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FULANI AGRO-PASTORALISTS' PRODUCTION STRATEGIES:

ADAPTATION TO CLIMATE VARIABILITY IN MOPTI REGION, MALI

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ABH	Aliment Bétail HUICOMA
a.s.l.	above sea level
CBPP	Contagious Bovine Pleuro-Pneumonia
FAO	Food and Agriculture Organization of the United Nations
FCFA	Franc Communauté Française de l'Afrique; 1 Euro = 655,957 FCFA
GDP	Gross Domestic Product
HUICOMA	Huilerie cotonnière du Mali
IER	Institut d'Economie Rurale du Mali
PRA	Participatory Rural Appraisal
SANREM CRSP	Sustainable Agriculture and Natural Resource Management Collaborative Research Support Program (conducted by the Virgiania Tech University) http://www.oired.vt.edu/sanremcrsp/
SODECOTON	Societe de Developpement du Coton du Cameroun
SSA	Sub Saharan Africa
TLU	Tropical Livestock Unit; 1 TLU = 250 kg liveweight

1 INTRODUCTION

Agricultural production in the Sahelian region operates under a challenging climatic environment. The semi-arid climate is dominated by variability and unpredictability of rainfall through seasonal and interannual fluctuations. Precipitation varies considerably both in spatial as well as in temporal dimensions. In West Africa between latitudes 12° and 17° mean annual rainfall varies from 100 mm to 1200 mm (BADINI AND DIONI 2005) with coefficients of variation ranging from 15% to 30% (FOX AND ROCKSTRÖM 2003) The length of the growing period fluctuates from 90-180 days (FAO 1983). The succession of wet and dry years is a typical feature of the Sahelian climate (KANDJI ET AL. 2006). In fact, extreme years occur so frequently, that some studies argue whether the notion of 'normal rainfall' is relevant in the context of the Sahelian climate (HULME 2001). Thus, production systems in this region owe their existence to their ability to adapt to this fluctuating rainfall supply.

But not only the climatic environment entails high demands on the knowledge and practice of agricultural producers. In addition to their exposure to rainfall variability, Sahelian production systems are characterised by low availability of natural and economic resources, together with a high temporal and spatial variability of this resource availability (UDO AND CORNELISSEN 1998).

Producers that manage their production system under these variable conditions must possess sophisticated knowledge in order to successfully adapt to the environmental variability. Due to the fact that recent climate change studies point to an increase in climate variability in the Sahelian region (KANDJI ET AL. 2006) it is of particular interest to identify production strategies of agricultural producers and analyse them in order to learn about their management of their resource-poor production system and their adaptation strategies to climate variability.

In order to do so, this study investigates the production system of Fulani agro-pastoralists in the Mopti region, Mali. Research objectives are as follows:

1. To describe the production system as a human activity system, with emphasis on the identification of the different management practices carried out by Fulani agro-pastoralists throughout the course of the year. (Descriptive)
2. To reconstruct the rationality behind actions of the agro-pastoralists in two management areas: cattle feeding, and millet cultivation. (Analytical)

The description is based on the perspective of the agro-pastoralists, hence the information they provided in communication tools and interviews. It focuses on *how* agro-pastoralists produce and not primarily on *what* they produce. This provides complementary information to production system analysis based on production theory that focuses on inputs and outputs. The analysis is based on cybernetic knowledge analysis. For specific management fields the analysis shows what the agro-pastoralists observe and on which rules they base their actions. This also reveals action possibilities for agro-pastoralists

a) in low external input systems
b) under climate variability.

2 LITERATURE REVIEW

2.1 AGRO-PASTORALISM

The term agro-pastoralism comprises a wide range of systems, which have in common that they combine farming and livestock keeping with animals grazing on natural pasture in semi-arid areas.

There is the ideal in several pastoral societies that nutrition should be based only on pastoral products (HOMEWOOD 2008) and in some pastoral groups formerly part of the population could seasonally totally rely on pastoral products. However, the ecology and economics of pastoral production make this the exception rather than the rule. The number of animals required to reliable support a family in Sahelian variable climate conditions would in any case be too large to be managed by the number of persons it can feed (HOMEWOOD 2008). Therefore it is evident that all pastoral people have to use other components of diet. To obtain them there are several ways, e.g. gathering/hunting (DE BRUIJN AND VAN DIJK 1995), fishing (CISSÉ ET AL. 2005), exchange, sale, commerce (HOMEWOOD 2008), many other forms of small scale diversification (LITTLE ET AL. 2001) or indeed farming, choosing the alternative of **agro-pastoralism** as does a big part of African livestock keepers in semi-arid areas. The integration of farming and herding has proved to be a successful, lasting production system (HOMEWOOD 2008).

Combining crop production with animal husbandry also improves food security for farmers because the extreme variability of rainfall makes cropping very risky. “In some areas of the Sahel, cropping would not be possible were it not for the presence of livestock which provide an alternative source of food for the human population when the periodic grain deficits caused by poor rainfall occur.” (WILSON 1986:9).

2.1.1 Definition

The Food and Agriculture Organisation (FAO) of the United Nations defines agro-pastoralism as a production system where producers derive “more than 25% but less than 50% of agricultural income from livestock keeping on natural pastures in areas with an annual rainfall between 400 and 600 mm and a length of growing period of 75 to 90 days, where cropping of millet and sorghum is possible.” (RASS 2006:7).

To classify different agro-pastoral production systems in the study area three criteria can be used: the main criterion is the degree of dependency on pastoral products for the gross revenue or food supply of the household or production unit. The second is the particular type of agriculture associated with the livestock system. A third criterion is the duration and distance of livestock movement (WILSON 1986).

The degree of dependence on livestock products can be classified as follows: a system where more than 50% of gross revenue (value of subsistence plus marketed products) or more than 20% of household food energy is directly derived from livestock or livestock-related activities is classified as a pastoral system. A system that derives between 10 and 50% of gross revenue from

livestock, meaning 50% or more from agriculture, is classified as an agro-pastoral system. A third system in which less than 10% of gross revenue is derived from livestock can be classified as agricultural system (WILSON 1986).

Concerning the **type of agriculture associated** with the livestock system in Mali WILSON (1986) distinguishes three subsystems in the agro-pastoral system: The first of these subsystems is characterised by its conduction in semi-arid regions with rainfed millet cropping mostly for subsistence. The second subsystem is conducted in the Niger delta inundation zone within the "Office du Niger" land tenure and irrigation scheme, the main crop being rice. The third subsystem is conducted in the southern sub humid zone, here animal production on natural pasture is a minor component; crop production is characterised by cash and subsistence cropping of millet, sorghum, groundnuts, cotton (WILSON 1986).

For the **duration and distance of livestock movement** it is possible to distinguish between nomadic, transhumant and sedentary (agro-) pastoralists. RASS (2006:7) defines the three types of pastoralism as follows: "Nomadic pastoralism is characterised by high mobility and often irregular movement of people and livestock. In general nomadic pastoralists follow established migration routes. However, erratic rainfall and dynamic external conditions require a certain flexibility, which often leads nomadic pastoralists to deviate from the established migration route. Transhumant pastoralism is based on regular movements of herds between fixed areas to exploit seasonal availability of pasture. Transhumant pastoralists often have a permanent homestead where the older members and the younger children remain throughout the year." Sedentary pastoralism is based on small scale movements close to the settlements of the livestock keepers.

This study will investigate the production system of Fulani agro-pastoralists whose agricultural activities belong to the first subgroup with rainfed millet cropping and whose livestock movements are following transhumant patterns.

2.2 PRODUCTION CONDITIONS IN AGRO-PASTORAL AREAS

As mentioned in the definition agro-pastoral production systems operate typically in semi-arid regions and are thus characterised by high climate variability. The following paragraph gives a general overview of production conditions of agro-pastoralists in Mali, detailing biophysical conditions (climate, soils, the Niger annual inundation) but also socio-economic and political conditions that influence the production system.

2.2.1 Biophysical conditions

All over Africa in the semi-arid regions characterised by high climate variability there is pastoral production, shifting to agro-pastoralism above the rainfall isohyets of 300 mm (BREMAN ET AL. 1998; HOMEWOOD 2008), which indicates the capability of these production systems to adapt to extreme environmental conditions.

Rainfall and seasonality

Due to the seasonal movement of the Inter Tropical Convergence Zone (ITCZ) precipitation in the Mopti and in the Sahel region in general is uni-modal with the rainy season lasting from June

to September. Rainfall shows a pronounced peak in July (average 125 +/- 53 mm) and August (average 155 +/- 68 mm) in Mopti region (BADINI AND DIONI 2005). The annual rainfall in Mopti region varies considerably from year to year, as typical for the semi-arid tropics. During the period 1968 - 2008, data from the Mopti meteorological station indicates a high variability of inter-annual rainfall: lowest was 242 mm in 2002, highest 635 mm in 1994, with a mean precipitation of 453 mm (DIRECTION NATIONAL DE METEREOLOGIE 2009). In the Mopti region in 55% of the years, rainfall deviates with an amplitude of +/- 20% from the long term average (HENGSDIJK AND VAN KEULEN 2002). Additionally the Sahelian climate is characterised by spatial variation, with fluctuations of rainfall in very small scale pattern (SCHAREIKA 2003).

The rainy season is followed by eight to ten mostly dry months. This dry season can be further subdivided. First there is a cool phase which lasts for about three to six months (average monthly temperatures between 20° to 25°). Especially at the end of this period, dust-loaded winds occur from northeast direction. This period is followed by the hot dry season with monthly average temperatures from 30° to 35° (maximum of 45° in the shade during daytime), which endures until the first rains occur, hence three to four months (KROHMER 2004).

Primary and crop production and soils

As a result of rainfall variability, primary production and species composition of the vegetation, on which human and animal populations subsist, varies strongly from one year to another and from one region to another. The production of staple crops as well as the biomass on the pastures oscillates wildly depending on climate, pests and diseases. In a case study in Mopti region HENGSDIJK AND VAN KEULEN (2002) calculate for millet production on a loamy clay soil that in 10% of years there is total crop failure and in the other 90% of years there is only a 6% probability to achieve yields within the range of +/- 50% of the average yield. In general, yields depend more on rainfall patterns than on average rainfall quantity (BREMAN ET AL. 1998).

The soils outside the delta in Mopti region are composed of a mosaic of two soil types: poorly developed, well-drained sandy-loam soils; and poorly drained silty-clay soils. The sandy-loam soils are infertile with a high fine-sand fraction, containing generally more than 65% sand and less than 18% clay (TURNER 1998:670; BREMAN ET AL. 1998). They are associated with eroded dunes and knolls lying from 2-5 m above nearby silty-clay depressions (TURNER 1998:670). The soils are likewise sensitive to wind erosion. Anyhow when soils dry the surface horizons tend to compact, causing problems for the instalment of the crops and water permeability (BREMAN ET AL. 1998).

In natural pasture areas the herbaceous layer is composed of annual forbs and grasses overlaid by a sparse layer of trees and shrubs. Species composition of both the herbaceous and lignaceous layer is influenced by edaphic condition (TURNER 1998:670). Dominant lignaceous species on sandy areas include *Balanithes aegyptica, Acacia albida, Acacia senegal* and *Boscia augustifolia*. Dominant herbaceous species include the following annual grasses: *Cenchrus biflorus, Schoenefeldia gracilis* and *Dactyloctenium aegypticum*. Dominant forbs are *Zornia glochidiata* and *Tribulus terrestris* (TURNER 1998:670).

The Niger delta

The Niger floodplain is fed by catchments in the humid zone 1000 km in the west. When the catchments rains cause the river levels to rise, the Niger floods around 15 000km² of the 30 000km² plain. Because of the lag in movement of the mass of water, the flood begins upstream in October, arrives in December in the mid-delta (Mopti region) and reaches the downstream end of the delta in February. The downstream areas stay flooded along after the upstream waters have drained away. The inland delta has a rhythm dictated by its own progression of flood and draw-down, onto which are superimposed the climate conditions explained above. The floods rise from June to July, peak in September to December, falling January-February finally porting their minimal water levels in March-May (HOMEWOOD 2008:107-108). A specific vegetation has adapted to this rhythmic change, which is used as a contra-cyclical fodder resource by livestock keepers. The *Echinochloa stagnina* (*burgu* in Fulfulde) pastures are the key grazing resource of the delta (CISSÉ ET AL. 2005). In the floods the *Echinochloa*-dominated swamp grass species float upright putting out prolific shoots and leaves. During drawdown the unsupported stems lie flat, putting out new roots from every node and forming an abundance of forage. It is palatable to cattle though of medium nutritional quality. The importance of *Echinochloa* lies foremost in the fact that this pasture is available in a season where forage is very scarce, thus providing a resource to which herders can revert in the dry season. However, due to the spread of rice cultivation formerly *Echinochloa* pastures are now cultivated and only accessible as post-harvest stubble or fallow, useful but not matching the dry-season green growth of the *burgu* (HOMEWOOD 2008). The floodplain of the inner Niger delta is an important dry season pasture for livestock in the region (November-June) with some of the highest regional stocking rates in West Africa. Around 1.5 million cattle and 2.5 million small ruminants converge on the 20,000 km² floodplain at the end of the rainy season (TURNER 1998:670). The *burgu* pastures are productive: *Echinochloa* and *Oryza* producing 7 000 – 25 000 kg DM/ ha*a compared with the rainfed pastures production of 800 – 2 500 kg DM/ ha*a (BREMAN ET AL. 1998).

2.2.2 Socio-economic conditions

Principle traits of the Malian economy correspond to essential characteristics of developing countries. I.e. per capita gross domestic product (GDP) is low: 8 599 US$ in 2008 (UNITED NATIONS 2008), the gross national income per capita is 650.1 US$ (ibid.). The first sector is generating the biggest share of the gross value added, namely 37.7% (ibid.). Principal exports are commodities: cotton, livestock, gold and diamonds (BREMAN ET AL. 1998) and the main imports are machines and vehicles, agricultural products and petrol products (ibid.).

Mali has a population of 12.7 million inhabitants among them 68.4% live in rural areas (UNITED NATIONS 2008). Like other African countries Mali has recently undergone a period of economic transition, characterised by realisation of structural adjustment programs, which means disengagement of the state and divers economical reforms. Main measures taken have concerned progressive market liberalisation of cereal market, reform of the cotton commercial system, limiting public expenses, especially those for state employed personnel, and final a reform of the public enterprise sector: dissolving, privatisation and reorganisation (BREMAN ET AL. 1998).

Animal products and their commercialisation

Animal products marketed are: living animals, meat, milk, leather, hides and wool. Living animals are mainly produced to be exported to the big cities (Bamako, Abidjan, Dakar and others). Local markets in Mopti region that are most frequented by exporters are Fatoma, Sofara, Douentza, Djallassagou, Hombori, Konna, Mopti (KODIO AND SAMAKÉ 2008). Meat produced in the region is locally consumed. Generally in rural areas slaughtering only takes place on market days or for festivities and even then mostly small ruminants or ill/injured cattle are slaughtered. Other than for the Tabaski feast slaughtering for family consumption is rare. Milk is processed and marketed exclusively by women. The money is used to satisfy the needs of the family or the women's own needs. The utilisation of draught animals is frequent and they are valuable means of agricultural production. Leather and hides are used by local artisans for further processing. Recently the informal sector of marketing leather and hide is developing (KODIO AND SAMAKÉ 2008).

Cereal products and their commercialisation

In Mali around 2 million ha are annually cultivated for crop production, mainly in rainfed farming systems (KERGNA ET AL. 2008). Table 1 shows cereal prices during the dry season of 2009 in the eight county capitals of Mopti region.

Table 1: Cereal prices in county capitals in Mopti region in February 2009 in FCFA/kg

Market	Millet	Sorghum	Rice
Bandiagara	150	142	360
Bankass	127	n.a.	400
Djenné	150	150	250
Douentza	150	150	400
Koro	120	112	400
Tenenkou	160	160	320
Youwarou	170	170	325
Mopti	175	155	350

1 Euro = 655,957 FCFA

Source: MINISTERE DE L'ADMINISTRATION TERRITORIALES ET DES COLLECTIVES LOCALES 2009

Production activity, ethnic group and gender

Due to its history, the Malian population is constituted by a number of different ethnic groups who live and operate together in close interaction. The prevalent ethnic groups who live in the Mopti Region are Bambara, Fulani, Bozo, Bobo, Malinké, Marka, Dogon (CISSÉ ET AL. 2005) to name just the most numbered. Historically these ethnic groups are principally associated with different production systems, based on millet, rice, livestock, fish, etc. These systems are in transition as herders, farmers and fishers seek new means of survival in a changing ecology (ibid.).

Pastoralists and sylvo-pastoralists[1] are becoming sedentary; agro-pastoralists are increasingly using trees for animal feed and soil-fertilization, and farmers are raising more livestock. Today ethnic flexibility with respect to production practices can be found in all the production systems of Mopti region. An individual can be a farmer, livestock keeper, or other, regardless of his ethnicity, but in general, the probability of meeting *Fulani* livestock keepers and *Bozo* fishers is still high (CISSÉ ET AL. 2005). It was only in the 1980s that the Fulani became a predominantly sedentary population, expanding their pastoral production system into agricultural production thus becoming agro-pastoralists. Transhumance still occurs according to the old mobility schemes, but now all extended families provide members with a permanent residence (CISSÉ ET AL. 2005).

Furthermore the same division can be found even within one ethnic group. For example in Fulani society there are different social categories, with the people belonging to each category following different livelihood strategies. DE BRUIJN and VAN DIJK (1995) distinguish the following: first there are the *Weheebe* who form the political elite and are considered as the traditional rulers of great parts of Mali. Secondly there are *Moodibabe* who form the Islamic elite, there are merchants called *Jawaambe*, artisans *Nyeeye*, livestock keepers *Jallube* and the former slaves *Riimaybe* who are traditionally occupied with cropping activities (DE BRUIJN AND VAN DIJK 1995).

A division of labour also exists within households, because members are typically assigned specific tasks by age and gender. Usually planning and decision making are left to senior members of the household, most frequently the male household head (CISSÉ ET AL. 2005). For the most part women are charged with household and reproductive tasks (food preparation, collecting water and firewood, childbearing, childcare and so on.) They also tend the livestock kept around the homestead and in particular, are charged with milking and processing dairy products. Men's tasks include clearing and preparing land for cultivation, herd management (herding, castrating, vaccination, slaughter), and digging wells (POINTING 1995 in CISSÉ ET AL. 2005).

Family labour allocation decisions have to be made between the different production strains, with two major constraints: optimal production strategies are not followed, because of periodic appearance of work peaks which cannot be covered with the existing labour force, or the inefficient use of other production resources (e.g.fields) due to unqualified labour and inappropriate production implements. (CISSÉ ET AL. 2005)

Herd entrustment

Livestock entrustment is the predominant labour contract that governs the organisation of herding of other's cattle (TURNER 1999a:276). As former farmers increasingly use cattle as a way of stocking their wealth, the distribution of cattle ownership has "changed significantly since the early colonial period." (ibid.). The new owners however have no experience in livestock husbandry and entrust their livestock to Fulani agro-pastoralists: "As in other areas of the Sahel, a declining share of livestock [in the delta region] is actually owned by the managers of livestock (BONGLIOLI 1985; GRAYZEL 1990; WHITE 1990)." (TURNER 1999a:276). In Mopti region a larger fraction of the livestock population is being managed as entrusted livestock by economically vulnerable herding families. TURNER (1999a) found in a case study that of the 2 310 cattle man-

[1] Sylvo-pastoralism = mobile fishing system

aged by one family clan 76% are not owned by the managing families. 61% of the source for funds for livestock investment came from outside the livestock sector (ibid.). “Increasingly, livestock-deficient Fulbe must depend on attracting livestock entrustments to meet their subsistence requirements.” (TURNER 1999a:277). This also has an effect on labour allocation within the managing families: “More and more of a herd patriarch’s time is spent begging livestock owners to ‘give’ (entrust) him an animal.” (TURNER 1999a:277). Additionally TURNER (1999a) observed “a cattle owner does not entrust or take back cattle from a herd patriarch based on the productivity of the herd (calving rates, weight gain, etc.).” (TURNER 1999a:279). This results in the fact that good livestock management is not rewarded by attracting a higher number of entrusted animals. Consequently as more and more Fulani (agro-)pastoralists have sought to maintain herd sizes via cattle entrustments the levels of compensation have declined: “Presently, the owner, in entrusting his cattle, retains the right to temporarily take back as many as half of his lactating cows to milk for himself.” (ibid.)

2.2.3 Political conditions

Regulation of access to natural resources – the Dina system

This study focuses on production strategies of agro-pastoralists, but these strategies are as much a result of social and political dimensions as of biophysical ones. Social institutions, which are governing tenure, regulate access to resources thus shaping and framing the management decisions taken by the individual. In Mali the still existing land tenure and pasture management system has its roots in the 19th century. During the Hamdallahi regime (1818-1862) the before already existent political and social hegemonic Fulani management scheme was imparted into a formal land tenure and pasture management code called the ‘Dina’, which still influences pasture access for different groups, although officially abandoned. Under the Dina the Delta region was divided into 37 pastoral territories (*leydi*) each under the administration of a local pasture and herd master (*jowro*), in order to maximise mobility and coordinate opportunistic grazing in the pastoral management system. The *leydi* included not only the pasture lands, but also farmer and fisher’s villages and their production sites. Although village heads had control over local uses of the village territory, *jowros* administered pasture use by regulating access rights for different groups, scheduling use and negotiating annual exchanges of pasture with other *jowro* (CISSÉ ET AL. 2005). The current land management and pastoral movement are embedded in the Dina-imposed social structure. The official body to regulate grazing schemes in the Delta today is the communal government, who is regulating access dates etc, but the *jowros* still exist as institution, obliging livestock keepers to pay for gaining access to the resource, and controlling animal numbers (CISSÉ ET AL. 2005).

Competition for space

As previously mentioned, livestock keepers are becoming increasingly sedentary and taking up cropping activities. It is observable that pastoral spaces are lost to crop production (CISSÉ ET AL. 2005). The decrease of available pasture is creating competition. This competition has two dimensions: first there is competition within production units: e.g. successive use of the same pasture by two herds from different origins. When the first herd is late to leave the space and hinders

the entrance of the next competition within production units occurs. Likewise, there can be competition for resources between production units: e.g. destruction of crop fields by animals or destruction of animal corridors by farmers (CISSÉ ET AL. 2005).

2.3 PRODUCTION STRATEGIES

Producers that manage their production system under their variable environmental conditions have developed certain production strategies in order to successfully produce outcome. The following chapter presents information from recent literature concerning agro-pastoral production. It is divided into three sub chapters: crop production, animal production and crop livestock interactions. For crop and animal production it is structured as follows: Firstly, information is provided about resources used, secondly the management strategies are detailed. In the section crop livestock interactions the linkages between the two management fields are detailed.

2.3.1 Crop production

Crop production in the Sahel is predominantly subsistence cultivation (KROHMER 2004). Cultivation schemes differ articulately between the different agro-ecological zones and the type of farming system to which they belong (e.g. agro-pastoralism, sedentary farmers without animals, additional cash cropping or not etc.). Rainfall patterns, soils and socio-economic factors determine the multiplicity and complexity of the production system (BREMAN ET AL. 1998).

The following paragraph gives an overview of production strategies in agro-pastoral crop production systems focusing on rainfed millet production (c.f. classification of production systems in chapter 2.1.1).

Ressources: crops

Most dryland agro-pastoral systems of sub Saharan Africa (SSA) grow pearl millet (*Pennisetum glaucum* (L.)R. Br.), sorghum (*Sorghum bicolor* (L.)Moench), and maize (*Zea mays* L.) as the principal cereals. Fonio (*Digitaria exilis* (Kippist) Stapf) and woandzou *(voandzeia subterranean)* are important in some areas, and rice (*Oryza* spp.) is cultivated in delta areas and along river and stream borders. The legumes cowpea (*Vigna unguiculata* (L.) Walp.) and groundnut (*Arachis hypogaea* L.) are both subsistence and cash crops; grain and hay may be sold (KROHMER 2004; POWELL ET AL. 2004:496; SÉHOUÉTO 2006; IIYAMA ET AL. 2007:60; KOURESSY ET AL. 2008).

Millet is a photoperiodic sensitive plant, which means that it requires sun radiation of a certain number of days to induce its maturity. Two main ecotypes of millet are cultivated in the traditional agro-pastoral crop production system: one type (*Sunnari* MÜLLER 1990:51) requiring 120-170 days for lifecycle, the other type (*Sannoori* MÜLLER 1990:51) can get to maturation within 70-100 days. The growth period where it is possible to cultivate millet lies between the range of 60 to 150 days. For sorghum both late- and early-maturing ecotypes are prevalent in semi-arid areas (BREMAN ET AL. 1998).

Ressources: fields

In most rainfed farming systems there is a considerable distinction of different types of fields managed differently according to their distance from the farmer's homestead. The fields closer to the village (so called home-fields) are cultivated with other crops and crop combinations: there is relatively more millet monoculture on home-fields and relatively more millet/cowpea intercropping in bush-fields (SAMAKÉ 2005). Also there is a different soil fertility management for the more far away "bush-fields". On fields close to the village, manure from the farm compound and organic household waste is applied near the crops or broadcast (GRAEF AND HAIGIS 2001:228). Bush-fields generally receive less fertiliser, resulting in a lower fertility compared to the home-fields (SAMAKÉ 2005).

Management

In Mopti region farmers seed with the onset rains, after ploughing, in mid- to late June. Reseeding is often necessary due to erratic rainfalls. Planting can continue through July in most years. Two weeding turns are customary, although these are dependant on labour availability and the prospect of potential crop yield. Harvesting is usually done in late October to mid-November for millet and sorghum and late December for rice. However, crop calendar varies depending on rainfall pattern. Yields are strongly dependant of time of planting, while higher yields are possible if crops are planted early, a practice often constrained by late or interrupted rainfall (CISSÉ ET AL. 2005).

The following paragraph provides more detailed information concerning management strategies in agro-pastoral crop production. The management strategies about which information can be found in recent literature are:

a) Preparing the fields
b) Ploughing
c) Seeding
d) Mixed cropping
e) Pest and weed control
f) Harvest
g) Gathering

They will be explained in this order in the following paragraph.

a) Preparing the fields

HEISS (2003) gives an overview on the course of working steps throughout the year in a rainfed farming system in Niger in a similar agro-ecological zone. The first working step in agro-pastoral production after the dry season is the field preparation. This entails the clearing of fields from roots of last year's crops and from small bushes (HEISS 2003:45–47). Additionally organic fertiliser such as manure is applied before the beginning of the growing season. (RAMISCH 1999; BROCK ET AL. 2002; SAMAKÉ ET AL. 2005). KROGH AND PAARUP-LAURSEN (1997:194) observe that farmers in northern Burkina Faso tend to cultivate large areas, even more than can later be weeded in the case of abundant rainfall.

b) Ploughing

The second working step is soil cultivation. The function of soil cultivation is seedbed preparation and weed control. It can be done either by the use of oxen ploughs or with hoe based tillage. Ploughing allows the cultivation of larger areas in shorter time. Additionally ploughing decreases labour demand, so in considering whether to use a plough or hoes, farmers take opportunity costs of labour input into account (RAMISCH 1999:14). However, a disadvantage of plough usage is the higher need for fertiliser. Ploughing tends to decrease the plant available nutrient content (e.g. through increased exposure to erosion, leaching etc.) which has to be redelivered (RAMISCH 1999; de ROUW AND RAJOT 2004). According to RAMISCH (1999) for Fulani agro-pastoralists this was not a big constraint because they would possess enough livestock to make up the nutrient loss with organic manure, but that other ethnic groups or Fulani with small herds impoverished their soils by plough tillage due to lack of fertiliser. Additionally he observes that yields are decreased in plough utilisation systems compared to hoe-based systems (RAMISCH 1999).

c) Seeding

Millet is sown "immediately after a 'good' rain that will allow germination" (KROGH AND PAARUP-LAURSEN 1997:194). A case study from Niger reports that before seeding producers "check the rainfall amount by testing the soil moisture to a certain depth" (GRAEF AND HAIGIS 2001:228). Seeds are sown into planting pockets in wide distance (1.6–1.8 m) (KROGH AND PAARUP-LAURSEN 1997:194), according to expected rainfall and soil type. Repeated seeding is common, due to instalment problems of the culture (BREMAN ET AL. 1998).

Generally seeding dates fluctuate widely due to erratic rainfalls. For example in Bankass region SAMAKÉ (2005) reported seeding dates during three years, ranging from seeding 20th May to 30th May in 1998 in the village Lagassagou to seeding during 20th July to 10th August in 2000. Determining seeding dates has an influence on the length of the millet growing period, millet water supply and on weed pressure (SAMAKÉ ET AL. 2005).

d) Mixed cropping

The main association systems observed by SAMAKÉ (2005) in three Malian villages included millet/cowpea, millet/roselle (*Hibiscus sabdarifa*), groundnut/roselle and wouandzou/roselle (SAMAKÉ ET AL. 2005). Mixed cropping allows risk diversification, to merge labour inputs, and to profit from long raining periods in good years. The legumes, mainly cowpea and sometimes groundnut, also contribute to maintain soil fertility because of their nitrogen-fixing capacity (BREMAN ET AL. 1998).

e) Pest and weed control

The most prevalent pest in millet is the parasitic weed *Striga hermonthica* which causes annual crop yield losses up to US$ $7x10^9$ in Africa (M'BOOB 1989 in SAMAKÉ ET AL. 2005). To control striga and other weeds, weeding is done by hand-hoes (BREMAN ET AL. 1998).

f) Harvest

Average yields in the Sahel zone are reported to be between 100–600 kg/ha for millet (but can take up to 1 060 kg/ha in home-fields (SAMAKÉ ET AL. 2005)) and 250 kg/ha for cowpea (BREMAN ET AL. 1998). For Ségou (Mali) MÜLLER (1990) reported yields for the *Sannoori* millet type of 600-900 kg/ha and for the *Sunnari* millet 700-1 200 kg/ha. The harvest process itself is conducted in repeated visits to the fields. Every day the farmers selectively cut and harvest only those spadices that have already attained maturity. However, there is time pressure during harvest because it has to be finished before the cattle return from transhumance to feed on the crop residues (HEISS 2003:61–64).

g) Gathering

Additionally to field crop cultivation Sahelian farmers make use of a variety of tree species. This created a characteristic spaciously spread tree vegetation, because trees with high value are not used for fire wood. Generally prevalent tree species are *Butyrospermum paradoxum, Parkia biglobosa, Lannea microcarpa, Faidherbia albida* and *Adansonia digitata* but there can be various other species according to local importance and ethnic group of farmers (BREMAN ET AL. 1998).

2.3.2 Animal production

Sahelian livestock production is operating in a challenging variable environment. The following section will give an overview of management strategies used in livestock production of agro-pastoral production systems. It is structured as follows: Firstly, information is provided about resources used, secondly the management strategies are detailed.

Resources: animals and herd composition

According to the national statistics (MINISTÈRE D'ÉLEVAGE ET DE LA PÊCHE 2007) in 2006 Mopti region had an estimated livestock population of 2.1 million cattle, 1.4 million sheep and 1.6 million goats. Mopti region represents 22% of the national livestock population (own calculations based on data from MINISTÈRE D'ÉLEVAGE ET DE LA PÊCHE 2007). In the Mopti region nomadic pastoral livestock husbandry, transhumant and to some extent sedentary agro-pastoralistic livestock keeping can be found. 58% of the livestock in inner Niger delta during the dry season can be attributed to transhumant agro-pastoralism (KODIO AND SAMAKÉ 2008).

Agro-pastoralist herds - or in an even broader sense pastoralist herds in general – usually have a broad range of livestock species (e.g. cattle, sheep and goat). This characteristic species diversity allows complementary rangeland use, as all of them have their specific demand and adaptation to different forage plants (MCCABE 2004). It allows further complementarity in productivity (growth rates, reproductive rates, lactation timing and duration) (DAHL ET AL. 1976), complementarity in disease management and drought recovery and in wealth storage for management of income and expenditure (HOMEWOOD 2008).

Management

The following paragraph gives an overview of management strategies in agro-pastoral production systems as they are described in recent literature. The management strategies about which information can be found are:

a) Transhumance
b) Herding
c) Supplementation and water management
d) Breeding
e) Health care

a) Feeding schemes: Transhumance

The core management strategy of providing animals with quality feed in a variable environment is the use of temporal/spatial movement patterns. Pastoralists themselves distinguish clearly between two main types of mobility: daily mobility and transhumance (SCHAREIKA 2003; ADRIANSEN 2008:213). "Transhumance can be defined as the seasonal movement of livestock herds between spatially distant sites so as to make best use of pasture, water and mineral resources, to minimise exposure to disease and risk of crop damage; and/or to take advantage of other temporary opportunities (markets, social gatherings, etc.) dictated by seasonal changing conditions." (HOMEWOOD 2008:83). Fulani pastoralists in Mali relate their movements to the four seasons (de BRUIJN AND VAN DIJK 1995):

- Rainy season – *ndunngu* (June–August).
- Post harvest season – *yaawnde* (September–November)
- Cold dry season – *dabbunde* (December-February)
- Hot dry season – *ceedu* (March–May)

The seasons are similar to the findings in this study and comparable but slightly different from the findings among Senegalese Fulani investigated by ADRIANSEN (2008) and Fulani in Niger investigated by SCHAREIKA (2003).

SCHAREIKA (2003) identifies overcoming the feed supply crunch as the primary goal of pastoralists during the dry season. This is achieved through a focus on animal nutrition whereby pastoralists seek to make cattle gain weight in the rainy season so that animals have enough reserves to survive the long dry season. During the dry season the cattle loose weight, but only the reserves (SCHAREIKA 2003; MORITZ 2010). Traditionally, pastoralists restrict weight loss by sophisticated grazing regimes and by seeking to move their animals to the rangelands with the highest quality and quantity of forage.

Generalising the picture given by MORITZ AND TARLA (1999), data from SCHAREIKA (1998) as well as others, (WILSON, 1986; COPPOLILLO 2000; FERNÁNDEZ-GIMENEZ AND SWIFT 2003; GOLDMAN 2003; HOMEWOOD 2008) there seems to be a wide spread pattern in Sahelian pastoralist grazing management. With the first rains pastoralists seek to reach new pasture where fast-growing annual grasses and herbs (MORITZ AND TARLA 1999) of high nutritional value start to

sprout (ADRIANSEN 2008). For this purpose they seem to like pastures that have a light soil where water can infiltrate easily and that remain dry so that cattle can walk on them (SCHAREIKA 2003).

As the rains begin to decrease and the rainy season comes to end pastoralists continue towards rangelands with clay soil where water does not rapidly infiltrate but stands on the surface. However, these soils can store moisture and perennial grasses grow slower (MORITZ AND TARLA 1999) which is appreciated as a fodder resource as fast growing annual grasses quickly lignify and become less nutritious. Sahelian strategies tend to integrate livestock feeding on crop stubble after harvest and manuring of fields (HOMEWOOD 2008).

During the dry season there is no general pasture use pattern since for all pastures grasses have dried and are of low quality, now other features become more important, such as availability of supplement (e.g. crop residues) or water resources.

b) Herding and the choice of good pasture

Besides transhumance, the second type of movement in pastoralists' perception is that of daily movement patterns with which the herders select the pasture on which their animals feed. This day-to-day management has a considerable effect on animal nutrition and livestock productivity (MOULIN 1993; WAGENAAR ET AL. 1986 in TURNER 1999a:270).

