen voor het beheer van natuurlijke hulpbronnen. Het was daarom essentieel dat het theoretisch perspectief niet te observerend en afstandelijk was maar voor een actor-perspectief koos.

In eerste instantie leek de actor-netwerk theorie (ANT) (Law, 1987; 1992; 1994; Callon, 1987) het best te passen. Deze theorie bestudeert de interactie en de permanente transformatie van geordende netwerken van mensen en zaken. Echter, de uitwerking van het concept ‘agency’ (de capaciteit om te handelen en een verschil te maken) is binnen ANT problematisch: volgens ANT hebben individuele actoren als zodanig geen ‘agency’. In lijn met de redenering van Giddens (1984), veronderstel ik dat een actor-netwerk structurele kenmerken heeft. Actor-netwerken hebben een zekere ordening en een referentiekader, bestaande uit: (a) regels van interpretatie (kennis), (b) normatieve regels (waarden en normen) en (c) machtsbronnen (vaardigheden, materiele middelen, en de notie van eigen kunnen). Voor het bepalen van hun actie laten individuele actoren zich min of meer leiden door het referentiekader, maar zij hebben tegelijkertijd een zekere bewegingsvrijheid: zij kiezen en onderhandelen actief voor bepaalde regels van interpretatie, normen en waarden, en machtsbronnen. De actor-geöriënteerde benadering (Long, 1992; Long & van de Ploeg, 1989; 1994; 1995) en de theorie van de ‘geplande actie’ (Ajzen & Madden, 1986; Ajzen, 1988) leverden vervolgens het benodigde actor-perspectief en de variabelen over leren: de contextgerelateerde en de actor-netwerk gerelateerde variabelen. Om een beter inzicht te krijgen in modelondersteunde leerprocessen gebruik ik elementen van ANT, van de actorgeorienteerde benadering en van de theorie van de geplande actie. Dit resulteert in een nieuw theoretisch raamwerk: ‘het lerende actor-netwerk’.

Hoofdstuk 5 beschrijft de gebruikte onderzoeksmethode. In deze studie volg ik geen strikte onderzoeksmethodologie, maar ik pas de principes voor ‘reflexief’ onderzoek toe. Giddens definieerde ‘reflexivity’ als ‘het permanent monitoren van eigen handelen, in interactie met andere mensen en de natuur’. De principes van reflexief onderzoek gaan niet alleen over de noodzaak van een systematische behandeling van het empirisch materiaal, maar wijzen ook op de invloed van de ideologische en politieke achtergrond van de onderzoeker, de noodzaak om zich bewust te zijn van de eigen interpretatie, en de relativiteit van de autoriteit en de relevantie van het onderzoek. De onderzoeker moet zich ervan bewust zijn dat niet alleen hijzelf, maar ook de mensen die bestudeerd worden en de uiteindelijke lezers van het proefschrift allemaal hun eigen ideeën, en interpretaties van onze wereld hebben. De uiteindelijke relevantie en autoriteit van het onderzoek hangt af van het samenvallen van de interesses en het verklarend vermogen van de theorie met het empirisch materiaal, de mensen die bestudeerd zijn en de beoogde lezers.

Deze studie is het product van een permanent koppelen van empirisch materiaal met socio-psychologische theorieën; van doorleefde ervaringen en zorgen met wetenschappelijke argumentatie; van details met het algehele proces van leren. Mijn betrokkenheid met het ontwikkelingswerk kleurde de uiteindelijk interpretatie: ik wilde meer inzicht krijgen in de rol van computermodellen in leerprocessen en het praktisch nut van MGLP-modellen voor leren over het beheer van natuurlijke hulpbronnen.

Hoofdstuk 6, 7, 8 en 9 behandelen het veldonderzoek. In deze hoofdstukken behandel ik de volgende drie onderzoeksvragen:

a) Kan het model een leerproces op gang brengen?
b) Hoe beïnvloedt modelgebruik het leerproces van de bedoelde gebruikers?
c) Interactief of inclusief leren vereist leren voor coherentie en leren voor correspondentie. Kan modelgebruik dit faciliteren?

Hoofdstuk 6 gaat in op onderzoeksvraag (a). Over het algemeen worden computermodellen gebruikt voor leren voor correspondentie. Daarvoor is het noodzakelijk dat het model en de gebruikers een gemeenschappelijk referentiekader en doel hebben. Een onderzoek naar, en vergelijking van de kennis en de interesses van de PEDI-staf en de lokale bevolking met die van SHARES geeft aan dat er geen gemeenschappelijk referentiekader en doel was. Dit betekent dat de kans klein was dat SHARES de bedoelde gebruikers daadwerkelijk kon helpen bij het leren voor correspondentie.