According to MORITZ AND TARLA (1999) there are four dimensions that play an important role in pastoralists evaluating their pastures. When asked to explain their pastures the pastoralists refer to a set of morphological attributes.

First they look at the quantity of the vegetation**,** which can be classified into "low", "medium" or "high". The second characteristic observed is the prevalent vegetation type: either the pasture can be characterised by perennial grasses or annual grasses. Thirdly pastoralists consider soil types. The three options are a) clay soil (*loopere*), b) sandy soil *(`yoolde*), and c) both soil types. Finally, hydrology plays a role, as pastures are characterised by stating whether a) rainwater flows away, b) infiltrates the soil, or c) stands on the pasture. (MORITZ AND TARLA 1999:3–7)

c) Water management and supplementation

Water sources for the animals can be rivers, springs, boreholes, dams and rainwater, all under communal use. All animals are watered at least once a day throughout the year (MWACHARO AND DRUCKER 2005), for Senegalese Fulani, ADRIANSEN (2008) found that in the dry season the pastoralists shift from a daily watering scheme to watering their cattle only every second day.

In agro-pastoralist systems feed supplementation is practiced throughout the year. Fulani pastoralists in West Africa have supplemented natural forage with sorghum, millet stems and cottonseed for centuries (MORITZ 2010), agro-pastoralists can utilise their own crop residues from crop production and if not sufficient purchase from neighbours (MWACHARO AND DRUCKER 2005).

Although sorghum, millet, and corn stems continue to provide an important source of nutrition and roughage, cottonseed cakes and hulls are now the primary source of feed for cattle during the dry season, such that they substitute rather than supplement natural forage. The intensification of

the agro-pastoral system through the increased use of cottonseed cakes has been an incremental and piecemeal process that started in the early 1980s, but really took off in the early 1990s (MORITZ 2010). By feeding the village herd cottonseed cakes, pastoralists have increased the capital inputs per unit of production, in which the unit of production is cattle rather than land. The "intensification thus involves a transition from a production system that relies on free natural forage to a capital-intensive system that relies on costly cottonseed cakes, cottonseed hulls, sorghum stems, and other commoditized inputs" (MORITZ 2010:6). Because of rising human population pressures rangelands are disappearing, and the intensification process is a response to changing environmental conditions. The majority of livestock keepers feed their cattle only enough cottonseed cake to survive the dry season, thus there is no body-condition improvement. MORITZ (2003 in MORITZ 2010) found however that in the dry season of 2000-2001 reproductive rates were higher with cottonseed feeding than in grazing systems.

Inputs required are not only the capital for cottonseed purchase, but also labour demand has increased due to the increase in cottonseed cake supplementation. Cattle are fed cottonseed cakes twice daily, morning and evening, and each time they are fed one by one individually from bowls rather than from a common through. In addition to one person feeding the animals, another must control the waiting animals, which are eager to get their twice-daily ration. Depending on the number of animals, feeding can take more than 3 hours a day (MORITZ 2010). The purchase of cottonseed cakes and hulls is also time-consuming and stressful because of unreliable and insufficient supplies. MORITZ (2010) observed that pastoralists in Cameroon perceive the cottonseed cake market as speculative because only wealthy and well connected businessmen are able to purchase cottonseed cakes in large quantities and as the dry season proceeds the prices may rise considerably. At the end of the dry season livestock keepers may spend hours in search of and bargain for cottonseed cakes at the lowest price possible (MORITZ 2010).

Concerning the class of animals supplemented it is typical in agro-pastoralist systems that oxen are to be the first to be supplemented, followed by cows, calves, bulls and finally other young stock - clearly illustrating the importance of oxen-power in the production system (MWACHARO AND DRUCKER 2005).

Management of the working oxen

Management of the working oxen differs from that of the general herd. In the dry season the oxen are herded with the group of village cattle on fields close to the homestead. Late in the dry season or early in the rainy season they are withdrawn from the main herd, which departs for the annual transhumance. The oxen are then kept in the house compound at night and graze freely throughout the day, when not required for ploughing or transportation use. They are the first to be supplemented with cottonseed cake in order to maintain their draft force.

Oxen are usually trained to plough at the age of four years. It is possible that both in the millet and in the rice subsystem oxen are being kept to an age at which they are relatively inefficient producers of power. This results from the low growth rate and late maturity of this class of stock, the difficulties in replacing them and resulting amortisation costs.

d) Breeding strategies and selection criteria

African cattle keepers commonly replace their breeding stock from their own herd (WURZINGER ET AL. 2008). In addition, breeding animals are obtained from neighbours, friends or relatives and to a lesser extent through purchase at local markets.

Selection is carried out on both the male and the female sides but with different criteria being applied to the two sexes (WURZINGER ET AL. 2006). Cows tend to be selected for their milk production, while more emphasis is placed on growth and physique or beauty-related traits for bulls. It seems that the phenotypic features (coat colour, horns) are more important in bulls than in cows. Other studies also mention bull phenotypic appearance (horn shape and colour, coat colour, size of the neck, dewlap and hooves) as important selection criterion in addition to information about the bull's father, temperament and milk yield and milk quality of the bull's mother (NDUMU ET AL. 2008; WURZINGER ET AL 2008). In both sexes, additional traits like disease resistance, temperament and ancestral information are mentioned by cattle keepers, but have less influence on the selection decision (WURZINGER ET AL. 2006; NDUMU ET AL. 2008).

Concerning breeding strategies WILSON (1986) states that breeding time is not controlled and the seasonality that occurs is a result of the environmental conditions. The highest conception rates are during the rainy months of July, August and September, resulting in the highest birth rates of the year at the end of the dry season in May and June. In a case study with Kenyan agro-pastoralists it was recorded that natural uncontrolled mating is the prevalent mating system (MWACHARO AND DRUCKER 2005:644ff). All herd owners had at least one breeding bull which they usually recruited from their own herds' offspring. In contrast to the bull's sires, dams were usually known for bulls born in the respective herds. Breeding males and female animals were culled on average after being used for 7.5 and 12 years respectively. Reasons for culling were "age, poor health, poor production, poor reproduction, poor body condition, poor traction ability and bad temperament" (MWACHARO AND DRUCKER 2005:645).

e) Health care

Producers usually conduct vaccination where they are effective with low risk of side-effects and great impact of the disease (e.g. high mortality rates, e.g. CBPP) (GRAEF AND HAIGIS 2001). The decision of whether or not to vaccinate animals is based on the cost of the vaccination and the relative gain of vaccination (i.e. expected effectiveness in the prevention of losses). Immunization may add to the survival and subsistence value of the herd as a whole (ibid.). Similar to vaccinations another strategy is the controlled exposure of livestock to endemic disease in order to allow animals to build-up a certain level of resistance. As many diseases are transferred to animals by vectors, there are two ways to deal with this. On the one hand it is possible to control for the vector pressure by grass burning. On the other hand possible strategies involve movements to avoid vector exposure (e.g. tsetse fly) such as only passing through dangerous areas in seasons when the vector pressure is reduced. Finally, a sufficiently high herd size and diverse composition can be used as a strategy to buffer against unpredictable mortality due to illnesses (GRAEF AND HAIGIS 2001).

2.3.3 Crop livestock interactions

Cropping and livestock husbandry are rarely the exclusive concerns of specialised farmers, instead agro-pastoral systems are common and the two activities are closely interwoven (POWELL ET AL. 2004). In central Mali there has been a shift toward closer linkages during the last 50 years (MORITZ 2010). Pastoralists have moved south into agricultural zones (BOUTRAIS 1986; BASSETT 1994; BASSETT AND TURNER 2007) while agriculturalists have moved north into the pastoral zones (THÉBAUD 2002). A consequence of these shifts is the closer integration of farming and livestock keeping both geographically and socially (RAYNAUT 1997). Farmers have increasingly invested surplus wealth by purchasing livestock (MORITZ 2010), which results in better access towards manure and draught power.

Crop-livestock interactions generally bring along the challenge of resource competition and the chance of complementarities. In the following paragraphs the four most important interactions will be explained in further detail. These are: income linkages, soil fertility and manure, crop residues and fodder, and draught power.

a) Income linkages

Income from crop production is increasingly invested in livestock. In this case livestock functions as an "insurance system in case of crop failure" (POWELL ET AL. 2004:472) and as a coping strategy for annual rainfall variability (GRAEF AND HAIGIS 2001:228). Furthermore, livestock can serve as a source of "liquidity and investment capital in the absence of savings and credit institutions." (POWELL ET AL. 2004:472). Income from the livestock sector can significantly improve crop production by providing the investment capital needed to enhance productivity (e.g. investment in carts, fertiliser, hired labour). The other way around is income from crop production used to hire herders, buy supplements or to purchase more livestock and increase flock numbers. Hence crop livestock interactions can serve to provide cash income from one sector that can be invested in the other sector respectively (ibid.).

b) Soil fertility – manure

Various studies in Mali have drawn attention to the perceived risk of soil nutrient loss (GRAEF AND HAIGIS 2001; BROCK ET AL. 2002; IIYAMA ET AL. 2007) because they observe monocultures and prolonged crop rotation intervals which lead to nutrient depletion. Additionally it is stated that farmers do not use sufficient fertiliser to balance the nutrient outtake (BROCK ET AL. 2002). However, several case studies also show that farmers do have access to manure and apply it, regardless of whether they are livestock keepers or not (BROCK ET AL. 2002; RAMISCH 1999). However, conducting agro-pastoralism can increase the availability of manure for crop production (RAMISCH 2005).

In central Mali generally cattle and small ruminants manure is used, but the average rates of application seem to vary to a great extent (RAMISCH 1999). Due to the traditional distinction of activities of different ethnic groups, even in agro-pastoral villages, there can be shortage of manure for some ethnic subgroups. As the animals of agro-pastoralists are often absent from the village, further manure is accessed by either having a well where livestock keepers assemble their herd to water them in the dry season or by ownership of a sufficient number of cattle that

can be corralled on harvested land in the dry season (BROCK ET AL. 2002). The manure of village animals is collected at the tethering spot by owners (in the compound or near the hut), and transported to the fields. Additionally all households that cultivate in the village field zone gather some manure during the dry season when animals graze crop residues freely (RAMISCH 1999).

c) Crop residues – fodder

In Mali's semi-arid region village cattle are pastured in the village territory throughout the year, and corralled in movable enclosures at night in the bush. After harvest, the animals graze freely on crop residues on the village fields. Millet stems are gathered and stored for use in building furniture, fences and roofing material (BROCK ET AL. 2002). Cowpea hay and sometimes groundnut foliage are gathered and stored on hangar roofs and principally used to feed donkeys, horses and cattle. The method of storage exposes crop residues to the sun wind and rain, which is not beneficial for longer storage. Forage plants are not explicitly produced, the livestock feed relies on natural pasture and crop residues (RAMISCH 2005).

d) Draught power

The use of animal draught power is common in central Mali (BROCK ET AL. 2002). The fact that more people use animal draught power than own animals can be explained by the existence of institutional exchange arrangements. Households negotiate with each other to secure access to a range of resources. Therefore there is close crop livestock integration, sometimes not obvious on household level, but focusing on the village level the linkages become evident. Farmers that use draught animals tend to be able to cultivate larger areas than those that have no draught animals Carts for transport can significantly reduce labour requirements and workloads in both cropping and household activities (POWELL ET AL. 2004).

2.3.4 Summary: Agro-pastoralism in Mopti region

In Mopti region agro-pastoralism is mostly effectuated either by now sedentary livestock keepers (usually Fulani) who have started to cultivate (CISSÉ ET AL. 2005) or by farmers (especially Marka, and Bambara) who invested in livestock but often let their livestock be herded by Fulani herders.

In Mopti region the dominating cropping pattern is millet (*Pennisetum glaucum)* and sorghum (*Sorghum vulgare*), generally intercropped with cowpea. The lowland areas in the Niger Delta are used for rice cultivation. In some areas more favorable small scale patterns, such as lower areas, cultivation of watermelon (*citrullus lanatus)*, okra (*Hibiscus esculentus)*, and roselle (*Hibiscus sabdariffa*) are found. Average millet yields in Mopti region between 1984 to 2008 were 602 kg/ha ranging from 370 kg/ha in 1984/85 to 1245 kg/ha in 1987/88. At the same time sorghum yields in the Mopti region were on average 545 kg/ha ranging from 324 kg/ha in 1984/85 to 953 kg/ha in 1986/87 (MINISTÈRE DE L'AGRICULTURE 2008). Farmers seed with the onset rains, after ploughing, in mid- to late June. Reseeding is often necessary due to erratic rainfalls. Planting can continue through July in most years. Two weeding turns are customary, although these are dependant on labour availability and the prospect of potential crop yield. Harvesting is usually done in late October to mid-November for millet and sorghum and late December for rice. However, crop calendar varies depending on rainfall pattern. Yields are strongly dependant

of time of planting, while higher yields are possible if crops are planted early, a practice often constrained by late or interrupted rainfall (CISSÉ ET AL. 2005).

Many households in Mopti also own livestock, generally mixed herds with cattle, sheep and goats (CISSÉ ET AL. 2005). As soon as the first rains take place in June, the herds move towards the high lands (plateaux), which are less intensively used for agriculture. This period is commonly called "petite (small) transhumance" in the French literature (PALLAS 1986). Most herds leave to the northwest of the delta. Others go to the southeastern hill-lands (Séno Bankass, or as far as Burkina Faso) or north up to Douentza. They travel laps of approximately 15 km each day, distances between the different pasture areas are 100 – 200 km (TURNER 1999a:282). When they arrive at their rainy season destination, the herders camp near surface ponds while scouts seek patches of new flush after localised rainstorms, directing the cattle to the best patches of pasture. In this manner, they spend the rainy season. Immediately after harvesting, part of the herds return to the villages to graze on crop residues during approximately one month (PALLAS 1986). When the crop residues are exhausted the livestock is taken to the interior Niger Delta grazing on the flooded *burgu* pastures (see chapter 2.2.1). There are entry dates fixed for each herd, between November and January. In the delta herds are slowly proceeding along the declining floodwaters, making use of the fresh pastures that emerge. By February/March the declining water level has exposed most of the Delta pastures. At this time of the year hundreds of thousands of cattle from east and west Mali and Burkina Faso and Mauritania are dispersed in the Delta, profiting from good forage, abundant water and warmer nights. With the onset of the rains and the rising inundation, the cycle begins again. (HOMEWOOD 2008).

2.4 SYSTEM APPROACH

A system can be defined as “a group of interacting components operating together for a common purpose, capable of reacting as a whole to external stimuli: it is unaffected by its own output and has a specific boundary encompassing all significant feedbacks” (SPEDDING 1988).

Applied to an agricultural production system, the objective of the system approach is to grasp the farm as a whole system in order to explain the functioning of the production system with its interrelations (NOE AND ALROE 2003). The system approach defines agricultural production as “a *unique goal-setting* (i.e., purposeful) *open stochastic dynamic artificial* (i.e., man-made) *system* having a major aim of generating income (in cash or kind) for its stakeholders through agricultural production” (DILLON 1992).

Therefore the systems approach is based on the view that although a system consists of interdependently functioning components, it “is more than the mere sum of its parts” (MACCONNELL AND DILLON 1997). The system itself is not fully understandable from the behaviour of its parts considered in isolation. The binding element that connects these components and forms the purposeful whole are the control mechanisms imposed by the producer (i.e. the controller of the system). The system approach recognises that the operation of purposeful systems is controlled by purpose driven effects arising from decision making of the producer (ibid.). The management is interpreted as the farm’s controlling system (controlling the production system through measurement and adjustment) (NOE AND ALROE 2003:3). From the perspective of farm system theory

any farm system - being a purposeful man-made organization - is seen as an activity of humans (SPEDDING 1988). The producer influences the characteristics of the production system (e.g. crops, animals) over time through his management practices (KAUFMANN 2007). In this respect, a livestock farm as purposeful system is depicted in Figure 1.

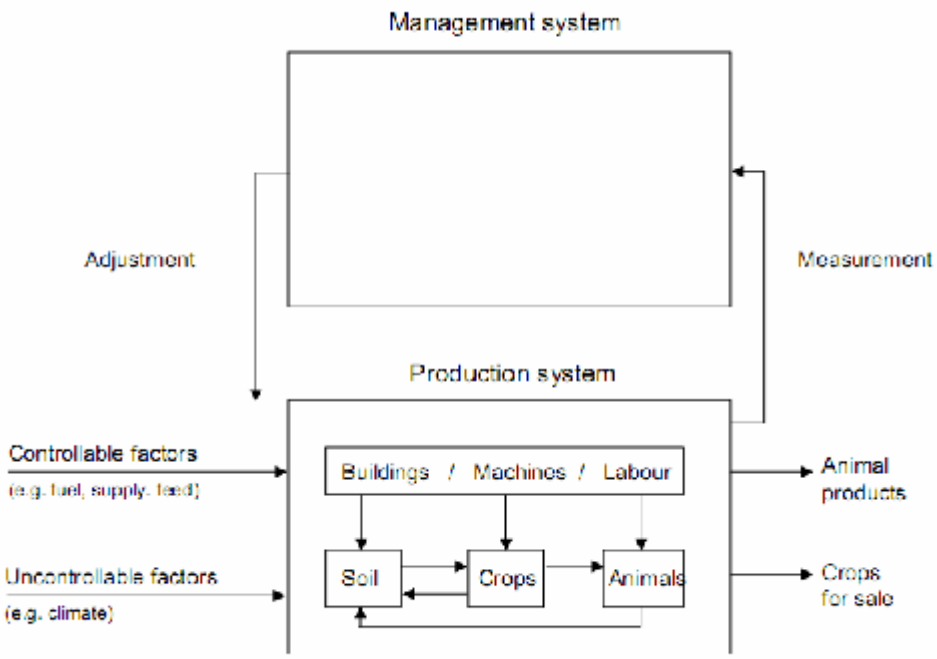

Figure 1: SØRENSEN AND KRISTENSEN's (1992) model of a livestock farm as a cybernetic system

The production system consists of several production assets (soil, crops, animals) that produce a certain outcome: animal products and crops for sale. The purposefulness of the system is ensured by the human activity which enables the system to vary its objectives under a given environment. The system interacts with its environment as controllable factors (e.g. fuel, feed) and incontrollable factors (e.g. precipitation) influence the functioning and eventually the outcome of the system (see Figure 1). The management measures the outcome and adjusts controllable factors in order to attain the envisaged outcome. Any system is a mixture of abstract and concrete elements. The concrete elements are the physical activities and processes that occur on the farm (*what* is done). The abstract elements relate to the production strategies and underlying reasoning (*how and why* it is done).

The view of the farm as a purposeful open stochastic dynamic system (DILLON 1992) is a conceptual device. Beyond emphasising that the farm system should be recognised, understood and managed as a purpose-driven system, rather than just a set of disjointed parts, the systems approach in itself provides no analytical tools aimed at analysing farm management.

2.4.1 Resource poor systems

Regarding the cybernetic model of a livestock farm in Figure 1 it is noticeable that within the production system SØRENSEN AND KRISTENSEN (1992), who work on agricultural systems in industrialised countries, distinguish between controllable factors (e.g. fuel, feed) and uncontrollable factors (e.g. climate). Transferring this approach to a development context one has to consider that in the respective regions the controllable production factors are available to a lesser extent. Generally it can be stated that in the Sahelian region prevailing smallholder and pastoral systems are "characterised by low availability of natural and economic resources, both on long and short term basis, together with a high temporal and spatial variability of the resource availability" (KAUFMANN 2007:3). This leads to the existence of less control possibilities because the strategy of controlling the production system by controlling inputs is limited. Hence the management of these systems has to adapt to a greater extent to the uncontrollable factors such as the climate.

2.4.2 Adaptation to climate variability

Adaptability in the context of farm system theory is the capacity of producers in a system to manage their system's resilience. **Resilience** again can be defined as "the capacity of a system to experience shocks while retaining essentially the same function, structure, feedbacks, and therefore identity." (WALKER ET AL 2006). Depending on subjective assessments of risks, vulnerability, constraints and assets available, farm households make certain adjustments in their choice of production strategies. These can be interpreted as the adaptation strategies that this study is examining. According to COOPER ET AL. (2008) such adaptation strategies can be broadly grouped into three categories: (a) ex-ante risk-management options such as choice of risk-tolerant varieties, investment in water management and diversification of both farming and other associated livelihood activities, (b) in-season adjustment of crop and resource management options in response to specific climatic shocks as they evolve, and (c) ex-post risk management options that minimise livelihood impacts of adverse climatic shocks (e.g. distress sale of assets, borrowing, cut expenditures on non-essential items).

Examples of adaptation strategies

Several studies already dealt with the question of adaptation to climate variability (e.g. BERKES ET AL. 2000; BUTT ET AL. 2009; COOPER ET AL. 2008; GRAEF AND HAIGIS 2001; LITTLE ET AL. 2001). There are diverging views on how well Sahelian producers deal with their environmental and economic conditions (MERTZ ET AL. 2009:806). Recent studies point to dryland populations as operating in a vulnerable system that is under stress due to climate variability (REYNOLDS ET AL. 2007). Others emphasise the resilience of Sahelian producers and their ability to cope with crises (GRAEF AND HAIGIS 2001; de BRUIJN AND VAN DIJK 1995). Further it is argued that the value of local knowledge for adaptation has received little attention (MERTZ ET AL. 2009:806). Sahelian producers apply various valuable adaptation strategies. Some findings in recent literature are summarised in

Table 2 and Table 3 for livestock and crop production respectively.

Table 2: Overview of possible adaptation strategies in livestock husbandry systems in SSA

Scale/unit/asset	Time frame			Source
	Ex-ante	In-season	Ex-post	
Herd	Mixed herds	Splitting animals into discrete herds that are differently managed		MCINTIRE (1991) (FERNÁNDEZ-GIMENEZ AND SWIFT 2003)
	Choose hardy, robust breeds		Reducing stock numbers in order to avoid animal deaths and damage to vegetation	(O'FARRELL ET AL. 2009)
Movement	Short-distance movement between key resource areas in normal years	Movement on a larger scale Following general fodder shortage and in severe drought, large-scale transhumance	Sending livestock far away to relatives that live in areas not affected by poor rainfall	(O'FARRELL ET AL. 2009)
Pasture	Wide spread and seasonally available pastures	Mobility that allows for response to seasonal variation in pasture productivity		MCINTIRE (1991) FERNÁNDEZ-GIMENEZ AND SWIFT (2003)
	Grazing reserves	Timing of grazing		FERNÁNDEZ-GIMENEZ AND SWIFT (2003)
Commercialise		Sell animals in order to buy fodder for the rest		(O'FARRELL ET AL. 2009)
Human resources			Working as wage labourers	MCINTIRE (1991)
Social networks			Trading commodities	MCINTIRE (1991)
Production system	Shift to agro-pastoralism			TOLOSSA (2008)

Source: MCINTIRE 1991; FERNANDEZ-GIMENEZ AND SWIFT 2003; TOLOSSA 2008; O'FARRELL ET AL. 2009

Adaptation strategies of Sahelian livestock producers include mobility, grazing strategies, selection of species and breeds etc. (O'FARRELL ET AL. 2009).

For crop production also a range of adaptation strategies are reported (BERKES ET AL. 2000; GRAEF AND HAIGIS 2001; BUTT ET AL. 2009). These strategies base on weather and site observation of the producers. Reported adaptation strategies involve (1) time elements such as dry seeding, re-seeding and the use of different maturing crop varieties and (2) a spatial component such as the cultivation of large and widely dispersed fields. Other measures aim at sustaining agricultural productivity in a more general way, e.g. fallows and soil amendments are managed on a

very detailed scale within field level (GRAEF AND HAIGIS 2001).

These strategies enable farmers to concentrate their activities on specific fields depending on rainfall development during the rainy season and to ensure at least a minimum field production. A total production loss is then unlikely and will only occur in very dry years (GRAEF AND HAIGIS 2001).

Table 3: Overview of possible adaptation strategies to climate variability employed by farmers in semi-arid West Africa

Scale	Time frame		
	Before the season	During the season	After the season
Plant	Dry seeding Variety selection for stress tolerance/resistance	Replanting with earlier maturing varieties	
Plot	Staggered planting dates. Low density planting. Intercropping. Run-off management. Delayed fertiliser use Fallow to increase fertility Cultivate large areas. Use dispersed fields	Changing crops when re-planting. Increasing or decreasing plant density at replanting or by thinning	Grazing of failed plots for animal maintenance
Farm		Shifting crops between land types	Late planting for forage
Household, village, region	Cereal stocks. Livestock. Social and off-farm employment networks	Matching weeding labour inputs to expectations of the season	Asset sale for cereal purchases. Food transfers. Migration employment

Source: adapted from MATLON AND KRISTJANSON (1988); GRAEF AND HAIGIS (2001)

Whilst these two matrixes provide a broad general picture, it has to be further recognised that there will be region-to-region, village-to-village and household-to-household variation in adaptation strategies that have evolved. However, a closer look for what the cases have in common shows that key adaptation strategies in resource poor systems consist in the following features (FERNÁNDEZ-GIMENEZ AND SWIFT 2003):

- **Diversity**: mixed herds, use of different crop varieties etc.
- **Mobility**: nomadic, transhumance (elevation or latitude), shifting cultivation etc.
- **Buffers**: grazing reserves, fallow land etc.
- **Flexibility**: herd splitting, emigration etc.
- **Reciprocity**: livestock lending, sharing seeds etc.

In general, the stronger, more resilient and more varied the asset base, the greater is people's adaptive capacity (COOPER ET AL. 2008).

3 MATERIAL AND METHODS

3.1 STUDY AREA

The study was conducted in Mopti region, in the center of Mali in West Africa (Figure 2).

Study villages

1 Yongosiré

2 Nérékoro

3 Sadia Peulh

4 Ouandiana

Figure 2: Study area: Mopti region in central Mali

Mopti region is one of 8 regions in Mali and covers an area of 79 000 km² that accounts for 7% of the country. Mopti region borders Timbuktu region to the north, Burkina Faso to the east and south and Ségou region to the west. It is crossed by the inland Niger delta, which annually inundates a surface area of avarage 16 000 km² during August - December. The arable land covers 15 000 km² which is 19% of Mopti's land area.

For this study four villages, in two different ecological zones, where chosen (Figure 2). The selection process is described in chapter 3.2.1. Yongosiré lies in the inner delta of the Niger river. Nérékoro is located at the delta's border. The two villages Sadia Peulh and Ouandiana are located in the Séno Bankass area, which belongs to the Bandiagara tableland in the semi-arid zone of the southern Sahel.

3.1.1 Climate

Mopti region is situated in the central zone of Mali between the rainfall isohyetes of 300 mm to 600 mm. The climate in the study area is semi-arid. Rainfall is distinctly unimodal but highly variable in amount and duration (see Figure 3). During the period 1968 - 2008, data from Mopti meteorological station indicate a high variability of inter-annual rainfall: lowest was 242 mm in 2002, highest 635 mm in 1994, with a mean precipitation of 453 mm. In Mopti region there is 55% probability that, rainfall deviates with amplitude of +/- 20% from the long term average. (HENGSDIJK AND VAN KEULEN 2002).

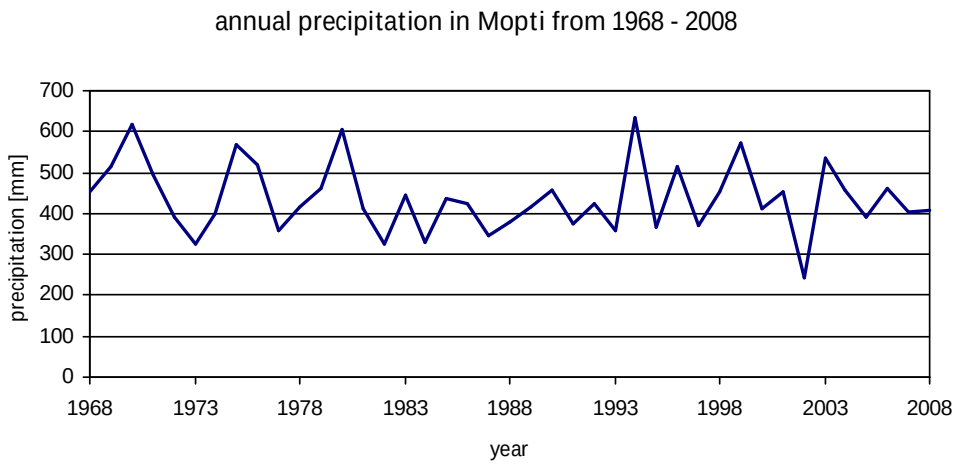

Figure 3: Annual precipitation in Mopti from 1968 – 2008
Source: own illustration based on data from DIRECTION NATIONALE DE LA MÉTÉREOLOGIE (2009)

Average daily mean temperatures vary between 23 °C in the cold season (December – February) when minimum temperature in the night is 15°C and 33 °C in the dry season (March – May) with daily maximum temperatures of up to 45°C.

The rainy season lasts in general from July to October. The Niger Delta is annually flooded during August until December. The months June to October are suitable for crop production as is indicated in FFigure 4

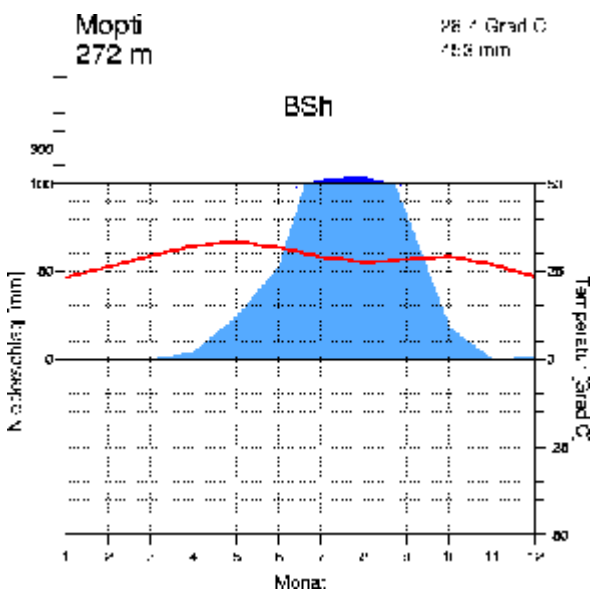

Figure 4: Climograph of Mopti weather station
Source: MÜHR 2007

3.1.2 Natural resources

Land area

Around 1/6 of the region consists of the inland Niger delta alluvial plain which's prevailing land form is flat with low plateaux and basins and a mean altitude of 272 m a.s.l. Soils are deep and consist of clay-loam to silt-loam. These are subject to seasonal inundation with poor and imperfect drainage. The underground water is at shallow depth, and due to the annual inundations irrigated agriculture is predominant.

East of the delta rises the Bandiagara cliff with altitudes ranging from 400 – 1000 m a.s.l. which merges into the flat tableland of the Séno area. The Séno zones comprise the Séno-Bankass zone (i.e. Séno-Gondo) with 6 527 km^2 and the Séno-Mango zone with 9 300 km^2. Together, they represent about 23% of the total area of Mopti region. Parent materials are mainly formed by eolian sand deposits originating from weathering of the sandstone of the Plateau. Most soils are deep with loamy-sand to sandy-loam at the surface, with a low water holding capacity and a low fertility (VAN DUIVENBOODEN AND VEENEKLAAS 1993 IN SAMAKÉ, 2003). Loamy clay represents 28% of the total area of the Séno-Mango and is used for pasture. This zone is suitable for cereal cropping and herding. Millet is the main cereal in this zone. Sorghum is grown only in depressions, i.e., low parts in the area where soil fertility and moisture contents are relatively high (SAMAKÉ ET AL. 2005).

Vegetation

The inner delta carries rich vegetation that is influenced by the duration and the height of the inundation. The forage potential is very high and the delta is used as dry season pasture (BADINI AND DIONI 2005). The most important forage plant is the in Fulfulde called *burgu (Echinochloa stagnina).* Other typical plants of the inundation zone of inner Niger delta are herbaciuos plants such as *Vetiveria nigritana* or *Andropogon gayanus, Oyza longistaminata, Nymphea maculata, Pistia stratiotes, Vossia cuspidata, Nymphea lotus.* Less frequently inundated areas are dominated by woody vegetation with species like *Piliostigma reticulatum, Diospyros mespiliformis, Mytragina inermis, Acacia sieberiana.* On permanently cultivated soils *Acacia seyal, Pterocarpus lucens, Loudetia togoensis* and *Pennisetum pedicellatum* can be found. (VAN DER RIET 2008)

Outside the inundation zone the dominant vegetation is grassland with a changing proportion of shrubs and small trees. The dominating tree species are thorny leguminosae such as *Pterocarpus lucens, Acacia seyal, Acacia laeta,* and *Dichrostachus cinerea*. On sandy terraces *Acacia albida* is an important species and is much appreciated as dry-season forage of high protein value (KROHMER 2004). Grasses are mainly annuals, including *Cenchrus biflorus, Schoenefeldia gracilis* and *Dactyloctenium aegypticum*. Dominant forbs are *Zornia glochidiata* and *Tribulus terrestris* (TURNER 1998:670).

Cultivated crops

Mopti region grows 40% of Mali's rice production and 20% of the national millet and sorghum production (VAN DER RIET 2008). Crop production is conducted either as rainfed agriculture outside the delta or as inundated rice production in the delta zone. Table 4 shows average annual yields per hectar for the main cereals respectively. Due to high rainfall variability, cereal yields are instable.

Table 4: Annual cereal yields per kg/hectar in Mopti region

Season	Millet	Sorghum	Rice	Maize	Fonio	Total
1994/1995	489	533	932	19	272	2 245
1995/1996	768	605	622	474	429	2 898
1996/1997	877	572	998	720	433	3 600
1997/1998	807	520	498	1 400	487	3 712
1998/1999	799	824	1 199	555	464	2 643 199
1999/2000	913	743	1 265	696	515	2 868 265
2000/2001	746	488	971	530	299	3 034
2001/2002	452	689	1 127	297	515	1 954 127
2002/2003	678	435	634	494	352	2 593
2003/2004	711	417	1 224	603	448	2 180 224

Source: MINISTERE DE L'AGRICULTURE (2008)

3.1.3 Animal population

Agro-pastoralists in Mopti region own mixed herds composed of cattle as large stock and small ruminants as small stock. Average herd sizes upon entering the delta are 150 cattle and 200 small ruminants (DIAKITÉ 2007:37). Households that own more animals usually split their herd in several smaller herds. Table 5 reports data from the ministry of animal husbandry, which gives an overview of animal numbers in the inundation zone and the non-inundated zones in Mopti region.

Table 5: Livestock numbers in Mopti region per breed and zone

Breeds	Total inundated zone	Total non-inundated zone	Total Mopti
Bovins	600 000	700 000	1 300 000
Ovins	800 000	1 250 000	2 050 000
Caprins	560 000	1 490 000	2 350 000
Equins	37 300	84 500	122 000
Asins	45 500	80 500	126 000
Camelins	860	4 140	5 000
Porcins	100	8 900	9 000
Poultry	1 550 000	1 950 000	3 500 000

Source : MINISTERE D'ÉLEVAGE ET DE LA PECHE, 2007

The majority of animals in Mopti region animals are kept in a pastoral or agro-pastoral system with seasonal transhumant movement patterns. There are also animals which are kept in a sedentary system where animals stay in villages and are sent for grazing around the village. Additional some animals from nomadic livestock keepers are frequently encountered in Mopti region (VAN DER RIET 2008).

Prevailing breeds are local breeds such as the Sudanese Fulani cattle, the Toronké variety of the Fulani sheep and the Western Sahelian goats (WILSON 1986).

3.1.4 Human population

Mopti region has a population of about 1.5 mio people, this is about 15% of the national population. Agriculture and animal husbandry are the main economic activities, contributing 46.2% (agriculture) and 34.4% (livestock) to total revenues (KODIO 2001).
Mopti region is mainly inhabited by the ethnic groups Bozo, Dogon, Songhai, Fulani and Bambara among which the Fulani can be classified as pastoral/agro-pastoral group. They inhabit villages all over Mopti region and make use of the inland delta pasture areas as well as the surrounding Bandiagara plain and the northern areas close to Sahara dessert. Historically, the different ethnic groups living in the region are associated with different production systems, e.g. Fulani are traditionally engaged in animal husbandry, Bambara and Songhai are farmers, Bozo are known as fishermen. These systems, however, are in transition and ethnic flexibility with respect to production practices is possible (CISSÉ ET AL. 2005).

3.1.5 Infrastructure

Infrastructure in Mopti region is better than in most of Mali's remote areas, due to transportation on the river Niger during the rainy season. However, the inner delta zone is not accessible by car except during the dry season. Besides, there is only one continously tarmaced road leading from Gao to Bamako. The fish road (Mopti – Bankass – Burkina Faso) is partly tarmaced until Bandiagara.

The region is criss-crossed by corridors for the animal transhumant routes *(burti)* and places for herd encampments *(billé).*

Electricity and telephone facilities are restricted to the region's townships (Bandiagara, Bankass, Djenne, Douentza, Koro, Mopti, Tenenkou, Youwarou) and electricity outages are frequent. Mobile phone network coverage in rural areas is incomplete, but generally available within walking distance. All townships except Youwarou had a radio station (public or private) in 2007 (VAN DER RIET 2008) and radio transmission is available all over the region as well as television.

Market outlets

The instability of cereal yields leads to high seasonal price fluctuations (VAN DER RIET 2008). Agricultural products are self-consumed or sold in more southern regions due to the relatively low purchasing power of Mopti region compared to the southern regions in Mali (ibid.).

Livestock trade is considerable, important markets are Bankass, Boni, Douentza, Hombori, Korientzé, Boré, Toguéré-Coumbé, Tenenkou, Diondiori, Diallassagou, Koro, Douma, N'Gouma,

Mopti-Sévaré, Sofara, Konna and Fatoma. Due to the high supply of livestock, the terms of trade are unfavourable for animal products compared to cereals, sugar and other commodities; this is increased by high transportation costs and poor infrastructure.

3.2 DATA COLLECTION

3.2.1 Selection of villages

The villages that were chosen as study site were selected at a workshop at the Institut d'Économie Rurale (IER) in Mopti 19/02/2009. Participants were Fatoumata Bah[1], Salmana Cissé[1], Lassine Diarra[2], Kaïmama Djenepo[1], Brigitte Kaufmann3, Moussa Keita[1], Odiaba Samaké[1], Mamadou Satao[4], Magdalena Werner[4] and Karim Diarra[5] (who was consulted via mobile phone).

Four villages in the two different ecological zones were chosen (see Table 6) according to the following criteria:

- Distance to market
  "Far" from market had been defined as more than 10km. The criteria should help to divide villages were the production is more versus less market oriented.

- Distance to the river
  "far" from the river had been defined as more than 5km. The criteria should help to divide villages were access to fodder and water during the dry season is or is not a constraint.

- Main activity of inhabitants: agro-pastoralism
  Assumption: agro-pastoralism is a typical Fulani activity, thus villages with the majority of inhabitants belonging to the ethnic group of Fulani have been chosen.

With regard to the criteria "far from river" Mopti region was divided in three different zones: the Delta, the Gourma and the Séno. In the delta all villages are near to the river, because practically all livestock has access to pasture and water during the dry season (system "Bourgoutière"). In the Gourma access to pasture during dry season is possible, but the pasture is not always of good quality. In the Séno it is difficult to access good pasture in the dry period, there livestock feeds on crop residues. In order to have two sets of villages that are as different as possible in the respect of the cited criteria two villages from the delta and two from the Séno area have been chosen, and within the set always one close and one far from market (see Table 6).

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[1] Équipe système IER Mopti
[2] IER Bamako
[3] Senior scientist at DITSL
[4] Master student conducting the fieldwork
[5] IER Bankass

Table 6: Criteria for selection of villages

	Close to market	Far from market
Close to river (= delta)	Nérékoro	Yongosiré
Far from river (= Séno)	Sadia Peulh	Ouandiana[2]

Soure: own data

For facilitating the research and in order to increase comparability of the results the following auxiliary criteria were additionally taken into account:

- Accessibility for the research team
- Size of village between 500 – 1 000 inhabitants
- No open social conflicts in the village
- Currently no other project
- Availability of secondary data
- Expected cooperation of the agro-pastoralists

3.2.2 Methods

Data was collected from February to May 2009. Focus was on qualitative methods, using a Participatory Rural Appraisal (PRA) approach. The research team lived for two weeks in each of the villages and conducted participant observations, semi-structured interviews, and communication tools. All group sessions and interviews were animated in French by the author and translated into Fulfulde by Fatoumata Ba (Nérékoro) and Ibrahim Diallo (all other villages), likewise answers were given in Fulfulde and were translated into French.

3.2.2.1 Participatory rural appraisal

The participatory rural appraisal approach developed end of the 1970ies as a "semi-structured process of learning from, with and by rural people about rural conditions" (CHAMBERS 1992:298). It emerged from the growing "belief that all people, regardless of age, gender, or level of education, have a right to participate in decisions that claim to generate knowledge about them" (VAN DER RIET 2008:551). Eventually the participative rural appraisal approach is a collection of qualitative research methods and tools that allow rural people to contribute their interests and their knowledge to the research process (KRUMMACHER 2004). For more details on the specific research methods see SCHÖNHUTH AND KIEVELITZ (1993).

Participant observation

Participant observation was conducted in a rather unsystematic way throughout the whole time in the field. Whenever the occasion came up the research team accompanied people that were carrying out activities on their farm and generally asked questions about what they were doing and

[2] Ouandiana had not been in the selection beforehand, actually Sadia Peulh had been selected as village in the Séno that is far from market. However reality in the field showed that Sadia Peulh is very close to the important market of Bankass (8km) and production is market oriented and therefore another village had to be selected. Method of secondary selection was a visit to the mayor in Diallassagou to whom the criteria were explained. According to these criteria Ouandiana was then chosen by the two students conducting the fieldwork.

why. The information obtained by this activity was collected in written field notes. The purpose of participant observation was to get a direct insight into the production and livelihood system of the people, to gain background information and observe actions and to draw attention on aspects of the production system that were not mentioned in communication tools and interviews. It also served to crosscheck information obtained within the main data collection and if possible to learn about tacit knowledge that people can - due to the nature of this knowledge - not express in interviews. However, the constraints of participant observation were the lack of local language skills of the author of this study and the need of rest of the translator, which restricted the use of this method in a large extent. However, the following activities were observed:

- Milking of cows and calf feeding
- Preparing fodder and feeding village animals
- Watering cattle
- Branding of calves
- Ploughing
- Vaccinating sheep
- Manure transportation
- Gathering from trees
- Food processing
- Fabrication of bricks
- Construction work

Communication tools

Communication tools were used in all four villages during public sessions, lasting 1-2 hours with between 3 – 25 active participants. Table 7 shows all conducted tools and what kind of information was obtained. Group session appointments were always programmed so that they would not coincide with market days. Care was taken to include different age groups and all ethnic subgroups, because traditionally they conduct different activities within agro-pastoralism and therefore have different knowledge about it. It was aimed at including both men and women, which worked well, except in Ouandiana, for cultural reasons. For more detailed information on the conduction of the different tools see annex 11.1.

The sessions were recorded by a digital voice recorder; additional notes were taken during the sessions. The visual information from posters produced by the participants during the session later was put on record in a written document using the audio records and notes to complete the information.

Table 7: Conducted communication tools

Communication tool	Number of participants				Information obtained
	N	Y	O	S	
1. Village resource map	25	18	14	7	– Structure of the village – Availability and accessibility of resources – Quality of resources
2. Livelihood analysis	8	18	14	4	– Livelihood strategies – Assets – Outcomes
3. Seasonal calendar animal husbandry	11	8	7	9	– Routine activities – Seasonal movements – Information concerning: Feeding, Reproduction, Off take, Health
4. Seasonal calendar crop production	14	10	10	11	– Crops cultivated/fruits collected – Course of work throughout the year – Routine activities
5. Focused group discussion based on the seasonal calendar	8	9	8	8	– Major differences in a dry year – Coping strategies
6. Pair wise ranking animal breeds	3	*	*	9	Criteria for selection
7. Pair wise ranking cow beans/millet/rice	*	8	*	4	Target values for trait expressions
8. Pair wise ranking pasture	*	*	4	*	

Source: own data, * = not conducted in this village

3.2.2.2 Triangulation and feedback seminars

Triangulation as well as feedback seminars are inherent parts of PRA, but to underline their importance for this study they are explained in the following section in detail.

Triangulation refers to the diversification of perspectives in order to reduce bias that can occur because an issue is regarded from a limited viewpoint. In this study, triangulation was obtained through the use of a variety of tools (e.g. group sessions, semi-structured interviews, participant observation). The objective was that data about one issue was always obtained by at least three different tools.

A second important mean to reduce bias was the conduction of feedback seminars. The principal objective of feedback seminars is to inform the informants about the results of the study and to serve as a forum for them to give comments, objections and criticism on the conduction and conclusions (GRUND 2004). Additionally they were used to clarify contradicting information and open questions.

After the completion of data collection and a preliminary analysis, feedback seminars were conducted in all four villages on 06/05/09 (Nérékoro), 07/05/09 (Yongosiré), 10/05/09 (Sadia Peulh) 11/05/09 (Ouandiana). The feedback seminars were structured similar to a scientific seminar. They started with a recall of the research question, followed by an explanation of the research methods and what kind of data was obtained by which method. The results were presented in

form of diagrams using the same symbols the informants themselves had introduced in the sessions before. Finally, the findings and conclusions were critically discussed with the informants. The feedback seminars were recorded with a digital voice recorder and partly transcribed.

3.2.2.3 Semi-structured interviews

Semi-structured interviews were conducted in all four villages. Informants were selected by village heads according to the following criteria:

- Ethnic group (Fulani or Riimaybe)
- Household head
- Has knowledge about the topic (crop production or animal husbandry)
- Is open and will like to talk with the research team
- Is available (has time and is presently in the village)

It is likely that village heads chose informants according to other additional criteria that were not communicated. However, the researcher had only at some occasions in the village Sadia Peulh the impression that the selection was biased.

Informants were always visited in their houses at times that were convenient to them. Before starting the interview, the informants were assured of anonymity. The research question was explained to them, and it was stressed that their thoughts and observations on the topic are of relevance, and that the research team wants to learn from *them*. Finally, the functioning and purpose of the voice recorder was explained and permission was asked to use it for the interview session. The opening question was “si vous regardez l’année pasée et votre speculation et l’élevage, pourriez vous nous racontez le deroulement de l’année passée avec des evenements lesquels vous avez rencontrez?” [Concerning your cultivation and livestock husbandry, could you please talk about the course of events of the last year?]. The structure of the interview was following the seasonal calendars, covering all the annual cycle. The paper presentation from the comunication tool “seasonal calendar” was brought to the interview for orientation. The final question was asking for a comparison between the last year and a year that is especially dry and to explain differences.

3.3 DATA HANDLING AND ANALYSIS

3.3.1 Communication tools and feedback seminars

In the first step recorded and visual data from the communication tools and the feedback seminars were transferred to a written document. In the field every evening the information from the visualisation was collected, the digital voice records were heard again and the information was summarised in a written document (note: no real transcripts, only sometimes parts that contain a lot of information were transcribed).

The written documents were later used to merge the information, for each communication tool respectively. The four documents from the different villages were compared, similar information was subsumed, diverging information was noted and explained in the presentation of results.

3.3.2 Qualitative content analysis

1. Selection and preparation of interviews used for content analysis

The semi-structured interviews built the core of the analysis of this study. Altogether 22 interviews were conducted. Among them 12 interviews were used for content analysis. The choice was made according to the quality of the interview in terms of quantity of information obtained in relation to the research question. 6 interviews had to be sorted out because they had not been successfully conducted as semi-structured interview[3] and thus were not suitable for content analysis (Table 8). Interview C6 had a very special topic (orientation on the stars during transhumance movement) that was not mentioned in any other interview or communication tool; hence because of lack of triangulation it had to be sorted out.

In a first sorting 15 interviews had been chosen for content analysis. 3 of them have been paraphrased and transcribed in parts only because information was not very dense. Paraphrasing was done in German, thus changing the language of the information. 3 interviews were completely transcribed and 9 interviews were sent to Mali to be re-translated by another translator El-Hadj Sy. The re-translation was necessary beause the first translation on the spot turned out to be too vague and often not exact enough to be suitable for content analysis. The re-translation was based on the original recorded audio file. Out of these 9 interviews 6 interviews were re-translated and 3 interviews were finally left out due to time constraints of the translator. Hence, the primary document for content analysis contains altogether 12 interviews and consists of 104 text pages.

Table 8: Overview of conducted and analysed interviews

Handling	Interviews[4]	Number
Conducted interviews		22
Sorted out due to poor quality	A5,C2b, C3a, C7b, D4b, D6b	6
Sorted out due to lack of triangulation	C6	1
Sorted out due to time constraints of translator	A4b, C8b, D5b	3
Interviews used for content analysis		12
Paraphrased	A1b, A2a, A3b	3
Transcribed	C4a, D2a, E4a	3
Re-translated	B1a, B2b, C1a, C5b, D1b, D3b	6

Source: own data

[4] In order to guarantee anonymity of the interviewees the interviews were assigned identification codes: A = village Nérékoro, B = Sadia Peulh, C = Ouandiana, D = Yongosiré, E = Yongosiré during the second visit for feedback seminars; a = Riimaybe, b = Fulani, the numbers refer to the order in which the interviews were conducted

[3] The objective of semi-structured interviews is to let the informant lead the interview and allow him to raise topics and give context as he judges information to be of importance. However in the six interviews that had to be sorted out, informants answered very short and did not express their ideas or reasoning. So if there is not enough free speech of the informants the texts are not suitable for content analysis, hence had to be sorted out due to their shortness and limited information content.

2. Coding

After transforming the recorded data into written text via paraphrasing, transcription or re-translation, the primary document was read through and headings were added to the text. The objective of the headings was to name as precisely as possible the topic about which information is given in the text. The headings were stated in German, constituting the first language shift (except those 3 interviews that had already been paraphrased in German). The headings were collected and constructed the **set of categories** used for further analysis. Annex 11.2 and 11.3 show the set of categories that was derived from the headings. In a second turn the material was carefully read through and every passage was coded with a category.

3. Extracting, restructuring and summarising the data material

In this step of abstraction the data material was restructured. Information was extracted out of the context and put together according to category. Category for category information was extracted, generalised and summarised. At this abstraction level the complete text concerning crop production was transformed into German. Information concerning animal husbandry was analysed ensuing and could be left in French due to increasing analysis and language skills of the author.

The so attained condensed coded information was then used to derive general information about the agro-pastoralists production system (results 4.1, 4.2.1-4.2.3 and 4.3.1-4.3.3). Based on this general description topics were selected for a more detailed analysis. The choice of topics which were analysed in more detail was made according to their relevance for the producers. The indicator for relevance was the amount of information that was given by the agro-pastoralists, assuming that in semi structured in-depth interviews the interviewee will talk most detailed about topics that seem important to him.

3.3.3 Cybernetic approach

There are many different definitions of cybernetics as it is used in many different research disciplines but it can generally be stated that the objective of cybernetics is to understand and define the functions and processes of dynamic systems (VESTER 2008). Cybernetics is the "theory of regulation and information processing in dynamic systems." (WIENER 1948 IN KAUFMANN 2007). Dynamic systems consist of different parts that function in a certain dynamic order in relation to each other. Cybernetics assumes that dynamic systems tend towards a specified state (objective of the system). It is possible to model a cybernetic control loop (see Figure 5) for the prevalent, but eventually for any, agricultural production system. Actions are based on sensing actual values and comparing them with target values. According to underlying reasoning decisions are taken in order to control the process and thereby obtain the envisaged outcome.

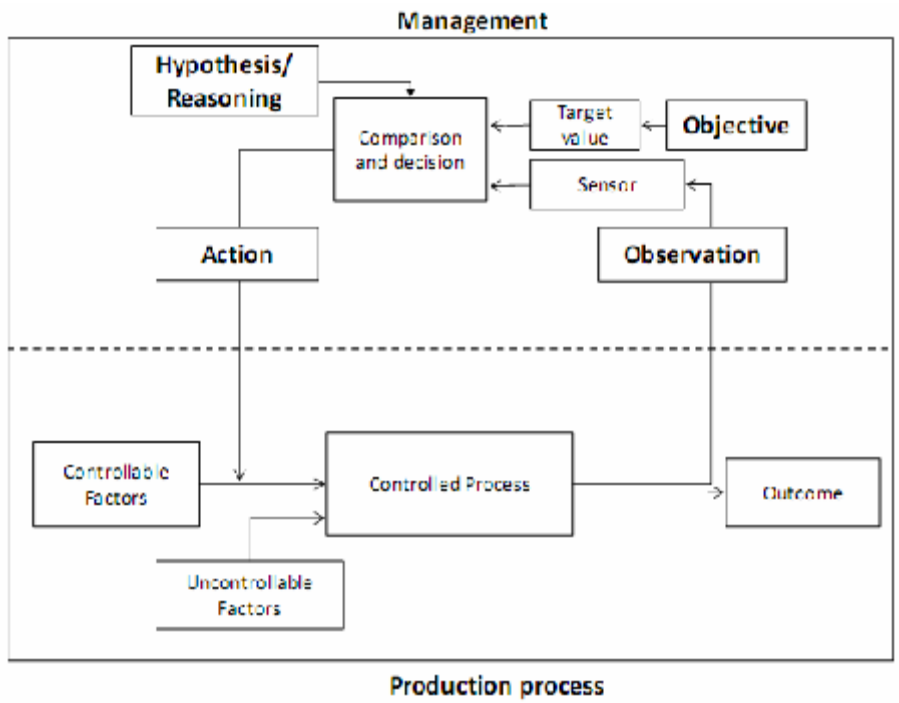


Figure 5: Control loop to model agro-pastoral production as purposeful system
Source: adapted from KAUFMANN (2007)

Based on this approach in a second turn the material was carefully read through on a higher abstraction level and analysed for the dimension of the information. The following were used as **analysis dimensions** (KAUFMANN 2007):

- Observation (trait carrier, traits, trait expression observed)
- hypotheses, reasoning
    - „in order to“ actions: give information about objectives
    - „because“ actions: give information about underlying reasoning and hypotheses
- actions:
    - „if/then“ actions: rules of action
        - routine rules
        - problem solving
        - selection rules

When conceptualising agro-pastoral production as a purposeful system, one focuses on the processes that the agro-pastoralists conduct in order to influence the trait expressions of their animals, herds, crops and fields, and thereby to achieve the system's output. Based on this approach the previuosly assigned analysis dimensions were used to identify:

- **Objectives** and different levels of objectives, from objectives of single actions up to objectives of the production system, in order to find out what the agro-pastoralists want to achieve.
- **Observations** of the agro-pastoralists to learn what is relevant to them on the level of trait carriers (e.g. soils) traits (water stocking capacity) and trait expression (e.g. low) and if possible also to learn about their observation method

- **Reasoning and hypotheses** because this shows which cause-effect relationships agro-pastoralists take into consideration or assume when assessing the production processes. These considerations point also to disturbance factors that have an influence on the production processes.
- **Actions** of the agro-pastoralists to identify by which actions the agro-pastoralists try to control their production process and on **rules** upon which the producers base their actions.

4 RESULTS

The explorative approach of this study brings about results to a variety of topics. One of the challenges of such a study is structuring and connecting the results in a plausible way. In order to do so the prevalent study in the following chapter first presents general characteristics, available resources and livelihood activities, which sets the production system into the context of the study sites and the local situation (see chapter 4.1). Based on this general understanding the following chapter presents an analysis of the agro-pastoral production itself (4.2 -4.3).

For a general overview of the agricultural production system see Figure 6. In the conceptual design of this study, based on the view of Malian agro-pastoralists, their production system can be divided into four components: the animal resources, the crops, factors that influence the system's outcome (simplified in the figure as climate, because they all depend on, or refer to the climate) and the producer. Note that this division does not claim to capture a complete picture, but in contrast this is a strong simplification, which depicts only certain aspects of the production system. This figure can only be seen as a tool for structuring the findings. Following this structure it can be stated that animal husbandry as well as crop production aim to yield a certain outcome. In the case of animal production this is: producing offspring meat, milk and provision of draught power for the crop production. In crop production the main objective is to secure food supply[5]. These envisaged outcomes are influenced by outside factors (such as rainfall patterns, diseases, pests, soil characteristics and others = the climate). The producers control their system by applying certain management strategies in order to control trait expressions of the plants and animals and eventually control the outcome.

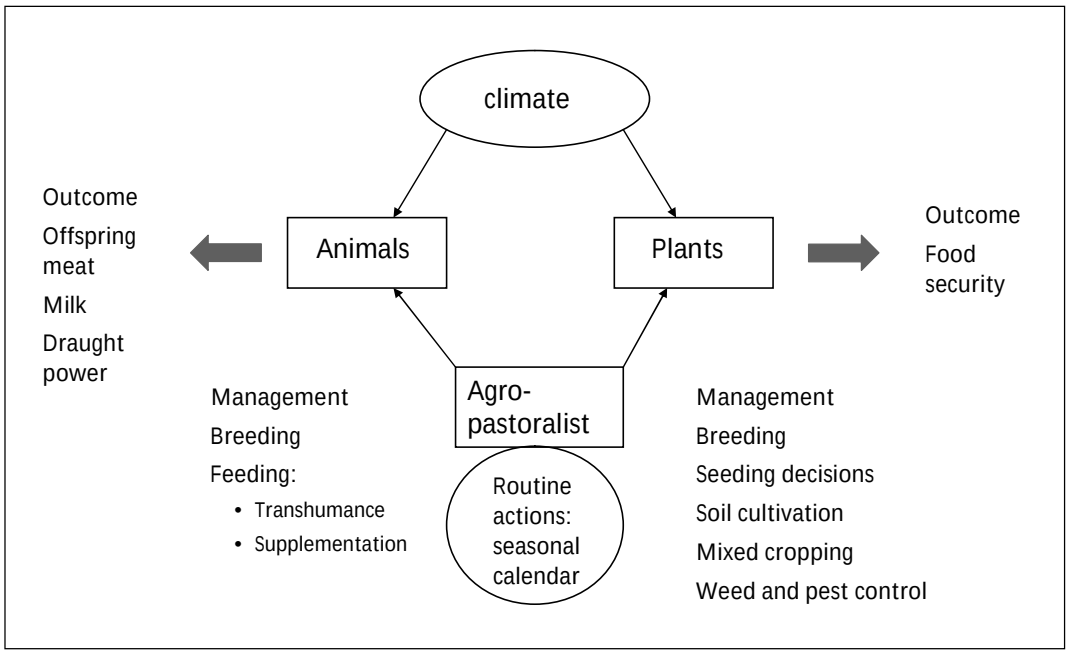


Figure 6: Concept of the study
Source: own illustration

[5] only in Ouandiana it was reported that cereal trade is a livelihood activity and there only three persons conduct cereal trade

In a production system with limited resource availability (as is the prevalent case) there also is limited freedom of choice. Generally, one can distinguish three types of action rules among which producers can choose to manage their production system and to yield the envisaged outcomes (KAUFMANN 2007: 153 – 157)

1. Routine control: these are activities that are routinely done when there are no special events, e.g. this would be milking the cows in the morning and in the evening, weeding millet fields after germination etc.
2. Problem solving control: these are done to solve a problem when it is occurring, e.g. medical treatment of ill cows, fighting pests, when they arrive
3. Selection: these are actions that are taken when the producer cannot control certain features of the production assets but however he can chose between the utilisation of different asset alternatives, e.g. he cannot influence soil characteristics, but he can chose different sites with different soil types.

In the following section the study will first provide general information about the production system. Then it will present more in-depth information on animal production and crop production respectively. The structure of both sub chapters (animal production and crop production) is similar. They begin by explaining production factors. This is followed by information about the seasonal calendar. Based on this general understanding the study will go deeper into the contexts of the selected topics animal feeding schemes and millet production respectively. The choice of topics which were analysed in more detail was made according to their relevance for the producers indicated by the amount of information provided on the respective topics. They are analysed in more detail giving an insight into action rules and production strategies of the agro-pastoralists. The respective paragraphs (4.2.4 and 4.3.4) provide information on the topics which are subsumed under the heading management in Figure 6.

4.1 GENERAL INFORMATION

4.1.1 General characteristics

The four study villages can be classified in three groups depending on their location: the two villages in the Séno zone, which are shaped by similar environments as one group. Then the village at the Delta's border (=Nérékoro) has its unique characteristics as has the village in the Delta interior (= Yongosiré). The most outstanding village is Yongosiré because it is unique in its characteristic of being inundated six months of the year.

a) Infrastructure

The infrastructural endowment differs between the four villages (see Table 9). All four villages are connected by dust pists. Distances to tarmac roads differ between 4 km (Nérékoro) and 45 km (Ouandiana). Yongosiré in the rainy season becomes an island and is only accessible by boat. All villages have market access. However, the quality (size and importance) of the respective market and the distance to the market is considerably different. Mopti, Bankass and Diallassagou

are considered big important markets for livestock trade whereas Madiama is rather small and unimportant. Water supply is as secured in all of the four villages. They all have several wells, ranging from 2 (Ouandiana) to 5 (Nérékoro). The wells are used depending on their water quality, either for human use, animal use or for washing only.

Table 9: General characteristics and resource endowment of the four studied villages

Characteristic	Niger delta		Séno	
	Nérékoro	Yongosiré	Sadia Peulh	Ouandiana
Number of inhabitants[6]	771	683	680	662
Number of households	112	98[1]	97[1]	95[1]
Distance to tarmac road [km]	4	34	8	45
Market access distance [km]	Madiama 2.5	Mopti 34	Bankass 12	Diallassagou 5.5
Distance to school and health post [km]	2.5	In the village	1.5	5.5
Religious facilities	Small mosque	Big mosque holy tomb	Small mosque	Small mosque
Household water sources	5 wells	2 wells 1 pump	2 wells 1 pump	2 wells

Source: own data

b) Other aspects

Other differences between the villages in the Séno and the Delta, or the two villages in the Séno, respectively concern:

- Space and housing
- Livestock production system or crop production system

Space and housing

Because of the seasonal inundation, Yongosiré is located on a slope which results in a limitation of space and respective construction. Figure 7 and Figure 8 illustrate this difference: the houses in the Séno villages are round and flat, homesteads are wide with open courts, whereas in Yongosiré the houses are rectangular and sqeezed together.

[6] Estimation based on average household size of Nérékoro and own observation

Figure 7: Housing in Yongosiré

Figure 8: Housing in Ouandiana

Focus on livestock production or crop production

Comparing the two villages in the Séno it can be stated that although they are both based on agro-pastoralism the emphasis of the production activity can be more livestock oriented (as is the case in Sadia Peulh) or more crop oriented (which is the case in Ouandiana). This differentiation can be made according to the characteristics summarised in Table 10. This table is based on focused group sessions, informal conversation and own observations. The main difference in a livestock based system towards a crop based system is the fact that livestock is raised to be marketed, whereas in the crop based system livestock is kept for self-consumption.

Table 10: Comparison of livestock based and crop based production

Indicators of importance	Livestock based Sadia Peulh	Crop based Ouandiana
Self declarance during focus group session	Animal husbandry is the main activity	Cereal production is the main activity
Reputation of the cereal producing inhabitants (Riimaybe)	Low reputation, live apart, are not allowed to speak in village assembly	High reputation, first village counselor is Riimaybe
Preferred traits in cattle	In addition to performance traits market oriented exterior traits, such as shape of horns and colour are named	High milk yield is ranked as most important
Prevalence of cereal trade	Not existent	Existent, although only practiced by 3 people

Source: Livelihood analysis, Nérékoro, 24/02/09; Livelihood analysis, Sadia Peulh, 14/03/09; Livelihood analysis, Ouandiana, 14 participants, 27/03/09; Livelihood analysis, Yongosiré, 21/04/09, participative observation, informal conversations

4.1.2 Resource availability

A resource is defined as a means of supplying some want or deficiency (BREMAN ET AL. 1998). The resources available to the agro-pastoralists can be divided in resources used for crop production or animal production.

a) Resources for animal production:

All villages are endowed with water for the animals. Figure 9 shows exemplarily the village resource map which was drawn by 14 agro-pastoralists in Ouandiana during focus group session on 27/03/09. In the rainy season they use non-permanent water holes, additionally Nérékoro is passed by a *yamé* (non-permanent river that holds water in the rainy season). Nérékoro (~25km) and Yogonsiré (~5km) have access to the river Niger. However, in the dry season in all of the four villages' livestock keepers have to water their animals by time and labour intensive manually taking water from wells.

The villages differ strongly from each other concerning the availability of pasture (Figure 9). In the Séno, where the population is less dense, the agro-pastoralists use a crop/fallow rotation scheme with the fallow being used as pasture, including all four sides of the village (Sadia Peulh) or at least three sides (Ouandiana). In Nérékoro and Yogonsiré there is no rotation, but there is a reserved pasture area which is never used for cropping. However, they manage the scarcity of land in modification of use of the resource. For example in Nérékoro the agro-pastoralists harvest two weeks earlier than in their farming-only neighbour villages, in order to let their animals graze on the crop residues.

In Yogonsiré dried *burgu* plants *(Echinochloa stagnina)* are easily available as dry season fodder which is not the case in the other villages.

b) Resources for crop production

In Figure 9 fields are indicated in circle 2. Yongosiré has alluvial heavy clay soils in the inundation zone of Niger resulting in the focus on rice production and cultivation of other crops only in small gardens or in courts. In contrast, in the Séno there is no inundation but sandy soils, resulting in a focus on millet production. In Nérékoro the same holds true, although some loamy clay soils are available (12 farmers in Nérékoro also possess inundated rice fields).

Agro-pastoralist use local trees (circle 1; Figure 9) in and around the village for gathering fruits and leaves, for home consumption, selling, and as resource for the provisioning of firewood. In Yongosiré this resource is available at a distance of around 20 km, at the border of the Delta.

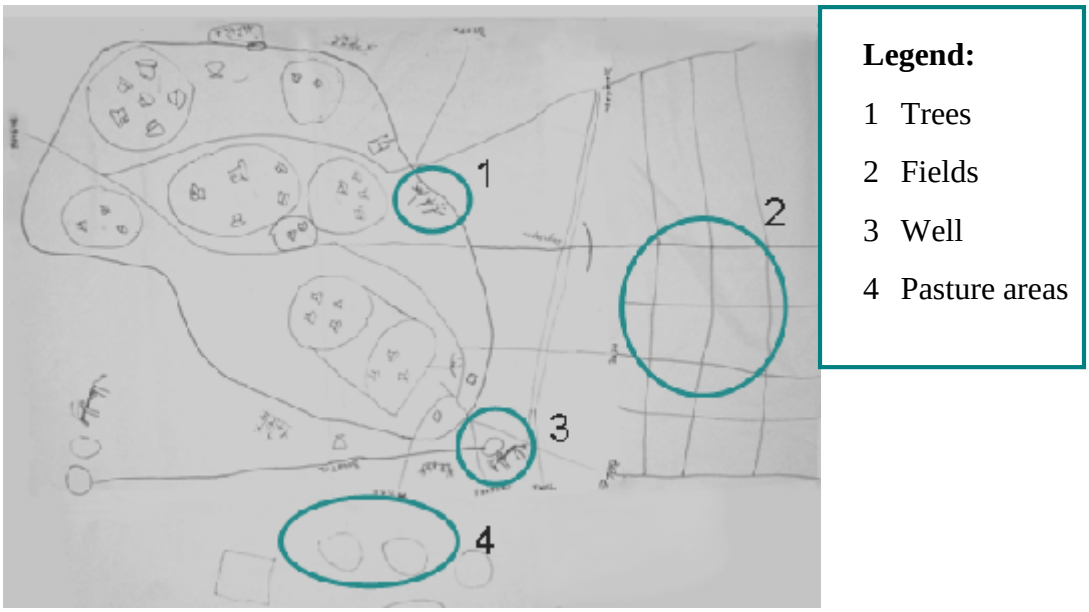


Figure 9: Ouandiana village resource map
Source: Village resource map, Ouandiana, 14 participants, 27/03/09

4.1.3 Livelihood activities

Livelihood activities in this study are understood as the activities that are carried out by the agro-pastoralists for subsistence production or in order to earn income in kind or cash. They were collected in all four villages in focused group discussion supported by a collective drawing produced by the agro-pastoralists during each session respectively. The principal activities are always animal husbandry and crop production. However, the ranking of the two main activities differs. Ouandiana and Yongosiré stated that crop production is the principal activity, whereas Sadia Peulh and Nérékoro consider animal husbandry their principal activity. Altogether 36 different livelihood activities have been mentioned in the sum of the four villages. The village with the least different activities is Sadia Peulh with 17 different activities and Yongosiré's inhabitants mentioned the highest number with 24 different livelihood activities. Some activities are conducted by all persons in the village and some only by women or by certain ethnic subgroups (e.g. Riimaybe or Fulani). Table 11 shows the different livelihood activities that were conducted at least in two of the villages, as well as the assets needed, the outcome of the activity and the persons that are involved. It is based on data collected by Mamadou Satao in collaboration with the author of this study.