Hoofdstuk 7, 8 en 9 beschrijven het actie-onderzoek en het leerproces van de stafleden van PEDI. Zij verschaffen het empirisch materiaal voor de onderzoeksvragen (b) en (c). Hoofdstuk 7 laat zien dat een leerproces door meerder factoren wordt beïnvloed en een toevallig en onvoorspelbaar karakter heeft. In dit geval zette de preoccupatie van de donorgemeenschap de stafleden ertoe aan om een consistente bottom-up voorlichtingsstrategie te ontwikkelen. Zij probeerden om met Participatory Rural Appraisal (PRA) methoden boerenleren te initiëren. Maar de boeren onderhandelden: zij zagen meer heil in directe materiële ondersteuning dan in een gezamenlijk leerproces met onzekere afloop. Na aandringen door de staf, identificeerden zij uiteindelijk wel een aantal praktische leerbehoeften. Tijdens de evaluatie drong het echter tot de stafleden door dat zij nu wel praktische leerpunten hadden, maar nog niet wisten waar de boeren eigenlijk naar toe wilden.

Om het leren van boeren goed te kunnen ondersteunen moesten zij de logica en de belangen van boeren begrijpen. Gezamenlijk leren voor correspondentie kon niet zonder expliciete aandacht voor 'leren voor coherentie'. De PEDI-staf besloot om het SHARES-model te gebruiken om hun professionele, technisch-economische georiënteerde, logica te illustreren en de boeren vervolgens te vragen hierop te reageren, en waar nodig kritiek te leveren. Op deze manier zouden zij elkaars perspectief beter leren kennen en mogelijk gezamenlijke doelen kunnen identificeren.

Hoofdstuk 8 gaat over het leersproces van de PEDI-staf met betrekking tot Gainsa, een dorp met een serieus gebrek aan landbouwgrond. Het beschrijft hoe stafleden met behulp van SHARES de bedrijfsmogelijkheden van verschillende categorieën van boeren onderzochten. SHARES gaf specifieke informatie voor het dorp en maakte de ernstige biofysische beperkingen inzichtelijk. Voor het eerst realiseerde de stafleden zich dat de boeren in Gainsa weinig tot geen ontwikkelingsperspectief hadden en met een structureel armoedeprobleem kampten. Dit terwijl zij altijd met algemene richtlijnen en adviezen hadden gewerkt, ervan uitgaande dat 'alles langzaam verbeterde'. Zij werkten vooral met dynamische boeren die ambitieuze plannen hadden en stonden niet echt stil bij signalen van extreme armoede. SHARES drukte hen met de neus op de feiten en het kostte het de stafleden vervolgens weinig moeite om de redeneringen en het gedrag van boeren in Gainsa te plaatsten en te begrijpen.

Hoofdstuk 9 beschrijft een soortgelijk leerproces voor het dorp Koglabaraogo, een dorp waar gebrek aan landbouwgrond geen rol speelde. De boeren bezaten meer land dan hun zuidelijk collega's en hadden daardoor een bepaald ontwikkelingspotentieel. SHARES liet zien dat de boeren hun inkomen konden vergroten mits zij voor een meer commerciële bedrijfsstrategie kozen: als zij meer kunstmest en bestrijdingsmiddelen gebruikten en hun producten op het juiste moment en de op meest lucratieve markt verkochten. In Koglabaraogo leidde de SHARES-presentatie tot verhitte debatten over normen en waarden. Door de confrontatie van de SHARES-logica met die van de boeren ontdekten de stafleden dat moraliteit bij het handelen van boeren een grote rol speelde. Bij dit leerproces was het van cruciaal belang dat de stafleden een open instelling hadden: zij gebruikten SHARES niet op een normatieve manier, maar veeleer om zelf iets te ontdekken en het perspectief van boeren beter te leren kennen.

In hoofdstuk 10 worden de conclusies getrokken en een aantal aanbevelingen gedaan. Het veldonderzoek liet zien dat leren een onvoorspelbaar proces is en voor een deel van het toeval afhangt; het is onderdeel van het proces van wederzijdse beïnvloeding van actor-netwerken en hun projecten. Modellen als zodanig zijn niet flexibel en normatief: zij representeren een bepaalde kennis, een specifieke belangstelling en serie van oplossingen. Als het referentiekader van een model samenvalt met dat van de bedoelde gebruiker, dan kan het model 'leren voor correspondentie' faciliteren: het helpt iemand om belangrijke details van zijn omgeving te onderscheiden en geeft aan welke acties tot het gewenste resultaat leiden. Anderzijds is de kans groot, vooral als het model zonder consultatie van de gebruikers is ontwikkeld, dat de referentiekaders niet samenvallen en het model niet aansluit bij de leerbehoefte van de gebruiker. In dat geval kan het model nog wel van belang zijn om nieuwe issues op de agenda te zetten: een model kan dingen laten zien die in de dagelijkse werkelijkheid moeilijk zichtbaar en abstract zijn, en daarom niet opgepikt worden. Het is daarnaast ook mogelijk om zo'n model te gebruik ter illustratie van een bepaalde gezichtspunt en zo een uitwisseling van visies en opvattingen te initiëren.