Table 11: Livelihood strategies

Assets	Strategies	Outcomes	Implied persons	Village
Pasture, veterinary care, herder, animal feed, water, bourgoutière, money	Animal husbandry	Milk, draught animals, food, money, barter	Traditionally more Fulani	All four
Fields, plough, draught animals, boat[7], labour, water	Crop production	Nutrition, money, barter	Traditionally more Riimaybe	All four
Knowledge, Koran, tablet, ink, nutrition, housing	Koran school	Knowledge of the religion, culture, income	Koran teacher and students	All four
Animals, market	Livestock trade	Income	Fulani only	All four
Kitchen utensils, cereals, money, firewood	Household work	Food	Women	All four
Cattle, herder	Milk trade	Income	Fulani women	All four
Store, clients, merchandise items	Small trade	Income	2 – 10 mainly women	All four
Travel expenses, blessing, identity card	Rural migration[8]	Income, motor bike, illness, poverty	Young men	All four
Pan, oil, millet/rice	Selling fried cakes[9]	Income	1-3 women per village	All four
Draught animal, carriage, labour	Transportation	Income	Riimaybe	Yongosiré, Ouandiana, Sadia Peulh
Plastic sacks	Fabricating ropes	Ropes, income	Elderly people	Yongosiré, Ouandiana, Nérékoro
Gras, labour, sickle, carriage, rope	Fabrication of mats	Income, construction of roofs for houses, shelter, granaries	Men	Ouandiana, Nérékoro, Sadia Peulh
Water, clay, health, mould, millet bran, hoe	Brick making	Houses, income	Riimaybe	Ouandiana Nérékoro
Money, nurse, midwive	Health center	Well-being, health, advice	Used by all villagers	Yongosiré, Nérékoro
Unity, teacher, furniture, money, food	School	Education, culture, employment, political power, knowledge of the law	Children	Yongosiré, Nérékoro
Carriage, draught animal, manure, labour	Transportation of manure	Fertiliser	Riimaybe	Sadia Peulh, Ouandiana

[7] Only in Yongosiré

[8] Was not listed during the group session in Nérékoro, but mentioned in interviews

[9] Was not listed during group session in Sadia Peulh, but cakes were sold in all villages (participant observations)

Assets	Strategies	Outcomes	Implied persons	Village
Cereals, money	Seling cereals	Income	All villagers in Yongosiré, 3 persons in Ouandiana	Ouandiana, Yongosiré
Plants, rope, labour	Making matrasses[10]	Income, accommodation of guests	Old women	Sadia Peulh, Ouandiana
Cotton, yarn	Weaving	Income, clothing, decoration	3 personnes in Sadia, 2 in Nérékoro	Sadia Peulh, Nérékoro
Water, nets, fish hook, lure	Fishing	Food, income, enriching the diet	All villagers Yongosiré, Riimaybe in Nérékoro	Yongosiré, Nérékoro
Bricks, means of transportation, water, labour	Constructing houses	Income, houses, granaries	Dogon and Riimaybe	Yongosiré, Sadia Peulh, Ouandiana[11]
Sickle, means of transportation	Haying	Raw material for roofs, income, animal fodder	Men	Yongosiré, Ouandiana
Health, clothing	Hairdressing	Income, beauty	Women	Yongosiré, Nérékoro
Beautiful clothing, instruments	Music	Glory, presents, ceremonies, income	Riimaybe	Sadia Peulh, Nérékoro
Cotton/wool, converter	Spinning	Clothing, decoration, coal, income, presents	Old women	Yongosiré, Ouandiana

Source: Livelihood analysis, Nérékoro, 8 participants, 24/02/09; Livelihood analysis, Sadia Peulh, 4 participants, 14/03/09; Livelihood analysis, Ouandiana, 14 participants, 27/03/09; Livelihood analysis, Yongosiré, 18 participants, 21/04/09

4.2 ANIMAL PRODUCTION

The following paragraph provides information on management strategies in animal production. It firstly presents information concerning the production factor animals. Secondly the objectives of the animal production system are explained. Thirdly a general overview is provided concerning the order of the crops and the farming activities of the year based on a seasonal calendar. Finally this chapter presents detailed information on the selected topic ‘feeding schemes’. The idea of the selected topics is to report the results from the cybernetic analysis concerning the field of management about which the most data was provided by the agro-pastoralists. The chapter selected topic presents observations, hypotheses and action rules of the agro-pastoralists upon which they base their management strategies in their feeding management.

[10] This kind of matresses are not used in the other villages

[11] Was not mentioned in group session, but observed

4.2.1 Production factors: animals

a) Species and breeds, animal numbers

The main production factor in animal husbandry in resource poor systems are the animals. Mopti region belongs to the semi-arid zone, where livestock typically consists of **mixed herds** with cattle, sheep and goats. In the villages the agro-pastoralists also additionally keep working oxen, some donkeys, rarely horses and some poultry (chicken and guinea fowls). The prevalent cattle breed is called Zebu Peulh (Figure 11). For the sheep there is a local breed called *keteeji* (Figure 12) in Fulfulde and another breed *sagaaji* (Figure 13). According to the agro-pastoralists *sagaaji* is bigger and achieves higher milk yield but is more demanding in maintenance concering fodder supply and because the *sagaaji* sheep "do not come back when sent out to graze, [they] always need a herder" (pair wise ranking, Nérékoro, 06/03/2009, 3 participants). For the goats as well there is the breed called *keteeji* (Figure 10) which is prevalent all over the zone.

Figure 10: *Keteeji* goat, Nérékoro February 2009

Figure 12: *Keteeji* sheep, Yongosiré May 2009

Figure 11: Zebu Peulh cattle, Yongosiré May 2009

Figure 13: *Sagaaji* sheep, Nérékoro February 2009
Picture: B. Kaufmann

As commonly mentioned in literature, it is very difficult to find reliable data on animal numbers in Mali. This is due to the fact that there is a poll tax for cattle as well as a vaccination program that obliges livestock keepers to vaccinate every single head and to pay per number of animal vaccinated. Therefore, livestock keepers understandably have a high interest in keeping the real herd size as a secret.

For **Nérékoro** the data available has been collected during the research project of the Sustainable Agriculture and Natural Resource Management Collaborative Research Support Program (SANREM CRSP) run by the Office of International Research, Education, and Development at Virginia Tech in collaboration with the IER Mopti. For **Yongosiré** some data is available, but only at the level of the municipality Koubaye which consists of eight villages. **Ouandiana** belongs to the municipality Dialassagou which consists of twenty five villages. **Sadia Peulh** belongs to the municipality of Bankass which consiststs of twenty six villages, and also contains the circle's capital Bankass city. Animal numbers on the municipality levels are comprised in Table 12.

Table 12: Livestock numbers in the four municipalities of the study villages

	Bovines	Ovines	Caprines	Asines	Camelines	Equines	Porcines	Poultry	Source
Madiama	24 279	12 407	16 966	720	n.a.	267	n.a.	57 008	[1] 2002
Koubaye	15 569	7 808	5 543	1 584	26	224	n.a.	10 268	[2] 2009
Diallassagou	15 000	14 000	13 960	600	9	108	10	4 000	[3] 2005
Bankass	8 350	4 150	5 350	1 025	5	395	4	12 560	[4] 2006

Source: [1] SANREM project Mai 2002
[2] Personal communication with ADAMA MAIGA, April 2009
[3] MINISTERE DE L'ADMINISTRATION TERRITORIALE ET DES COLLECTIVITES LOCALES (2005)
[4] COMMISSARIAT A LA SECURITE ALIMENTAIRE (2006)

Because of the difficulties to attain reliable data of animal numbers on household level in this study key informants were asked to make an estimation of the aggregated number of cattle that are owned in the respective village. Based on this information cattle numbers per household were calculated. Table 13 gives an overview of cattle numbers per village and household. Herd sizes differ considerably between 37 cattle in Nérékoro to 515 cattle in Sadia Peulh.

Table 13: Numbers of cattle per village and household 2009

Village	Estimated number of cattle per village	Number of households	Number of cattle per household
Yongosiré	5000	49[12]	103
Ouandiana	10000	47[12]	211
Sadia Peulh	25000	49[12]	515
Nérékoro	2000	54[13]	37

Source: telephone interview with resource persons from the villages, own calculations

[12] Calculated based on average household size of Nérékoro

[13] Information from the Sanrem project in 1999

b) Characteristics and selection of animals

In the system approach (see 2.4) animals are regarded as one of the production factors, which the producers try to control. However, it is impossible to directly control genetic trait expression at the level of the animal. Therefore, the producer has to use selection rules. In this prevalent agro-pastoral production system there are two levels of selection. With the division of the herd, the producers can control the instant performance of the herd by assigning individual animals to the respective groups. Through breeding management, the producers influence herd performance by controlling animal traits of the next generation on the herd level.

Division of the herd and selection of the bendis

The agro-pastoralists stratify their cattle herd in several groups of animals. The total of the herd is called *séouré*. The *séouré* is divided into the *gartjis* and the *bendis*. The *gartji* herd is the main transhumant herd, comprising approximately 80% or more of all cattle (TURNER 1999a: 273), and is composed of steers, heifers, dry cows and some milking cows to provide milk for the herders. Transhumance herds are herded by the younger men of the family and are rarely near the home village because they follow a long transhumance cycle (see chapter 4.2.4.2).

Working oxen and all non-*gartji* milk cows and their calves are managed as a milk herd (*bendi*). Although cows are routinely transferred between *bendi* and *gartji*, the *bendi* are managed as a separate herd. The *bendi* are the cows on which the family depends for milk used to trade for cereals. The day-to-day management of *bendi* is performed by the older men and young boys of the family. Given their economic importance, the *bendi* remain in or close to the family's village. The *bendis* are chosen from the herd and exchanged twice a year at the moment when the *gartjis* pass by the village (in May and October, see seasonal calendar). New lactating females are selected to stay in the village, as well as working oxen. The choice is made according to the following criteria (D3b, A3b):

- The cow has recently calved
- The cow is still (at the moment of selection) gestating, but will calve soon
- The cow has an appearance of resistance

Additional other criteria might be considered but have not been mentioned. The third point was underlined in the village of Yongosiré. Because it is situated in the middle of the Delta the animals suffer of very high insect pressure (Ixodidae), therefore resistance to diseases is a very important trait in cows. In Nérékoro it was reported that animals are sometimes taken from the *gartjis* if they have an appearance of weakness in order to stay in the village and recover (SCT1).

Breeding management

The selection is limited on the side of the bull, however, females can be excluded from the herd if the breeder is not satisfied with their performance: "si on constate que chaque fois que la vache donne un veau, quelques jours après le veau meurt. C'est-à-dire lorsque les petits nés d'une vache meurent après la mise bas. On décide de ne pas garder cette vache dans le troupeau. On se

débarrasse de telle vache. On vend la vache et on là remplace par une autre vache qu'on suppose bonne." (C5b)[14] The cow then is culled and replaced.

On the side of the bull, the preferred traits that were named by agro-pastoralists are:
- Milk performance of the bull's mother (quantity)
- Soft teats of the bull's mother
- Tame behaviour of the bull's mother
- Big size of the bull and his mother
- Shape of the horns

In females preferred traits are:
- High milk production
- Well development of its calves
- Gives birth to many calves
- Resistance towards drought
- Have a beautiful hump and big horns

In group sessions in Sadia Peulh the agro-pastoralists also mentioned colour, but they reported that they do not breed for colour explicitly. However, they stated that "on the market if you want to sell working oxen, the Riimaybe prefer to buy bulls that have three colours, but the Fulani do not select for that in breeding because even a one coloured bull will anyway often produce more coloured offspring." (Pairwise ranking, Sadia Peulh, 21/03/09, 6 participants)

4.2.2 Objectives of the system

The agro-pastoralists' activities have the objective to produce a certain outcome, which is in this case:

1. Offspring (meat) production: to achieve this goal the livestock keepers aim at high reproduction rates = high fertility, low mortality, short calving interval. But this also means having well nourished flock, in order to achieve high prices when selling
2. Provision of drought power: production of working oxen that are strong and resistant against diseases
3. Milk production: here the main goals are high quantity and quality of milk per animal

The relative importance of the three objectives which are not totally complementary varies between the different villages, as well as between individuals, as they were not all mentioned in all interviews. But this variation was not measured and cannot be depicted here. Therefore in this study they will be treated as equally important.

Beyond mere output the agro-pastoralists also pointed out the importance of durability of their production system. Their aim is to keep a durable equilibrium for the family, which means to be

[14] In the following sections original French quotations from the interviews are used to illustrate and to prove information in the text. They do not introduce any new facts and their essence is always given in the English text, so that readers not understanding French will not miss any essential information. It was decided not to translate the quotations as in translation always some meaning gets lost and the objective was to give some unfiltered voice to the agro-pastoralists themselves.

able to satisfy the needs of the family on the long term (including further generations), and maintain the equilibrium of the family:

"…notre souci c'est de bien faire le travail pour réussir, satisfaire les besoins de la famille…le souci d'un chef de famille c'est de maintenir un équilibre constant de sa famille pour que les gens ne disent pas que depuis la mort de un telle cette famille est devenu une source de famine." (D1b)

An additional objective in livestock production was reported to be the investment and saving of money in form of livestock.

In order to pursue these objectives the producers manage their production system within their limits of resource availability. In chapter 4.2.4 the study analyses prevalent **management practices** and how the producers control their system to obtain the envisaged outcomes. The next section provides information about management activities as they are conducted in the course of the year, based on a seasonal calendar.

4.2.3 Seasonal calendar animal production

Fulani agro-pastoralists use a lunar calendar where each month consists of 29 or 30 days. The year begins with the month Haaram. In 2009 the lunar calendar corresponded to the Gregorian calendar in the following way:

1. Haaram = 9.1.08

1. Mini Haaram = 8.02.08

1. Almawluudu = 8.3.08
(27.02.09= 1.Almawluudu)

1. Mini Almawluudu = 7.4.08

1. Radjibi Awru = 6.05.08

1. Radjibi Hoddaaru = 5.06.08

1. Horteendu Moodibaabe = 4.7.08

1. Yaawa = 3.08.08

1. Koorka = 1.09.08 (Fête de Ramadan)

1. Juldaandu = 1.10.08

1. Siwturaandu = 30.10.08

1. Layya = 29.11.08 (Fête de Tabaski)

The seasonal calendar drawn by agro-pastoralists during focused group discussion contains climate data, which they indicated for orientation. There is one rainy season. In Nérékoro informants reported that in 2008 the rain started already in April, in Ouandiana and Sadia Peulh rain started end of May while in Yongosiré the rain started around 20th June. April, May and June were indicated in all villages as the hottest months. Table 14 is a synthesis of the four different seasonal calendars that had been drawn in each of the studied villages respectively. Similar information is summarised; where information differs between the villages, the deviating information is added in the text. A table of the calendar is attached at the end of the chapter (p. 52).

The pattern of transhumance annually follows two big cycles. During the months of November – June the animals go on big transhumance to the dry season areas. Before the rainy season starts, the herds pass by the village on their way to the rainy season pastures. They stay 1-5 weeks in the villages before continuing to nearby pasture areas where they stay during the planting season until harvest. After the harvest, the herds return from their rainy season pasture and graze on the

crop residues of the village fields for some weeks. If the producers want to guide their herd into the Bourgoutière the duration of the stay of animals depends on local administration because it sets the dates when rice harvest has finished and the river Niger can be crossed by the livestock keepers and their herds in order to enter the Bourgoutière. However, not all herds enter the Bourgoutière. The respective pasture areas differ in the different villages as well as for individual households. More details are explained in chapter 4.2.4.2.

Concerning fodder quality the agro-pastoralists expressed that the best pasture quality of the year is in July whereas in April and May the pasture is generally very poor and there is only dry pasture vegetation available (see Figure 14).

Figure 14: Cattle grazing on dry pasture close to Ouandiana, April 2009

In the Séno villages the agro-pastoralists feed the animals salt regularly throughout the year (informants stated one exception: April, May because then animals would not feed enough so they would not need salt), in Nérékoro likewise, only in Yongosiré they give salt solely during the rainy season.

During the dry season there is water shortage. The animals are watered twice daily. Especially in May when many herds coincide in the village this can lead to water scarcities. In the rainy season they can take water ad libitum at seasonal water holes and small rivers.

Concerning illnesses and mortality rates the agro-pastoralists clearly distinguish between the causes. The highest mortality rate due to poor fodder supply occurs in the months April-May while the highest mortality rate due to diseases like *Babesiosis* and *Tripanosomiasis* is observed in November, December and January. These statements were made concerning cattle and sheep. For goats only one period of high mortality rates in November to December is observed. In Yongosiré problems with insect born diseases were reported to affect the village animals. During April and May, tick pressure was reported to be high. During that time the animals are treated with insecticide powder weekly, but once the animals are well nourished in June, July the problem with the ticks is overcome. In October after the insect[15] pressure has decreased the agro-pastoralists treat the animals with Berenil (Diminazen against *Babesiosis* and *Tripanosomiasis).*

In Yongosiré agro-pastoralists stated that sheep are in the best condition from March to June, which is astonishing because there is the worst fodder supply at that period.

Highest birth rates for cattle occur between May-July, goats and sheep have highest birth rates from November-December. Following fodder supply and calving schemes milk yield is high in rainy season. Cattle trade occurrence differs for the three villages Ouandiana, Sadia Peulh and Yongosiré (see Table 14); for Nérékoro there is no data available.

[15] Ixodiae and two insects in Fulfulde called *"Buubii"* and *"Bouwdi"* that could not be identified

Table 14: Seasonal calendar livestock

	January	February	March	April	May	June	July	August	September	October	November	December
	1 Haaram	2 Mini Haaram	3 Almaw luudu	4 Mini Almaw luudu	5 Radjibi Awru	6 Radjibi Hod-daaru	7 Horteen-du Moodi-baabe	8 Yaawa	9 Koorka	10 Jul-daandu	11 Siwtu-raandu	12 Layya
Rainfall					Rainfall starts	Raining	Heavy rainfall		Raining			
Temperature	Cold season			Hottest period							Cold season	
Transhumance	go to Bourgoutière or other region				1-5 weeks in the villa-ge	Rainy season grazing area				Pass by the village	Graze on crop resi-dues, go to Bour-goutière or other region	
Fodder basis Pasture	Dry vegetation			Bad quality, vegetation is dry		Good quality pasture, fresh vegetation[16]				Good fodder: crop residues		
Water availabi-lity	Watering two times daily at wells, if herds are in the Bourgoutière they have free access				Animals take water themselves at water holes					Go far with the herd to search for water	Watering two times daily at wells, if herds are in the Bourgoutière they have free access	
Body condition and health status Cattle & sheep	Period with the most cases of illness			Highest mortality rate due to hunger	Highest mortality rate due to hunger; highest occurrence of ticks	Highest occur-rence of ticks		Good physical conditi-on		Good physical condition High tick pressure in the Delta	Period with the most cases of illness due to insect borne diseases[17]	
Health status goats	Highest mortality rate											Highest mortali-ty rate
Reproduction					Highest birth rate for cows						Highest birth rate for small ruminants	

[16] Begin of July best fodder of the whole year: fresh green vegetation

[17] Most likely *Babesiosis* and/or *Tripanosomiasis*

Extraction Milk			No milk		End June: milking re-starts	Lots of milk					
Extraction offspring[18]	High activity of livestock trade in Sadia Peulh		High activity of livestock trade in Ouandiana	High activity of livestock trade in Ouandiana, Yongosiré			High activity of livestock trade in Yongosiré				High activity of livestock trade in Sadia Peulh
others	Obligatory vaccination (Ouandiana)	Castrating, putting noserings, flagging (Ouandiana)		Treatment against ticks every weak (Yongosiré)					Treatment after insect[19] pressure decreased (Yongosiré)		
Sedentary animals	Fodder supplements			Supplements, Animals are herded	Animals are herded				Collecting stems of millet and fodder herbs (Ouandiana)		Fodder supplements

Source: Seasonal calendar, Nérékoro, 11 participants, 28/02/09; seasonal calendar, Sadia Peulh, 9 participants, 18/03/09; seasonal calendar, Ouandiana, 7 participants, 01/04/09; seasonal calendar, Yongosiré, 8 participants, 27/04/09

[18] No data available for Nérékoro

[19] Ixodiae and two insects in Fulfulde called *"Buubii"* and *"Bouwdi"* that could not be identified

4.2.4 Selected topic: feeding schemes

In the conception of the producers, the feeding scheme plays a crucial role in maintaining the system. This is why it will be analysed in detail in the following section. In all interviews with livestock keepers the essentiality of good feeding was underlined[20]:

- "Si une vache est bien nourrit, elle sera vite suivit par les bœufs, par contre si elle est n'est pas bien nourrit elle va faire quelques années sans avoir des petits" (D1b)
- "Parce que la personne qui a les animaux bien nourris aura plus du lait et plus d'argent après la vente d'un animal." (D1b)

Two types of feeding schemes must be distinguished, which have different objectives and therefore proceed according to different rules. On the one hand there are the sedentary *bendis* (see chapter 4.2.1) that are fed with stocked animal feed during part of the year. On the other hand there are the *gartjis* that are fed by selecting good pasture for them. Because of these two different procedures, the feeding schemes have different objectives.

a) *Bendis:* provide them efficiently with as much nutrients as possible so that they achieve high milk production

b) *Gartjis:* Low input costs are an essential requirement for the *gartjis* as the whole herd cannot be fed using animal feed. Therefore, the objective is not to have the animals in good body condition all year round but to have the animals well fattened during the rainy season in order to bring them over the dry season: "…celui qui a pu faire bien nourrir ces animaux pendant l'hivernage, n'aura aucune crainte à affronter la saison sèche, en ce moment tu es sûr qu'aucun animal ne va tomber par faim. Donc cela va t'épargner de dépenser beaucoup d'argent pour entretenir ces animaux avec le tourteau." (D1b) So the essential mean to provide fodder to the *gartjis* is the transhumance. The following paragraph will first explain the feeding schemes of the *bendis* before concentrating on the transhumance and the concept of good pasture as it is perceived by the agro-pastoralists

[20] In the following sections original French quotations from the interviews are used to illustrate and to prove information in the text. They do not introduce any new facts and their essence is always given in the English text, so that readers not understanding French will not miss any essential information. It was decided not to translate the quotations as in translation always some meaning gets lost and the objective was to give some unfiltered voice to the agro-pastoralists themselves.

4.2.4.1 Feeding the village animals

The *Bendis* feed on crop residues and on fallow areas (see 4.1.1). During the growing season they are herded to avoid damage on the fields. During the dry season (January – June) the pasture resources get scarce and the milking cows and working oxen receive additional supplementation. This can be dried fodder plants such as *yengere*, *gamaradji* (a collection of different dried plants – like hay), rice bran, millet and rice stems, millet cobs and leaves from trees. This fodder is collected throughout the year and stored on roofs (see Figure 15).

Figure 15: Dried fodder stocked on roof, Nérékoro, February 2009
Photo: Kaufmann

In addition, it is possible to buy dried Bourgou at markets. During the last 20 years there has been a transition process going on (SATAO in preparation), which entails an increase in the number of Bendis kept in the villages (e.g. seven instead of three milking cows) and a shift from traditional animal feed towards feeding "aliment bétail Huicoma" (ABH) an industrially produced concentrate, based on cottonseed cake, provided by l'Huilerie cotonnière du Mali (HUICOMA).

In addition, it is possible to buy dried Bourgou at markets. During the last 20 years there has been a transition process going on (SATAO in preparation), which entails an increase in the number of Bendis kept in the villages (e.g. seven instead of three milking cows) and a shift from traditional animal feed towards feeding "aliment bétail Huicoma" (ABH) an industrially produced concentrate, based on cottonseed cake, provided by l'Huilerie cotonnière du Mali (HUICOMA).

Data was obtained concerning prices for cottonseed cake as well as for milk prices. In May 2009 producers received 200 – 250 FCFA/l milk, while the prices for cottonseed cake were at around 144 FCFA/kg cottonseed cake (4 observations). Assuming a production function (rule of thumb) with 0.5 kg concentrate = 1l milk, the average return of milk production based on feeding cottonseed cake is 128 – 178 FCFA/l milk.

Besides cottonseed cake, other animal feed can be purchased. Table 15 shows different types of animal feed that have been mentioned in semi-structured interviews and their prices.

Table 15: Prices of different kinds of animal feed

Feed	Serving	Price/serving [FCFA]	Price/kg [FCFA/kg]
Cottonseed cake	Sacks of 50kg	6 500 - 8 050	144
Rice bran	Sacks of 50kg	2 000	40
Dried Burgu	n.a.	n.a.	n.a.
Hay	Carriage	1 500 - 2 000	n.a.
Grains of roselle	Sacks of 50kg	5 000	100

Source: semi-structured interviews A3b, C5b, D1b, D3b

During the interviews, the livestock keepers underlined that the feeding of cottonseed cake is becoming more and more important: “il faut toujours payer du tourteau, si non les animaux vont beaucoup souffrire.” (D3b). This was expressed especially in the more densely populated Delta region, whereas in the Séno the feeding of *bendis* with local available feed is prevalent. However, supplementing the *gartjis* was reported by informants to be a reaction towards bad years where there is feed shortage due to poor rainfall: “…cette année les conditions des animaux sont acceptables [….]. Par contre les années précédentes, les animaux ont trop souffert, on a payer du tourteau [= ABH] pour les soutenir jusqu’en hivernage.” (C5b).

Informants reported as reasons for preference towards cottonseed cake the higher milk performance of animals fed with ABH and the fact that it is possible to buy cottonseed cake on credit, which is not the case for the other animal feed.

Watering in the dry season is done by leading the animals to the river (at Yongosiré) or at wells twice a day. The agro-pastoralists reported that “in the dry season the good water brings more return than the fodder [millet straw or Bourgou]” (SCP4). During the rainy season, the animals water themselves at seasonal dams and non-permanent rivers (*yamé).*

4.2.4.2 Transhumance

The transhumance management strategy can again be splitted up in several sub topics. Information provided by Fulani agro-pastoralists concerns:

a) Transhumance routes
b) Pasture resource management
c) Daily routine of a herder on transhumance
d) Supplementation of animals on transhumance
e) The concept ‘good pasture’
f) *Ceeduwa*: prolonged dry season

About topic f) the most detailed information was obtained. Hence, for this field of management the analysis allowed to extract objectives, underlying reasoning and action rules, which are presented in that order.

a) Transhumance routes

Transhumance routes are the main management tool which controls for feed supply of the *gartji* herd. Tables 16-19 give an overview of transhumant routes of the different villages. Note that these routes are not always strictly followed and there are households or individual herders who choose alternative routes and pasture areas. The location of the explained pasture areas is indicated in Figure 16.

Table 16: Transhumance routes **Nérékoro** and respective pasture characteristics

Seasons	N`Dungu	Jawre	Dabbounde	Ceedu
	June, July, August	September, October, November	December, January, February	March, April, May
Pasture areas	Pays Bobo	Pays Bobo village	Deep in the Bourgoutière, other side of Bani river	In the Bourgoutière; return along Bani river
Characteristics of respective area	High quality fodder plants „Yengere“ are available	In the village animals feed on crop residues	Burgu plants available High value fodder plants Good water quality Enough space	Burgu plants available High value fodder plants Good water quality Enough space

Source: Focus group discussion based on seasonal calendar, Nérékoro, 11 participants, 28/02/09

Table 17: Transhumance routes **Sadia Peulh** and respective pasture characteristics

Seasons	N`Dungu	Jawre	Dabbounde	Ceedu
	June, July, August	September, October, November	December, January, February	March, April, May
Pasture areas	Séno Gondo	Village (crop residues) and continue to Dogon plain	Dogon plain	Dogon plain Some (but view) went to Bourgoutière
Characteristics of respective area	n.a.	In the village animals feed on crop residues	n.a.	n.a.

Source: Focus group discussion based on seasonal calendar, Sadia Peulh, 9 participants, 18/03/09

Table 18: Transhumance routes **Ouandiana** and respective pasture characteristics

Seasons	N`Dungu June, July, August	Jawre September, October, November	Dabbounde December, January, February	Ceedu March, April, May
Pasture areas	Dogon Plain or Séno Gondo	Dogon plain/ Séno Gondo village	Bourgoutière or Samori	Bourgoutière or Samori
Characteristics of respective area	*Dogon plain:* Temperature in the night is nice and cool No ticks and other parasites Comfortable for the herder: there is shelter between the rocks High groundwater level Many trees on which animals can feed Populated: they can buy salt and sell milk	*Séno Gondo:* Good soil and good fooder plants Many trees on which animals can feed Lots of space, not crowded with animals No parasites, even no intestinal parasites and few illnesses Soil is salty: they can dig there and the herd benefits from the salt Good water quality and big dams (in rainy season) Millet is expensive	*Samori:* See column to the right *Bourgoutière:* Burgu available Forage is very nutritiuos, and highly appreciated by animals Many different forage plants In Bourgoutière animals can take water themselves, no need to tear it from wells: less physicalyl demanding Good food available for the herder: rice and fish Have to pay for the right of access and transportation (boat) when crossing rivers, higher living expenses (food) compared to Samori	*Samori:* One big lake, enough water Forage is less nutritious (than Bourgoutière) Crossing rivers does not demand fees and there are even bridges Good food available for the herder: rice and fish Close to Ouandiana: if it rains they can return to the village (without animals) to sow *Bourgoutière:* See column to the left

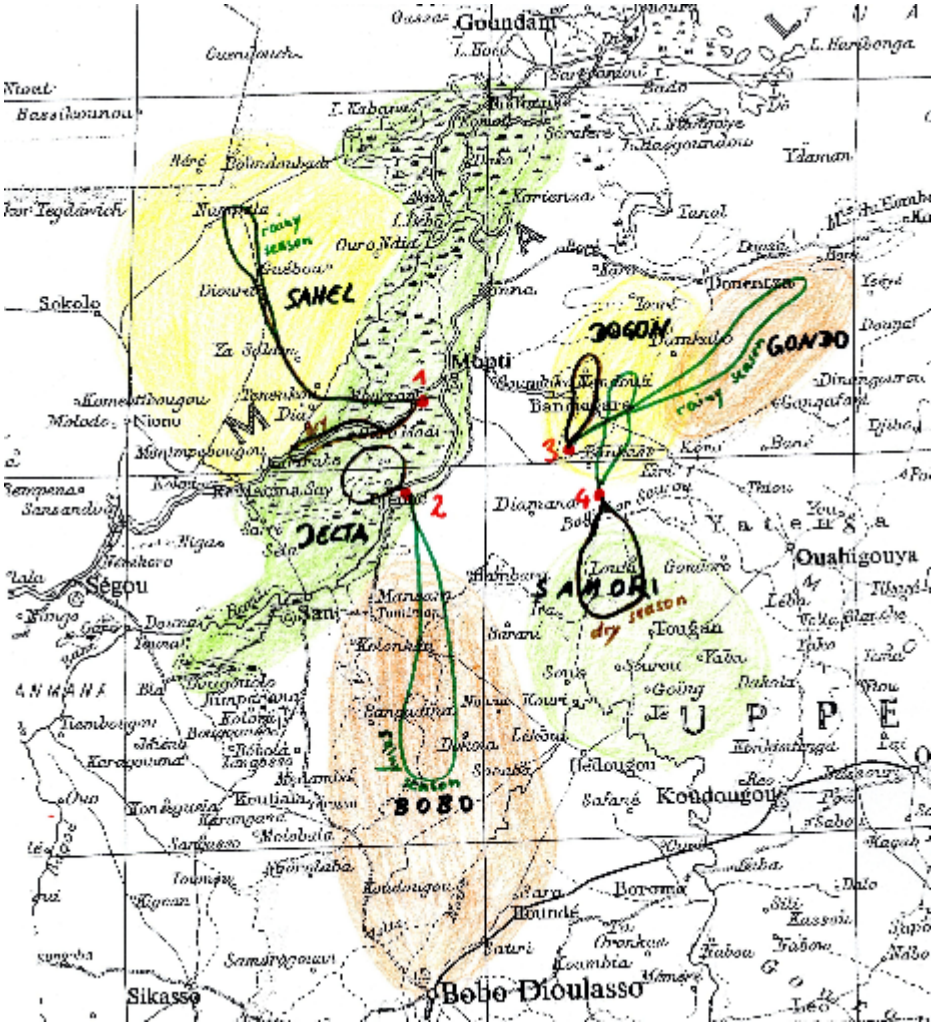
Source: pairwise ranking, Ouandiana, 4 participants, 04/04/09; informal conversation, Ouandiana, 12/05/09

Table 19: Transhumance routes[21] **Yongosiré** and respective pasture characteristics

Seasons	N`Dungu June, July, August	Jawre September, October, November	Dabbounde December, January, February	Ceedu March, April, May
Pasture areas	On their way to Nampala	Sahel Around Nampala	Bourgoutière	Close to Yongosiré
Characteristics of respective area	n.a.	n.a.	n.a.	n.a.

Source: semi-structured interview D1b

[21] For more details about transhumance routes of Yongosiré see annex



Villages

1 Yongosiré

2 Nérékoro

3 Sadia Peulh

4 Ouandiana

Figure 16: Pasture areas and transhumance routes of the four villages respectively

Discussions during the pair wise ranking activity and informal conversations showed that factors that influence the herder's decision in which area he will lead his herd are the following (among others that might not have been pronounced):

- Availability and quality of water
- Expected pasture quality
- Space
- Parasite pressure
- Distance to the village
- Costs (living expenses of the herder and his family, transportation costs, fees for access rights)
- Regulation of access rights or freedom of choice
- Existence of facilities (bridges, Fulani settlements)

b) Pasture resource management

Land use rights of the inner delta pasture areas go back to traditional land tenure and pasture management code called 'Dina' (see 2.2.3). Today the Dina's economic and social organisation has persisted despite French colonial rule and the foundation of the modern state of Mali. Access rights are still granted by the *jowro*, who demands fees in order to permit access to

pasture areas. The fees differ according to the quality of the area, whether it has been grazed by other herds before, herd size but also kin relations between *jowro* and herder. Fees can be around 100 000 FCFA to 300 000 FCFA per herd (100 – 200 cattle and 200 small ruminants) and season, or one to three bulls, but fluctuation of fees is high. Additionally there is state authority which sets dates for entering the delta area after the rice harvest is finished. If a herder is caught with his herd outside the allowed timeframe he is obliged to pay a penalty or bribe the local authority.

c) Daily routine of a herder on transhumance

Table 20 gives an overview of daily routine work of a herder. The herder has three main tasks: provide the herd with forage by guiding them to pasture areas, milk lactating cows and do calve care.

Table 20: Daily routine of a herder on transhumance

Time	Herder maintenance	Milking and Calve care	Herd
6:00	Milk that has been milked the evening before has become curdle, stir it up and drink for breakfast	Milk lactating cows Calves can suck afterwards	
7:00	After milking fill up a bottle with milk and hang it on a tree	Lead calves the opposite side than the cows	Lead the herd on good pasture
16:00	Take the bottle filled with milk, shake it until butter floats at the surface. Collect butter in a clean calebash and drink butter milk	Tie the calves on the calve cord	Leave the herd and come back to the camp to tie calves
17:00	Put fresh milk next to mat	Milk lactating cows and untie calves so that they can drink	Return of the herd
19:00	Sleep		Rest and ruminate
24:00			Lead herd to graze
04:00	Drink milk and sleep		Return to camp

Source: semi-structured interview C5b

d) Supplementation of animals on transhumance

Supplementation of animals in transhumance is regularly done when the pasture quality decreases before the beginning of the rainy season. However, only selected animals (lactating or gestating cows or ill animals) are supplemented with cottonseed cake bought on local markets. Only in the delta region, around the lake Debo, is the pasture quality so high that this is not necessary. But the access rights for this area are around 250 000 FCFA to 300 000 FCFA per herd (100 – 200 animals) and season.

Agro-pastoralists from Nérékoro reported that they bridge the period at the end of the dry season before the first rains fall by breaking leaves from trees and feeding to those *gartjis* that are not selected to get cottonseed cake.

The objective of supplementation during transhumance is to feed weak cattle when pasture

quality becomes too poor, in order to avoid that they loose too much weight: “les animaux qui sont là aujourd’hui sont nourris déjà par le tourteau, il ne faut pas attendre le début de l’hivernage, si non ils ne pourront pas supporter, avant les herbes prochaines, ils seront très maigres.” (D1b)

e) The concept ‘good pasture’

The producer chooses his management practices in order to influence the outcome of his production system. The practices are based on the livestock keeper’s knowledge. This means that the livestock keeper observes his system and builds hypotheses about reasons for what he observes. He also builds hypotheses on how to influence the system’s characteristics in order to obtain the envisaged purpose (KAUFMANN 2007: 54-55). Using this approach the concept of the ‘good pasture’ will be explained by exploring the following questions:

- Objectives: what is the intention in looking for the good pasture?
- Underlying hypothesis: what shapes the quality of a pasture, what does the decision maker observe?
- Indicators: how can the herder recognise the good pasture?
- Rules of actions: which action rules does he draw from his observations?

Objectives

The intention is the optimal feeding of the animals, to positively influence the outcome of the production system: “Une fois que tu décides de conduire les animaux, tu prends la responsabilité de ces animaux. Donc tu dois comprendre que c’est le bon pâturage qui peut servir à l’entretien des animaux, alors il faut préparer des stratégies pour identifier chaque jour le bon pâturage.” (D1b)

Underlying hypothesis

One important factor that the agro-pastoralists perceive as responsible to inherently shape the quality of a pasture is the soil. The analysis identified three relevant soil characteristics and their consequences. First, there is the **soil potential** (water stockage and nutrients) which influences pasture quality. This is caused by the soil type, which then again influences water storage capacity and the overall capacity of the soil to conserve and provide nutrients. Here the agro-pastoralists observe that clay soils have an advantage compared to sandy soils. On sandy soils plants dry out quickly, but on clay soils the agro-pastoralists observe fresh vegetation, even if the rain is interrupted for some days : “Dans les sols argileux il peut avoir des herbes fraîches, par contre dans les sols sableux avec la rupture des pluies, les herbes deviennent sèches” (C5b).

Additionally clay soils are more fertile and further the **current state of the soil**, meaning whether it is nutrient saturated or deficient also influences pasture quality. “c’est en fonction des zones, se sont les zones infertiles (*nanti*) qui donnent généralement des herbes non riches. Ce n’est pas dû à la qualité de l’herbe, mais c’est l’état de la zone” (C5b). The agro-pastoralists observe “*nanti*” soils: the plants that grow there are poor in nutrients. This is influenced by a combination of soil potentials and the current state of the soil. The soil characteristics influence the combination of varieties of plants, the state of the plants (dried or

fresh), as well as the inner quality of the fodder plants. Which then again build the feed value and thus constitute the pasture quality.

Thirdly, the pasture is not only influenced by the inner characteristics of the soil, but also the **position of a soil in the landscape**: “Si tu vas vers le plateau, tu choisi le flanc des collines dans les ravins où il y a des sols argilo limoneux, tu trouveras de bonne pâturage, si non sur la colline avec la chaleur les herbes sèchent vite.” (C5b).

Indicators

Two types of indicators are used to identify good pasture. There are direct indicators and, the more commonly used indicators, indirect traits that are not observed on the pasture level, but on the herd level. These indirect indicators look at effects of feeding on a certain pasture on the animals, and from this derive conclusions about the pasture’s quality.

Direct indicators for a good pasture are:

1. *Indicator plants*:

In the four villages the agro-pastoralists were asked to name such plants that indicate good pasture, their answers are depicted in Table 21. . Several indicator plants were named repeatedly: *Dayye* (4 times), *Dengeere* (2 times), *Fakuuje* (2 times), *Garraabal* (4 times), *Kebbe* (2 times), *Pagguri* (2 times), *Sinkaare* (3 times) and *Yengere* (3 times).

Table 21: Plants that indicate good pasture

Name in Fulfulde	*Scientific name*
Bayeeriwo	n.a.
Bounjaari	n.a.
Cellebode	*Gynandropsis gynandra*
Dayye	*Andropogon gayanus*
Dengeere	*Zornia glochidiata/Melliniella micrantha*
Diidere	n.a.
Djelbi	n.a.
Fakuuje	*Corchorus spp. (C. tridens, C. olitorius)*
Garraabal	*Diheteropogon hagerupii/Diheteropogon amplectens*
Kaarinje	n.a.
Kebbe	*Cenchrus biflorus*
Kelbi	n.a.
Kelli	*Grewia bicolor* Juss.
Layndi	n.a.
Mangelldanngule	n.a.
Mbulunku	n.a.
Ndaneeriho	n.a.
Njello	n.a.
Pagguri	*Panicum leatum*
Sinkaare	n.a.

Uuloroowol	*Cassia obtusifolia*
Walawaande	*Commelina forskalaei*
Wuluunnde	*Cymbopogon schoenanthus*
Yengere	n.a.

Source: own data and KINTZ (1981)

2. *Virgin state of the pasture*: "la qualité d'un bon pâturage se reconnaît, lorsque les herbes dans un endroit, aucun berger n'a passé dans cet endroit, donc la biomasse c'est-à-dire l'herbe est grande et peut être appétée par les animaux. C'est à ça le bon pâturage quand tu es la première personne à venir avec les animaux." (D1b)

Indirect indicators for a good pasture are:

Milk production:
"on fait la comparaison de la production du lait et la comparaison de l'état des animaux" (C5b)

Physical condition of the animals:
"Si c'est un endroit favorable, les animaux vont grossir dans le cas contre on quitte le lieu. Cette observation ne doit pas dépassée 8 jours pour un bon éleveur." (C5b)
"il [le berger] regarde la corpulence de l'animal, on regarde les cotes et le ventre si les os sont visibles ou pas. Si on voit les os des cotes et si l'animal n'est pas en forme cela veut dire qu'il manque quelque chose." (C5b)
If the animals are not in good physical condition the herder concludes that there is something missing on the pasture.

Satiation of the animals:
" …tous les suis jour et nuit, dans la nuit si tu les amène au pâturage, à partir de minuit déjà tu peux savoir si l'herbe qu'ils mangent est riche ou pas, parce que si l'herbe est riche une fois que les animaux sont rassasiés, ils se regroupent dans un endroit et se couchent tranquillement. Mais si les animaux se promènent durant toute la nuit sur l'aire de pâturage, cela veut dire que l'herbe n'est pas riche, même si elle est abondante….Si le pâturage est disponible, les animaux ne partent même pas loin." (C5b)
The herder measures the time needed for grazing. If the animals are still not satiated and ruminating until midnight the herder concludes that the pasture is of low quality.

Behaviour:
"La chaleur des animaux dépend de leur condition de vie, si les animaux sont bien rassasiés ils s'accouplent vite. Tu vois les mâles tournés autour des femelles et souvent on assiste à des combats entre les mâles. Souvent même si les animaux sont pleins au pâturage, ils courent en rentrant au campement. Si tu as beaucoup de mâles, ils font toujours des combats et le meilleur s'impose toujours." (C5b)
On good pasture the animals are lively: they are running on return from the pasture and the males start fighting with each other.
Reproduction :
"Si les animaux commencent à s'accoupler cela veut dire que l'endroit est bon." (C5b)
When the animals start mating it means that the pasture is of good quality.

Action rules:

In this paragraph the "good pasture" will be analysed based on the cybernetic analysis approach (see chapter 3.3.3).

The *controller* is the herder and the *controlled process* is in this case is the feeding of the cattle. The *target value* is having well nourished cattle with high performance (milk, reproduction, growth). The controller here conducts *problem solving control* because he only takes action when the actual value deviates from the target value. The controller hence follows rules suitable to reduce this deviation and to ideally re-obtain the coherence of target value and actual value. When the herder leads the cattle on a certain pasture he cannot yet exactly determine the pasture's quality, therefore he has to test and to observe what happens. Disturbance factor here is the risk that the herder puts the cattle on a bad quality pasture. When such a disturbance occurs, the herder decides what he wants to achieve (*command signals*), in which management domain (*actuating element*) he can achieve it, and which measures he has to take in detail (*manipulated variables*). Four possible factors that can cause a bad nourishment of the cattle are described in Table 22.

Table 22: Rules for identifying the good pasture

Target value	Well nourished cattle: Animals produce milk, are in good condition, mate			
Sensor	Observation on milk production, physical condition and behaviour			
Actual value	Animals decline physically, females do net get to heat, milk production decreases and animals behave tiredly			
Observations on disturbance factor	Drought: plants cannot grow because of lack of water	Polluted water hinders the animals from good reabsorption of nutrients	Plants on the pasture do not contain a lot of nutrients	Pasture does not contain many high value fodder plants
Command signals	Lead the herd into a region where there has been rain	Supply the animals with better water so that they can recover	Proceed with animals on high quality pasture	Proceed with animals on high quality pasture
Actuating element	Decision about the route of transhumance	Watering scheme	Chose direction in which to proceed	Chose direction in which to proceed
Manipulated variables	Try to find an area where there has been some rain Call people in different areas, go to markets and listen to the radio to find out where it has rained recently Orient on stars to find other areas	Lead the animals to wells and water them there	Change the place towards better pasture	Change the place towards better pasture

Source: semi-structured interviews C5b, D1b

f) Ceeduwa: prolonged dry season

The term *ceedu* in Fulfulde refers to the dry season. In this study, one of the objectives was to learn about strategies of alterations of management in a year with poor rain in order to find out the agro-pastoralists' adaptation strategies. However, the fieldwork showed that there is no fundamental alteration in a dry year and that the concept of an especially dry year does not even exist in the conception of Fulani agro-pastoralists. For them overcoming the *ceedu* already is a challenge each year and when they were asked "what is different in a dry year?" they expressed that this question makes no sense to them.

However, detailed analysis of the data revealed some differences during a prolonged dry season (which is indicated by the term *ceeduwa*) compared to a year with regular rainfall. They are depicted in Table 23. One the one hand there are observations concerning three levels: the environment as such, the animals and the markets. On the other hand, there are actions/choices of the agro-pastoralists concerning the transhumance. These are depicted in Table 24. There are aspects that concern the delta as well as aspects concerning the transhumance route in general, and there are alternatives to the livestock keeping activity.

Table 23: Observations of differences in a dry year of Fulani agro-pastoralists in Mopti region

Observation	Source
Environment	
Rain is not sufficient	C5b
The Delta is not much inundated	A3b
Fodder plants do not grow well	A1b, A3b
There are not enough fodder plants	A1b, A3b
There is not enough burgu or rice residues	A3b
Poor yields of field crops	C5b
Animals	
Animals are weak if it does not rain enough	A3b
Animals suffer from lack of fodder	C5b
Animals are hungry	C5b
Lactating cows do not produce milk	C5b
Animals do not gain weight, come back from transhumance in poor body condition	A3b
If the dry season is prolonged there are animal losses	A3b
If the animals start to loose weight there are many animal losses	A3b
Markets	
Cottonseed cake price rises when animals start to loose weight	A3b
All animal feed prices rise, it is not possible to feed the animals as one should	A3b
Animal prices decrease	A3b

Source: Semi-structured Interviews A1b, A3b, C5b

Table 24: Actions that can be taken in a dry year

Actions	Source
General aspects	
Lead the animals to good water in order to check the hypothesis that bad water quality causes the bad body condition of the animals	C5b
The herder is obligated to take a lot of care[22] of the animals while searching fodder	C5b
Sell animals to buy cereals[23]	A1b
Access to resources	
Bribe the local authorities in order to be able to enter the bourgoutière earlier (already in September)	A3b, C5b
Collect information	
If you see an animal that is well nourished ask from which side it comes from	C5b
In the cold season the herder can follow the star constellation "*assima kayna*" which lead them to fresher places	C5b
Collect informations where there is some pasture and then go there	C5b
Alternatives outside the livestock production system	
Rural migration	C5b

Source: Semi-structured Interviews A1b, A3b, C5b

In a prolonged dry season conflicts between farmers and livestock keepers can occur due to crop damage caused by hungry animals. Informants reported that if this happens the herders are usually held responsible and they have to pay compensation (ranges are 8 000 – 10 000 FCFA per year) but it does not occur every year: „C'est cette mauvaise saison ceeduwa qui amène les conflits entre éleveurs et agriculteurs, parce que en ce moment si tu ne fais pas attention, les animaux vont rentrer dans les champs pour faire des dégâts. Il n'y a pas à manger dans les pâturages, donc si les animaux vont sentir l'odeur des champs verts, ils vont toujours vouloir aller dans ces champs, donc c'est ce qui amène la guerre entre les paysans et les éleveurs" (C5b).

4.3 CROP PRODUCTION

In focus group sessions the agro-pastoralists emphasised the importance of livestock within their production system. Nonetheless, crop production is an inextricable part of agro-pastoral production and thus will be presented in the following paragraph. The structure is similar to the animal production chapter. Firstly it will provide information on the production factors. Secondly objectives of the crop production are presented which is thirdly followed by a general overview based on the seasonal calendar. Finally the chapter concentrates on millet production as seleced topic.

[22] This statement indicates that there is a lot of knowledge about that topic that was not yet obtained in this study

[23] This activity can be considered as outside the livestock production system only if destocking takes place. If the informant here talks about normal offtake this action is inherently within the production system as in this case it would mean the usual output absorption.

4.3.1 Production factors: plants and fields

a) Fields

The agro-pastoralists distinguish between two types of fields. They use homestead fields that are close to/around the village and fields that are more far away (up to 70 km). Homestead fields are used for crops that demand a high supply of nutrients or maintenance like vegetables (e.g. squash, okra) or maize. They can be considered as more fertile because they are more intensively manured than distant fields (own observation). The distant fields are cultivated by constructing non-permanent cultivation huts where the labour forces live until the field work on this respective field is finished (e.g. two weeks of weeding). Households own fields that are scattered around the village at all sides, the fields of one household are usually not connected. Approximate field sizes are 0.5 – 2.5 ha (own estimation based on semi-structured interviews).

b) Species and varieties

Table 25 shows the crops that the agro pastoralists listed as answer to the question "what crops do you grow?". It is evident that this list might be lacking some crops that only some persons in the village grow, who might not have been present. However, in general it can be assumed that the main crops are named. Results then show that crop production in the Séno area is based on millet and sorghum whereas in the Delta the crop production focuses on rice. Nérékoro with its location at the delta's border can grow both types of cereals, however, millet and sorghum are also cultivated there on a larger scale and only 12 farmers possess rice fields (feedback seminar). Generally the Sèno villages are more diversified in their crop production, also Ouandiana more than Sadia Peulh.

Table 25: Cultivated crops

In all four villages	Séno and Nérékoro	Séno only	Ouandiana only	Delta (Yongosiré & Nérékoro) only
Cowpea *Vigna unguiculata* (L.)Walp.	Millet *Pennisetum glaucum* (L., R.Br.)	Sesame *Sesamum indicum* L.	Fonio *Digitaria exilis* (Kippist, Stapf)	Rice *oryza sativa*
Groundnuts *Arachis hypogaea*	Sorghum *Sorghum vulgare*	Roselle *Hibiscus sabdariffa*	Kenaf (fiber) *Hibiscus cannabinus*	
Maize *Zea mays*			Calabash *Lagenaria siceraria*	
Okra *Abelmoschus esculentus*			Melons *Citrullus aedulis*[24]	
Squash *Cucurbita pepo* (L.)	voandzou *voandzeia subterranean*[25]			

Source: Seasonal calendar, Nérékoro, 14 participants, 27/02/09; seasonal calendar, Sadia Peulh, 11 participants, 19/03/09; seasonal calendar, Ouandiana, 10 participants, 31/03/09; seasonal calendar Yongosiré, 10 participants, 26/04/09

[24] Also grown in the Delta

[25] Nérékoro only

Additionally **trees** were named as an important source of spices, fruits and nuts. Table 26 gives an overview of utilised trees for each village respectively.

Table 26: Utilised trees for each village respectively

Nérékoro	Sadia Peulh	Ouandiana	Yongosiré
Lannea acida	Baobab	Baobab	*Diospyros mespiliformis*;
	Adansonia digitata	*Adansonia digitata*	
Néré	*Detarium microcarpum*	Fig	"Nenuphar"
Parkia biglobosa		*Ficus gnaphalocarpa*	(not identifiable)
Saba senegalensis	Fig *Ficus gnaphalocarpa*	Shea nut	*Ziziphus mauritiana*
		Vitellaria paradoxa	
Shea nut	Tamarind	Tamarind	
Vitellaria paradoxa	*Tamarindus indica*	*Tamarindus indica*	
Tamarind	Wild dates	Wild dates	
Tamarindus indica	*Balanithes aegyptiaca*	*Balanithes aegyptiaca*	
		Ziziphus mauritiana	

Source: Seasonal calendar, Nérékoro, 14 participants, 27/02/09; seasonal calendar, Sadia Peulh, 11 participants, 19/03/09; seasonal calendar, Ouandiana, 10 participants, 31/03/09; seasonal calendar Yongosiré, 10 participants, 26/04/09

Concerning millet varieties the agro-pastoralists distinguish between the short-cycle *Sunnari* and the long-cycle San*n*oori. Table 27 shows different traits associated with the different varieties.

Table 27: Traits of different millet varieties

trait	*Sunnari*	*Sannoori*
Development of the plant	Short-cycle, the plant is smaller	Long-cycle, the whole plant is bigger
Panicle	are smaller and the grains are harder	has bigger and longer spadices, thus higher yields
Storage and taste	n.a.	it is longer storable and has a better taste

Source: pairwise ranking Nérékoro, 3 participants, 06/03/2009

Breeding

Selection of seeds is done every year during harvest and is considered to be crucial for the long-term success of a farm: "La sélection est très importante dans toute activité pour avoir une meilleure qualité" (C1a). The best seeds are chosen and stored to serve as seeds the following year. For all crops the agro-pastoralists search to select early maturing varieties: "Cette sélection des semis nous permet d'avoir des variétés hâtives et connaître les variétés tardives. Compte tenu de l'incertitude des pluies il faut toujours semer des variétés rapides." (C1a). Further selection criteria in millet are:

- Fast ripening
- Dense panicle
- Good and vital stems
- Long panicle
- Heads filled with big grains that are healthy and without any diseases
- Resistant towards drought
- Plant without visible pest attack

4.3.2 Objectives of the system

The purpose of crop production is food security. The envisaged outcomes are therefore **high and secure yields**. Agro-pastoralists additionally stated further sub-objectives of certain management practices which can be grouped in three categories:

a) Avoid crop losses
   - Minimise exposure of seeds to bird attack
   - Avoid damage of animals on young emerged seedlings
   - Increase the chance for sufficient water supply
   - Have plants tolerant against pests
   - Good germination (5/10 seeds germinate)
   - Millet attains maturity

b) Advance the plants' conditions in order to increase yields
   - Attain good soil aeration
   - Provide sufficient distance between the plants
   - Decrease weed concurrence
   - Cultivate big/many plots

c) Sustain long-term resource preservation
   - Conservation of soil fertility
   - Enrich soil with nutrients
   - Preserve trees on the fields
   - Facilitate physical work

4.3.3 Seasonal calendar crop production

The seasonal calendar followed the local system of counting the months (for more information see chapter 4.2.3). It was drawn by agro-pastoralists during focused group discussions and contains climate data that they indicated for orientation. The calendar presented here is a synthesis of the results from the different group sessions in Nérékoro, Sadia Peulh and Ouandiana. Information that differs is explained in detail in the text. A table of the calendar is attached at the end of the chapter (p. 72).

For the delta village of Yongosiré the seasonal calendar is different for its focus on rice production, and is therefore presented separately at the end of this chapter.

The agricultural year starts in the Séno with the transportation of manure to the field. This manure consists of kitchen wastes and animal droppings from village animals that spend the nights in the homesteads. This is an ongoing activity, performed whenever the farmer has the possibility of using a means of transportation. The manure is put in several small heaps on the ground. It is later spread on the field and worked into the soil by the incipient rain.

Cultivation period is induced by the onset of rainfall at the end of May – begin June. **Millet** is sown as the principal crop. In Nérékoro the seedbed is prepared through plough tillage (Figure 18). This also serves as a first means of weed control. In Sadia Peulh and Ouandiana seedbed preparation is done predominantly by hoes (Figure 17). The farmers dig holes, sow 5-10 seeds per hole, which are then closed with the heel, forming little pockets. In 2008 it took

about one month to seed (Ouandiana and Sadia Peulh), so they finished at the end of July. This is a crucial point in their management because the seeding has to be as fast as possible in order to prolong the length of the length of photoperiod favourable for millet development. Farmers in Sadia Peulh reported that in the year 2008 they had to sow three times, because every time they had sown and the millet had germinated, early season dry spells had occurred drying out the seedlings. They consider this as common and normal in their environment.

15 days after seeding the first of two weeding turns begins. The weeding is done either by ploughing or with the hoe. One turn takes approximately one month (in Ouandiana), directly after the first turn the second begins, resulting in each field being weeded twice with a time lag of 30 days.

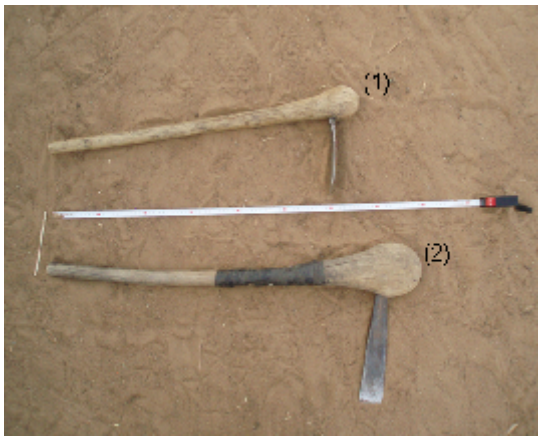


Figure 17: Different types of hoes for weeding (1) and cutting woody plants (2)

Figure 18: Soil cultivation with plough

During the second weeding cycle, redundant tillers of millet are thinned out, with the aim of having no more than 5 seedlings per pocket. After the second weeding cycle the fields are guarded by children to protect them against pests and the village animals. Before harvest the agro-pastoralists go to the fields and eliminate "ill plants[26]".

Figure 19: Granary in Nérékoro
February 2009
Picture: Kaufmann

In 2008 at the beginning of October the harvest began in all four villages, taking 42-45 days. The millet stems are cut and the spadices are collected in one corner of the field. They are transported either at the end of the day or after the whole field has been harvested to the homesteads, where they are stored in specially constructed granaries (see Figure 19).

[26] plants infected with smuts (e.g. caused by *Helminthosporium* spp.) or downy mildew

Farmers in Nérékoro reportedly harvest earlier than their neighbour Bambara villages so that the animals can come and feed on the crop residues before they go on to the transhumance "pour laisser profiter les animaux". At the beginning of December 2008, the harvest and transportation was finished and all the harvest was stored.

Fonio and **Sorghum** are cultivated in the same way as millet and sorghum, the only difference is that fonio is weeded exclusively by hand and that Sorghum is planted during the first weeding cycle of millet (Sadia Peulh).

There are two ways of cultivating **cowpea**

a) In association with millet: during the weeding of millet the farmers sow the cowpea, this work takes about 7 days. In 2008 they started this at beginning of July.
b) Only cowpea: at the beginning of July the farmers plough the field and sow directly. 20 days later the weeding follows, which takes two days. The cow-pea harvest is at the end of September/ beginning of October.

The **groundnuts** are cultivated the same way as cowpea, although they are sown at the end of June. For the groundnuts weeding has to be especially intensive. If sown densely less weeding is needed. There are differences in the cultivation of groundnut between the villages. In Ouandiana and Sadia Peulh the groundnuts are sown at the beginning of June and harvested at the beginning of October. If grown in association with millet, cowpea and groundnut are harvested before the millet harvest starts. Farmers in Nérékoro reported that they harvest groundnuts in mid August.

Maize is cultivated in small quantities and on homestead fields only. If it is sown at the end of May it can be harvested in July. During the growing period it is weeded once a week. It is not harvested all at once, but whenever they want to eat some maize the farmers go to the fields and collect a portion for direct consumption.

Okra was sown around June 25th in 2008 by preparing the seedbed with a hoe. Two weeks later okra was weeded for one day. When it rains, ash was put onto the okra fields. At the end of August the harvest of okra started continuing until end October. In the village okra is cut in pieces and dried in the sun.

Sesame was also sown around June 25 th by broadcast seeding. After this the seeds are covered with soil using a hoe. In mid July weeding takes place, which takes about three days and is done by hand. At the beginning of September they harvest the sesame.

Roselle was sown at the beginning of August during three days. At the beginning of September it was weeded during 5 days. Harvest was at the beginning of November.

Squash was cultivated in very little quantity behind the houses. It was sown at the beginning of May and 5 days later the small plants are strutted with sticks. The first of the squash can be harvested in August, and the agro-pastoralists can continuously harvest the fruits until about the end of October.

For cultivating **calabash and melon** only three months are needed. They were planted in July and could be harvested at the end of September. Harvest continued as the melons ripen little by little until the end of January.

Table 28: Seasonal calendar crop production Séno and Nérékoro

	January	February	March	April	May	June	July	August	September	October	November	Dezember
	1 Haaram	2 Mini Haaram	3 Almaw-luudu	4 Mini Almaw-luudu	5 Radjibi Awru	6 Radjibi Hoddaaru	Hor-teendu Moodi-baabe	8 Yaawa	9 Koorka	10 Juldaandu	11 Siwtu-raandu	12 Layya
Rainfall					Rainfall starts	Raining	Heavy rainfall		Raining			
Temperatu-re	Cold sea-son			Hottest period							Cold season	
Millet, sorghum	Continuously put manure on the fields					B[27]: Seed-ing millet; E[28]: weed-ing, same day seed-ing sor-ghum	Weeding (hoe)	Weeding contin-ues, thinning redun-dant tillers	Guarding the fields	Guarding the fields, End of month harvest starts	Harvest, End of month harvest finished	Continuously put manure on the fields
Maize						Seeding once a week weeding	Wee-ding, Harvest begins	Pick when consu-med				
Cowpea						Sow, if not in associa-tion	Sow cowpea in asso-ciation with millet	E: har-vest of cowpea (mono-culture)	E: har-vest (associa-tion)			
Ground-nuts						B: sow	Weeding	Weeding	E: har-vest	Harvest		

[27] B = begin of the month

[28] E = End of the month

Okra						Ploughing and seeding ~25.6.	Weeding (hoe) When raining putting ash	E: harvest starts	Harvesting and drying (at homestead)	Harvesting and drying (at homestead		
Sesame						Broadcast seeding end of month	Mid July weeding (by hand)		B: harvest			
Fonio						B: sow	Weeding (per hand)		Harvest and E: transport			
Roselle								B: seeding	B: weeding (by hand)		B: harvest	
Squash					B: seeding, 5 days later strutting			Harvest	Harvest	Harvest		
Calabash, melon	Harvest	B: harvest ends					Seeding one week later you put manure around the planting bulbs	Every 20 days weeding	E: harvest can start	Harvest		

Trees												
Nérékoro	Fruits of tamarind	Fruits of tamarind		B: Néré-fruits End: leaves of tamarind	Leaves of tamarind; Fruits of Shea butter, *Lannea acida* and *Saba sene-galensis*	Leaves of tamarind; Fruits of Shea but-ter, *Lan-nea acida* and *Saba senegalen-sis*	Leaves of tamarind	Leaves of tama-rind; tama-rind in blossom E: Fruits of Tama-rind, Sousou, *Ziziphus mauriti-ania*	Leaves of tama-rind, Fruits of tama-rind, Sousou, *Ziziphus mauriti-ania*	Fruits of tamarind, Sousou, *Ziziphus mauritiania*	Fruits of tamarind, Sousou, *Ziziphus mauriti-ania*	
Sadia Peulh	Fruits of tamarind	Fruits of baobab	Fruits of *detarium microcar-pum*,	Fruits of *detarium microcar-pum*, Leaves of baobab, tamarind						Fruits of *balanithes aegyptiaca*	Fruits of *balanithes aegyp-tiaca,* Fig and tamarind	Fruits of fig and tamarind
Ouandiana	Fruits of tamarind and wild dates	Fruits tamarind	Fruits tamarind, fruits fig	Leaves tamarind, baobab, fruits shea butter, fig	Leaves tamarind and bao-bab, Fruits shea butter	Leaves baobab	Leaves babo-bab, fruits baobab, fruits *Ziziphus mau-ritiana*	Leaves baobab; fruits baobab, *Ziziphus mau-ritiana*, wild dates	Fruits baobab, *Ziziphus mau-ritiana*, wild dates, tamarind			

Source: Seasonal calendar, Nérékoro, 14 participants, 27/02/09; seasonal calendar, Sadia Peulh, 11 participants, 19/03/09; seasonal calendar, Ouandiana, 10 partici-pants, 31/03/09

The trees

The use of trees differs between the villages. Table 28 gives an overview of which fruits and leaves are collected when in each village respectively.

Rice production

Yongosiré's seasonal calendar is predominantly shaped by rice cultivation (see Table 29). Although other crops are cultivated, farmers did not consider them important enough to put them in the calendar. The agricultural year starts with ploughing in March, April and May. In the heavy clay soil of the alluvial Delta area this work is usually done in the early hours of the morning. Farmers stop at 10:00 a.m. to avoid working in the day's heat. This is why the ploughing takes three months. In June with the first rainfalls again the farmers plough the wettened soil and sow broadcast. Some farmers reported that they harrow afterwards but this does not seem to be standard practice. Around July the water level rises and the emerged seedlings are soon covered with water. The first turn of weeding has to be done by boat. In December, after the flood-level has decreased, the harvest starts. The rice is harvested and threshed directly on the field, before being transported to the village and stocked in rice sacks inside the houses.

As explained in paragraph 4.1.1 in Yongosiré trees are more distant than in the other villages. Thus tree use is less frequent than in the other villages and only conducted during the dry season.

Table 29: Seasonal calendar Yongosiré

	January	February	March	April	May	June	July	August	September	October	November	December
Rainfall					Rainfall starts	Raining	Heavy rainfall	Raining				
Temperature	Cold sea-son			Hottest period							Cold season	
Rice	Harvest with sickle	Threshing, before that the rice has to dry	Dry ploughing	Dry ploughing	Dry ploughing	Wet ploughing with seeding after-wards; harrowing		Start of weeding	Weeding by boat	Weeding by boat	Weeding by boat	Harvest
Trees												
Diospyros mespiliformis	Collection of Fruits	Collection of Fruits										
Ziziphus mauritiana	Collection of Fruits	Collection of Fruits										
Nenuphar				Collection of Fruits								

Source: seasonal calendar Yongosiré, 10 participants, 26/04/09

4.3.4 Selected topic: millet production

The following paragraph will give an overview of the millet production system in the way it is perceived by the producer. It concentrates on millet production as it is the main staple crop that secures daily food supply. "…ma principale motivation est qu'ici notre alimentation de base est le mil, donc je cultive le mil dans la plus grande superficie" (B1a).

Crop production management can be subdivided into:

- Prerequisite management: this concerns management decisions that shape the development of the cultures by setting the prerequisites, such as choosing cultivation sites, association patterns etc.
- Maintenance management: controlling plant stand development

The different types of management operate on different levels. Prerequisite management aims at achieving the best possible conditions for the plant. Most of the identified management rules are selection rules, because the agro-pastoralists are not able to influence traits such as soil characteristics, despite they are able to choose the best sites for each crop and its requirements. Maintenance management is applied when prerequisite choices have already been made. This level of management concerns stand development and most rules are problem solving rules, e.g. pest control

4.3.4.1 Prerequisite management

Concerning prerequisite management in millet production the analysis identified three relevant fields of management. These are **soil cultivation**, **seeding** and **mixed cultivation**. The paragraphs are structured as follows: firstly, for each management field, observations and derived *hypotheses* of the agro-pastoralists are explained as those constitute the basis for their decision making. Secondly, *action rules* that are derived from these hypotheses are explained.

4.3.4.1.1 SOIL CULTIVATION

The following paragraph about soil cultivation refers exclusively to information from the villages Ouandiana (Séno) and Sadia Peulh (Séno). In Nérékoro no information about soil cultivation was available and in Yongosiré the conditions are so different that it is not comparable. Topics dealt with in this paragraph are soil characteristics, soil cultivation techniques, and fallow – crop rotation.

Underlying hypothesis

Soil characteristics

The agro-pastoralists observe two main characteristics of the soil. One is water holding capacity and the other is soil fertility. Both are shaped by the soil type. In interviews agro-pastoralists distinguish between clay, and sandy soils. Table 30 gives an overview of the different traits that are associated with the two soil types.

Table 30: Comparison of traits associated with sandy soils and clay soils

Traits	Sandy soil	Clay soil
General characteristic	Needs little water, promotes higher yields in dry years, but less in humid years	Fertile soil that needs a lot of humidity to reach its yield potential
Water infiltration rate	Fast infiltration cannot hold back water for slow infiltration	Slower infiltration rate
Water holding capacity	water holding over longer period	Soil dries fast when there is an interruption in rainfall, after 10 days already the millet dries on clay soil
Fertility	Poor in nutrients	Contains more plant available nutrients
Germination	Soil is rapidly water saturated and too much water delays germination Fast infiltration cools down the soil, but seeds need a certain soil temperature to germinate.	Contains more nutrients to support the soil in fulfilling its task for the germination[29] Germination is better supported and faster
Growth regime	With high rainfall development of millet can be delayed	n.a.
Yield	Higher yield than clay soils in dry years, but overall lower yield potential	Higher yield than sandy soils in wet years, higher overall yield potential
Conclusion	Is advantageous when there is little rain, also when there are longer interruptions of rainfall	Is advantageous when there is a lot of rain, and especially with continuously rainfall

Source: Semi-structured interviews A2a, B1a, C1a, C4a

The different characteristics of soils in the respect of water holding capacity are due to soil texture. Sandy soils with a larger corn size can faster infiltrate the water and retent it longer[30]. "…dans les années sèches, c'est la zone sableuse qui produise mieux, parce qu'elle conserve longtemps plus d'humidité que la zone argileuse. Dans les sols argileux, une fois que la pluie est interrompue, le sol sèche très vite, donc la production ne sera pas bonne" (B1a).

Soil cultivation

The agro-pastoralists have a detailed understanding how soil cultivation influences soil characteristics. They focus on measures to increase soil nutrient content rather than water infiltration/holding traits because they observed that these first measures have a higher yield effect. This is due to the fact that the majority of their cultivated soils are more or less sandy, thus nutrient content is the major problem. In their perception the soil nutrient content is greatly influenced by soil cultivation. Therefore the current debate among agro-pastoralists in Sadia Peulh and Ouandiana concentrates on hoe vs. plough based soil cultivation. Table 31 gives an overview of the envisaged objectives, conducted measures and underlying reasoning.

[29] This hypothesis of the agro-pastoralists does not conform to the scientific explanation: During germination the seedling nourishes from the seed. Before it has not built a root it does not take up nutrients from the soil. However these linkages are unobservable for the agro-pastoralists (micro-level) thus they find their own explanation which conforms to their conceptual framework.

[30] The scientific explanation for this phenomenon is the following: When the rain stops evaporation from the soil is very high. Then the coarse pores of the sandy soil in the upper soil horizons dry fast, but then the capillary rise is interrupted and the adhesive water in the micro-pores in greater depth will not be sucked out. The millet however with its long taproot can reach this adhesive water and use it during drier periods.

Table 31: Management concerning soil cultivation

Purpose /intention (in order to)	Measure	Reasoning (because)	Observation (this can be seen at…)
Conserve soil fertility	Shallow working depth, non turning tillage (hoeing)	Ploughing turns the soil upside down, nutrients on soil surface are exposed to erosion and are not available to the millet's roots	With ploughless tillage it is possible to cultivate the same field several times without it loosing it's fertility With ploughless tillage millet is more vigorous, bigger and thicker
Accumulation with nutrients	Piling up the spread manure and form pockets (by hoe) in which seeds are sown	Millet needs manure	This method achieves higher yields
Conservation of trees on the fields	Work around the trees with the hoe	Trees inhibit desertification	n.a.
Good soil aeration	Accurate seedbed preparation	Enhanced root development	Faster growth, thicker stems of the plants
Enough distance between the millet plants	Form pockets, do not sow in rows (only possible in ploughless tillage)	Plants need sufficient air circulation	n.a.
Decrease competition of weeds	Hoe/plough before seeding	Resistance against weeds costs the millet capacities and hinders emergence of seedlings	If weeds reach a certain height emergence of millet is constrained
	Hoe between the plants within the row	Millet needs sunshine (to transpire) and good aeration; both is constrained by weeds that reach a certain height	If there are too many weeds, millet development is delayed
Cultivation of big plots	Use oxen plough	Much faster, thus necessary to avoid too late seeding dates if rain onset is early	Plough is faster: more area/time
Facilitation of physical work	Use oxen plough	Working with plough is less physical demanding than hoeing	n.a.