Tot voort kort hielden landbouwonderzoeksinstituten en voorlichtingsdiensten zich voornamelijk bezig met leren voor correspondentie, maar de noodzaak van leren voor coherentie wordt steeds duidelijker. Gezamenlijk leren vereist beide typen van leren. MGLP-modellen zijn zogenaamde strategische modellen. Voor landbouwdeskundigen zijn deze modellen waardevol omdat zij: (a) locatie- en actor-specifieke informatie bevatten en (b) bepaalde typen ontwikkelingsstrategieën aanbevelen. Zij verschaffen deskundigen meer inzicht in de biofysische situatie van boeren en roepen vaak strategische discussies op. Op deze manier helpen MGLP-modellen professionals om de boerenrealiteit beter te kennen en gezamenlijke leerprocessen aan te gaan.

Voor het communaal beheer van natuurlijk hulpbronnen zijn MGLP-modellen slechts van beperkt belang. Communaal beheer betekent dat er diverse belanghebbenden zijn, die verschillende ideologische, organisatorische, institutionele en/of technische problemen ervaren en daarover willen leren. Het is moeilijk, zo niet onmogelijk om dit scala aan perspectieven, normen en belangen in één MGLP-model te vatten. Het maakt zo'n model complex en onhandelbaar. Het sterke punt van MGLP-modellen zijn de technisch-economische analyses. Dit beperkt echter ook hun bruikbaarheid. Een Multi-Agent System (MAS) model integreert het fysieke met de menselijke dimensie en biedt daardoor meer mogelijkheden voor collectieve leerprocessen. Desondanks blijven computermodellen (ook MAS) dure tijd- en expertise verslindende leermethodes die moeilijk aan tussentijds opkomende leerbehoeftes kunnen worden aangepast. Collectieve leerprocessen zijn complex en grillig, en vragen om simpele, flexibele en goedkope leermethodes.

Kort samengevat, biedt deze studie een nieuw theoretisch kader om socio-technisch leren met betrekking tot het beheer van natuurlijke hulpbronnen te analyseren. Het theoretisch kader vestigt de aandacht zowel op de biofysische als op de sociale aspecten, en het verschaft Bèta en Gamma professionals de mogelijkheid om leerprocessen beter te begrijpen en adequaat te interveniëren. Het veldonderzoek concentreerde zich op het gebruik van een MGLP-model voor leren in Sanmatenga, Burkina Faso, en gaf praktische inzichten in het gebruik van MGLP-modellen voor gezamenlijk leren. Dit leidde tot de aanbeveling om MGLP-modellen vooral te gebruiken voor het reflexief leren door landbouwdeskundigen.

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Curriculum Vitae

Annemarie van Paassen was born in Voorschoten on 22 March 1962. In 1980, after completing secondary education at the Jeroen Bosch College in ‘s Hertogenbosch, she started her university education in ‘Economics of the developing countries’ in Wageningen. She followed an extended MSc programme (Legal Anthropology, Extension Science, Economics of the Developing Countries and Co-operations and Credit systems). During her study, she stayed one year at Ambon, Indonesia, to study the change of social security systems within the emerging market economy of Tulehu.

From 1988 till 1991 she was employed by the Netherlands development Organisation (SNV) and worked as a feasibility researcher for the women’s organisation YWCA in Botswana. She joined the gender policy group of SNV Botswana and in 1992-1993 she undertook a policy research on the socio-economic position of women in Mahalapye District, their needs and prospects with respect to vocational training, employment and small enterprise development.

In 1994, she started in West Africa and worked for SNV at the forestry project ‘Tahoua Vert’ in Niger. Main tasks were: the training and coordination of extension workers, capacity building for communal natural resource management (CNRM), the implementation of adult education, save-and-credit activities and monitoring & evaluation. In 1996, she was employed by DGIS and moved to the integrated rural development programme PEDI at Kaya, Burkina Faso. Amongst others, she advised and supported her counterpart with the elaboration of the participatory and gender-sensitive extension approach, the training and coordination of facilitators, adult education, capacity building of village committees, monitoring and evaluation. Towards the end of her contract, she became more involved with agricultural extension programme and started the fieldwork for her PhD research on the added value of multiple goal models for learning for CNRM. In 2001, she returned to the Communication and Innovation Studies group at the Wageningen University to finalise the theoretical part of her thesis. She can be reached at annemarie.sef@hetnet.nl

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