Source: Semi-structured interviews A2a, B1a, C1a, C4a

Action rules

To manage soil traits the producers conduct several activities. The analysis identified the following routine rules:

- To increase soil fertility the agro-pastoralists continuously transport manure to the fields during the dry season.
- If enough time and labour is available, they use hoe-based tillage, however there is a strong restriction due to seeding parameters (see 4.3.4.1.2)
- All of this is especially important in low fertile sandy soils. In clay soils however,

there is common use of plough based tillage, because there the soil is hard - hoe tillage is too exhausting and the question of soil fertility conservation is less urgent in clay soils.

- When the rain begins the agro-pastoralists start soil cultivation based on hoeing (see seasonal calendar). However, when time runs short because the rains start falling abundantly and regularly (providing optimal crop development conditions) and there is still a larger area to be cultivated, they cultivate the remaining fields by ploughing. There is a certain break even point from which yield reduction due to delayed seeding date exceeds the gain that can be reached by no tillage soil cultivation.

Fallow – crop rotation

Fallow times are conducted within a collective system that is managed at the village level: "…la gestion est l'ensemble du village. On s'assoit et on décide la partie de la jachère et la partie de culture" (C1a). This system is different in each of the four villages (see paragraph 4.1.2). In the two Séno villages there is a fallow on one side (Sadia Peulh) or on two sides (Ouandiana) that is used as pasture for the village cattle and small ruminants and rotates every three years. The objective of this measure is an increase in soil fertility. The producers state that soil without fallow becomes degraded. In contrast they observe that in the first year after a fallow this soil promotes the highest yields. Especially at the places of *winde* (place where the animals sleep), the soil becomes fertile. In the first and the second year after fallow it is possible to cultivate without any problems. If in the third year they apply a lot of manure they have a good yield, on condition that there is sufficient precipitation: "…tous ces débris organiques permettent de fertiliser le sol, par contre le sol qui est cultivé toutes les années s'appauvrit vite. La partie laissée en jachère donne plus de mil en cas d'une bonne pluviométrie." (C1a)

4.3.4.1.2 SEEDING

Concerning the seeding as a management strategy, agro-pastoralists provided information on decisions about seeding dates, the choice of varieties, and the choice of cropping sites. These will be presented in that order in the following section.

Seeding dates

The development of the millet plants depends on weather conditions during the vegetation period. Especially important is the moment in which rainfall begins. The start of precipitation induces seeding, although it is a sophisticated task to find the best moment. Early seeding decreases low yield risk due to the period of grain filling coinciding with the period of most reliable rainfall. Additionally, millet as a photoperiodic sensitive plant requires an adequate length of growing season in order to mature. However, seeding early increases the risk of exposing seedlings to high radiation, high temperature and lower rainfall probabilities.

Determining the seeding date is not the only measure the producers can apply to control millet production. Table 32 gives an overview of objectives in seeding, different measures and the reasoning which explains the choice of the respective measure.

Table 32: Management concerning seeding decisions

Purpose /intention (in order to)	Measure	Reasoning (because)	Observation (this can be seen, because…)
Good germination (5/10 seeds germinate)	Seedbed preparation with the hoe, which also serves for weeding	Millet needs air to germinate. Too much moisture hinders good germination. Dew dripping from weeds prevent good germination, seeds lack air.	If weeds are to high and dens, germination is prohibited
	Early seeding date	At an early seeding date soil temperatures are higher (soil is cooled down by the rain) and that allows faster germination	If it rains too much, germination is delayed
Millet attains maturity	Early seeding date	If the photoperiod with enough humidity is too short, the millet will grow, but panicle initiation will fail	n.a.
	Choose cultivation site there where first rainfalls occur (condition: soil is suitable)	Rainfall is spatially highly variable, at least these fields contain moisture so millet will germinate	n.a.
Minimise exposure of seeds to bird attack	After seeding plough low-depth between the rows to cover the seeds with soil	n.a.	n.a.
	Late seeding date	If rain onset is delayed early sown seeds do not germinate and are exposed to birds attacks	n.a.
Avoid damage of animals on young emerged seedlings	Late seeding date	If the germination is too early, animals might not be herded yet and cause damage on the fields	n.a.
Plants tolerant against pests	Early seeding date	Animal pests (rodents, birds, insects and especially rats) appear from the middle of the planting period on. If sown early enough, plants are already robust and more resistant towards pests	
Avoid crop failure	Choose adequate variety	See next paragraph	See next paragraph

Avoid crop failure	Re-sow if rainfall was interrupted	n.a.	n.a.
Increase the chance for sufficient water supply	Sow on sandy soils	Sandy soils can deliver water longer in dry periods[31]	On clay soils: after 10 days of rainfall interuption millet starts to wilt, this is not the case on sandy soils
High yields	Sow on clay soils	Clay contains more nutrients	If there is no water problem yields are higher on clay soils
	Late seeding date	Because early plants receive much water during vegetal development biomass accumulation is high but panicle develoment is poor, whereas late sown plants at a certain development stage begin panicle initiation	if rainfall is abundant and regular, later sown millet achieves higher yields, because of positive panicle/stem ratio
	Early seeding date, but if rainfall is abundant and germination fast, animals are send to the fields[32]	Graze on millet fields as long as vegetation point is still on the soil surface. This retards shooting, hence results in the same effect than late seeding (see above) by avoiding the risk of a late seeding date	Stems are shorter and panicles longer and full

Source: Semi-structured interviews A1a, B1a, C1a, C4a

Table 32 shows that for some objectives several measures are undertaken. In addition it becomes evident that not all objectives are convergent. There are some objectives that are contradictual such as obtaining high yields and avoiding crop failure. In these cases the agro-pastoralists have to make decisions according to their preferences (i.e. their degree of risk aversion).

Additionally it was reported in interviews that there is one week at the end of June where seeding is not possible, because if seeded in that week, pest pressure (probably *Heliocheilus albipunctella* or *Coniesta ignefusalis)* will be higher than usually (B1a, C1a).

[31] On sandy soils with a higher corn size water can infiltrate faster and be stored. When the rain stops, evaporation from the soil is very high. Then the big capillaries of the sandy soil in the upper soil horizons empty quickly, but then the capillary rise is interrupted and the absorbed water in the smaller capillaries at a greater soil depth is retained. The millet with its long taproot can reach this water and use it during drier periods.

[32] This practice was only reported in Sadia Peulh

Avoid crop failure by choosing adequate varieties

The onset rainfall induces seeding, but it is a sophisticated task to find the best moment. The main problem is that local millet breeds are photoperiodically sensitive, which means that they obligatory need a certain number of days to gain maturity. If the time "window" with enough humidity is too short, the millet will grow but not ripen, hence yields will fail. There are two types of millet available to the agro-pastoralists: one is the short-cycle *Sunnari* and the other the long-cycle *Sannoori* (Figure 20).

Figure 20: *Sannoori* and *Sunnari* varieties of millet

Because of its shorter vegetation time there is less risk with the cultivation of *Sunnari* because of the higher probability that grain filling still coincides with high precipitation. However, the advantage of *Sannoori* is that it has a much higher yield potential, which means that in years with good conditions it can achieve much higher yields than *Sunnari*. Usually the agro-pastoralists do not choose one type and totally neglect the other type, but to avoid risks they plant both (feedback seminar Nérékoro). The decision concerns then the proportion of area that is planted with one or the other variety. Table 33 shows factors that influence the respective decision.

Table 33: Factors influencing the decision of choosing adequate varieties in millet production

Factors influencing the decision	*Sunnari*	*Sannoori*
Amount of cereal stock at begin of planting season	Low stock	Sufficient amount of cereal in stock
Date of onset rainfall	Late rainfall	Early rainfall
Persistence of rainy season	Interruptions, reseeding necessary	Regular rainfalls, no/ only short interruptions
Availability of tools (plough and draft animals)	Delays are probable due to poor availability of tools	Plough available, oxen in good condition, labour at hand: no delays
Experiences in past years	Short rainfall period in past years, *sannoori* did not attain maturity	Long rainfall period in past years, *sannoori* did attain maturity
Risk attitude of decision maker	Lower yield risk	Higher yield risk

Source: feedback seminar Nérékoro, 18 participants, 14/05/2009

If a farmer runs out of stock before the new cultivation season he will plant *Sunnari* to accelerate harvest and gain food. If the seeding is delayed (due to reasons such as: poor rainfall at the beginning of the cultivation period, or lack of plough, weak conditions of draught animals etc.) the farmers will plant a larger area with the fast growing *Sunnari*. Also they reported that after some years of poor harvest they will almost always give preference to the *Sunnari*.

Choice of cropping sites

In the choice of cropping sites the agro-pastoralists react with great flexibility. An important point that serves for risk diversification is the spatial spread of fields. Since precipitation is so variable on a scale of a few kilometres, farmers have their fields scattered around the village in all directions.

Agro-pastoralists reported that they have a determined order of crops. If there is no disturbance, the cultivation work for millet will be conducted first. Millet will be sown first, then fonio, then groundnut. After seeding, the first weeding of millet fields follows. When finished the first millet weeding the farmer will work on the fonio field for about one month (also weeding), after this, the groundnut is mature and will be harvested, then follows the millet harvest and then fonio harvest (see seasonal calendar).

Millet planting is first because of its importance for food security, and it is always planted on the best sites. Millet is sown on the side where it rains first - if there are fields[33] suitable for millet production. In the case of dry spell on millet fields, other fields, in which rain is more abundant, are now taken to sow millet there in spite of that they have been programmed to be planted with other crops. This is done in order to at least secure millet supply. This disturbs the order of the crops and the work cycle, but reduces the risk of staple crop failure (C4a).

The first decision about crop sites is taken due to rainfall patterns. However, soil parameters are also taken into account. Although clay soils can provide higher yields (condition: high precipitation) agro-pastoralists also cultivate sandy soils, as in years with low precipitation and irregular rainfalls at sandy soil sites they harvest at least some yield, but on the clay soils there is a risk of total crop failure (see chapter 4.3.4.1.1).

Restrictions to this strategy of flexible choice of cropping sites however do exist. The producer has to have good labour organisation because there is a bottleneck of labour during the seeding period. He also has to have all of his tools functioning and prepared so that no time is lost through repairation. Additionally it is advantageous if the producer began manure transport early so that at the onset of rain all fields are well prepared. The producer also has to be flexible in his decision making when the order of the crops is changed because then he cannot follow the routine sequence of work anymore.

[33] For more information about the fields see chapter 4.3.1 production factors: fields

Other decision rules that were mentioned by the agro-pastoralists are:

- The first year after a fallow on sandy soil it is not possible to grow fonio
- The second year after a fallow they sow sorghum
- If the soil is too sandy, sorghum does not grow well, in contrast, clay soils are good for sorghum
- Millet can grow on any soil type
- Millet and sorghum can be cultivated in a mixed cropping system, or monoculture, both can work
- Millet is sown on the majority of the area, because it constitutes the basic staple food

Beyond seeding decisions there is another interesting aspect that was reported in Sadia Peulh only. In some defined cases agro-pastoralists allow animals to graze on newly emerged millet. The underlying reason is the observation that early emergence in combination with regular and abundant precipitation causes too high stem/ panicle ratios and lowers the yield. One solution to this problem would be to delay seeding dates. However, this is too risky because of high rainfall variability. If they choose a late seeding date and then the rains stop early, there will be a total yield failure. Therefore they opt for a second alternative: if they observe an early good precipitation without interruption and the millet seedlings are already emerged, they let their animals graze in the millet fields. This reduces the leaves, but since the millet has not yet shooted, the apical vegetation cone is not harmed. In this way this measure delays the millet cycle only for those some days that the millet seedlings need to rebuilt the first leaves, but does not affect the overall plant development.

4.3.4.1.3 MIXED CULTIVATION

There are five main crops in the millet subsystem that were discussed in the frame of crop association. They are millet, cowpea, fonio, roselle and groundnut, thus providing theoretically ten possibilities of combination if always only two are associated. Table 34 gives an overview of possible combinations and the underlying hypotheses. The producers reported to associate crops according to tolerance of competition, their growth (twining, height), to heat emission (two heat emitting crops cannot be associated), and the length of the vegetation period and organisation of workflow (e.g. sorghum is sown during the first weeding of millet).

Table 34: Possible crop association partners and underlying reasoning

Crop	Traits	Association possible	Association impossible
Millet *Pennisetum glaucum*	Emits a certain heat Grows into height	Roselle: Works well but condition: enough distance, at least 5m between the rows Cowpeas: If they are too dense they will overwhelm the millet	Fonio and groundnut: Both do not like the heat in the millet field, also millet needs a longer vegetation period
Cowpea *Vigna unguiculata*	Winds up	Millet	Fonio Groundnut: does not tolerate the concurrence
Fonio *Digitaria exilis*	Grows very high	Roselle	Groundnut: fonio is higher than groundnut, which does not tolerate competition
Roselle *Hibiscus Sabdariffa*	Emits a certain heat	Millet: the moment when the roselle starts elongation the millet lowers its leaves, so there is enough aeration; condition: 5m spacing between rows	
Groundnut *Arachis hypogaea*	Cannot tolerate concurrence	Roselle	Millet, fonio, cowpea

Source: Semi-structured interviews C1a, C4a

The recommended plant associations are millet – roselle, however the roselle is not planted in the fields, but it can be planted around the field, forming an enclosure. Millet – cowpea is also a recommended and common association.

Additional to the association of different crops the agro-pastoralists also associate different varieties of the same crop in one field. For example a long cycle millet variation will be planted on the field in a depression which retains some humidity, while the part of the field that dries fast will be planted with a short cycle variety (feedback seminar Nérékoro).

4.3.4.2 Maintenance management

Concerning maintenance management in millet production the producers provided information about two relevant fields of management. These are weed control and pest control. The paragraphs are structured as follows: firstly, for each management field observations and derived hypotheses of the agro-pastoralists are explained as those constitute the basis for their decision making. Secondly, action rules that are derived from these hypotheses are explained. For pest control no information concerning action rules was provided (for possible reasons see 5.2.3).

4.3.4.2.1 WEED CONTROL

Underlying hypotheses

Besides variation in precipitation, farmers perceive weeds as the major constraint on production. In the beginning of the millet development cycle the weed already constrains germina-

tion: if it has reached a certain height, germination is delayed. In the perception of the agro-pastoralists the seed needs sun to be able to transpire, and good aeration which the tall weeds are held responsible for preventing. The farmers observe that the millet is growing, but slowly. They explain this by the fact that the dew that falls down from weeds permanently wets the millet which prevents it from transpiring and thus from growth[34]. "Le mil pousse, mais le problème est qu'il pousse très lentement, parce que la rosé des grandes herbes qui tombent sur le mil, rend les plants humide de façon permanent, alors cette rosé empêche les plants d'avoir du soleil pour transpirer. Donc c'est pour cela qu'il faut enlevé les herbes pour faciliter l'aération des plants. Si non les plants ne vont pas grandir." (C1a). Additionally there is the competition for nutrients and water. "Parce que tan que les herbes sont plus grandes la concurrence est plus forte." (C1a). If the weed has grown before the millet it will dominate. The resistance against the weed costs the millet capacities and renders growth more difficult for the young millet plant. "L'herbe à acquit des capacités de résistance […] donc avec trop d'humidité la germination est difficile pour les jeunes plants." (C1a).

Action rules

Weeding is done by ploughing and hoe weeding. The agro-pastoralists usually use two turns of weeding in millet. After the germination of the millet they plough between the rows. The farmer follows the plough with the hoe and cuts remaining weeds between the plants within the rows. At the same time redundant tillers are thinned. Fifteen days later follows the second weeding, which is conducted similarly. If the farmer has used ploughless tillage he has to weed twice. If he has ploughed for seedbed preparation three times weeding is necessary (no data was obtained concerning the reason). Care has to be taken not to cover the seedlings with soil and to ensure the draught animals do not trample the millet planting beds.

4.3.4.2.2 PEST CONTROL

Underlying hypotheses

In the course of the narrative interviews insect pests, rodents and birds have been mentioned. No agro-pastoralist mentioned fungus problems or plant diseases.

The pests that are considered to constrain production are:

- Birds (*Quelea quelea)*
- Termites *(Isoptera)*
- Grasshoppers (*Acrididae*)
- Millet head miner (*Heliocheilus albipunctella*)
- Millet stem borer (*Coniesta ignefusalis*)

Birds are considered to cause problems especially in the beginning of the millet cycle when they feed on seeds before they can germinate.

Termites in contrast do not directly constrain production, but they constrain harvest. The usual harvest procedure entails that the millet heads are collected at the side of the field before being transported to the homestead. At this moment termites attack the millet heads and can

[34] This concept is not shared in scientific understanding.

cause high losses. If the agro-pastoralists have problems with termites, they cut down only as many heads as they can transport to the granary the same day. Or they prepare the storage place on the field by applying some chemicals (they could not say which) to prevent termites from attacking the millet heads deposed there. Alternatively it is also possible to carefully sweep the collection site and to apply ashes before placing millet on this site, but this is reported to be not so effective against the termites.

Grasshoppers are reported to cause the highest production losses if they appear, however their appearance is much less likely than that of the other pests. But if they do appear they cause severe damages. The agro-pastoralists do not apply any measures to control for grasshoppers.

Some hypotheses about the millet head miner and millet stem borer have been reported. Agro-pastoralists seem not to distinguish between the two different animals. Table 35 gives a summary of observations concerning the two lepidoptera based on the semi-structured interview B1a. The respective agro-pastoralist had some fields last year that were particularly affected by this pest. The concerned acreage had been fallow in the year before, is sandy soil and had been fertilised with animal manure and kitchen waste before cultivation.

Table 35: Observations of millet head miner and miller stem borer

Topic	Observation	Hypotheses	Corresponding lepidoptera
Life cycle of the pests	Moment of appearance: grain filling		*Heliocheilus albipunctella*
	Moment of apperarance: tillering		*Coniesta ignefusalis*
Attacked plant organs	Attack panicle		*Heliocheilus albipunctella*
	Attack stem: bore into the heart of stem and attack the main head; plants die and do not attain maturity		*Coniesta ignefusalis*
Previous use of field	Last year (2008) attacked field had been fallow	Connection unclear	unclear
Manure	When manure is applied intensively problems with lepidoptera increase	Lepidoptera arise from the manure	*Coniesta ignefusalis*
	Last year (2008) lepidoptera have gained additional force through manure application		
Precipitation	Last year at the moment of appearance the rain had been interrupted, later it had restarted what decreased the crop loss	If at appearance of lepidoptera there is high rainfall the damage is decreased	*Heliocheilus albipunctella*
Point of attack	Lepidoptera choose sites where plants are dense or where there are trees	They like shade	n.a.

Source: semi-structured interview B1a

5 DISCUSSION

The aim of this study was to gain an insight into the production system of Fulani agro-pastoralists in Mopti region. The first step describes the different management practices as they are conducted by the producers throughout the course of the year. In a second step the rationality behind the actions was analysed with a cybernetic approach in order to understand what the agro-pastoralists observe and on which rules they base their actions. The discussion thus mainly focuses on the management strategies.

Before discussing the results, the methodology will be reflected upon, because results can better be interpreted if the methods from which they derive have been critically reflected on beforehand.

5.1 DISCUSSION OF METHODS

5.1.1 General approach

The overall research approach was to gain an insight into the Fulani agro-pastoralists' production system in order to learn action possibilities for producers in low external input system and under climate variability. Because it is impossible to ask questions about things of which we do not even know that they exist, for this study an open research approach was considered to suit best the demands of a system analysis. This means that there were no prefixed questionnaires but that the data collection was designed to be as open as possible, letting the informants lead and collecting the information that they consider to be important. This ambitious approach is demanding for the researcher and requires personal capabilities. In order to facilitate data collection and reduce data collection errors three precautions were taken. Firstly the research team was composed of a student from Germany and one from Mali in order to complement each other and to help facilitate cultural understanding. Both students responsible for data collection were trained for one week following the Master course "local knowledge" by Brigitte Kaufmann at the University Kassel. Thirdly in the first village students were accompanied by an experienced supervisor (B. Kaufmann).

Despite these precautions both students were not experienced in collecting qualitative data which assumingly led to lack of data and misunderstandings that may not have been occurred with a more experienced researcher. Another researcher could come up with a different set of data, which shows that there is no perfect reliability and reproducibility. However, the approach of letting the informants lead and collect the data that they present should automatically lead to the fact that the data contains the most important information about the production system in the view of the producers. Hence the data set can be assumed to be to a certain extent independently of the person who conducts the research, and thus is considered to be reliable to a satisfying extent.

5.1.2 Participatory rural appraisal tools

Strengths of the approach are its suitability for informant based data collection. Problems encountered in the application of the PRA tools range from general shortcomings of the approach to detailed and individual problems encountered in this fieldwork. In the following section general issues will be discussed first before coming to personally encountered problems.

As mentioned in literature there "are concerns about the value of…knowledge [obtained with PRA] and the extent to which it can claim to be a "truthful" representation of reality." (VAN DER RIET 2008:559), which is certainly a legitimate concern. But especially in respect of the concern of validity PRA contains certain characteristics that even increase validity. Firstly it is commonly acknowledged that "a respectful and trusting rapport between researchers and participants is assumed to make accounts more truthful, and therefore provide more accurate data. Another key assumption is that co-ownership leads to vested interest in the process, therefore participants are unlikely to give false or misleading judgments" (VAN DER RIET 2008:560). Further it can be assumed that the "participatory and inclusive nature of the participatory processes" (VAN DER RIET 2008:560) increases the number of voices and perspectives on an issue, which can be further expected to increase validity. This even increases the chance that the knowledge produced is consistent with the complexity of the investigated system and captures many of the system's aspects.

However, there are also characteristics that might decrease validity of data obtained. One important issue in that respect is reporting bias. There are three possible factors that may lead to purposefully wrong information giving.

The first factor is the deference effect, meaning that informants tell the scientist what they think he/she wants to know in order not to offend or please him/her. Such behaviour is entirely logical from the informant's perspective because informants want to maximise short term benefit and minimising any negative repercussion. (VAN ASTEN ET AL. 2009)

The second factor that might bias information provided by informants is the official character of group sessions. No matter how relaxed and informal the PRA appears, for the participants it is always a formal and public event (KRUMMACHER 2004:37) in which they participate with their own objectives and hidden agenda. Additionally, public sessions tend to create a consensus that might not reflect reality: "The more public something is, the more the power structure of the community dominates the representation of ideas. The plenary and group processes might draw out the community's official view of itself and encourage the expression of consensus, that is, what ought to be, rather than what is, underplaying differences in views and emphasizing a unitary view" (VAN DER RIET 2008:554).

The third factor is the divergence between objectives of the scientist and the informants. The PRA-Team, equipped with the paraphernalia of 'typical' development experts (large offroad vehicles, clip-boards and baseball caps) represents development organisations (KRUMMACHER 2004:44). Hence no matter what they tell the informants about their research objectives, it is very likely that certain expectations evolve of the research team which influences the relationships between villagers and the research team, also influencing results.

These three factors were tried to be overcome in this study by carefully explaining the procedure and the objectives of the research project. Further, the data collection design in itself reduces bias as it heavily applies triangulation. Data collection was designed to base on threefold back-up: participative observation, communication tools and the supplementation of information from the PRA-tools with semi-structured in-depth interviews. This effort can be assumed reduce bias to a great extent.

Beyond general problems inherent to the methodology, the research team further encountered special difficulties related to the PRA approach during the fieldwork that will be discussed in the following section.

Firstly there was the lack of an appropriate translator. This difficulty led to severe misunderstandings in focus group discussions and interviews. It could be partly overcome by retranslation of interviews by a second interviewer after the field work period (El-Hadj Sy).

An additional point that led to misunderstandings was the lack of knowledge of the cultural background by the scientist. This could be overcome by building a research team with a student from Mali and discussing the issues at question together.

Finally it was observed during the fieldwork that the promise of visualization does not hold true in the field. The PRA claims to use visualization, letting the informants draw and express their thoughts in their way, using local symbols etc. because this should enable all participants in focus group discussions to follow and present information in their own way. However, in the field it became evident that this expectation cannot be fulfilled. Scientists still are dominating and introducing their point of view. Already the simple fact that results were put to paper in the form of tables can be considered as cultural domination. In the course of conducting the fieldwork it turned out that the majority of informants were not capable of understanding the structure of a table, hence visualization in the form of tables is already limiting freedom of expression of the informants. This problem could not be overcome as it only became clear in retrospect.

In Yongosiré the research team encountered another problem. Due to lack of space here group sessions were organised at the main intersection in the village centre. Unfortunately in this intersection there was a lot of transit traffic. People came and stopped by and threw in their comments not understanding what the session was about. Almost no participant participated from beginning to end. This problem was counteracted by altering the methods: reducing group sessions and making more intensive use of interviews. Hence here the threefold base on different methods proved its strength.

5.1.3 Semi structured interviews

During fieldwork it became clear that it was of considerable importance to the informants that the research team visited them at their houses. The attempt was to get a direct insight into the production and livelihood system of the people, to gain background information and observe actions and to draw attention on aspects of the production system that were not mentioned in the interviews. Additional, it turned out to be a sign of respect to visit someone at his house in Fulani culture. In this case it turned out to be positive but in the same way not understanding

cultural subtleties can hinder research.

In conducting semi-structured interviews there are certain effects that bias information obtained. Firstly there is the so called response effect which means that data obtained depends on the interviewer, informants and environments. That alone is not yet a bias, but during the analysis it has to be taken into account that certain characteristics of the interviewer (e.g. sex, skin colour, ethnic heritage) can influence the information. In this study the response effect was not very prevalent because the interviews focused on agricultural practices that are usually conducted outdoors and thus no sensitive issues that would be influenced for example by gender or ethnicity of interviewer.

A more important point is the deference effect (see above) meaning that informants tell the scientist what they think he/she wants to know in order to avoid offence, or please him/her. This effect can be larger due to a perceived hierarchy between a scientist equipped with a research budget, technical tools (notebook, digital voice recorder etc.) and the agro-pastoralists. This effect was reduced by carefully introducing the research procedure and underlining that the research team came to learn from the agro-pastoralists, as well as showing respectful behaviour. However, in the course of the analysis six interviews eventually had to be sorted out because informants gave very short answers and did not express their ideas or reasoning. Possible reasons for this could for example be cultural prejudices, different expectations between researcher and informants, experienced pressure from the village head (because he chose informants). But although the deference effect had occurred in the interviewing phase it is not expected that it biases the results to a great extent because it was realised and it was possible to exclude those interviews from the analysis where it had occurred.

The expectancy effect means that things that the scientist expects to turn-out do, because he/she influences informants in a way that they give the respective answers. This certainly is an issue, even in an open designed approach. However, with the principle of ‘letting the informants lead’ the expectancy effect is assumed to be reduced.

The same holds true for the distortion effect, which means seeing what the researcher wants to see, even if it is of minor importance. But being aware of these effects and critically question obtained data can be helpful to reduce bias due to the distortion effect. Conducting Feedback seminars is also a tool to reduce bias due to distortion effect.

SUMMARY DATA COLLECTION

It can be summarised that although every one of the data collection method has its disadvantages, the principle of triangulation and the combination of different methods is an effective means to countervail the respective shortcomings of each method. This means that the design of data collection with its basis on seasonal calendars supplemented by additional information from semi-sructured in-depth interviews and participative observation is suitable to overcome shortcomings of the respective methods. Especially the triangulation principle and the conduction of feedback seminars help to reduce bias. Hence the strength of the research design lies in the combination of these different methods, which increases reliability and validity of data.

5.1.4 Qualitative content analysis

During qualitative content analysis, as conducted in this study, at the step 2 the problem of transmutuation occurs when compiling categories through transformation of the language. The step of abstraction, structuring and summarising contexts demands high abstraction capabilities. Due to lack of sufficient linguistic skills this step had to be conducted in German (for crop production). Hence the problem of potential transmutuation occurs. If a text is at the same time transformed from one abstraction level to the next and translated in another language, it has to be expected that certain expressions are summarised imprecisely, and thus context is lost or even altered. This problem is presently out of the scope of methodological discussion in recent literature (GLÄSER AND LAUDEL 2009, MAYRING 2007) and also could not be resolved in this study to a satisfying extent. One approach would be letting several students conduct this analysis step parallelly and then checking whether they obtain the same results. However, this was not possible in this study. Here transmutuation was to be controlled through three measures. Firstly, already realising and articulating this problem enabled the author to most accurately conduct this step and thus avoid some transmutuations. Secondly, translated parts were repeatedly cross-checked with the original text and corrected if necessary. Thirdly, quintessences were submitted as original and in the summarised form to experts (Eric Tielkes and Brigitte Kaufmann) in the respective fields and checked together with them for logical context and coherence.

In spite of this shortcoming of language transmutuation the method of qualitative content analysis brings about the advantage that by sticking to the code of practice it is guaranteed that the complete data material is egally used. For every piece of information the analyser has to decide whether it is relevant or not, i.e. the exclusion of relevant but “not fitting into the image” information becomes very unlikely (GLÄSER AND LAUDEL 2009).

5.1.5 Cybernetic analysis

The collection of data with an open approach in combination with using cybernetic analysis is a challenging attempt. Especially with data collection conducted during three month fieldwork by unexperienced researchers it is difficult to obtain the necessary data quality for a detailed cybernetic analysis aiming at the identification of target values, observation, decision making and action rules of the producers. But despite the high demands on data quality the cybernetic anaysis is a suitable and reasonable approach corresponding to the research question of the study. The cybernetic analysis delivered interesting insights. It allows to analyse the production system as a purposeful system as it explicitly analysis *how* the production functions, it analyses underlying hypotheses and reasoning of decision making, and with which strategies the purpose is pursued by the producers. Comparing the approach of this study with SØRENSEN AND KRISTENSEN’S (1992) model of a livestock farm as a cybernetic system it shows that in their approach the management strategies are regarded as a black box. This is overcome in the prevalent study by a detailed analysis of production strategies, so that now the management itself can be depicted. This was possible by analysing hypotheses, reasoning and action rules with the cybernetic analysis. Hence it can be a valuable tool to gain important insights in producer’s management strategies.

5.2 DISCUSSION OF RESULTS

This study focuses on the identification of the management strategies of Fulani agro-pastoralists and the rationality behind actions. Based on this approach the following section discusses the results focusing on the two selective topics cattle feeding and millet production.

The literature review reveiled that, as remarked by MÜLLER (1990), the local production technologies of Sub-Sahara African (SSA) farmers are in science still the "vernachlässigte Unbekannte" [the neglected unknown]. Since then apparently not much has changed. There are some approaches that highlight specific fields of production especially in the fields of soil fertility maintenance (KROGH AND PAARUP-LAURSEN 1997; OUDWATER AND MARTIN 2003; de ROUW AND RAJOT 2004; SAMAKÉ ET AL. 2005; OUATTARA ET AL. 2007; HAYASHI ET AL. 2009) and pest control (COOP AND CROFT 1993; ABATE ET AL. 2000; KIROS-MELES AND ABANG 2008). Solely the anthropological study of HEISS (2003) gives a detailed description of millet cultivation practices in his dissertation focusing on the complexity of farmer's field work.

Thus in contrast to recent studies that focus on management of specific fields within the production system, this study provides broader insight into the production system and hence provides complementary information to existing local knowledge analysis literature as it captures information based on the production system.

5.2.1 Objectives and restrictions of the system

Agro-pastoralists in the Mopti region operate in **a low external input system** under **climate variability** (see chapter 4.1.2 and chapter 3.1.1). This shapes the objectives the agro-pastoralists pursue in their production system. In contrast to intensive agricultural production systems the producers focus on **risk minimisation** and the **preservation of available resources** in addition to high animal reproduction (high fertility, low mortality, short calving interval), provision of draught power, high milk production and high crop yields.

Results of this study show that managers in the prevalent low external input system adapt their decisions and production strategies to their environmental conditions. While in intensive agricultural systems the typical strategy is to manage the production system in a way to make it more deterministic and then control inputs and production conditions, this is not possible in low external input systems. Here the strategy of choice is to flexibly optimise the use of available resources, for which it is crucial to preserve these resources in the long run.

Adaptation to climate variability is reflected in the objective of avoidance of losses. This points to the fact that risk minimisation is equally or even more important than maximising yields. KROGH AND PAARUP-LAURSEN (1997:194) also state that production practices can be attributed to reducing variances in the outcome of the production system, which is often achieved at the expense of trying to maximise yields. This can be shown in this study at the choice of low yielding but early maturing millet varieties (see paragraph 4.3.4.1.2) or in the fact that millet is seeded on sandy soils which yield lower in years with abundant rainfall but

which stock moisture longer in years with dry spell (see paragraph 4.3.4.1.1).

High yield potentials do not play an important role because the probability that environmental conditions are so good that the plant/ animal will achieve its potential is very low. In contrast, high resistance and tolerance to negative/ sub optimal environmental conditions are much more important traits as these characteristics allow the producers to attain at least some yield in case of unfortunate environmental conditions. For example the preferred trait of fast ripening in millet points into this direction.

Another risk avoidance strategy that was identified is the use of livestock as a form of investment and saving. Livestock often serves as a stock of wealth and hence as a kind of insurance in resource poor systems (MASIKE AND URICH 2008:13). Especially small ruminants can easily be sold in case of need, thus constituting a means of responding to climate variability and providing the family with cash income that can be used to purchase cereals in case of bad yields. But also milk production is an important outcome that secures the satisfaction of daily needs of the producers' households by creating cash income (KODIO AND SAMAKÉ 2008). This was also confirmed in semi-structured interviews in this study (see paragraph 4.2.2). Further objectives are provision of animal draught power and supply with manure (MWACHARO AND DRUCKER 2005:642). This was also reported by Fulani agro-pastoralists, especially in their description of soil management where they all mentioned the transportation of manure to the fields as routine rule (see seasonal calendar crop production 4.3.3).

5.2.2 Selected topic: feeding schemes

The section animal husbandry focuses on feeding schemes. It can be assumed that this topic is of major importance in the perception of the agro-pastoralists. In a resource poor system the producers do not have many possibilities to influence the outcome of the system by controlling the use of inputs. Therefore they are obligated to manage their system by applying selection rules as major action rules. This can be seen in the fact that selecting the best pasture is the core of their feeding scheme.

5.2.2.1 Feeding the village animals

As target values in the management of the *bendis*, the agro-pastoralists mentioned high milk yield and good development of the calves. How can the milk yield (which also influences the calves development) of the *bendis* be influenced by the producer? There are two levels of possible actions:

First, one would suppose the most logical action would be the optimization of **fodder supply**. But at this point it becomes evident that it is very important to include restrictions and limitations of the system in the analysis. In the prevalent resource poor system optimal fodder supply inducing high milk yields is only possible during the rainy season, when fodder plants are fresh and abundant. Throughout the rest of the year however it is impossible to supply the cows in a way that they produce their maximum level of milk. The restriction is availability of pasture in the dry season and the cost of concentrated animal feed. Hence the producers can-

not control optimal fodder intake. As a result their only possibility to influence milk yields is to use selection rules. One example is the selection of the *bendis* from the *séouré* (see paragraph 4.2.1).

However, in spite of the high prices, supplementation with concentrate becomes increasingly important in the prevalent system. The following section will discuss issues related to the supplementation of *bendis*.

a) Supplementation

The objectives of the supplementation are the maintenance of draught oxen and to increase milk performance in cows. It plays the role of assurance in bad seasons, because if the producers have managed to stock/ buy enough fodder, these animals will give some milk, even if the big herd is dry, on which they can live in order to bridge some bad months.

The intensification and increase in cottonseed cake supplementation observed by MORITZ (2010) in Cameroon can also be stated for the Mopti region's agro-pastoralists. However, there is a difference in the amount of cottonseed cake and importance of its utilisation. In the feedback seminar in Nérékoro it was stated by agro-pastoralists that a wide range of other supplementation feed stuffs are available such as dried fodder plants, rice bran, millet and rice stems, millet cobs, leaves from trees, and the like but they prefer cottonseed cake because it increases milk production. Also, the possibility of purchasing cottonseed cake on credit has a considerable impact on the preferences. During the dry season agro-pastoralists are especially short of cash: cereal prices are high and animal prices are low. In spite of the bad terms of trade, producers of Ouandiana even reported considerably more activity in livestock trade in the dry season, which also supports the argument that there is a great need for cash income. Thus it makes a considerable difference if the supplementation of feed stuff has to be paid at once in cash, as is the case for the "traditional" supplements, or if it is possible to purchase it on credit and pay debts after harvest.

In general qualitative interviews revealed that there is no commonly shared understanding of cottonseed cake supplementation among Fulani agro-pastoralists. The study summarised the discussion among them as follows:

The first step in overcoming the dry season is to feed locally available supplements (brans, leaves, dried and stocked fodder plants). However, if producers want to achieve milk yields in spite of the dry season they feed cottonseed cake. Also, if an animal is ill due to hunger it will be fed with cottonseed cake in order to recover. Some agro-pastoralists hold the view that if one practices good herding cottonseed cake is not necessary. This statement supports the view of SCHAREIKA (2003) that pastoralists seek to make cattle gain weight in the rainy season so that animals have enough reserves to survive the long dry season, and thereby prevent weight loss in the dry season (SCHAREIKA 2003; MORITZ 2010).

However, the fact that producers use cottonseed cake as a problem solving device and not on a large scale as a routine rule for all their cattle is different to the situation described by MORITZ (2010) for Cameroon where the pastoralists feed cottonseed cake in dry season to all their cattle. Reasons for that could be the lower price of the concentrate in Cameroon or the fact that for agro-pastoralists traditional supplements (cereal husks, bran etc.) are more avail-

able and thus present a relative advantage compared to purchased cottonseed cake, so that it is more beneficial for agro-pastoralists compared to pure pastoralists to use these traditional supplements first.

MORITZ (2010) stresses the fact that the reason for the intensification in cottonseed use was not the objective of intensifying the production system for increased production, but rather livestock keepers aimed to get their cattle through the dry season crunch and prevent a decline in animal production and reproduction. The Fulani agro-pastoralists themselves explain the increase in the feeding of cottonseed cake with their perception that pasture quality has decreased. But it is also observed that the number of *bendis* kept in the village has increased (SATAO in preparation). It is not clear whether the availability of cottonseed cake induced a shift towards keeping more *bendis* in the village or whether because of the shift of keeping more *bendis* the purchase of cottonseed cake became necessary.

Another interesting aspect in this context is the procedure of decision-making. If not familiar with the cultural context one would assume that producers will perform some kind of calculation, subtracting the profit from the milk barter with the cost for the supplementation necessary to produce this milk. However, in the case of the Fulani, profits and costs cannot be so easily compared as they are managed by different people. It is the task of the women to sell the milk and it is that of the men to feed the milking cow. This division of fields of activities can lead to a situation where there is an information deficit and hence it is difficult to do a rentability calculation. It is also imaginable that women put pressure on their husbands to feed cottonseed cake in order to be able to increase milk quantity and to attain more money, which can be used by them at their discretion. Hence there may be several, yet unknown driving forces towards an increase in concentrate supplementation.

b) Watering schemes

Results of this study report a watering scheme, which consists of leading the animals to the river (at Yongosiré) or watering them at wells twice a day in the dry season. This is astonishing because there are pastoral production systems where animals are watered once daily or even every second day only (WURZINGER ET AL. 2008, BERNUS 1990). In contrast to these findings, the producers in the prevalent production system decide to water cattle twice a day in spite of trade-offs. Much labour is needed to water animals at wells where water has to manually be scooped from low groundwater levels (more than 10 m was observed) in the dry season. The reason why the high labour demand of this activity is no limitation could be due to cultural particularities. Traditionally there is a division of labour between Fulani and Riimaybe. Whatever the reason is, it was observed that most of the dry season activities are considered to be Riimaybe tasks (e.g. construction work, transportation of manure, ploughing), whereas watering is a Fulani task. This could potentially explain why there is no labour shortage with regards to the twice-daily-watering activities.

Additionally, there is a trade-off in terms of grazing time. During watering the cattle cannot graze and have to cover the distance from the well to their grazing area. But grazing time is a limiting factor for nutrient intake. “Especially during the dry season it is important to provide animals with a sufficiently long grazing period to allow them to selectively graze — ingesting

only particular plant parts of particular species. By the end of the dry season, livestock nutrition is often limited by grazing time." (TURNER 1999a:282). Confronted with these hypotheses the agro-pastoralists argumented that: "in the dry season the good water brings more return than the fodder [millet straw or *burgu*]" (Seasonal calendar crop production, Yongosiré). Apparently the agro-pastoralists hold the view that good and sufficient water supply supports the nutrient intake in the digestive system. Thus it is the animals' metabolism that necessitates this strategy, potentially because there are no cattle breeds tolerant to water scarcity available.

5.2.2.2 Transhumance

Low input costs are an essential requirement for the *gartjis*. The whole herd cannot be fed on animal fodder. Hence animal performance is influenced by searching the good pasture. Also it is important to note that the objective here is not to have the animals in good physical condition all year round. In contrast, the producers are well aware that there is annual fluctuation. So the pronounced target is to have the animals well fattened during the rainy season in order to bring them through the dry season: "…celui qui a pu faire bien nourrir ces animaux pendant l'hivernage, n'aura aucune crainte à affronter la saison sèche, en ce moment tu es sûr qu'aucun animal ne va tomber par faim. Donc cela va t'épargner de dépenser beaucoup d'argent pour entretenir ces animaux avec le tourteau." (D1b)

Hence the essential means with which to provide fodder to the *gartjis* is the transhumance. Selection rules are most important since the producers cannot directly influence the characteristics of the pasture but can influence the outcome of the production system by selecting the best available pasture, which is the function of the transhumant movement.

a) Transhumance routes

The list of factors that influence the herder's decision over transhumant routes indicates that beyond pasture quality other factors, be it social, economic or political (MCCABE 2004) play important roles. BAKER AND HOFFMANN (2006:779) state that "differences in the personal situations of herders, a small gap between the costs and benefits of mobility, and the absence of an authority to enforce a universal management scheme" are responsible factors that determine an individual herder's transhumant movement patterns in the Paulshoek pastoral system, South Africa. Further factors in the choice of pasture area are rainfall patterns, availability of good water source in dry times, better forage, possibility to share labour with other herders (TURNER 1999a:777). Except the aspect of labour sharing these factors have been stated by Fulani agro-pastoralists, but they additionally mentioned space, parasite pressure, costs, access rights and distance to the home village. Especially the last point is of importance for agro-pastoralists as in crop production there are work peaks at certain moments of the year (e.g. during weeding) which can be smoothed by herders returing to the village and helping out (so reported in Ouandian) which is facilitated by not too far a distance between pasture area and home village.

It becomes evident in this study as well as in literature that the herder's decision is a substantial strategy in the management of the agro-pastoral production system. The strategic choice of pasture areas in the low external input production system can serve as risk minimising

strategy reducing environmental risk (e.g. climate variability) but also economic risks and thus avoiding losses. BAKER AND HOFFMANN (2006:779) show that frequent movements can reduce livestock mortality, which supports the argument that the choice of pasture area can minimise the risk of climate variability or even make use of the variability. However, BAKER AND HOFFMANN (2006:778) also show that the choice of pasture area alone does not determine the success of the herd (success being measured in birth rate, milk production and mortality). An additional factor influencing herd performance is introduced by TURNER (1999a) who shows that the herder's "diligence" has an effect on herd performance. He shows that "herder effort can […] very much affect the variety of forage offered animals over the grazing itinerary as well as the disposition of the animals to eat that forage." (TURNER 1999a:283). Thus not only the choice of pasture area but also the herding in terms of length of grazing period or other activities plays an important role (see below).

b) Pasture resource management

Beyond ecological restrictions, agro-pastoralists in Mopti region are restricted in their management on a household level by the collective resource management of the delta pastures. At large however, this collective management enlarges the room to manuever because it protects resources from over exploitation. In the long run this restriction thus expands resource variability which increases flexibility and the adaptive capacity of producers to climate variability.

c) Herding and the concept 'good pasture'

Herding and leading the animals to good pasture on a day-to-day basis is the core management of the agro-pastoral livestock production: "…tu dois comprendre que c'est le bon pâturage qui peut servir à l'entretien des animaux, alors il faut préparer des stratégies pour identifier chaque jour le bon pâturage." (D1b). But what is considered to be good herding? TURNER (1999a) identified three important aspects of herding. Firstly, that the grazing time matters: "Especially during the dry season, it is important to provide animals with a sufficiently long grazing period to allow them to selectively graze […]. By the end of the dry season, livestock nutrition is often limited by grazing time." (TURNER 1999a:282). The repeated emphasis of the necessity that especially in years of poor rainfall "the herder is obligated to take a lot of care of the animals while searching fodder" (e.g. C5b) might point into this direction, although informants did not exactly specify these statements.

Secondly increasing the length of the grazing radii from the herd concentration point "improves the efficiency of livestock ingestion by presenting herds with less heavily grazed swards" TURNER (1999a:284). This is supported in this study as producers name "virginity of pasture" as an important pasture quality criterion (see paragraph 4.2.4.2).

Thirdly the variety of forage offered to the herd is important (TURNER 1999a:284). This is supported by the findings of this study, as when asked for plants that indicate a good pasture, informants name 25 species which shows that they appreciate a wide variety of different fodder plants. Again this points to features of a resource poor system and underlines the importance of resource variability.

Concerning the measurement of the quality of a pasture this study revealed interesting com-

plement information to recent literature. As reported in chapter 2.3.2 recent studies name four dimensions that play a role in evaluating a pasture: quantity of vegetation, vegetation type, soil types and hydrology. Among these direct indicators in this study the first four have also been reported. However, it was stated by informants that in evaluating a pasture's quality these direct indicators are only auxiliary devices and that much more important are indirect indicators such as animal behaviour and body condition of the animals grazing on the respective pasture. This fact entails interesting insights into the way the agro-pastoralists create their knowledge. In contrast to the scientific world the agro-pastoralists have no means of directly observing the nutritious value of a pasture. But this is also not their main interest. For them the importance of the pasture quality lies in the feed value of the pasture for their cattle. In this respect it makes complete sense to observe the consequences of the pasture and not the pasture characteristics directly. The valuable information is the effect of the action "take the cattle to pasture xy" on the cattle.

d) *Ceedu*

The term *ceedu* in Fulfulde refers to the dry season. In this research one of the objectives was to learn about strategies of alterations in a year with poor rain in order to find out adaptation strategies. At this point one of the advantages of the explorative approach and the sensitive collection of local knowledge becomes evident. The fieldwork showed that there is no great alteration in a dry year and that the concept of an especial dry year does not even exist in the conception of Fulani agro-pastoralists. For them overcoming the *ceedu* is a challenge each year in itself and when asked "what is different in a dry year?" they expressed that this question makes no sense to them.

These results show that in the production system itself with its inherent flexibility there is enough scope and also the need for the decision maker to react on all kind of environmental fluctuations. There is no fixed plan and a deviation from it in dry years, but the whole system is an ongoing system of balancing and reacting to environmental conditions on a day-to-day basis. This is why the question of deviation in a dry year does not make sense. The producers do not pursue any other strategy in a dry year than in a normal year, because the whole management system is oriented towards the profiting of positive circumstances as they occur as well as to compensate/ avoid negative conditions.

5.2.3 Selected topic: millet production

The results concerning millet production strategies (see chapter 4.3.4) show that the producers observe their system, having clear target values of their plant production in mind (e.g. good germination = 5/10 seeds per planting hole that germinate). Through applying cybernetic theory and the corresponding terminology one can state that *target values* as well as *deviation* from these values are observed and if the deviation is too high actions are taken in order to influence the observed *actual value* to approach *target values* (e.g. if germination rate is too low – re-sow).

The producers also observe the factors that influence the outcome of their production system *(disturbance variables)* and build detailed hypotheses about observed interrelations. Often

they cannot control plants and animals directly so they aim to manipulate the influencing factors (e.g. soil nutrient content) in order to achieve a positive influence on plants and animals and thus reach envisaged outcomes. At this point, features of external input poor systems can be shown. For example, since it is not possible to use synthetic fertiliser from outside the system and organic manure is scarce, the producers influence their system according to selection rules (e.g. field site choice). The application of selection rules is typical for resource poor systems (KAUFMANN 2007). Furthermore, it has to be noted that the producer is not helplessly exposed to his environmental conditions and climate variability but that the whole management system is designed in a way that enables the producer to cope with or even make use of climate variability to a certain extent. Where the producers can influence the environmental conditions under which their crops grow they are able to control the plant's growth in order to manipulate a favourable stand development and yield (HEISS 2003:89). In this study the factors that were identified to have an influence on crop development are soil characteristics (water holding capacity, nutrient availability), water supply, length of vegetation period, technical parameters (plant densities, association of plants, etc.), weeds and pests.

a) Selection of field sites

The water holding capacity of soils depends mostly on the granulometric composition of the soils. This trait cannot be influenced by the producers. But they can control for **water supply** of their crops by the selection of crop cultivation sites (see paragraph 4.3.4.1.1). Due to the high spatial variability of precipitation the agro-pastoralists cannot predict where the rain will fall. Even if there is a quite low rainfall at one field site there is still a high probability of both higher or lower rainfall at another field within a radius of a few kilometres. GRAEF AND HAIGIS (2001:228) report that in Niger farmers cultivate fields at different locations within the village district, which also is the case for Fulani agro-pastoralists in Mopti region. The selection of field sites (i.e. where to cultivate) can be seen as an important adaptation strategy. During interruptions in rainfall the sandy soils have a higher content of plant available water than the clayey soils upon receiving equal amounts of precipitation[35]. This results in a preference of sandy soils to clayey soils in years of relative dryness. By cultivating across various toposequence positions with texturally highly contrasting soil types farmers try to minimise field yield covariation and thus to cope with the uncertain precipitation and possible water shortages. A feature of resource poor systems is the dependency of resource variability (necessary for selection rules, which again are key in the management in resource poor systems) (KAUFMANN 2007: 165). So by scattering of fields the farmers virtually increase the variability of their resources thus enlarging their alternative options and eventually minimising the risk of crop failure.

Plant available nutrient content is also influenced by the selection of field sites as different soil types have different characteristics in this respect. But choosing nutrient rich clay soils can also have its disadvantages, namely if rainfall is interrupted millet plants dry fast on clay

[35] When the rain stops evaporation from the soil is very high. Then the coarse pores of the sandy soil in the upper soil horizons dry fast, but then the capillary rise is interrupted and the adhesive water in the micro-pores in greater depth will not be sucked out. The millet however with its long taproot can reach this adhesive water and use it during drier periods.

soils whereas sandy soils retain moisture longer[37] (see paragraph 4.3.4.1.1). This points to the fact that there is a trade-off between the amount of production (potential high yields if conditions are favourable) and security in production (reduction of yield risk in case that conditions are unfavourable). However, due to resource availability it is not an either or decision but producers can plant some millet on sandy soils to secure their nutrition and some portion of their millet on clay soils to potentially profit from favourable conditions if they occur. This again points to the importance of resource variability for the functioning of the production system.

b) Soil cultivation

Generally it can be stated that soil characteristics can be influenced to a limited extent only. However, the information obtained concerning soil is the most detailed. Although this could be due to the fact that the data collection was conducted during the dry season which coincides with the moment of field preparation activities i.e. tillage activities, hence the focus of informants at this moment is on topics concerning soil, it can also indicate that despite the limitation of soil manipulating possibilities, the activities that are conducted do make an important difference.

There is ongoing discussion in literature and among Mopti region's farmers (see chapter 4), about if, where and when utilisation of the plough can be advantageous in contrast to no-tillage systems (de ROUW AND RAJOT 2004; RAMISCH 2005; SAMAKÉ ET AL. 2005; OUATTARA ET AL. 2007). The utilisation of the plough entails a number of interdependencies within the production system. Due to rainfall variability there is a short time window for seeding of photoperiodic sensitive plants (as e.g. millet, sorghum and others). Ploughing allows cultivation of larger areas in shorter time, which is a crucial strategy in order to maintain flexibility. Since soil productivity is low, field expansion constitures a production strategy to guarantee satisfying minimum yields. KROGH AND PAARUP-LAURSEN (1997:194) report for a case study in northern Burkina Faso that there the producers cultivate as large an area as possible even in excess of what can be weeded during the growing season. In this study the findings also point in that direction when farmers discuss the use of plough tillage argumenting that the importance of the plough utilisation is grounded in the fact that it allows cultivating large areas, which indicates that this is an important strategy. This strategy of field expansion does not influence the plants directly but can be regarded as a deliberate strategy to incorporate **buffers** in the production system. This increases action alternatives and thus resilience in an environment with uncertain precipitation: as observed by KROGH AND PAARUP-LAURSEN (1997) in the course of the season the farmers can concentrate their weeding and thinning operations on those parts of the fields that germinated well and can be predicted to have the highest probability of good yields.

The use of plough based tillage further tends to increase the possibility to plant during the ideal seeding date, which allows influencing the **length of the vegetation period**. If rainfall onset is early it can happen that not yet all fields are cultivated. In that case a problem solving rule is applicated: the producers make use of plough tillage, which decreases the time needed for cultivating a certain area. These findings are confirmed by RAMISCH (1999) in a case study in southern Mali: "The main incentive for using ploughs was the ability to cultivate larger

areas than hoe cultivation allows. Both hoe and plough cultivators, however, seek to plant in a timely fashion, racing to work after each rain storm. The best yields of cotton (which is photoperiod sensitive) are also obtained only if the seed is planted during a narrow "window" of about a week in early June."(RAMISCH 1999:14). Thus the application of plough based tillage can again increase the action alternative of the producers and thus allows adaptation to climate variability by enabling profiting from positive circumstances as they occur.

The soil tillage system also has an influence on **plant available nutrient content**. Although plough usage is advantegous for the strategy of field expansion (see above) a disadvantage of plough based tillage is the higher need for fertiliser. Ploughing tends to decrease the plant available nutrient content (e.g. through increased exposure to erosion, leaching etc.) which has to be redelivered. RAMISCH (1999) observed that yields are decreased in plough utilisation systems compared to hoe-based systems, which is also reported by informants in this study. According to RAMISCH (1999) for Fulani agro-pastoralists this was not a big constraint because they would possess enough livestock to make up the nutrient loss with organic manure, but that other ethnic groups or Fulani with small herds impoverished their soils by plough tillage due to lack of manure. However, results of that study point to the fact that the producers are much concerned with soil fertility and that manure is not abundant, especially since the herds pass by the village only twice during the year.

Another strategy to manage soil nutrient content is fallow, which is practised on a collective level by the whole village. However, the risk minimising strategy of scattering of fields and seeding a large area to account for losses increases the pressure on the available land resources and the cultivation of marginal land. Seeding of all fields reduces both the area under fallow and the fallow period length, which leads to a reduction of soil fertility (GRAEF AND HAIGIS 2001:228).

c) Determination of seeding dates

The **length of the vegetation period** is a key factor for the millet's development as photoperiodic sensitive plant. It can be influenced by the producer to some extent, namely by the determination of seeding dates. In this respect it is of advantage to sow as early as possible. Relating to that GRAEF AND HAIGIS (2001) report an interesting seeding strategy called 'dry-seeding'. This means planting some portion of the land in advance of rains while the soil is still dry. With this strategy producers avoid labour peeks in the seeding period. Nevertheless there is the risk of losing the seed in the case of a long dry spell, because high soil temperatures may spoil the seeds (GRAEF AND HAIGIS 2001:227). However, GRAEF AND HAIGIS also report that "as the temporal rainfall variability increased, the use of this strategy decreased" (ibid.). In this study dry seeding is not reported as a production strategy, following the argumentation of GRAEF AND HAIGIS (2001) this might be grounded in the fact that rainfall variability is higher in Mopti region than in their investigated study area (south-west Niger).

In this study results show that although on the one hand it is of advantage to sow as early as possible, then on the other hand the risk of dry spell and drying out the young emerged seedlings rises. In the determination of seeding dates also the indirect influence on **water supply** for the plant is considered. A late seeding date increases the probability that the soil already

stocked enough moisture and additionally that rainfalls are more regular than in the early rainy season. Eventually, the producers sow whenever it has rained in order not to miss the chance of profiting from good rainfall, at the expense of seeds since this strategy often necessitates re-seeding several times.

From the twelve reported measures concerning seeding decisions (see Table 32) eight relate to the avoidance of losses (i.e. are performed in order to either increase chance of sufficient length of growing period or minimise exposure to bird attack or avoid damage of animals or increase plants' pest tolerance or avoid yield failure) and only three measures are performed in order to obtain high yields. This clearly indicates the emphasis on the importance of risk minimisation compared to yield maximisation as adaptation strategy.

d) Choice of varieties

In rainfed agriculture the **water supply** itself cannot be influenced by the system manager. Here the only control possibility is the mentioned choice of soils for cropping sites and the selection of drought resistance crops and varieties. The high number of cultivated crops (e.g. 13 different species in Ouandiana) also increases selection possibilities. With this the producers do not control water supply but control their system through reacting to precipitation patterns by choosing suitable crops. The use and the scope of this strategy is however limited because not all of these crop species are staple crops and some of them only serve to enrich nutrition, hence their cultivation can not be considered as securing feed supply.

Despite the strategy of determining seeding dates the influence of management strategies on the length of the vegetation period is limited as it mainly depends on the precipitation patterns. If rainfall onset is late and rainfalls end early, the vegetation period can be so short that some millet varieties do not reach maturity. One strategy to despite control the plant's growth is the selection of suitable varieties. If rainfall onset is early and rainfall is abundant, producers will plant a larger area with high yielding but late maturing *Sanoori,* whereas late rainfalls induce the choice of the lower yielding but faster maturing *Sunnari* millet (see paragraph 4.3.4.1.2). Here again it is evident that variability in resources increases the producers' adaptive capacity and that "genetic diversity appears to be an important factor in the resilience of the cropping systems in areas with higher climatic risks." (KOURESSY ET AL. 2008:95). However the results also point at the trade-offs between the amount of production and security in production that the farmers face. The high yield potential of *Sanoori* in many years is not achieved because the environmental conditions are not favouring it. In these cases the use of the *Sunnari* variety can be interpreted as an adaptation and risk minimising strategy. Hence the availability and the use of different maturing varieties allow adaptation to climate variability.

e) Mixed cropping

Technical parameters are the easiest to be controlled for by the producer. With mixed cropping and plant densities the producers can control environmental conditions such as concurrence, aeration, to some extent sun radiation, nutrient availability (through N_2 fixation of legumes – although this phenomenon is not perceived by the producers). DE ROUW AND RAJOT (2004) show that low planting densities increases yields as well as it reduces risk of crop fail-

ure. Applying mixed cropping the producers make use of selection rules by selecting suitable crops that can be planted together. Also mixed cropping is a strategy to profit from resource variety through selection as it increases the number of action alternatives. It was reported in feedback seminars, that mixed cropping is so refined that producers plant one crop species on elevations on the fields and the other that needs more moisture in a depression on the field. This is done in order to influence the plant's condition so as to increase yields. This shows that although external inputs to optimise plant development conditions are not available, the producers have adapted to their prevailing conditions and make optimal use of variety in the asset base so as to control for crop development and eventually control the outcome of their system.

f) Weed control

For weed control the producers apply mainly routine roules. Besides variation in precipitation, farmers perceive weeds as the major constraint on production. Consequently they have developed the routine of two to three weeding turns that they conduct routinely during the planting period. As disturbance factors informants mentioned lack of labour or illnesses, which eventually also result in lack of labour. In this case problem solving actions can be the hiring of labour, to skip one weeding cycle or to be on delay for other field work.

Determining seeding dates can also be a strategy for weed control, but is not much applicated, although late seeding dates of millet reduce infestation with *Striga hermonthica* and minimise yield reduction (SAMAKÉ ET AL. 2005). But a too late seeding date might reduce the number of days suitable for millet growth and potentially preventing the millet from attaining maturity if the growing period is not sufficiently long. Thus, late seeding is not a strategy used for weed control as rainfall is too limited and unpredictable hence making this strategy to risky.

g) Pest control

There was not much information obtained concerning pest control. Contradicting findings of HEISS (2003:89–90) there seem to be limited possibilities to control pests. The fact that no agro-pastoralist mentioned any fungus problem neither plant diseases, indicates that the producers do not perceive these pests as a constraint to production. In contrast to that, recent studies find that crop losses due to pests are severe in Mali (COOP and CROFT 1993; WEBB and SMITH 1996; ABATE ET AL. 2000). Another explanation for the lack of special pest control measures could be the fact that "pest management practice in traditional agriculture is a built-in process in the overall crop production system rather than a separate well-defined activity." (ABATE ET AL. 2000:631). In this study informants reported that in the determination of seeding dates pest control plays an important role. Late seeding increases pest pressure. There even is one week at the end of June where producers avoid seeding, even if it rains, because they consider seeding at that time as increasing pest pressure. This ex-ante strategy to control for pests can again be interpreted as a risk minimising strategy which once more shows the adaptation of the whole system in its interrelations.

ADAPTATION STRATEGIES

Explicit adaptation strategies that are only performed in case of poor rainfall were not identified. However, the results show that the production system in itself provides the chance of adaptation to climate variability, within the constraint of low external input availability. Agro-pastoral production comprises of different action possibilities among which the producers choose in reaction to the present situation. The emphasis on preservation of the quality of available resources serves to maintain a variable resource basis. This can be interpreted as an adaptation strategy as the availability of a high number of varied resources increases resilience (COOPER ET AL. 2008). In this view all management strategies that manage resources or increase the producers' action alternatives can be interpreted as adaptation strategies.

6 CONCLUSION

The current study analyses the Fulani agro-pastoral production system as human activity system. With its focus on production *strategies* rather than on input and outputs it provides complementary information to classical production system analysis. Aim was to understand *how* agro-pastoralists produce rather than *what* they produce.

It further provides complementary information to existing local knowledge analysis literature. In contrast to other studies that focus on management strategies of specific fields within the production this study focuses on seasonal aspects in the production system and this from the perspectives of the producers.

The results show that agro-pastoral production can be modelled as a purposeful human activity system. The producers pursue certain objectives with their production system. They base their actions on observations of traits of their production environment and their production assets. Agro-pastoralists translate their hypotheses and reasoning into target-oriented action on the basis of structured comparison and decision making.

The rationality behind actions of the agro-pastoralists in the two management areas cattle feeding and millet cultivation could be reconstructed. Results of this study show that managers adapt their decisions and production strategies to their environmental conditions in a low external input system and under climate variability. In their production system there is only a limited possibility to control the outcome of their system through a control of inputs. Hence they mainly rely on selection. Adaptation is reflected in the objectives of preservation of available resources as this increases selection possibilities, as well as in the avoidance of losses and the importance of risk minimising strategies.

The identified key management strategies in cattle feeding are the year-round selection of pasture areas in different regions through transhumance and day-to-day selection of good pastures by the herder. The rationality behind these strategies lies firstly in the avoidance of losses through well fattening the animals during the rainy season and thus creating a buffer. Secondly the producers reduce risks by flexibly reacting on environmental fluctuations and to profit of positive circumstances as they occur (e.g. proceed to the area where rainfall has occurred) as well as to compensate/ avoid negative conditions.

For millet production key management strategies can be divided in time- and space dependant actions. Time-dependant actions include practices such as choosing seeding dates and selection of early or late maturing millet varieties. Examples for space-dependant actions are choosing cultivation sites for each culture respectively, and preservation of available resources, such as decisions about tillage system, soil fertility management, fallow periods etc. In crop production it shows that risk minimising is equally or more important than maximising yields.

Explicit adaptation strategies that are only performed in case of poor rainfall could not be identified. This is due to the fact that producers do not pursue any other strategy in a dry year than in a normal year, because the whole management system in itself is an ongoing system of

balancing and reacting to as well as anticipating environmental conditions in a deliberate way and on a day-to-day basis. As the availability of a high number of varied resources increases resilience, all management strategies that manage resources' variability (such as employing a number of different species in livestock production (mixed herds) as well as in crop production (use of a high number of different crops), scattering of fields or crop association) or increase the producers' action alternatives (such as incorporating buffers: well fatten animals in rainy season or field expansion, conducting transhumance) can be interpreted as adaptation strategies.

Based on these findings further research could concentrate on the question how to reinforce the capacities that allow the agro-pastoralists to successfully conduct these strategies in order to be able to cope with the projected increase in climate variability due to climate change.

7 SUMMARY

Climate data show that the Sahel region and its neighbouring regions are exposed to reduction of precipitation and an increase of climate variability that might result from climate change. In the Mopti region, former pastoralists of the Fulani ethnic group have settled after the severe droughts in the 80th of last century. Besides livestock keeping, they increasingly depend on crop production. In both production lines, they have to cope with high climate variability and low availability of external resources, and have developed strategies to manage their production system in this environment. The study examines production strategies of Fulani agro-pastoralists and their ways of adaptation to climate variability. Data collection was conducted in four villages in two different ecological zones (Séno and Niger delta) with a focus on qualitative methods. The author lived for two weeks in each of the villages and conducted village resource maps (n=4), seasonal calendars (n=8), pair wise rankings (n=4), and semi-structured in-depth interviews (n=12). All data collection sessions were recorded with a voice recorder. The interviews were transcribed and re-translated in parts. The data were first analysed using content analysis. The information provided on management was analysed using a cybernetic analysis tool.

The results of this study show that agro-pastoral production can be interpreted as a purposeful human activity system in terms of the system approach. Two types of results could be obtained. Firstly, it was possible to identify different management practices carried out by Fulani agro-pastoralists throughout the course of the year, including livelihood activities, livestock production and cropping activities. Secondly, the rationality behind actions of the agro-pastoralists in the two management areas cattle feeding and millet cultivation could be reconstructed. Identified key management strategies in cattle feeding are selection of feed supply through transhumance and day-to-day selection of good pasture by the herder. For millet production key management strategies can be divided in time- and space dependant actions. Time-dependant actions include practices such as choosing seeding dates and selection of early or late maturing millet varieties. Examples for space-dependant actions are choosing cultivation sites for each culture respectively, and preservation of available resources, such as decisions about tillage system, soil fertility management, fallow periods etc.

The study concludes that Fulani agro-pastoralists adapt their decisions and production strategies to their environmental conditions in a low external input system under climate variability. In their production system there is only a limited possibility to control the outcome of their system through a control of inputs, hence they mainly rely on selection. As the availability of a high number of varied resources and of action alternatives increases resilience, adaptation is reflected in the objectives of preservation of available resources as this enables the producers to make use of different selection possibilities. Adaptation is also reflected in the avoidance of losses and the importance of risk minimising strategies.

8 ZUSAMMENFASSUNG

Klimadaten der Sahelregion weisen auf eine Reduktion des Niederschlags und eine Zunahme der Klimavariabiliät hin, die möglicherweise durch den Klimawandel hervorgerufen werden. Nach den Dürren der 1980er Jahre haben sich in der Region Mopti frühere Pastoralisten der ethnischen Gruppe der Fulani niedergelassen. Neben Tierhaltung sind sie in zunehmendem Maße auf Pflanzenproduktion angewiesen. In beiden Produktionszweigen ist ihr Produktionssystem gekennzeichnet von hoher Klimavariabilität und einem Mangel an verfügbaren externen Ressourcen. Um trotzdem produzieren zu können, haben sie Strategien entwickelt, um ihr Produktionssystem in dieser Umwelt erfolgreich zu steuern. Diese Studie untersucht die Produktionsstrategien der Fulani Agro-Pastoralisten und ihre Anpassungsstrategien an die Klimavariabilität in einem ressourcenarmen System. Die Datenerhebung erfolgte in vier Dörfern in zwei verschiedenen ökologischen Zonen (Séno und Niger Delta) mit einem qualitativen Ansatz. Während eines zweiwöchigen Aufenthalts in jedem der Dörfer wurden die folgenden PRA-Werkzeuge angewendet: village resource map (n=4), seasonal calendars (n=8), pair wise ranking (n=4). Zusätzlich wurden semi-strukturierte narrative Interviews (n=12) durchgeführt. Alle Sitzungen zur Datenerhebung wurden mit einem digitalen Aufnahmegerät aufgezeichnet, die Interviews wurden transkribiert und teilweise nachträglich übersetzt. In einem ersten Schritt wurden die Daten mit einer qualitativen Inhaltsanalyse ausgewertet, im zweiten Schritt wurden Informationen bezüglich des Managements mit einer kybernetischen Analyse detailliert untersucht.

Die Ergebnisse zeigen, dass das agro-pastorale Produktionssystem als zweckorientiertes sozio-biologisches System modelliert werden kann. In der deskriptiven Untersuchung des Produktionssystems wurden verschiedene Produktionsstrategien in den Bereichen livelihood Aktivitäten, Tierhaltung sowie in der Pflanzenproduktion identifiziert. Desweiteren wurde die dem System zugrunde liegende Ratio der Agro-pastoralisten in den Bereichen Rinderernährung und Hirseanbau rekonstruiert. Kernproduktionsstrategien in der Tierproduktion bestehen in der Auswahl des Futterangebots durch Auswahl der Transhumanzroute und die tägliche Auswahl der Weide. Als wichtige Produktionsstrategien im Hirseanbau identifiziert wurden zum einen zeitabhängige Handlungen: Wahl des Saatzeitpunktes und Auswahl früh- oder spätreifender Sorten; zum anderen raumabhängige Handlungen: Auswahl der Anbaustandorte für die jeweiligen Kulturen; sowie darüber hinaus der Erhalt der verfügbaren Ressourcen: Wahl des Bodenbearbeitungsverfahrens und des Bodenfruchtbarkeitsmanagements.

Es wurde gezeigt, dass Fulani Agro-Pastoralisten ihre Entscheidungen und Produktionsstrategien an ihre Umweltbedingungen in einem ressourcenarmen System mit hoher Klimavariabilität anpassen. In diesem Produktionssystem verfügen die Produzenten nur eingeschränkt über Kontrollmöglichkeiten des Outputs durch die Kontrolle von Inputs, deshalb greifen sie hauptsächlich auf Auswahlregeln zurück. Die Anpassung der Agro-Pastoralisten zeigt sich zunächst in ihren Strategien zur Vermeidung von Verlusten und zur Risikominimierung. Eine große Ressourcendiversität und damit eine große Auswahl an Handlungsalternativen erhöht die Anpassungsfähigkeit eines solchen Systems. Anpassung der Agro-Pastoralisten an die Klimavariabilität zeigt sich demzufolge auch in ihren Strategien zum Erhalt der natürlichen Ressourcen.

9 RÉSUMÉ

Des données climatiques montrent que le Sahel et ses environs sont exposés à une réduction des précipitations et à une augmentation de la variabilité climatique, résultants éventuellement du changement climatique. Après les sévères sécheresses des années 80 du siècle passé, les anciens pastoralistes du peuple Fulani se sont sédentarisés dans la région de Mopti. En outre de l'élevage, ils dépendent de plus en plus de la production agricole. Dans les deux systèmes de production, ils sont confrontés à une forte variabilité climatique et une faible disponibilité de ressources externes; et ont donc développé des stratégies pour gérer leur système de production dans cet environnement. L'étude examine les stratégies de productions des agro-pastoralistes Fulani et leurs manières d'adaptation à la variabilité climatique. La collecte de données, basée sur des méthodes qualitatives, a été menée dans quatre villages dans deux zones écologiques différentes (Séno et delta du Niger). Pendant un séjour de deux semaines dans chaque village les PRA outils suivants ont été appliqués: village resource map (n=4), seasonal calendars (n=8), pair wise ranking (n=4). En plus, des interviews semi-structurées (n=12) étaient effectuées. Toutes les sessions de collecte de données ont été enregistrées avec un dictaphone. Les interviews ont été transcrites et une partie a été traduite ensuite du fulfulde en français. Les données ont été d'abord évaluées par une analyse qualitative du contenu. Les informations obtenues sur la gestion ont été ensuite analysées à travers une analyse cybernétique.

Les résultats de cette étude montrent que la production agro-pastorale peut être modulée comme un système utilitaire socio-biologique. Dans la partie descriptive de l'étude, plusieurs stratégies dans les domaines d'élevage et d'agriculture ont pu être identifiées. En plus, il était possible de reconstruire le raisonnement qui est à la base des stratégies des agro-pastoralistes dans les domaines d'alimentation de bétail et de la culture de mil. Les principales stratégies de gestion identifiées dans l'alimentation de bétail sont la sélection d'aliment bétail à travers de la transhumance, et la sélection quotidienne de bon pâturage par le berger. Pour la production agricole, les principales stratégies de gestion incluent des activités liées au temps: c'est-à-dire choisir les dates de semi, sélection des variétés tardives ou précoces; et des activités liées à l'espace: c'est-à-dire choisir le site pour chaque culture; ainsi que la conservation des ressources disponibles, c'est-à-dire le choix de culture de sol, la gestion de la fertilité des sols, les périodes de jachère.

L'étude conclut que les Fulani agro-pastoralistes adaptent leurs stratégies de gestion aux conditions environnementales caractérisées par une faible disponibilité de ressources externes et une forte variabilité climatique. A cause des limites de la possibilité de gérer le résultat de leur production par la gestion des intrants, les agro-pastoralistes appliquent principalement des règles de sélection. L'adaptation se montre premièrement dans des stratégies d'évitement de perte et de réduction des risques. La disponibilité d'une grande variété de ressources et ainsi d'alternatives d'actions augmente la capacité d'adaptation. L'adaptation des agro-pastoralistes à la variabilité climatique se montre donc deuxièmement dans leurs stratégies de conserver leurs ressources.

10 REFERENCES

Abate, T.; van Huis, A. and Ampofo, J. (2000): Pest management strategies in traditional agriculture: An African perspective. In: *Annual Review of Entomology,* Vol. 45: 631–659.

Adriansen, H. (2008): Understanding pastoral mobility: the case of Senegalese Fulani. In: *Geographical Journal,* Vol. 174(3): 207–222.

Albert, K.D. (2004): Was Fulani bewegt - Umweltkonzepte und Handlungsmotive agropastoraler Fulani in Burkina Faso, Benin und Nigeria. In: Deutsche Forschungsgemeinschaft (ed.): Mensch und Natur in Westafrika. Wiley-VCH, Weinheim, Germany.

Ambach, B. (1996): Nomads on the river: Mali's fishermen threatened by change. In: *Development and Cooperation,* Vol. 3: 20-23.

Asten, P.J.A. van; Kaaria, S.; Fermont, A.M. and Delve, R.J. (2009): Challenges and lessons when using farmer knowledge in agricultural research and development projects in Africa. In: *Exploring Agriculture,* Vol. 45: 1–14.

Badini, O.; Dioni, L. (2005): Landscape and soil characterization of Madiama commune. In: Moore, K. (ed.): Conflict, social capital and managing natural resources. A West African case study (pp. 35-51). CABI Publ., Cambridge, UK.

Bassett, T. (1994): Hired herders and herd management in Fulani pastoralism (Northern Cote d'Ivoire). In: *Cahiers d'Etudes Africaines,* Vol. 133(1): 147–173.

Bassett, T.; Turner, M. (2007): Sudden shift or migratory drift? Fulani herd movements to the Sudano-Guinean region of West Africa. In: *Human Ecology,* Vol. 35(1): 33–49.

Berkes, F.; Colding, J. and Folke, C. (2000): Rediscovery of traditional ecological knowledge as adaptive management. In: *Ecological Applications,* Vol. 10(5): 1251–1262.

Bernus, E. (1990): Dates, Dromedaries and Drought. In: Galaty, John G.; Johnson, D. (eds.): The world of pastoralism. Herding systems in comparative perspective. Guilford Press, New York, USA.

Bonfiglioli, A. (1985): Évolution de la propriété animale chez les Wodaabe au Niger. In: *Journal des Africanistes,* Vol. 55: 29-37.

Boutrais, J. (1986): L'expansion des éléveurs peul dans les savanes humides du Cameroun. In: Adamu, M.; Kirk-Greene, A.H.M. (eds.): Pastoralists of the West African savanna: selected studies (pp. 145-160). Manchester University Press, Manchester, UK.

Breman, H.; Sissoko, K. (eds.) (1998): L'intensification agricole au Sahel. Economie et développement. Editions Karthala, Paris, France.

Bruijn, M. de; van Dijk, H. (1995): Arid ways. Cultural understandings of insecurity in Fulbe society, central Mali. CERES series, no. 1, Thela, Amsterdam, Netherlands.

Brock, K.; Coulibaly, N.; Ramisch, J. and Wolmer, W. (2002): Crop-livestock integration in Mali. Multiple pathways of change. In: Scoones, I.; Wolmer, W. (eds.): Pathways of change in Africa. Crops, livestock & livelihoods in Mali, Ethiopia & Zimbabwe (pp.33-90). James Currey, Oxford, UK.

Butt, B.; Shortridge, A. and Winklerprins, A. (2009): Pastoral Herd Management, Drought Coping Strategies, and Cattle Mobility in Southern Kenya. In: *Annals of the Association of American Geographers*, Vol. 99(2): 309–334.

Chambers, R. (1992). Rapid but relaxed and participatory rural appraisal: Towards applications in health and nutrition. In: Scrimshaw, N. and Gleason, G. (eds.): RAP: Rapid assessment procedures: Qualitative methodologies for planning and evaluation of health related programmes (pp. 295-305). International Nutrition Foundation for Developing Countries, MA, Boston, USA.

Cissé, S.; Moore, K.M. and Brewster, C. (2005): The Lifescape: Production Systems and Social Institutions. In: Moore, K.M. (ed.): Conflict, social capital, and managing natural resources. A West African case study (pp. 23–34). CABI Publ., MA, Cambridge, UK.

Commissariat à la Sécurité Alimentaire (2006): Plan de sécurité alimentaire - commune rural de Bankass, Mali.

Coop, L.; Croft, B. (1993): Pearl-Millet Injury by 5 Grasshopper species (Orthoptera, Acrididae) in Mali. In*: Journal of econometric entomology*, Vol. 86(3): 891–898.

Cooper, P.; Dimes, J.; Rao, K.; Shapiro, B.; Shiferaw, B. and Twomlow, S. (2008): Coping better with current climatic variability in the rain-fed farming systems of sub-Saharan Africa. An essential first step in adapting to future climate change?. In: *Agriculture, Ecosystems and Environment*, Vol. 126: 24–35.

Coppolillo, P.B. (2000): The Landscape Ecology of Pastoral Herding: Spatial Analysis of Land Use and Livestock Production in East Africa. In: *Human Ecology*, Vol. 28(4): 527–560.

Dahl, G.; Hjort O. and Anders M. (1976): Having herds. Pastoral herd growth and household economy. Stockholm studies in social anthropology, 2, Stockholm, Sweden.

Diakité, N. (2007): Étude des Spécifités Environnementales des zones prioritaires. Edited by Sahel consult, Fonds de développement en zone sahélienne du Mali.

Dillon, J. (1992): The farm as a purposeful system. Miscellaneous publication, 10, University of New England, Amidale, USA.

Direction Nationale de la Météreologie (2009): Service National de la Météréologie. République du Mali, Bamako, Mali.

Duivenbooden N. van; Veeneklaas F.R. (1993): Impact of inorganic fertiliser availability on land use and agricultural production in the Fifth Region of Mali. I. Methodology and basic data. Fert. Res. 35: 193–204.

Fernández-Gimenez M.E.; Swift D. (2003): Strategies for Sustainable Grazing Management in developing world. In: Allsopp, N.; Palmer, A.R.; Milton, S.J.; Kirkman, K.P; Kerley, G.I.H.; Hurt, C.R.; Brown, C.J. (eds.): Proceedings of the VIIth international Rangeland Congress (pp. 821-831). 26th July – 1st August 2003, Durban, South Africa.

FAO (1983): Integrating crops and livestock in West Africa. In: Animal production and health paper, 41. Food and Agriculture Organization of the United Nations, Rome, Italy.

Fox, P.; Rockström, J. (2003): Supplemental irrigation for dry-spell mitigation of rainfed agriculture in the Sahel. In: *Agricultural Water Management* Vol. 61: 29–50.

Gläser, J.; Laudel, G. (2009): Experteninterviews und qualitative Inhaltsanalyse als Instrumente rekonstruierender Untersuchungen. 3. ed., VS Verlag für Sozialwissenschaft, Wiesbaden, Germany.

Graef, F.; Haigis, J. (2001): Spatial and temporal rainfall variability in the Sahel and its effects on farmers' management strategies. In: *Journal of Arid Environments,* Vol. 48: 221–231.

Grayzel, J. A. (1990). Markets and Migration: A Fulbe Pastoral System in Mali. In Galaty, J. and Johnson,D. (eds.), The World of Pastoralism. Herding Systems in Comparative Perspective. (pp 35-68), Guilford Press, New York, USA.

Grund, S. (2004): Development of body weight and body condition of Rendille camel types in northern Kenya. Diploma Thesis, Institute of Animal Production in the Tropics and Subtropics, Faculty of agricultural sciences, University Hohenheim, Stuttgart, Germany.

Goldman, M. (2003): Partioned nature, privileged knowledge. Community- based conservation in Tanzania. In: *Development and Change,* Vol. 34(5): 833–862.

Hayashi, K.; Abdoulaye, T.; Matsunaga, R. and Tobita, S. (2009): Appraisal of Local Farmers' Practices on Land Management for a Guideline of Agricultural Development in the Sahel Zone of Niger, West Africa. In: *Japan Agricultural Research Quarterly,* Vol. 43(1): 63–69.

Heiss, J. (2003): Zur Komplexität bäuerlicher Feldarbeit in Afrika. Eine Fallstudie in einem Manga-Dorf (Niger). Beiträge zur Afrikaforschung, 17, Lit Verlag, Münster, Germany.

Hengsdijk, H.; van Keulen, H. (2002): The effect of temporal variation on inputs and outputs of future-oriented land use systems in West Africa. In: *Agriculture, Ecosystems and Environment,* Vol.91: 245–259.

Homewood, K. (2008): Ecology of African pastoralist societies. James Currey, Oxford, UK.

Hulme, M. (2001): Climate perspectives on Sahelian dessiccation: 1973–1998. In: *Global Environmental Change,* Vol.11: 19–29.

Iiyama, M.; Maitima, J. and Kariuki, P. (2007): Crop-livestock diversification patterns in relation to income and manure use. A case study from a Rift Valley Community, Kenya. In: *African Journal of Agricultural Research,* Vol. 2(3): 58–66.

Kandji, S.; Verchot, L. and Mackensen, J. (2006): Climate Change and Variability in the Sahel Region: Impacts and Adaptation Strategies in the Agricultural Sector. Word Agroforestry Centre & United Nations Environment Programme (Kenya). Online available from http://www.unep.org/Themes/Freshwater/Documents/pdf/ClimateChangeSahelCombine.pdf, cited 05.06.2010.

Kaufmann, B.A. (2007): Cybernetic analysis of socio-biological systems. The case of livestock management in resource-poor environments. Kommunikation und Beratung, 81, Margraf, Weikersheim, Germany.

Kergna, A.O.; Ouattara, S.; Sanogo, Z.J.L. and Soumare, S. (2008): Perception des populations sur l'évolution de la vegetation dans leur système de production: étude de cas dans les régions de Mopti et de Sikasso. Institut d'Economie Rurale and University of Amsterdam. Bamako/Amsterdam, Mali/Netherlands.

Kintz, D.; Toutain, B. (1981): Lexique commenté Peul-Latin des flores de Haute-Volta. Institut d'Elevage et de Médecine Vétérinaire des Pays Tropicaux (ed.). Maison-Alfort, France.

Kiros-Meles, A.; Abang, M. (2008): Farmers' knowledge of crop diseases and control strategies in the Regional State of Tigrai, northern Ethiopia. Implications for farmer–researcher collaboration in disease management. In: *Agriculture and Human Values,* Vol. 25: 433–452.

Kodio, A.; Samaké, O. (2008): Plan stratégique à long terme de la recherche agricole. Plan regional de Mopti. Ministère de l'Agriculture. Bamako, Mali.

Kouressy, M.; Traoré, S.; Vaksmann, M.; Grum, M.; Maikano, I. and Soumare, M. (2008): Adaptation of Malian sorghums to climate variability. In: *Cahiers Agricultures,* Vol. 17(2): 95–100.

Krogh, L.; Paarup-Laursen, B. (1997): Indigenous soil knowledge among the Fulani of northern Burkina Faso: linking soil science and anthropology in analysis of natural resource management. In: *GeoJournal,* Vol. 43(2): 189–197.

Krohmer, J. (2004): Umweltwahrnehmung und -klassifikation bei Fulbegruppen in verschiedenen Naturräumen Burkina Fasos und Benins. Dissertation. Johann Wolfgang Goethe Universität. Frankfurt am Main, Germany.

Krummacher, A. (2004): Der Participatory Rural Appraisal (PRA)-Ansatz aus ethnologischer Sicht. PRA – a quick and dirty anthropology? Working Papers, Institut für Ethnologie und Afrikastudien, Johannes Gutenberg-Universität, Mainz, Germany.

Little, P.; Smith, K.; Cellarius, B.; Coppock, D. and Barrett, C. (2001): Avoiding disaster. diversification and risk management among east african herders. In: *Development and Change,* Vol. 32(3): 410–433.

MacConnell, D.; Dillon, J. (1997): Farm management for Asia. A systems approach. FAO farm systems management series, 13, Food and Agriculture Organization of the United Nations, Rome, Italy.

Maiga, A.A. (2009): Personal communication with Adama Assagaidou Maiga (working for Service Local des Productions et Industries Animales, République Mali) in April 2009.

Matlon, P.; Kristjanson, P. (1988): Farmer's strategies to manage crop risk in the West African semi-arid tropics. In: Unger, P. W.; Jordan, W. R.; Sneed, T. V.; Jensen, R. W. (eds.): Challenges in dryland agriculture. A global perspective (pp. 604-606). Proceedings of Amarillo/Bushland, Texas, USA.

Masike, S.; Urich, P. (2008): Vulnerability of traditional beef sector to drought and the challenges of climate change: The case of Kgatleng District, Botswana. In: *Journal of Geography and Regional Planning,* Vol. 1(1): 12–18.

Mayring, P. (2007): Qualitative Inhaltsanalyse. Grundlagen und Techniken. 9. ed., Beltz UTB, Weinheim, Germany.

M'Boob, S. (1989): A regional programme for Striga control in West and central Africa. In: Robson, T. and Broad, H. (eds.): Striga-Improved Management in Africa (pp. 190–194). Food and Agriculture Organization of the United Nations, Rome, Italy.

McCabe, J.T. (2004): Cattle bring us to our enemies. Turkana ecology, politics, and raiding in a disequilibrium system. Ann Arbor, University of Michigan Press, Michigan, USA.

Mertz, O.; Mbow, C.; Reenberg, A. and Diouf, A. (2009): Farmers' Perceptions of Climate Change and Agricultural Adaptation Strategies in Rural Sahel. In: *Environmental Management,* Vol. 43(5): 804–816.

Ministère de l'Administration Territoriale et des Collectivités Locales (2009): Rapport Commission Système d'Alert Precoce, Fevrier 2009. Mali.

Ministère de l'Administration Territoriale et des Collectivités Locales (2005): Plan Quinquennal de Développement de la Commune Rural de Diallassagou. Commune Rural de Diallassagou, Mali.

Ministère de l'Agriculture (2008): Enquête Agricole Céréalière. Cellule de Planification et de Statiques, Bamako, Mali.

Ministère d'Élevage et de la Pêche (2007): Recencement générale de l'agriculture. Bamako, Mali.

Moritz, M. (2010): Crop–livestock interactions in agricultural and pastoral systems in West Africa. In: *Agriculture and Human Values,* Vol. 27(2): 119-128.

Moritz, M.; Tarla, F. (1999): Fulani's pastoralists' perception and perspectives on rangeland and its degradation in nothern Cameroon. Mega-Chad Bulletin (1&2): 16.

Moulin, C.-H. (1993) : Performances animales et pratiques d'élevage en Afrique sahélienne: La diversité du fonctionnement des troupeaux de petits ruminants dans la Communauté Rurale de Ndiagne (Sénégal). Thèse de doctorat Département Élevage et Médecine Vétérinaire Tropicale. L'Institut National Agronomique Paris-Grignon, Paris, France.

Mude, A. et al. (2010): Index Based Livestock Insurance for Northern Kenya's Arid and Semi-arid Lands: the Marsabit Pilot, Project Summary, International Livestock Research Institute (ILRI), January 2010, Kenya.

Mühr, B. (2007): Klima in Mopti. Online available from http:// www.klimadiagramme.de/Afrika/mopti.html, cited 06.05.2010.

Müller, F. (1990): Flexibel aus Tradition - Strategien wirtschaftlichen und sozialen Handelns im mittleren Nigertal (Mali). Rites de passage, Trickster Wissenschaft, 4, Trickster, München, Germany.

Mwacharo, J.; Drucker, A. (2005): Production objectives and management strategies of livestock keepers in South- East Kenya. implications for a breeding programme. In: *Tropical Animal Health and Production,* Vol. 37: 635–652.

Ndumu, D. B.; Baumung, R.; Wurzinger, M.; Drucker, A. G.; Okeyo, A. M.; Semambo, D. and Sölkner, J. (2008): Performance and fitness traits versus phenotypic appearance in the African Ankole Longhorn cattle. A novel approach to identify selection criteri for indigenous breeds. In: *Livestock science,* Vol. 113: 234–24

Noe, E.; Alroe, H. (2003): Farm enterprises as self-organizing systems: a new transdisciplinary framework for studying farm enterprises? In: *International Journal of Sociology of Agriculture and Food,* Vol. 11: 3–14.

Nyangito, M. M. (2008): Range use and dynamics in the agropastoral system of southeastern Kenya, In: *African Journal of Environmental Science and Technology,* Vol. 2(8): 222–230.

O'Farrell, P.; Anderson, P.; Milton, S. and Dean, W. (2009): Human response and adaptation to drought in the arid zone: lessons from southern Africa. In: *South African Journal of Science,* Vol. 105(2): 34–39.

Ouattara, K.; Ouattara, B.; Nyberg, G.; Sedogo, M. P. and Malmer, A. (2007): Ploughing frequency and compost application effects on soil infiltrability in a cotton-maize (Gossypium hirsutum-Zea mays L.) rotation system on a Ferric Luvisol and a Ferric Lixisol in Burkina Faso. In: *Soil and Tillage research,* Vol. 95(2): 288–297.

Oudwater, N.; Martin, A. (2003): Methods and issues in exploring local knowledge of soils. In: *Geoderma,* Vol. 111(3-4): 387–401.

Orr, A., Mwale, B. and Saiti, D. (2001): What is an integrated pest management ''strategy''? Explorations in southern Malawi. In: *Experimental Agriculture,* Vol. 37: 473–494.

Pallas, P. (1986): Water for animals. Interrelations between the components of the system (man, water, livestock, rangeland). Food and Agriculture Organization of the United Nations, Rome. Online available from http://www.fao.org/docrep/r7488e/r7488e04.htm#3.3%20water%20and%20livestock, cited 31.08.2009.

Pratt, D.J.; LeGall, F. and de Haan, C. (1997): Investing in pastoralism. Sustainable natural resource use in arid Africa and the Middle East. World Bank technical paper, 365, World Bank, Washington, DC.

Pointing, J. (1995): Impact of social and economic change on pastoral women in East and West Africa. In: Stiles, Daniel (ed.): Social aspects of sustainable dryland management. Wiley, Chichester, UK.

Powell, J.; Pearson, R. and Hiernaux, P. (2004): Crop-livestock interactions in the west African drylands. In: *Agronomy Journal*, Vol. 96(2): 469–483.

Rass, N. (2006): Policies and strategies to adress the vulnerability of pastoralists in Sub-Saharan Africa. PPLPI Working paper, 37, Pro Poor Livestock Policy Initiative. FAO. Rome. Online available from http://www.fao.org/ag/againfo/programmes/en/pplpi/docarc/wp37.pdf, cited 11.06.2010.

Ramisch, J. (1999): The long dry season: crop-livestock linkages in Southern Mali. International Institut for Environment and Development. (Drylands Issue Paper, E 88). Online available from http://www.iied.org/pubs/pdfs/7413IIED.pdf, cited 11.08.2009.

Ramisch, J. (2005): Inequality, agro-pastoral exchanges and soil fertility gradients in southern Mali. In: *Agriculture, Ecosystems and Environment, Vol.* 105: 353–372.

Raynaut, C. (1997): Sahels: diversité et dynamiques des relations sociétés. Karthala,Paris, France.

Reynolds J.F., Smith D.M.S., Lambin E.F., Turner B.., Mortimore M., Batterbury S.P.J., Downing T.E., Dowlatabadi H., Fernandez R.J., Herrick J.E., Huber-Sannwald E., Jiang H., Leemans R., Lynam T., Maestre F.T., Ayarza M. and Walker B. (2007): Global desertification: building a science for dryland development. In: *Science*, Vol. 316: 847–851.

Riet, M. van der (2008): Participatory research and the philosophy of social science - Beyond the moral imperative. In: *Qualitative Inquiry*, Vol. 14(4): 546–565.

Rouw, A. de; Rajot, J. (2004): Soil organic matter, surface crusting and erosion in Sahelian farming systems based on manuring or fallowing. In: *Agriculture Ecosystems and Environment*, Vol. 104(2): 263–276.

Samaké, O. (2003): Integrated crop management strategies in Sahelian land use systems to improve agricultural productivity and sustainability: a case study in Mali. PhD Thesis. Wageningen University, Wageningen, Netherlands.

Samaké, O.; Smaling, E.; Kropff, M.; Stomph, T. and Kodio, A. (2005): Effects of cultivation practices on spatial variation of soil fertility and millet yields in the Sahel of Mali. In: *Agriculture, Ecosystems and Environment,* Vol. 109: 335–345.

Schareika, N. (2003): Westlich der Kälberleine. Nomadische Tierhaltung und naturkundliches Wissen bei den Wodaabe Südostnigers. Mainzer Beiträge zur Afrika-Forschung, 9, Lit Verlag, Münster, Germany.

Schönhuth, M.; Kievelitz, U. (1993): Partizipative Erhebungs- und Planungsmethoden in der Entwicklungszusammenarbeit. Rapid rural appraisal; participatory appraisal; eine kommentierte Einführung. Schriftenreihe der GTZ, 231, TZ-Verlags-Gesellschaft, Rossdorf, Germany.

Séhouéto, L. (2006): Localised agricultural knowledge and food production in sub-Saharan Africa. In: *International social science journal,* Vol. 58(1): 121–128.

Sørensen, J.T; Kristensen, E.S. (1992): System Modelling: a research methodology in livestock farming. In: Gibon, A. and Matheron, G. (eds.): Global Appraisal of Livestock Farming Systems and Study on Their Organisational Levels: Concepts, Methodology and Results (pp 45-57). CEC proceedings EUR14479.

Spedding, C.R.W. (1988): An introduction to agricultural systems. 2nd ed., Elsevier Applied Science, London, UK.

Thébaud, B. (2002): Foncier pastoral et gestion de l'espace au Sahel. Karthala, Paris, France.

Thornton, P.K.; van de Steeg, J.; Notenbaert, A. and Herrero, M. (2009): The impacts of climate change on livestock and livestock systems in developing countries: A review of what we know and what we need to know. In: *Agricultural systems*, In Press, Corrected Proof. Online available from http://www.sciencedirect.com/science/article/B6T3W-4WDNBY3-1/2/f5fa2fe1191afd880a5fd0837f784280, cited 19.03.2010.

Tolossa, D. (2008): Livelihood transformation from pastoralism to agro-pastoralism as an adaption strategy among the Urrane of north eastern Ethiopia. In: *Quarterly journal of international agriculture,* Vol. 47(2): 145–165.

Turner, M. (1998): Long-Term Effects of Daily Grazing Orbits on Nutrient Availability in Sahelian West Africa: Gradients in the Chemical Composition of Rangeland Soils and Vegetation. In: *Journal of Biogeography,* Vol. 25(4): 669–682.

Turner, M. (1999a): Labor Process and the Environment: The Effects of Labor Availability and Compensation on the Quality of Herding in the Sahel. In: *Human Ecology,* Vol. 27(2): 267–296.

Turner, M. (1999b): Merging Local and Regional Analyses of Land-Use Change: The Case of Livestock in the Sahel. In: *Annals of the Association of American Geographers,* Vol. 89(2): 192–219.

Udo, H.; Cornelissen, T. (1998): Livestock in resource-poor farming systems. In: *Outlook on Agriculture,* Vol. 27(4): 237–242.

United Nations (2008): Country profile: Mali. Online available from http://data.un.org/CountryProfile.aspx?crName=Mali, cited 14.06.2010.

Vester, F. (2008): Die Kunst vernetzt zu denken. Ideen und Werkzeuge für einen neuen Umgang mit Komplexität; ein Bericht an den Club of Rome. 7. ed., Deutscher Taschenbuch-Verlag, München, Germany.

Walker, B.H.; Anderies, J.M.; Kinzig, A.P. and Ryan, P. (2006): A Handful of Heuristic and Some Propositions for Understanding Resilience in Social-Ecological Systems. In: *Ecology and Society*, Vol. 11(1): guest editorial.

Webb, M.; Smith, M. C. (1996): Biology of Striga hermonthica (Scrophulariaceae) in Sahelian Mali: Effects on pearl millet yield and prospects of control. In: *Weed Research*, Vol. 36(3): 203–211.

White, C. (1990). Changing animal ownership and access to land among theWodaabe (Fulani) of Central Niger. In: Baxter, P. T. W.; Hogg, R. (eds.): Property, Poverty, and People: Changing Rights in Property and Problems in Pastoral Development (pp 240-254). University of Manchester, Manchester, UK.

Wiener, N. (1948): Cybernetics or control and communication in the animal and the machine. John Wiley, New York; USA.

Wilson, R.T. (1986): Livestock production in central Mali. Long-term studies on cattle and small ruminants in the agropastoral system. ILCA research report no.14, International Livestock Centre for Africa, Addis Ababa, Ethiopia.

Wilson, R.T. (2003): The environmental ecology of oxen used for draught power. In: *Agriculture, Ecosystems and Environment*, Vol. 97: 21–37.

Wurzinger, M.; Ndumu, D.; Baumung, R.; Okeyo, A. M.; Semambo, D.; Byamungu, N. and Sölkner, J. (2006): Comparison of production systems and selection criteria of Ankole cattle by breeders in Burundi, Rwanda, Tanzania and Uganda. In: *Tropical Animal Health and Production*, Vol. 38: 571–581.

Wurzinger, M.; Ndumu, D.; Okeyo, A. M. and Sölkner, J. (2008): Lifestyle and herding practices of Bahima pastoralists in Uganda. In*: African Journal of Agricultural Research*, Vol. 3(8): 542–548.

11 ANNEX

11.1 DESCRIPTION OF COMMUNICATION TOOLS

Communication tool	Conduction
Village resource map	– Ask participants to draw on paper what is in their village – Ask if something is missing – Let them explain what is on the paper – Ask for infrastructure – What is missing in the village? When and why do they have to leave the village to conduct activities somewhere else? – Ask for the quality of the resources, are there differences, who can use what
Livelihood analysis	– Ask participants to name activities they conducted in order to gain their living – Collect them in symbols on a paper – Are there in the village other people that do something else? – Are there additional activities that are conducted only at special times of the year? – Let the activities be ranked for their importance – Which activities are conducted by everybody, which only by certain persons, why?
Seasonal calendar animal husbandry	– Ask beforehand a key informant for the division of the year, and indicate that on a paper – Explain the months – Ask in which month did id rain? When was it hot? Indicate the climate data for orientation – Collect all activities performed for livestock production last year – Ask for the course of the transhumance and when where the animals in which area – In which month last year was good/poor fodder quality? – How was the physical state of the animals in each month? – At which time of the year was the highest incidence of illnesses? When was mortality highest? Is there a difference for different species? – When is vaccination conducted? For which illnesses? – Are there other activities concerning animal health? – When is the highest birth rate? – Are there times when more milk/ animals is/are extracted? – Is there anything else related to livestock production that we have not yet talked about?

Seasonal calendar crop production	– Use the same division as for the seasonal calendar animal husbandry, already indicate division and climate data – What crops did you produce last year? First collect, then let the crops be indicated in a symbol in the calendar – What other things did you grow or collect? Add their symbols – Start with the first crop: what were activities you conducted to cultivate that crop? – What did you do which moment of the year? – Continue like that for all crops mentioned
Focused group discussion based on the seasonal calendar	Crop production: Ask for each crop (or if informants loose motivation ask for the five most important crops): How was the harvest? What had happened throughout the year? What were reasons for increase in yields/high success? Did you encounter some problems that could be solved? How? Livestock: Did you encounter any special events last year? Both topics: Referring at a year with bad rain: is the calendar different to this one? Are there activities you conduct only in a bad year/ in a year with especially lot rain?
Additional communication tools that were not conducted in every village	
Pair wise ranking animal breeds (Nérékoro, Sadia Peulh)	What different types of animals/ cow beans/ millet/ rice/ pasture are there? Compare always two: which one is better? Why?
Pair wise ranking cow beans/millet/rice (Sadia Peulh, Yongosiré)	
Pair wise ranking pasture (Ouandiana)	

11.2 QUALITATIVE CONTENT ANALYSIS CATEGORIES TYPE A: CROP PRODUCTION

Generelle **Produktionsziele**

Ertrag

Qualität

Konzept „gute Ernte“

Arbeit

Liste der Routinearbeiten

Reihenfolge der Kulturen

Arbeitsorganisation

Bedeutung der Arbeit

Zeitpunkte

Boden

Praktiken zur Konservierung der Bodenfruchtbarkeit / Bodenfruchtbarkeit /

Rotation

In Kulturnahme

Bäume in Feldern

Düngung

Bodenbearbeitung

Praktiken zur Verbesserung der Wasserinfiltration

Anbauentscheidung

Lage der Felder

Reisfeld in Bewässerung

Säen / Saatgut

Jäten/Unkrautbekämpfung

Ernte

Organismus Hirsepflanze

Keimung

Schaderreger

Vögel, Termiten

Hirseschädlinge

Würmer

Mischkulturen

Andere Pflanzen

Trockenes Jahr

11.3 QUALITATIVE CONTENT ANALYSIS CATEGORIES TYPE B: ANIMAL HUSBANDRY

Globale Ziele der Tierproduktion

Ziele in der Tierproduktion

Zielgrößen der Tierproduktion (Messgrößen)

Ziele im Herdenmanagement

Motivation des Produzenten

Anforderungen an den Produzenten

Arbeitsorganisation

Arbeit des Hirten

Qualitäten eines guten Hirten

Einteilung der Herde

Medizinische Behandlung und Gesundheitsstatus

Salz

Futterversorgung übers Jahr

Zustand der Tiere über das Jahr

Zustand der Tiere – heute

Entwöhnung der Kälber

Route der Transhumanz

Entscheidung der Transhumanz-Route

Kriterien einer guten Weide

Zustand der Tiere auf der guten Weide = Indikatoren einer guten Weide

Wasserversorgung auf der Transhumanz

Finanzierung der Ausgaben

11.4 TRANSHUMANCE ROUTE YONGOSIRÉ

Début Partie 2:

L : Excusez l'interomption…

D : Il dit que vraiment il ne voir pas aucun problème.

L : Donc, il était en train de nous expliquer son système d'élevage….

I : Au retour de transhumance les animaux traversent l'affluent de Diaka à Diafarabè, ils longent le fleuve un peu pour traverser une deuxième fois le fleuve Niger toujours à Diafarabè. Puis les viennent vers le terroir de Galandjiri situé entre Diafarabè et Kéwa. Après l'étape de galandjiri, les animaux viennent pour traverser à partir de Kéwa, pour se retrouver dans le terroir de Djarakoye pendant un moment, puis ils progressent dans la zone de Manga qu'on appel Kourendia où ils longent le fleuve pour aller à Yonga, c'est là où les animaux se séparent, les gartjis restent là bas pour un long séjour et les bendis poursuivent la marche en passant par Mourari pour rejoindre Wouro Modi. En suite de Wouro Modi, les bendis progressent pour venir à Sonnô puis ils se retrouvent au village à Yogonsiré. Mais où les animaux passent, nous avons des points d'escale c'est-à-dire des bilé, donc j'ai seulement donné le parcours.

L : apparemment chaque an c'est le même mouvement ou ça varie selon les années ?

I : chaque an c'est le même mouvement, le point de départ c'est ici à partir de l'hivernage pour remonter vers l'Ouest et traverser à Diaka puis progresser sur les cotes en passant par Karédji pour rejoindre Nampala. Après la saison pluvieuse les animaux redescendent de Nampala pour revenir à Karédji en passant par les cotes pour arriver à Péroubolè, puis ils rentrent à Nampala.

C'est-à-dire en hivernage les animaux quittent le village pour remonter à Sonnô, de Sonnô ils vont à Diabi, de Diabi ils remontent à Mboudou, de Mboudou ils partent à Dari, de Dari ils traversent un affluent « Mayol seyi », puis ils traversent à Diaka pour camper à Fombana, puis ils progressent à Ténéma, puis à Kassa, en suite à Garala, pour aller à Tomberie pour arriver dans la zone de Karè, puis à Djoura, à Mpèhe, puis à Mbiguél, puis à Gayrè Diamdi où on se retrouve dans la zone de Nampala.

Les chefs lieux de communes sont : Wouro Modi, Mourari, Seygho, Toguerie, Karerie, Pèrê et Nampala. Et les zones de destinations pour la transhumance sont : Nampala, Léré, Sahel Kroumarie.

Sur ces étapes aussi y a des mares creusées par l'état et des couloirs de transhumance pour les animaux. Ces mares sont : Ourogata, ségouba, Kolâ, baatawal, Nawori, puis à Nampala.

Eidesstattliche Erklärung

Hiermit versichere Ich, die vorliegende Arbeit selbstständig verfasst zu haben und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt zu haben.

Datum: Unterschrift: