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Identification of agro-pastoralists adaptation strategies to climate variability: A case study in Mopti-Mali

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Dedication

This report is dedicated to my Late father Mr. Jean Kuété.

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List of abbreviations

DM	Dry Matter
ENSO	El Niño-Southern Oscillation
FAO	Food and Agriculture Organisation
FCFA	Franc Communauté Financière Africaine; 1 Euro = ~655 FCFA
GDP	Gross Domestic Product
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IER	Institut d'Economie Rurale
IK	Indigenous Knowledge
IPCC	Intergovernmental Panel on Climate Change
NGO	Non-Governmental Organisation
PROLINNOVA	Promotion of Local Innovation
PPM	Parts Per Million
PRA	Participatory Rural Appraisal
SST	Sea-Surface Temperature
SOM	Soil Organic Matter
SSA	Sub-Saharan Africa
TLU	Tropical Livestock Unit; 1 TLU = 250kg live weight
UNDP	United Nations Development Programme
USAID	United States Agency for International Development

1 INTRODUCTION

Agriculture is an important sector in the Sahelian countries, due to its multiple roles in food security, employment and contribution to national GDP's. Despite of this important role, Agriculture in Sahelian countries is a highly under-developed sector. It is characterised by the low use of external inputs, absence of mechanisation, poor linkages to markets and a high dependency on rainfall, which in the Sahel vary in time and space (Kandji et al., 2006). In addition to the previous constrains is the growing pressure of climate change and variability's. However, climate variability's is not a new phenomenon in the West African Sahel, and farmers have developed and implemented adaptation strategies that have enabled them reduce their vulnerability.

According to the IPCC (2007), the world's climate is changing rapidly. All regions on earth would be affected by climatic changes, but more impacts would be felt in developing countries such as in the SSA and South Asia (Stern and Treasury, 2007). It is often said that developing countries would be more affected by climatic changes: because of the low adaptive capacity, their geographical exposure, greater reliance on small scale agriculture, a climate sensitive sector, and the lack of appropriate policies to support adaptation strategies (Stern and Treasury, 2007; Thornton et al.,2006). Pastoralists and marginal mixed crop-livestock systems (agro-pastoral systems) are highly vulnerable to climate variability´s and change, and most work on adaptation strategies so far relates to crop production (IPCC, 2007).

Livestock are a crucial coping mechanism in variable environments such as in the Sahel. As variability´s increases, livestock will become more important in such environments. That is why it is important to inform the development agenda, by doing research on livestock-specific adaptation strategies. This study focuses on understanding and documenting the wealth of indigenous coping mechanisms employed by agro-pastoral communities in the Séno-Bankaas, a Sahel region characterized by a short rainy season limited to 3 months y^{-1}, and a harsh dry season of at least 9 months y^{-1}.

The objective of this study is in three-fold:

- To gather adaption strategies promoted or supported by NGO's and governmental services in the study area.
- To identify climatic problems observed by agro-pastoralists and the impacts of observed changes on their production systems.
- To identify autonomous adaption strategies (innovations) currently in practice in the study area.

This study is divided into two main parts. It begins with a review on climatic changes (past, present and future), impacts and adaptation strategies that occurred in drylands areas of SSA, with a focus on the West African Sahel. The second major part is a case study from the drylands of Mopti region of Mali (the Séno-Bankass).

2 LITERATURE REVIEW

2.1 General information's on Mali

Mali is a developing country of West Africa, covering a land surface of 1 241 238km^2 (2/3 located in arid zone), and a population estimated to 14 517 176 inhabitants in 2010 (UNDP-Mali, 2010). It is considered a low income agro-pastoral economy, with about 60% of the population living under the poverty line (USAID, 2008). It is estimated that, about 80% of the population is engaged in primary production, and agriculture represents about 35,7% of the country's GDP. Livestock plays an important role in the Malian society; hence among the 35,7% of agricultural contribution to the GDP, 41,6% are from the livestock sector (FAO, 2005). The population is over 70% rural, mainly engaged in agriculture, livestock, fisheries, forestry, trade and handicrafts. Main cash sources which most households needs for their annual tax payment are migration earning, millet, cotton, groundnut, craftwork and livestock sales (Wilson, 1982; FAO, 2005; PANA, 2006).

More than 70% of daily calories requirements in Mali are met from cereals (Butt et al., 2005). The Food and Agriculture Organization (FAO, 2005) of the United Nations estimated that 28% of Malians are undernourished. Crop production in most villages is dominated by millet, sorghum, beans, groundnuts, cotton, maize, rice and roselle (Yossi et al, 2008). Agriculture is dominated by small scale traditional farming, covering 90% of the total cultivated land (FAO, 2005). The arable land is estimated to 14% of the total land area (PANA, 2006). Mali is the first cotton producing country in sub-Saharan Africa; hence its economic health is very much dependent on the price of cotton on the world market (Simonsson, 2005).

In general, food problems in Mali are attributed to low resource endowment and standard of living, worsen by inter-annual climatic variations, the successive years of drought and related factors (Simonsson, 2005).

On table 1 below is the trade in agricultural and livestock products for the past decades in Mali (Values in Million US $). The conclusion from this table is that, there has been an increase in imports in livestock products for the past decades, probably due to the inability of the sector to satisfy the demand of its growing population.

Table 1 Trades in livestock and agriculture in Mali 1980-2002

Product	**Exports (Million US $)**				**Imports (Million US $)**			
	1980	1990	2000	2002	1980	1990	2000	2002
Total	-	69	1,830	2,371	-	143	2,264	2,699
Agricultural	0.8	37.7	10.6	36.4	71.9	13.5	454.7	282.1
% agricultural	-	55.0	0.6	1.5	-	9.5	20.1	10.5
Livestock	0.0	0.0	0.4	4.0	4.2	0.1	9.1	22.5
% livestock	-	0.0	0.0	0.2	-	0.1	0.4	0.8

Source: FAO (2005)

2.2 Agro-Pastoralism in Mali

According to Wilson (1982), a system in which between 10 to 50% of the gross revenue (the value of subsistence plus marketed production) is either from livestock keeping or agriculture is classify as agro-pastoral. Based on his system of classification, three agro-pastoral systems do exist in Mali: The first is associated with rain fed millet cropping, mainly for subsistence, and confined to the central semi-arid region of Mali such as the

Séno, a region with rainfall varying between 400-800mmy^{-1}. The second system is associated with irrigated rice cropping, confined to the interior Delta of Niger, with an annual precipitation estimated to about 500mmy^{-1}. The third system much more similar to first system is associated with rain fed cash and subsistence cropping, confined to the southern central semi-arid and southern sub-humid regions, with annual precipitation between 700-1400mmy^{-1}. In this last system, work oxen are indispensable for cultivation, and mostly fed from crops residues (Wilson, 1982).

Although diversification characterises most household livelihoods activities nowadays in the Sahel, it is very common that, different ethnic groups identifies themselves as agriculturalists or pastoralists. For example, the Fulani's by nature pastoralists also grow crops at the present time, but still identify themselves as pastoralists. At the other side, other tribes such as the Dogon, which are by nature crop farmers keep livestock at the present time, but still identify themselves as crop farmers or agriculturalists (Roncoli et al., 2009).

Ramisch (2005) found that, an average Fulani household has nearly 20 times more cattle as an average non-Fulani household, but a non-Fulani household cultivate more crops than a Fulani household. Fulani's practicing agriculture own small crop fields, often with pure stands of maize or pearl millet planted on, whereas farming ethnic's cultivates bigger areas, with several crops such as millet, maize, groundnuts, cowpeas, cotton etc.

In agro-pastoral systems such as in Mali, cultivated fields are closed to home premises, and divided in two groups; the home fields and the bush fields. The home fields are often within a distance of 0 to a maximum of 2km away from the homes depending on the village population, and the bush fields are somewhere in the landscape. Samaké et al. (2005) carried a study on home fields and bush fields' usage and observed that, 100% of arable lands in home fields were intensively cultivated, against 87% in bush fields. From the total cultivated area in the home fields, at least 97% of the cultivated area was under millet monoculture, whereas the bush fields were under the intercropping systems, with major associate like millet/cowpea, millet/roselle *(Hibiscus sabdarifa),* groundnut/roselle, and the use of field manure exclusively to home fields (Ramisch, 2005; Samaké et al., 2005).

In such areas where there is a mixture of livestock and farming, animals grazed on bush pastures, as no crop is grown explicitly as fodder. However, village household stock crop residues such as groundnut haulms, maize and millet stover to feed animals in the dry seasons (Powell et al., 1993; Ramisch, 2005; Ayantunde et al., 2007). Crop farmer households in agro-pastoral systems often negotiate for farming equipments they don't have, such as animal draft-power for cultivation, or manure from livestock keepers. The most common arrangement is that of households borrowing a donkey cart to "pay" half of the transported manure to the cart owner's fields (Ramisch, 2005). Many of the cart owners actively sought out households that had manure or household wastes to transport, in order to profit from such deals. Similarly, households with full manure or compost pits often viewed this arrangement as a way to empty their pits, preferring therefore to use part of the manure as payment in lieu of scarce cash. Arrangements are also made between transhumant Fulani that are in need of camping areas in the dry season and households that wants manure in their fields (Ramisch, 2005).

Ogle (1996) argued that, this new evolution of mixed crop-livestock production is the most efficient and sustainable way to increased food production, and Harris (1999) see this combination as the most significant innovations that occurred in the Sahel for the past decades. It is often hypothesize that food production in such systems may increase, because animal traction and manure will be somewhat available, and crop residues would be converted into milk and meat (Powell et al., 2004). An example from a study in East Africa showed that, the integration of livestock with crops lead to 50% increased in productivity and incomes in Ethiopians highlands, and to 100% increase in Zimbabwe, as compared to smallholders depending only on subsistence cropping with no livestock (Ogle, 1996).

Based on the main crop, the agro-pastoral system in Mopti is grouped under two main systems; the system based on rain fed millet cropping in dry areas of the Séno, and the system based on irrigated rice cropping, confined to the interior part of Niger Delta (Wilson, 1982; Leten et al., 2010).

Table 2 Selected differences between the millet and rice agro-pastoral systems in Mali

Factors	Rice system	Millet system
Number of cattle per households	3 out of every 5 families	3 out of every 5 families
Mobility	In wet season: 80-100km from settlement	In dry season: 30-50km from settlement
Crop residues	Longer availability period and better quality	Limited availability in time, quality and quantity
Water availability	Abundant all year round	Restricted in dry season
Dry-season fodder	Weed re-growth on irrigated rice fields	Very limited, early browse in hot dry season
Supplementing feeding	Fairly common, mainly rice bran, legume haulms and leaves of *Khaya senegalensis*	Very limited, mainly millet residues
Energy expenditure	Lower for longer period, due to water proximity and longer growing period	High in dry season, due to longer distance to water and sparse feed availability

Source: extracted from Wilson (1982)

2.2.1 Livestock production

Location and distribution in Mali

The distribution of livestock in various ecological zones in Mali is shown on table 3. This table put forward that, livestock activity is very much concentrated in the arid regions of Tombouctou, Kidal and Gao, holding at least 97% of the country camels, 19,5% of cattle, 45% of both sheep and goats. However, the Inner Niger Delta has a high concentration of livestock as compare to other ecological zones, although it is just 6,34% of the total land area of the country.

Regarding livestock distribution in various ecological zones, the only exception is that of camels, which are more or less confined to arid zones, with a few thousands occurring in the Inner Niger Delta and the semi-arid zones.

Table 3 Livestock population in various ecological zones of Mali

Ecological Zone	Camels		Cattle		Sheep		Goats	
	Number	%	**Number**	%	**Number**	%	**Number**	%
Arid zone: Tombouctou, Kidal and Gao	826.352	97	1583.514	19,5	4402.472	45	6171.251	45,5
Semi-arid zone: Ségou, Koulikoro and Kayes	11.932	1,4	2953.721	36	2797.669	28,7	3936.551	29
Subhumid zone: Sikasso and Bamako	0	0	1324.616	16	761.403	7,8	890.345	6,5
Inner Niger Delta: Mopti	13.977	1,6	2279.609	28,5	1800.035	18,5	2594.916	19
Total	**852.260**	**100**	**8141.459**	**100**	**9761.578**	**100**	**13593.063**	**100**

Source: Calculated from Leten et al. (2010)

Livestock production systems of West Africa

The proposed typology for the West African livestock production systems is divided into two major systems: the livestock and the crop-livestock systems (Fernandez-Rivera et al., 2001). The livestock system is itself sub-divided in two sub-systems, the rangeland-based and landless, whereas the crop-livestock system has three sub-classes, the annual crop-livestock, tree-crop-livestock and the irrigated/ flooded crop-land livestock.

Annual crop-livestock system is predominant in drylands of West Africa, and dominated by crops such as pearl millet, cowpea, sorghum, and groundnut (Fernandez-Rivera et al., 2001; Powell et al., 2004). Crop residues in these systems are important source of livestock feedstuff especially during the 8 to 9 months dry season period, and also a source of income for households (Fernandez-Rivera et al., 2001; Ayantunde et al., 2007).
Figure 1 below show the proposed typology of livestock systems and associate, according to Fernandez-Rivera et al., (2001).

In mixed farming systems such as in drylands of West Africa, cattle provides draft-power for tillage, crop planting, weeding, crop harvest and transport, but also provide meat and milk for households, as well as cash income, invested in some cases in farm inputs. Despite of the fact that agricultural products are often used for home purposes, some outputs of rangeland (wood, bush straw), cropland (grains, crop residues and hay) and livestock (animals, milk, meat and skin) are mostly sold for household incomes (Powell et al., 2004).

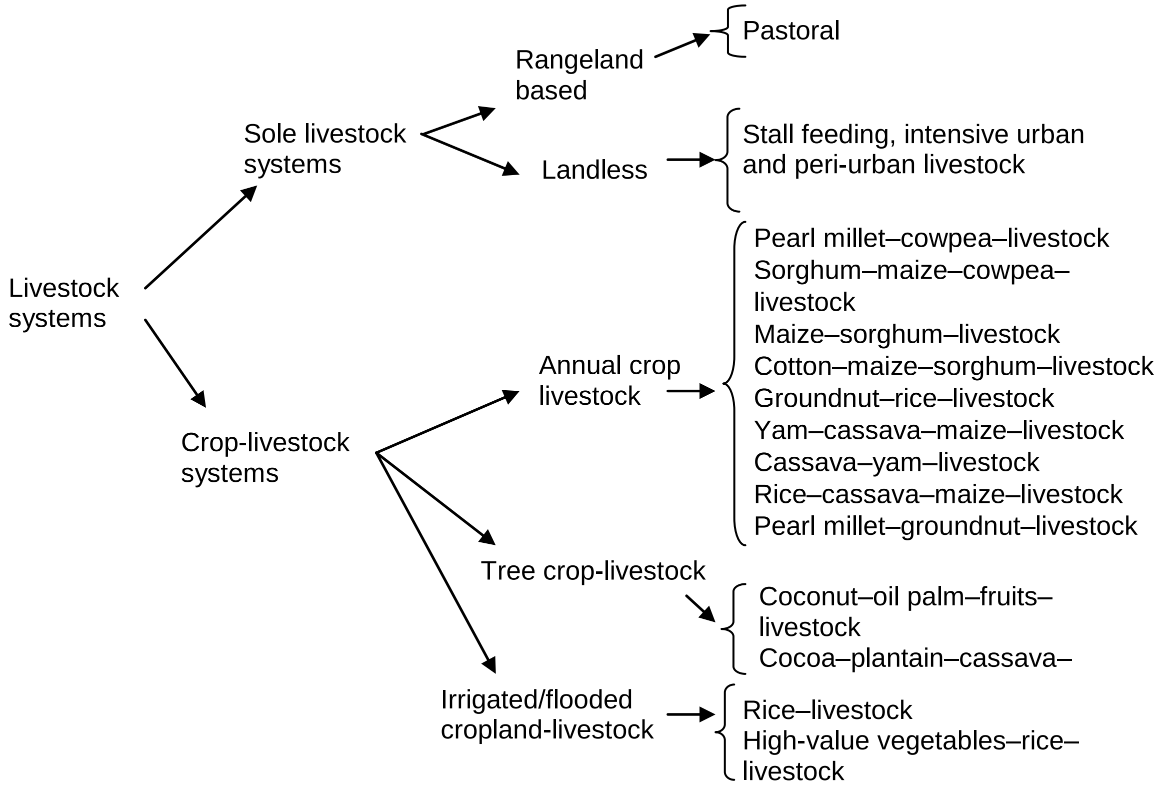


Figure 1 Proposed typology of livestock farming systems and associate in West African drylands

Source: (Fernandez-Rivera et al., 2001)

Livestock production systems in Mali

Livestock keeping in Mali is divided in two broad systems: the agro-pastoral system and the pastoral system. The pastoral system is described as a system in which more than 50% of family gross revenue is directly from livestock or livestock-related activities (Wilson, 1982).

In the arid regions, 50% of the cattle and 70% of the small ruminants are kept in a pure pastoral subsystem, and the rest unlike in the semi-arid regions is associated with rain fed cropping (Diakité, 2010). The livestock sector in Mali is ranked as the third income of the country, looking at its contribution to the total GDP, and the pastoral system is by far the predominant form of livestock keeping (Wilson, 1982; FAO, 2005; Diakité, 2010).

Selected characteristics of major livestock systems in Mali are presented in the table 4 below

Table 4 Characteristics of livestock production systems in Mali

System / **Sub system** / **Characteristics**	**Pastoral**			**Agro pastoral**		
	Pure	Associated with dry land cropping	Associated with floodplain grazing and farming	Associated with rain fed millet cropping (mainly subsistence)	Associated with irrigated rice cropping	Associated with rain fed cash/ subsistence cropping
Location and ecological zone	Northern arid/semi-arid	Northern central and northwestern semi-arid	Niger floodplain and Senegal basin	Central semi-arid	Dead Delta (central semi-arid)	Southern central semi-arid and southern sub humid
Rainfall (mm)	<400	300–600	200-(irrigation)	400–800	500-(irrigation)	700–1400
Importance of agriculture	Nil to negligible	Low	Can be quite important	Considerable	Very important	Paramount
Linkages with agriculture	Very weak	Some cultivation, manure exchanged for stubble grazing	Cultivate or arrange for cultivation of own crops	Cultivate own crops; work oxen are important and consume crop residues		
Current TLU/rural inhabitant	0.8–1.6	0.4–1.59	1.2–1.59	0.461–19	0.4–1.19	0.4–0.79
Production unit	Nuclear family often grouped (in camps)	Nuclear or extended family	Nuclear or extended family (important non-agnatic ties)	Extended family	Extended family	Extended family
Ethnic groups	Bella, Tuareg, Maure	Harratin Bella, Tuareg, Maure	Delta Fulani, Seno Fulani	Bambara, etc.	Various, including former immigrants	Bambara, etc.
Hired labor	Very occasional	Fairly common	Common	Seasonally frequent, occasionally longer term		
Mobility	High often irregular with no fixed base	High, usually more or less permanent with fixed base	High in wet season; precedence rights on stock routes and in Delta; fixed base	Low, short distances during crop growing period; permanent base		
Marketed production	Low (40%):barter of milk (and salt) for grains	Medium/high (50 or 60%) sale or purchase	Medium (45 or 50%): sale of animals and grain	Very low/medium (10–50%)	High (60%): rice	High (60%): cash crops

Source: Extracted from Wilson (1982)

Small ruminants' breeds

Sheeps and goats play an important role for livestock and country economy, due to their reproduction ability under harsh environmental conditions such as in semi-arid zones when cattle are less productive (Wilson, 1986). Studies (Wilson,1986; Leten et al., 2010) on small ruminants breeds and distribution in Mali obserbed that the majority of goats found in Mali are the Sahel goat and the Fouda Djallon goat. Sheeps are found in few types, mainly the West African long-legged types such as the Macina wool sheep, the Maure and Tuareg sheep, the Fulani and hairs sheep from the southern region of the country. The Toronké is the most common Fulani breed, commonly used by Fulani transhumants and agropastoral sendentary farmers in central Mali. The long hair black Maure is a breed occuring along the Mauritania and Mali border, and the hair is often used for tent-making. The white pied or fawn Tuareg breed is kept enterily by the nomadic or transhumant Tuaregs of the Gourma region, and in the north of Niger river, until the Niger Republic. The Macina breed is one of the few wooled breeds, and mainly owned by the agropastoral Fulanis', for their coarse wool which is used for the manufacturing of local blanket (Wilson, 1986; Leten et al, 2010).

Big ruminants' breeds

Cattle in Mali is mostly found in the semi-arid and Inner Niger Delta region, with two predominant breeds, the zébu breeds such as the the Maure, the Tuareg, the Azawak and the Fulani. The second breed is called the Taurine, with sub-species such as the N´dama and the Méré. Gobra are also present, but occuring at the border to Senegal, and the Maure cattle occur seasonally along the Mauritania border in the north, whereas the Azawak breed is only found in the East of Mali (Wilson, 1986; Wagenaar et al., 1986; Leten et al, 2010).

Livestock role in the Malian society

In Mali, livestock serves as major stores of wealth across a wide range of social groups, because farmers are not acquainted to keeping their money in banks (Kaya et al., 2000). Hence, economic surpluses registered by farmers, traders, Islamic priests and governmental officials are often invested into livestock (Turner, 2000). According to Cissé (1980), the reason why livestock is use as a long-range investment is that; "grains fed to livestock promises greater profits than does stored grains, because it improves the quality of existing animals and encourages long-term increases in herd size, whereas the value of stored grains may reduced or may become inedible". Alongside that central economic argument lies that of social order, that of a social prestige in owning a sizable herd, also seen in monetary terms in the society (Cissé, 1980).

Livestock is an important source of meat and milk for the domestic market (Ouma et al, 2006). Mali is considered one of the major livestock keeping country in West Africa, providing an integral part of livelihood income source in most rural areas, through milk trading. This sector also brings advantages such as the use of animal tracking power for cultivation and nutrient recycling through the production of farm-yard manure (Kaya et al., 2000). Livestock is a key component of the farming systems in Mali, and taking into consideration the central role of small livestock keeping systems in the rural Mali, the government has recently initiated a livestock development master program which includes: the investments in infrastructures, capacity building and market development in production areas (FAO, 2005; Kaya et al., 2000; Diakité, 2010).

2.2.2 Crop production

Soil types

Soils in semi-arid areas are classified in five main groups, the Vertisols, Arenosols, Acrisols, Luvisols and Oxisols. Those soils account for more than 80% of the total arable lands in semi-arid areas. The Oxisols type despite its clayey texture has a low water holding capacity, whereas the Vertisols, Arenosols, Acrisols and Luvisols are described as poor soils (Laryea et al., 1991; Eswaran et al., 1997).

Two soil types have been identified in dry areas of Mopti: the silty-clay soils and the sandy-loam soils. This later is described as infertile, and contain more than 65% of sand, with less than 18% of clay (Turner 1998 in Werner, 2010). However, alkalinity, acidity and salinity are major problems of such soils in semi-arid and arid zones of Africa, and affect more than 24% of the continent soils, exacerbated by a pH>8,5 (Laryea et al., 1991). Events such as the Harmattan winds from the Sahara raise the soil pH of most West African countries, but do not solve the problem of acidity or moisture stress. Studies revealed that, more than 25% of soils in semi-arid zones are prone to water erosion, and at least 22% to wind erosion (Laryea et al., 1991; Eswaran et al., 1997).

Soil preparation and seeding

Until the introduction the animal draft-power for cultivation, most farms were cultivated with a hand tool called "*daba"*. With this later, small sand dunes of about 30cm are made, distant between 80cm to 150cm, depending on expected moisture supply. With an animal draft-power, ridges are made in lines and distant less than a meter from each other, and up to 30cm in height. In both types, seeds are placed in dug holes of 10 to 20cm either with the *daba* on sandy soils, or a planting stick on clay soils, due to the need of physical force on these soils. Seeding is done depending on the soil moisture, and ranges between 4 to 10 seeds per dune, spaced between 150cm from every direction (Harlan and Pasquereau, 1969; Kouyaté et al., 2000).

Field cultivated with a *daba*

Field cultivated with a draft-power animal

Picture 1 Cultivated fields with *daba* and draft-power

Source: Own picture

Cultivated crops

Crop production in drylands of West Africa is dominated by cereal production, by pearl millet (*Pennisetum glaucum (L.)* R.Br), sorghum (*Sorghum bicolour* (L.) Moench), and maize (*Zea mays* L.). Other cultivated crops include Woandzou (*Voanzeia subterranean*) and Fonio (*Digitaria exilis* (Kippist) Stapf). Legumes crops are mostly cowpea (*Vigna unguiculata* (L.) Walp) and groundnut (*Arachis hypogaea* L.), both subsistence and cash crops. It is said that most farmers in West African drylands obtain more than 25% of their annual cash income from trading of crop residues (Renard and ICRISAT, 1997; Ayantunde et al.,2007; Werner, 2010). Rice (*Oryza spp.)* is cultivated along stream borders and river, such as in the interior Niger Delta, the Gambia Rivers and the flood plains around Lake Chad (Fernandez-Rivera et al., 2001; Powell et al., 2004). Sorghum and pearl millet are the most cultivated crops in drylands area of Mali, due to their drought tolerant characteristic. Millet for example is a photoperiodic sensitive plant, hence requires a considerable amount of sun radiation of a certain number of days to induce its maturity (Werner, 2010). In semi-Arid environments like in the Séno, two ecotypes of millet were identified, the early mature variety (*Sunnari*), which can mature within 70-100 days after sowing, and long cycle varieties (*Sannoori*) that varies between 120-170 days after sowing (Harlan and Pasquereau, 1969; Werner, 2010).

Figure 2 below is a representation of the farming system in drylands of West Africa, and show the interaction between various components of the system.

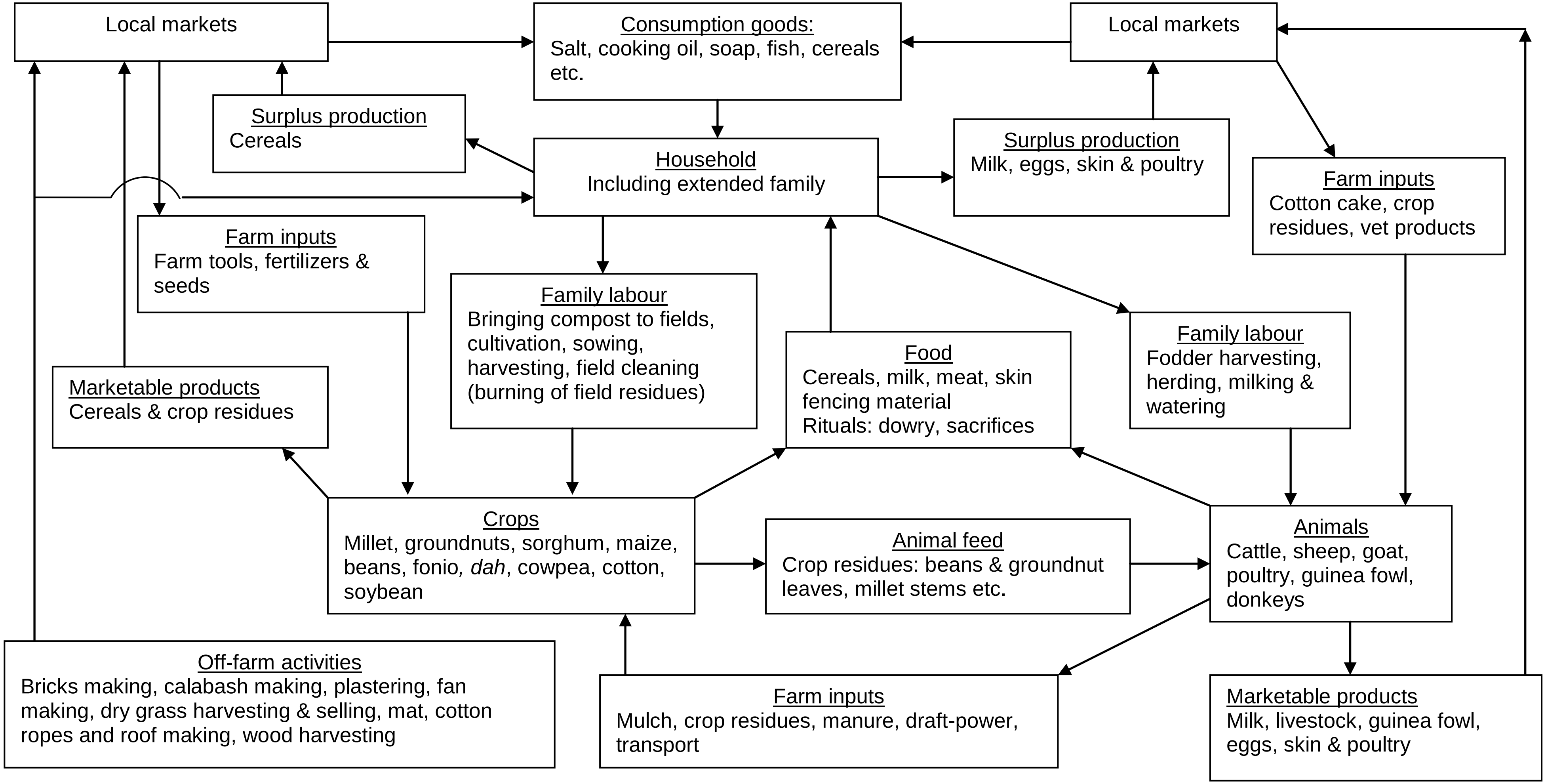


Figure 2 Farming system diagram of West African drylands

Sources: Extracted from Beets (1990) and Powell et al. (2004)

2.3 Climate change and variability's in the Sub-Saharan Africa

This chapter gives an overview on climate change and variability's in the Sub-Saharan Africa, however with a focus on Sahel countries of West Africa.

Climate change is the change in the regional climate (temperature, wind patterns and precipitation) associated to the accumulation of green house gases (carbon dioxide: CO_2, methane: CH_4 and nitrous oxide: N_2O) in the atmosphere (Houghton, 1995).

Present and future changes in the climate are observed or estimated based on climatic models. Selected studies that modelled those changes considered climate variables such as: changes in CO_2 concentration and in temperatures (Hulme et al., 2001; Kotir, 2010; Hulme and Viner, 1998; Butt et al., 2005), which are projected to increase. However, the degree of change in temperature from various studies varies depending on regions and type of models used. Rainfall is also projected to change (Hulme and Viner, 1998; Butt et al., 2005; Kotir, 2010). Other expected changes are of extreme weather events such as the increase occurrence of the tropical cyclones, droughts and floods events (Hulme and Viner, 1998; Walsh and Pittock, 1998; Hulme et al., 2001; Taylor et al., 2002; Adger et al., 2003). Nevertheless, future distribution of changes are still unknown, because present climatic models rely on guesses, and only projected changes in CO_2 concentration is reasonably sure (Downing et al., 1997).

Downing et al. (1997) argued that CO_2 enrichment, change in precipitation and changes in extreme weather events are the most important elements of climate change in Africa, and Kotir (2010) concluded further that the change in temperature and precipitation have a more direct connection to agricultural productivity in SSA, and play a significant role in the social and economic well being of rural communities. Temperature and precipitation would be given more focus in the subsequent chapters, due to their role in driving year-to-year production changes in the SSA, very much dependent on rain-fed agriculture (Abdelkrim, 2010).

2.3.1 Changes in CO_2 concentration and temperatures

Temperature is known to interact with CO_2 concentration (Sivakumar et al., 2005). One of the most comprehensive studies on African climate by Hulme et al., (2001) concluded that, for the past century there has been as increase in temperature in Africa. Observations have revealed that, Africa is at the present time warmer than a century ago, and temperatures increases at the rate of $0{,}5^0$C century^{-1} (Hulme et al., 2001). However, changes in temperature are worldwide, and the IPCC (2007) at the global level observed a linear increase of $0{,}7^0$C over the last century.

Generally, air temperature is relatively high in the Sahelian and Soudanian zones of West Africa, due the high radiation load and their geographical position between the tropical and subtropical latitudes, where temperatures are high throughout the year, with a high variation between day and night temperatures (Sivakumar et al., 2005; Kotir, 2010). Hulme (2005) studied the African climate and noticed a year-to-year variation in temperatures. He observed that the six warmer periods in Africa occurred between 80s and the 90s, with the years 1987 and 1998 the hottest years.

Hulme et al. (2001) observed a profound change in temperature within the months of June-August, and September-November. These months were known as cold periods, as compare to December-February and March-May, normal warm seasons of the year throughout the continent. Hernes et al. (1995) and Ringius et al. (1996) cited in Hulme et al. (2001) constructed the climate change scenarios of the Sahara and semi-arid land areas of Africa and concluded that, land areas temperature in these areas will increase to at least 1,6^{0}C by the year 2050s, and the equatorial countries experiencing until now lower soil temperatures may see an increase of 1,4^{0}C.

Regarding future prognosis, temperatures are expected to increase in most parts of world, but the degree of increase as mentioned above would vary from one continent to another, and from one ecological zone to another (Adger et al., 2003).

2.3.2 Changes in rainfall

Future changes in rainfall are in seasonality, magnitude, inter annual variability and frequency (Hulme and Viner, 1998). Agricultural productivity in most Sahelian countries is conditioned by the amount of precipitations, which vary in time and space (Yossi et al., 2008). It is one of the most important natural resource in the in semi-arid areas and mainland's of Africa (Sivakumar et al., 2005), however, the most critical problem is often its inter and intra-seasonal variability (Hatibu et al., 2005). Observation and model simulation revealed that, rainfall in most parts of the SSA is influenced by two phenomenon: The Sea Surface Temperatures (SSTs) from the Mediterranean, Gulf of Guinea and Indian Ocean (Patricola and Cook, 2010), and the El Niño-Southern Oscillation (ENSO) events in the tropical Pacific (Hulme et al., 2001; Kotir, 2010).

Patricola and Cook (2010) argued that rainfall in the Sahel is influenced by the SSTs, and suggest that, warmer or cooler SSTs result to a Wetter or drier Sahel, whereas Hulme et al. (2001) and Kotir (2010) suggested that ENSO is the climatic engine influencing rainfall on an inter-annual time-scale, and the most determinant of year-to-year climatic variability. However, quantitative analysis on the relationship between precipitation and ENSO in two regions of Africa observed a high amount of precipitation during a warm ENSO event in equatorial east Africa and a low amount of precipitation during a warm ENSO event in southern Africa (Hulme et al., 2001).

Several authors (Hulme et al. (2001), Sivakumar et al. (2005) and Kotir (2010)) studied the climatic data for Africa in the last century and concluded that, rainfall has reduced in most regions. In tropical North Africa for example, there has been up to a 30% reduction in the amount of precipitation during 1961-1990, as compare with 1931-1960 period. In the semi-arid and sub-humid zones of West Africa, rainfall has been on average 15-40% lower during 1968-1997 as compare to 1931-1960 period. Particularly in the Sahel, a decline by 20-49% of precipitation in the late 1960s and 1990s have been recorded, against a 5-49% decrease across other parts of Africa (IPCC, 2001 cited in (Kotir, 2010)). However, Hulme et al. (2001) argued that, rainfall in the Sahel has been stable to an annual average of 371mm from 1961-1990, whereas Hulme (1992) cited in Sivakumar et al. (2005) examined a widespread decline of around 0,4mmday^{-1} in the amount of rainfall within the months of June-July-August in the Sahel, between 1961 and 1990, accompanied by a shift of up to 2,2^0 latitude (*ca.*240km) in the position of the 200mm annual isohyets in the Sahel, between 1980-1990 decade.

Other forecasts are within the change in the core of rainy season and extreme rainfall events. Model simulations showed a change in the return periods of the rain, but argued that this may be compensated by maximum rainfall in short time interval. Hence larger rainfall events as much as $25mmday^{-1}$ would be registered in future throughout the tropics (Walsh and Pittock, 1998; Taylor et al., 2002).

The current water availability for most West African countries is estimated to about $4484m^3person^{-1}$, but model projections to a persistent reduction in rainfall suggest that, by 2025 countries like Cape Verde and Burkina-Faso will experience shortages in water availability down to 324 and $957m^3person^{-1}$ respectively in both countries (Abdelkrim, 2010).

2.3.3 Extreme weather events

Increase occurrence of tropical cyclones

Tropical cyclones are defined as: "short-lived phenomena, whose impacts can range from devastating floods, high winds and storm surges to beneficial drought-breaking rains" (Walsh and Pittock, 1998). Global warming would lead to an increase in the frequency and intensity of tropical cyclones (Walsh and Pittock, 1998). The most favourable factors that lead to its formation is the increase of the Sea Surface Temperature (SST), which may result from anthropogenic emissions of carbon dioxide, methane, nitrous oxide, the halocarbons and sulphur dioxide (Hulme and Viner, 1998). Therefore, with an increase of the SST at about 26^0C, there are high probabilities that tropical cyclones would develop (Walsh and Pittock, 1998). The increase in SST is said to influence not only the occurrence of tropical cyclones, but also responsible for long-term drought, such as ones that occurred in the semi-arid African Sahel between the 1950s and 1980s (Biasutti and Giannini, 2006).

Increase occurrence of drought and flood events

Drought and floods have been common in most parts of SSA, mostly in east Africa and in the Sahel (Kotir, 2010). The IPCC (2007) cited in Kotir (2010) defined drought as "a phenomenon that exists when precipitation is significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resources and production systems". Drought could result from too little precipitation or high evaporation, resulting from the increase in temperatures, which in turn leads to aridity (Kotir, 2010).

According to Kotir (2010), first droughts in the Sahel were registered in 1968, with the highest point 1972. After this time, the return was in the late 1970s, with the worse cases in 1980s. Regarding future projections, it is estimated that 1,1billion hectares of arid and dry semi-arid land may develop in Africa by 2080s. Other factor that may stimulate the increase in arid and dry semi-arid land areas is the reduction of the temperature growing season, expected to reduced to less than 120 days by 2080s, forcing large regions of marginal lands out of production (Kotir, 2010).

Flood events in West Africa appear to be at their high intensities, particularly in drier zones such as in southern Sahelian Soudanian zones, with peak intensities of precipitations exceeding $100mmh^{-1}$ (Lawson and Sivakumar, 1991). They studied the rainfall in Senegal (West Africa) and observed that half of the rains fall with intensities greater than $27mmh^{-1}$, and a quarter with intensities greater than $52mmh^{-1}$, with adverse impacts which shall be discussed in the subsequent chapter.

2.4 Current and future impacts of climate change on agro-pastoral systems

The interaction between climate and increased climate variability's with other drivers of change in livestock systems is a relatively neglected research area, hence very little is known about this interaction (Thornton et al., 2008). However, studies in this area suggested that, the Sahel countries (most underdeveloped) will suffer more the effects of climate change than developed countries (Mortimore, 2010). It has been hypothesized by several authors that, climate change can bring both positive and negative impacts on different land users, but exposes them to unfamiliar and new conditions (Ogle, 1996; Stern and Treasury, 2007; Osbahr et al., 2008).

2.4.1 Impacts on livestock production

A couple of studies (Rötter and van de Geijn, 1999; Butt et al., 2005; Thornton et al., 2008; Kassahun et al, 2008) hypothesized that, climate change would severely impact livestock keeping systems around the world, but the degree of impacts would vary depending on agro-ecological zones and the requirements of each species. For example, small ruminants are regarded more resilient to climatic stress as compared to cattle, due to their low demand in water and feed intake (Butt et al., 2005). Regarding climate change impacts on livestock, four main areas have been considered (Rötter and van de Geijn, 1999; Thornton et al., 2008). Those areas consist of the following:

- Feed grain availability and prices
- Forage crop production and quality
- Animal health, growth and respiration
- The distribution of livestock diseases and pests.

The distribution of livestock diseases and pest will occur due to the change in ecosystems. Hence, Thornton et al. (2008) argued that, this would depend on the ecosystems affected, the type of land-use change, disease specific transmission dynamics and the susceptibility of the livestock population at risk.

Under the prevailing climatic traits in the Sahel, different regions posed different traits to livestock keeping (Bassett and Turner, 2007). Thornton et al. (2008) argued that, high rainfall after drought periods leads to wide-spread outbreak of diseases such as Rift Valley Fever and bluetongue in the Eastern part of Africa, and the African horse sickness in Southern Africa.

Ogle (1996) argued that, a reduction in precipitation may also have positive impacts on livestock communities, because the economic importance of livestock in African farming systems increases with decreasing rainfall.

Impacts of changes in CO_2 concentration and temperatures on livestock systems

Livestock may be affected by heat stress; however, the degree of impacts would vary depending on species type, genetic potential, life stage and nutritional status (Thornton et al., 2009).

Carbon dioxide (CO_2) is an essential substrate for plant photosynthesis, a process whereby CO_2 and water are converted into sugars, driven by the energy from light (Rötter and van de Geijn, 1999). However, different plants exhibit different responses to increase concentration of

CO_2 and temperature. Regarding pasture areas, changes in atmospheric CO_2 concentrations and temperature are expected to bring changes in herbage growth, pastures composition such as the ratio of grasses to legumes, and changes in herbage quality and concentrations of water-soluble carbohydrates and Nitrogen at given DM yields (Thornton et al., 2008). Increase concentration of CO_2 and temperature may result in a loss of more palatable grass species (Orindi and Murray, 2005) .

livestock usually maintain an optimum body temperature at 37^0C, and cow for example can regulate this body temperature either by nose leaking or shivering (Rötter and van de Geijn, 1999). Extreme increase in temperatures would alter heat exchange between livestock and environment, reduction in feed intake, lower growth rate and reproduction, and increase in maintenance cost (Butt et al., 2005; Thornton et al., 2008). The reduction in intake may result in increased energy deficits, which could reduce cow fertility, fitness and longevity (Thornton et al., 2008).

A case study in Mali revealed that, the increase in temperatures in arid regions resulted to a resettlement of livestock in wet areas, a movement that potentially increase soil erosion and conflicts in these localities (Benjaminsen and Ba, 2009; Diakité, 2010). However, Ogle (1996) argued that soil erosion at these areas is possible only at extreme cattle density. Another study from Ethiopia in East Africa show that, during period of increased drought and temperature, there is a reduction in palatable grasses, increase dehydration of animals, chronic skin and respiratory diseases and a longer interval between calving and kidding (Kassahun et al, 2008).

The water demand with change of temperature in two cattle subspecies; *Bos indicus* and *Bos taurus* have been studied, and results show that water demand increases form 3kg per kg DM intake at 10^0C ambient temperature to 5kg per kg DM intake at 30^0C and reaches 10kg per kg DM intake at 35^0C for *Bos indicus* and the same change in temperatures showed a 3, 8 and 14kg per kg DM intake variation for *Bos Taurus* (Thornton et al., 2008). Regarding livestock diseases, Thornton et al. (2008) argued that the change in climatic conditions may lead to an increase or decrease occurrence of some pathogens. However, they believe that the development rate of pathogens or parasites that spend some of their life cycle outside their host would increase.

2.4.2 Impacts on crop production

Impacts of changes in CO_2 concentration and temperatures on crop production

As temperatures are projected to increase, evapotranspiration is expected to increase over Africa between 5-10%, by 2050 (Sivakumar et al., 2005). This increase is likely to have negative impact on crop production such as millet (one of the most common food crop in the Sahel), due to its photosynthesis characteristics (Abdelkrim, 2010).

Butt et al, (2005) argued that the impacts of climate change on crop production especially in Mali would vary, depending on the location and crop. He simulated crop yield to elevated CO_2 concentration, and predict increase yields in cotton production, in both humid and drier areas, whereas sorghum was the most susceptible to elevated CO_2 concentration. However, the increase in CO_2 concentration benefits cotton due to its biological characteristics as a C3 plants, as compare to sorghum a C4 plant, less dependent on CO_2 and can only tolerate temperatures range between 25 to 35^0C (Sivakumar et al., 2005).

Thornton et al. (2008) argued that atmospheric CO_2 concentration of 550ppm would positively impact C3 plants, which may register an increase in yields between 20-30%, against a 0-10% increase in C4 plants yields, whereas Rötter and van de Geijn (1999) suggested that an elevated atmospheric CO_2 concentration of 700ppm would result in a 30% increase in C3 plant yields.

Lawson and Sivakumar (1991) analyzed data from 64 climate stations in the southern Sahelian and Soudanian climatic zones and revealed that, air temperature at the time of sowing (May-June) easily exceed 40^0C, and vary from $28\text{-}42^0$C during the growing season. Such temperature result in a high decomposition rate of organic matter, limit soil micro fauna and microbial activity, with important implications to fertilizer use efficiency. On sandy soils in Niger, surface temperature varied between $45\text{-}50^0$C after a rain, resulting to a low stand survival, as crops are highly sensitive to high temperatures at the time of roots establishment. Crops such as cowpea, soybean and pigeon pea are adversely affected by soil temperatures exceeding 34^0C, against a 30^0C for maize (Lawson and Sivakumar, 1991).

The predominant soil type in agro ecological zones such as the Southern Sahelian zone of West Africa is sandy, where soil temperature could exceed 60^0C, and under such high temperatures, plant demand for water increases, accompanied by enzymes degradation, acceleration of plant growth and a reduction of the growing season (Downing et al., 1997; Sivakumar et al., 2005). Enzymes degradation limits photosynthesis, and if growth is accelerated in cereals when grains are filling, there are high probabilities that the quality of yields would decline (Downing et al., 1997).

Abdelkrim (2010) simulated the impacts of increase temperature on millet production in Niger and concluded that, with a $2\text{-}3^0$C increase with respect to 30 years mean in maximum temperatures, yield losses may vary between 20-40% in millet crop in the Sahel. Regarding the impact of increase temperature on plants, Sivakumar et al. (2005) argued that at temperatures greater than 40^0C, plant metabolism for many cereals start breaking down. Other impacts are: the higher crop respiration, which may lead to a reduction in the dry matter gain of plants (Rötter and van de Geijn, 1999), and the shortening of the growth cycle of crops such as millet. This reduction in the growth cycle is expected to vary between -8 to -9 days by 2080, corresponding therefore to a 10-50% reduction in Yields (Abdelkrim, 2010).

Temperature increase would modify the distribution of agro ecological zones. Highlands in particular may become suitable for annual cropping, mainly due to reduced frost hazards. For example, with an increase of $2{,}5^0$C in the current temperature, there would be at least 20% increase in agro ecological suitability in the highlands of Kenya, at the other flip, the same $2{,}5^0$C in temperature would result in a 20% decrease in calorie production in such areas (Sivakumar et al., 2005).

Impacts of change in rainfall on crop production

Water shortage in the root-zone limits the variety and quantity of crop that a smallholder can produce. The reduction of harvest limit the range of options for commercialization, and the extent to which small-scale producers can take advantage of opportunities arising from emerging markets, trade and globalization (Hatibu et al., 2005).

The surface water resources of the Sahel countries of West Africa is concentrated within limited number of river basins, namely the Niger, Lake Chad, the Senegal, Gambia and Volta river basin, and most countries are interdependent of these basins (Abdelkrim, 2010). Abdelkrim (2010) studied the change in rainfall in West Africa from 1968 to 1972 and observed a decrease in rainfall by 15-30% and the southward shift of the isohyets of about 200km during drought periods, with consequences such as the decrease in ground water level, increase runoff coefficient and the decrease in the main river discharges.

Due to changes in precipitations, a decrease in the flow rates of most West African rivers have been observed for the past decades, a reduction that is estimated to vary between 40-60% since the 70s (Niasse, 2004). Studies on the Niger River observed a reduction from 37 000km^2 at beginning of the years 1950 to 15 000km^2 in 1990. Same with the flood plains of Hadéjia Nguru in Northern Nigeria, where observations revealed a decrease in flow rates from 2.350km^2 in 1969 to about 1 000km^2 in 1995. Another observation was on the area of Lake Chad, estimated to 20 000km^2 in the year 1970 and reduced to just 7 000km^2 in the year 1990 (Niasse, 2004). Another study on the Sélingué dam in Mali observed a reduction in the annual flow from 350m^{3}s^{-1} for the period 1968-1980, to 200m^{3}s^{-1} in the period 1981-1997 leading to a decrease in major natural wetlands used for agricultural purposes (PANA, 2006). With the reduction of the water flow, water temperatures increases, leading to more eutrophication and the proliferation of invasive plants such as *Typha,* described as a giant aquatic carpet. This aquatic plant is found on major rivers of West Africa such as the Senegal and the Basin of Komadugu Yobe in Northern Nigeria. This aquatic carpet is one of the major obstacles for fishing and hydro-agricultural planning in these regions (Niasse, 2004).

A study on climate change impacts in the West African Sahel revealed devastating impacts on crop yields for the past five decade. In Niger for example, Sivakumar et al. (2005) observed a decrease in groundnuts yields from 850kgha^{-1} in 1966-1967 to 440kgha^{-1} by 1981, as a results of drought and other factors such as plant diseases.

As the growing season of crops is expected to reduce due to insufficient rainfall, crop failures in SSA were farming systems are running severe nutrients deficits (Ramisch, 2005) are likely to increase, due to mismatch between the water availability and crop phenology (Lawson and Sivakumar, 1991).

Impacts of extreme weather events on crop production

Kassahun et al. (2005) and later Stern and Treasury (2007) argued that, climate change would lead to more drought periods and hotter land surface temperature, leading to more evaporation and increase in noxious weed species on arable lands.

Models analysis of future impacts of climate change on cropland suggest that, by 2039 Africa is expected to have lost about 4,1% of its cropland, and projected to increase to at least 18,4% by the end of the century (Kotir, 2010).

The impacts of high intensities rainfall have been studied in several West Africa countries. These studies observed an increase in soil losses on arable lands and nitrogen leaching (Thornton et al., 2008). In Nigeria for example, soil losses on cassava and maize fields on a 5% slope fields ranged between 11-33tha^{-1}y^{-1}, similarly in the southern Sahelian zone of Niger, soil loss on sorghum and cotton fields was reported to reach 8.6tha^{-1}y^{-1}, and a 21tha^{-1}y^{-1} loss registered on bare soils of Senegal, under high rainfall of about 1300mm (Lawson and Sivakumar, 1991).

Another extreme weather event is the dust storm that occur before the rainy season, with violent winds that affects crops establishment by damaging seedlings through sand blasting, leading to suboptimal plant stands and replanting, with further damage such as wind erosion (Sivakumar et al., 2005).

Summary of the climatic changes and impacts in drylands of SSA

Table 5 Summary of climate change, effect and impacts on drylands

Climate change	Effect	Impacts	Source
CO_2 enrichment **Increase in T^o**	-Increased photosynthesis; reduced transpiration -Faster plant growth -High decomposition of OM -Higher demand for irrigation water and cooling -High crop respiration -Modifications in Agro ecological zones -Lost of appetite; reduction of intake -Migration from arid to wet zones	-Increased water use efficiency -Reduced agricultural yields -Higher stress in plants and other water delivery systems -Limit photosynthesis -More cropping lands on highlands -Reduction of fertility, fitness and longevity - Soil erosion	Downing et al. (1997), Lawson and Sivakumar (1991), Sivakumar et al. (2005), Butt et al. (2005), Rötter and Van de Geijn (1999) Abdelkrim (2010), Thornton et al. (2008), Butt et al. (2005)
Change in season and amount of precipitation	-Change in soil moisture -Change in ground water recharge -Reduction of the growing season -Outbreaks of diseases -Increase development of pathogens and pests	-Change in agricultural yields -Change in cropping systems -Reduction of yields	Downing et al. (1997), Sivakumar et al. (2005), Thornton et al. (2008), IPCC (2007)
Extreme weather events: -Dust storm -Floods -Tropical cyclones - Droughts	-Sand blasting -Spread of pathogens and pests -Soil losses -Water logging of soils -Higher evaporation	-Damaged seedlings -Logging of crops -Soil erosion -Inability to cultivate soils -Uprooting of trees - Lost of trees species -Increase in noxious weed species -Increase livestock dead -Increase in wildfire	Downing et al. (1997), Kassahun et al. (2005), Sivakumar et al. (2005), Stern and Treasury (2007), Lawson and Sivakumar (1991) IPCC (2007)

2.5 Adaptation strategies in drylands

The Millennium Ecosystem Assessment (2005) cited in UNDP (2009) defines drylands as "terrestrial regions where the production of crops, forage, wood and other ecosystem services are limited by water, which encompass all lands where the climate is classified as dry sub-humid, semi-arid and arid, exclusive of hyper-arid areas". Over 43% of the land in Africa is estimated to fall within the drylands, and characterized by low and erratic precipitation, high temperature and evapotranspiration. Some of the most vulnerable communities to the impacts of climate change inhabit those areas (UNDP, 2009).

For clarification, there is a clear difference between coping strategies and adaption strategies, which may sound similar and even used interchangeable in some literatures. Nevertheless, few authors make a distinction between them. Osbahr et al. (2008) argued those two can be differentiated by time scale, hence coping strategies are regarded as short time scale, whereas long time scale actions are portrayed as adaption strategies. Adger et al. (2003) suggested that coping strategies refer to actions taking place within existing structures, while adaptation frequently involves changing the framework within which coping takes place.

For the purpose of this report, adaption strategy would be considered. Adaptation or adaption may both occur in the subsequent chapter; however, they are used for the same meaning.

Definitions: Adaptation according to IPCC (2007) cited in Stern and Treasury (2007), is "any adjustment in the natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities". Smit et al. (2001) cited in Kitor (2010) defined adaptation as: "changes in processes, practices and structures to moderate potential damages or to benefit from opportunities associated with climate change". Other authors like Adger et al. (2007) regarded adaptation as "actual adjustments, or changes in decision environments, which might ultimately enhance resilience or reduce vulnerability to observed or expected changes in climate"

According to Stern and Treasury (2007), adaptive capacity is related to income and capabilities. Hence, taking into consideration the under-developed stage of most African countries, adaption to climatic changes in these places is likely to occur only when the impacts will be felt.

Adaption is likely to come about in two ways: policy driven adaptation and farm level adaptation or autonomous adaptation (Stern and Treasury, 2007; Kotir, 2010).

2.5.1 Autonomous adaptation

Autonomous adaptation is regarded more adapted to local conditions, because no other sectors are needed in their development and implementation (Kotir, 2010). From that viewpoint, it is likely that local communities and farmers in Africa have developed with time intricate systems of gathering, predicting, interpreting and decision-making in relation to their climate. However, the IPCC (2007) argued that there is little evidence that efficient and effective adaptation in such societies will be taken autonomously.

2.5.1.1 Adaption strategies for crop production in drylands

Resource poor farmers adjustments in response to climatic changes are within soil preparation periods, planting and harvesting dates, in order to match the prevailing temperature and amount of precipitation (Butt et al., 2005; Amsalu and de Graaff, 2006; Speranza et al., 2009). Most studies on adaptation observed that, resource poor farmers now use crop production strategies that strive to manage risks and reduce losses, by diversifying field locations, soil types, crop mixes, planting heat tolerant varieties or early maturing varieties, or by using crop varieties with high water use efficiency (Butt et al., 2005; Benhin, 2006; IPCC, 2007; Roncoli et al., 2009).

Adapting to rain or water scarcity

- **Improved trees management and planting**

Few studies have focused on the role of trees planting in reducing the impacts of climate change. A study in Burkina-Faso and Senegal observed that local land users in semi-arid areas engaged in trees planting and management, by using traditional pruning and fertilizing techniques. By doing so, these communities doubled trees density in their localities, with observed advantages such as: increase land cover, trapping of moisture in the soil, holding soils together and reversing the desertification process (UNDP, 2009).

- **Anticipation of drought times ahead**

Famers in Kenya, drylands of Burkina-Faso and Northern Cameroon anticipate drought period by adopting series of measures such as: planting the early maturing crops, drought tolerant crops, sowing of multiple varieties, and by storing their grains or stop to sell stored grains (Asah, 2008; Speranza, 2009). Particularly in Burkina-Faso, famers expanded cultivation into lowlands, but land shortage is a limiting factor to fully apply this strategy (Roncoli et al., 2009).

- **Rain-water harvesting**

Rain-water harvesting is the collection and concentration of runoff for productive purposes. This includes methods of concentrating, diverting, collecting, storing and utilization (UNDP, 2009). There is an increase harvesting of rain-water in most communities in the SSA, by using small-scale low-tech technologies like the use of rooftops and tanks, so as to harvest and store rainwater. This method is reported cheap and easy to construct (Orindi and Murray, 2005). It is an alternative to the exploitation of ground water, which is increasingly unreliable with the fluctuating water table, and also a means to control the proliferation of bore holes or shallow wells (Kirkbride and Grahn 2008).

Hatibu et al. (2005) identified three rain water harvesting techniques: the micro-catchment systems, macro-catchment systems and the macro-catchment systems linked with road drainage. The micro-catchment systems exploit the natural concentration of rainwater and nutrients flowing into valley bottoms, from surrounding high grounds in the landscape. The macro-catchment is designed to provide more water for crop growth, through the diversion of storm floods from gullies and ephemeral streams into crop or pasture lands. The macro-catchment systems linked with road drainage is used to reduce the cost of installing water control structure; hence farmers using this method locate their farms strategically to exploit the flash floods that occur for only few hours per year in semi-arid areas, mostly concentrated at road drainage systems.

Rainwater harvesting is view as one of the adaptation measure to water scarcity that do not require large capital investment, rather a management approach, to provide water resources that could be used for domestic, livestock and irrigation purposes (UNDP, 2009).

- **Field water conservation methods**

According to Hatibu et al. (2005), the effect of erratic rainfall on crop yield in semi-arid areas is apparent, thus efficient rainwater management seems to be a key to solutions. Few methods of water conservation have been described as typical of drylands: the rock bunds or stone strips, the half-moon technique and the Zaï technique, developed in Burkina-Faso (Maatman et al., 1998; Sidibe, 2005)

The rock bunds or stone strips technique*:* they are contour lines, arranged perpendicular to the slope of the land, so as to slow down water flow, encourage water infiltration and increase the sedimentation of the materials reconstituting soil (Sidibe, 2005), its use is often justified by its potential to recover degraded fields and to increase yields.

Picture 2 Rock bunds technique

Source: Yossi et al. (2010)

There are several ways of constructing rock bunds, depending on the slope of the land, stones availability and cost of transport. Depending on these factors, rock bunds can be with or without ditches, with single rows of stones or with more stones piled up against each other. Maatman et al. (1998) observed that the use of rock bunds is beneficial in both short term and long term. In short term, it improves the water balance on agricultural fields, and in the long run an increase in nutrient availability (Maatman et al., 1998).

The *zaï* technique: it an indigenous practice in Burkina-Faso, used for restoring degraded soils. This is done by creating a micro-environment favourable for crops, by digging and sowing in holes in which manure or compost has already been deposited (Sidibe, 2005)

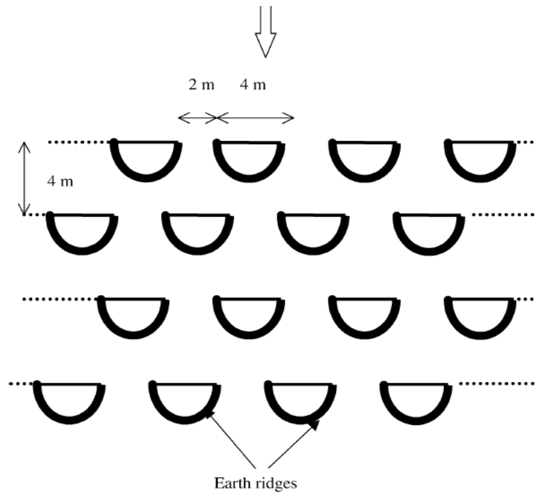
Picture 3 The *zaï* technique

Source: Botino and Reij (2009)

In this technique, holes are dug within 0,8 to 1,2m space from each other, with a depth of 10 to 15cm, and a diameter of 15 to 20cm. At the beginning of the rainy season, compost or manure (200-600g) is deposited in these holes, where 10-15 seeds of sorghum or millet are sowed (Sidibe, 2005). In these holes, the organic manure creates a micro-environment that enhances crop yields and plants resistance against drought. Although the use of *zaï* has shown an increase in crop yields, it demands enormous effort regarding labour.

For example digging 20 000 to 25 000 holes ha^{-1}, 780 hours can be used, with an estimate of 4 to 18 tons of compost ha^{-1}, in addition of seeds and transport of manure. Despite the high labour demand, *zaï* remains a commendable technique for regenerating poor soils (Maatman et al., 1998).

The half-moon technique



Picture 4 the half-moon technique

Source: Zougmoré et al. (2003)

The half-moons technique as shown on picture 4 is also used to rehabilitate sealed and crusted bare soils (Zougmoré et al., 2003). It is mostly practiced on fields with a gentle slope of < 3%. As shown on picture 4, holes are dug in a half circles, with cuttings arranged in semi-open circle upstream. The furrow collects the water trapped by the arms of the half-moon. The upstream of the ditch serves as a catchment area. This method enables plants grown in half-moon to receive more water than from direct rainfall. It may have a radius ranging from 2 to 3 meters and a depth of 30-40cm (Botino and Reij, 2009).

Adapting to high temperatures

- **Increase use of chemical fertilizers**

Agricultural intensification can be the solution to land degradation and climatic stress in SSA, and can be achieved by applying more inputs per units of land. However, in the context of pre-existing environmental risks, this appear to be a risky strategy (Paavola, 2006). Benhin (2006) observed that, to adapt crops production to an increase in temperature and evapotranspiration, farmers in drylands of South Africa resorted to the increase use of farm manure, so as to keep high moisture content of the soil and retain soil fertility. They also invested in the application of lime, so as to maintain the soil pH balance. However, the high costs of chemical fertilizers, lack of credit, poor transport and marketing infrastructure serve as disincentives for smallholder farmers (Ncube et al., 2006).

Adapting to extreme weather events

- **Diversification of livelihood**

Livelihood diversification includes agriculture and non-agricultural activities. It is highly opportunistic and involves quick responses to market opportunities (Siebert et al., 2008). Mortimore and Adams (2001) observed the following steps in livelihood diversification in farming communities in SSA. The first step is the diversification into livestock ownership, secondly, by diversifying incomes through trading, making articles for sale and providing services. Thirdly, there is off-farm diversity, where people pursue other activities, which in most cases involve high mobility between rural communities and urban or commercial farming zones. Most off-farm income in Sahelian countries are from trade, crafts, salaried work, small-scale mining and seasonal migration also play a strategic role in livelihood security, under climatic threats (Orindi and Murray, 2005; Roncoli et al., 2009). In affected societies alternative sources of income are sought and crucial (Mortimore and Adams, 2001).

- **Fields burning**

In the Sahelian drylands of Northern Cameroon, farmers engaged in using farm fire to mimic similar ecological disturbances as during drought periods. They burn fields before ploughing, targeting drought tolerant grass and shrubs that infest crop fields around the Logone floodplain of the Lac Chad basin. Mimicking those fine-scale natural disturbances hasten the local renewal cycles and minimize accumulation of coarse-scale disturbances (Asah et al., 2008).

- **Migration**

Migration is regarded as a coping mechanism used throughout history by societies, as a resource utilization strategies (Adger et al., 2003), and a means of adapting to climate variability's or extreme events such to droughts, floods and other factors that plays an important role in given societies (IPCC, 2007). Migration to more fertile and less moisture stressed areas either to engage in farming or non-farming activities is the only sustainable livelihood strategy to climate variability's (UNDP, 2009), but may fuelled conflicts in such areas, as people begin to compete with each other for natural resources and land (UNDP, 2009).

Remittances from migrant family members and relatives continue to play an important role in livelihood resilience nowadays in most developing countries. It is considered a dominant mode of labour, providing significant livelihood sources in drought and non-drought years in the societies concerned. People who receive remittances tend to be less affected by shocks in terms of access to food, health and school attendance (Adger et al., 2003; Orindi and Murray, 2005; Paavola, 2006; IPCC, 2007). Migration appears to be feasible in particular circumstances, and in those societies where desirable migration is not available to those affected, there is an ultimate need of displacement migration, usually taken as last resort, when other coping strategies have been exhausted (Adger et al., 2003).

- **Conservation practices**

Orindi and Murray (2005) and Benhin (2006) discussed a couple of conservation practices carried out by farmers due to increase occurrence of droughts. They observed that farmers in dry areas have adopted various soil conservation techniques, which enable them to maintain soil moisture and fertility. Such methods include the construction of water holding dams or trees planting around fields, to control erosion. The increase in fallow periods, to at least two agricultural seasons instead of continuous cropping, in order to allow the land to restore its nutrients, by keeping the crop residues from previous harvests on the field, the use of mulching so as to preserve soil moisture, cool the soil surface, stabilize the soil temperature, and the reduction of crop density to avoid soil mining (Orindi and Murray, 2005; Benhin, 2006).

- **Increase in cultivated areas**

Paavola (2006) observed agricultural extensification as an adaptive measure to increase erosion, worsened by climate variability's. In this case, agricultural extensification is achieved either by cultivating without fallow period, shortening the fallow period or by clearing and transforming forest areas into agricultural land.

- **Selecting drought tolerant crops and varieties**

There is no doubt that the crops choice in farming systems in Africa is extremely climate sensitive. A study carried out in 11 African countries revealed that, for different ecological regions, farmers selected adapted crops. In moderate warm regions for example, farmers selected crops like maize, beans and groundnuts, whereas in dry areas, crops such as sorghum, millet and groundnuts were mostly grown (Kurukulasuriya and Mendelsohn, 2007). In Tanzania, farmers switch from maize to sorghum and/or cassava when there was a threat of drought or food insecurity, and switch to rice or banana when rainfall was abundant (Paavola, 2006).

A study from Burkina-Faso revealed that, most sorghum farmers for the past 15 years switched from using long cycle seeds that matured between 120-150 days to adopt seeds that matured within 70-90 days (Kouressy et al., 2008). Another study in drylands of Mali observed that farmers have adopted early varieties of millet that could mature within 70-100 days (Werner, 2010). However, choosing these early varieties, farmers would have to deal with residuals cost (Stern and Treasury, 2007). This mean that, as farmers choose to plant the early matured varieties, they may also be confronted with lower crop yields and residues which are often used for livestock feeding during the dry seasons. This leads to the conclusion that, adaptation in any case is not an easy and cost free option (Stern and Treasury, 2007).

- **Crop diversification and mixed cropping**

A few studies (Orindi and Murray, 2005; Kurukulasuriya and Mendelsohn, 2007; Hassan and Nhemachena, 2008) observed that farmers in most SSA invest in mixed cropping systems, by selecting crop combination that will survive the harsh environmental conditions. The most frequent combinations were maize-beans and maize-groundnut in moderate warm regions, cowpea-sorghum and millet-groundnut in hot regions, and millet-groundnut in dry conditions (Kurukulasuriya and Mendelsohn, 2007). In Mali, Samaké (2005) cited in Werner (2010) observed the following crop combination in drylands: millet-cowpea, millet-roselle (*Hibiscus sabdarifa*), groundnut-roselle and wouandzou-roselle. These combinations provide farmers with more flexibility across climates than growing a single crop on its own, and reduce the risks of complete crop failure, since crops are affected differently by climatic events (Hassan and Nhemachena, 2008).

Adapting to land degradation

Land degradation is one of the environmental hazards, which is not necessarily caused by climate variability's, although it can be initiated or worsened by them (Simonsson, 2005). Land degradation in most cultivated areas in Mali is supposed to have resulted from several droughts periods that the country has experienced, and anthropogenic actions such as unsustainable agriculture. Hence judicious soil management, by adopting good agricultural practices that enhances soil fertility such as improved fallow, agro forestry, and biomass transfer will be important in future (Mowo et al., 2006). Yossi et al. (2008) argued that such practices which could enhance soil fertility may be hampered in future, as population density is expected to increase.

In the Sahel farmers increasingly invest in livestock, same as pastoralists taking up agriculture, in order to diversify their income (Yossi et al., 2008). A study in few villages of the region of Sikasso in Mali observed that, by combining livestock keeping and crop farming, there was a more positive balance in nutrients input on Fulani fields, against a deficit in nutrient balance on Non-Fulani fields. This difference was explained by the high number of cattle and small cultivated areas as compared to Non-Fulani farmers with large areas and a limited number of livestock, often small ruminants (Ramisch, 2005).

2.5.1.2 Adaption strategies in livestock systems

Davies (2008) argued that, "pastoralism can only meet its economic potential and continue to provide environmental services when the nature of pastoral poverty is understood and when efforts are made to build pastoralists' capacities secure their rights and strengthen, not substitute their livelihoods".

Adapting to high temperature

- **Shade and shelter**

When temperatures increases, livestock farmers in South Africa invest in trees planting, such as *Acacia karoo* and *Celtis Africana,* so as to provide natural shades for their livestock (Benhin, 2006). *Acacia karoo* is a tree of open woodland and wooded grassland. It is very adapted to dry conditions, with long taproot which enables it to use water and nutrients from deep underground. It is also good in fixing nitrogen, and provides a good shade for the proliferation of grasses and other plants. *Celtis Africana* is a fast and easy tree to grow under a wide range of conditions such as: open grassland, mountain slopes, along river banks and in dense forest. Matured seeds germinate easily, and leaves are browsed by cattle and goats (Benhin, 2006).

Adapting to rain or water scarcity

- **Mobility**

Climate variability's are very common in the Sahel, and pastoralists have been facing these changes at decadal time scales (Mertz et al., 2009). These variability's have generated long traditional movements within pastoralists, and intensified during the severe drought period between 1970s and mid-1980s (Eriksen and Lind, 2009).

Mobility is an inherent part of pastoralist existence, depending on rangeland availability and resources such as water and pasture (Moritz, 2006; UNDP, 2009). In order to be productive, less damaging to the environment, maximize access to water, and pasture areas and to make use of scare resources in arid landscapes, Turner (2000) suggested a more dissemination of livestock in potential grazing areas or water bodies. A study on pastoralist coping mechanism in the horn of Africa revealed that, the distance trekked to livestock water sources almost tripled during drought periods (Kirkbride and Grahn 2008). However, Diakité (2010) argued that, this movement of cattle to water bodies only reinforces soil erosion and silting of the streams at these locations.

A study on pastorals mobility in Mali by Basset and Turner (2007) observed a movement from the Sudanian zone to the Sahelian zone. In this Sahelian zone, there is a decline in range productivity, but compensated by an increase in forage quality. Due to this high quality forage, Fulani's move their herds seasonally to the northern Sahel during the summer rainy season, until the dry seasons when the water bodies are then depleted. The pastorals movement also result from cumulative effects of numerous decisions resulting from both drought and ecological adjustment to declining pasture productivity in the north (Bassett and Turner, 2007).

Other studies (Sere et al., 2008; Galvin, 2009; Diakité, 2010) on pastoral mobility argued that, the ability to move livestock would be hampered in the future, as conservation policies, wildlife conflicts and population density increases. As population density increases, impacts would include the reduction of pastoral lands and livestock corridors to potential grazing areas. This would eventually obstruct livestock mobility, and this inability to move livestock would need to be compensated by significant economic inputs such as intensification of production, or diversification of livelihoods (Sere et al., 2008; Galvin, 2009).

Mobility is also a strategy adopted by pastoralist, to deal with disease pressure such as the *trypanosomiasis*, one of the major economically devastating disease and major constraint to livestock production in tropical Africa (Ugochukwu, 2008). However the pressure on livestock depends on the location. In Mali for example, it declines when pastoralists move north from the Sudano-Guinean zone into the Sudanian-zone (Bassett and Turner, 2007). One of the most important adaptive traits to tropical livestock is disease resistance. Therefore ensuring the continuous use of indigenous breeds that co-developed in specific systems over long periods of time and well adapted to the local conditions will be important for livestock keepers in the Sahel (Thornton et al., 2007; Blummel et al., 2010).

- **Permanent migration**

Permanent migration of livestock keepers to more resources abundant areas has been observed in Mali. It is estimated that, since the year 2000, more than 200 families of Fulani Guelgodji from the neighbouring countries and mostly from Niger, permanently settled to the Gourma region of Mali, in search of better grazing areas for their livestock (Diakité, 2010).

Adapting to extreme weather events

- **Herd management**

This strategy includes several aspects of management such as herd diversity, herd splitting, maintenance of female dominated herds, and herd size (Kirkbride and Grahn 2008; UNDP, 2009; Galvin, 2009; Diakité, 2010).

Herd splitting: Kirkbride and Grahn (2008) observed that, sharing, loaning and gift-giving are very much common among East African pastoralists, and intensifies during and after drought periods when families run short of milk or meat consumption. The sharing of such assets among pastoralists are year-round activities, forming an integral part of the communal way of life. This practice is very much common in the Maasaï communities in Kenya, whereby herds sizes are reduced by distributing few heads to friends, relatives or family members who have access to better grazing lands, in drought periods (Galvin, 2009; Kirkbride and Grahn, 2008).

Herd diversity and breed: Pastoralists manage both grazing and browsing livestock species, so as to optimize different range resources and ensure the conservation of rangeland ecosystems. In East Africa for example, pastoralists stock their herds with a mixture of cattle, camels, goats and sheep (Kirkbride and Grahn, 2008; UNDP, 2009). A change in herd composition is also applied within species. Faced with the rapidly vanishing of grass in the semi-arid zone of Northern Nigeria, Fulani's have switched their herds from the *Bunaji* breed that is very much dependent on grass, to keeping the *Sokoto Gudali* breed, which can digest browse much more easily (Thornton et al., 2008).

Maintenance of female-dominated herds: this management strategy is used to offset long calving intervals, hence stabilizes milk production (Kirkbride and Grahn, 2008).

Herd size: this measure ensures livestock survival during subsequent drought, by building up the herd size in recovery periods between two droughts (Kirkbride and Grahn, 2008). In the southern part of Africa, farmers respond to long drought periods by adjusting the stocking intensity of their herds, through selling of animals at younger ages (Benhin, 2006). During periods of prolonged drought, affected livestock keepers had to choose between reducing stock numbers, which is not attractive due to loss of prestige and savings, and purchasing feed for livestock, limited by seasonal scarcity and high cost (Sidibe-Anago et al., 2006). Thus, after major droughts of 1972 to 1974 and that of 1982 to 1985 in Mali, pastoralists fractionated their herds. Herds with effectives between 250 to 400 heads were reduced to 150 to even 100 heads, in order to match the available resources (Diakité, 2010).

- **Livestock feed supplementation**

The UNDP (2006) argued that the practice of supplementation of livestock grazing with other feeds is common during periods of shocks such as droughts, hence should be considered as a climate change adaptation measure. Feed supplementation varies depending on livestock breed, farming system and the ecological zone.

Feed supplementation for small ruminants

Climate variability's are increasingly affecting grassland productivity in drylands, and alternative feedstuffs such as cotton cake is limited by seasonal scarcity and high cost, therefore the need to search for alternative feeds (Sidibe-Anago et al., 2006). Consequently shrub and tree fodders are becoming an important component of browsers (goats, sheep and camels) diet (Devendra, 1989). Shrub and tree fodders provide green biomass of high digestibility and protein content when other feed reserves such as crop residues are limited, or have a low nitrogen content (Renard and ICRISAT, 1997). Some of the most widely used shrubs and tree fodders in arid and semi-arid areas are: the tamarind (*Tamarindus indica*), the acacia, with several species such as (*Acacia catechu*), (*Acacia nilotica*) and (*Acacia siberiana*). Others include the pigeon pea (*Cajanus cajan*), cassava (*Manihot esculenta*) and baobab (*Adansonia digitata L*) (Devendra, 1989; Madzimure et al., 2011) etc.

In many parts of the tropics, feed shortages and droughts are recurrent, and subsistence feeding mainly on cereal straws results in problems such as the reduced live weight and perpetual low productivity of livestock, delayed age at first parturition, increased interval between parturitions, increased nonproductive life of the animals and herd wastage (Devendra, 1989; Renard and ICRISAT, 1997; Madzimure et al., 2011). Therefore, shrubs and tree fodders are adequate alternatives diet supplements, due to their supply of dietary nitrogen, energy, minerals and vitamins. Other advantages associated to the use of these forages resources are: the accessibility on the farm, the provision of variety in the diet, the reduction in the requirement for purchased concentrates and the reduced cost of feeding (Devendra, 1989).

Baobab seed cake

Baobab (*Adansonia digitata L)* is a common tree legume in most arid and semi-arid areas, and very tolerant to high temperatures and long spans of droughts (OSMAN, 2004; Madzimure et al., 2011). It is mainly grown for it sours fruit and leaves, commonly used to make soup, and the pulp is used as a beverage and in food preparation. It serves also as feed for small ruminants like goats, and the fruit consists of large seeds, embedded in a dry acidic pulp and shell. Fermented seeds are used as flavoring soups, and the roasted seeds are used as a side dish, substituting peanut (OSMAN, 2004). Baobab seeds also contain valuable oil which can be extracted and used in cosmetic industry, and the by-product is a cake, with a crude protein content of about 17%, but inadequate to be used as a sole protein source in mid-lactating cows (Madzimure et al., 2011).

Feed supplementation for big ruminants

Several studies (Kossila, 1988; Savadogo et al., 2000; Ngwa and Tawah, 2002; OSMAN, 2004; Sidibe-Anago et al., 2006; Madzimure et al., 2011) have looked on alternative feedstuffs for cattle in arid and semi-arid areas and observed the commonly use of cotton seed cake and crop residues such as rice straw, groundnut haulm, cowpea vine etc.

Cotton seed cake

Cotton is an important cash crop in most tropical countries, and its by-product (cotton seed cake) is used as feed for supplementing domestic ruminants in period of limited availability of forages (Sidibe-Anago et al., 2006). A study on its nutritional value revealed that, cotton cake contains 325g of crude protein and 10,3MJ ME (metabolizable energy)/kg dry matter. Although it has been observed that cotton cake has a positive impact on milk production, it contains gossypol, an antinutritional substance which at high concentration can negatively affect reproduction and milk production (Sidibe-Anago et al., 2006).

Crop residues

Livestock production is west African Sahel is constrained by the limited availability of suitable feed in the dry season (Novembers to June), a period at which the concentration of crude protein of range-land forages may fall below 6% (less than 1% Nitrogen) (Savadogo et al., 2000). The growing importance of crop residues, is also due to the decline in grazing areas, caused by the conversion of pastoral lands, stimulated by demographic pressure (Ayantunde et al., 2007).

Without any differentiation for big or small ruminants, the main crop residues used by livestock keepers in the West African Sahel are stover of cereals such as sorghum, maize (*Zea mays*), pearl millet (*Pennisetum typhoides*), haulms of leguminous crops such as cowpea, groundnut and bambara groundnut (*Voandzeia subterranea*), and other straws such as rice (*Oryza sativa*) and cotton (*Grossipium hirsutum*) (Savadogo et al., 2000). Despite this variation in residues, pearl millet stover is the most dominant residue in the dry semi-arid (annual rainfall, 400-500 mm; length of growing period: 75-120 days) Sahel, whereas cowpea and groundnut are the more nutritious grain legumes, with 21% and 17% crude protein contain respectively (Renard and ICRISAT, 1997).

Although crop residues are important feed sources for Sahelian pastoralists, (Kossila, 1988) argued that most are characterized by a low protein, phosphorus content, marginal in calcium, high in fiber and lignin, leading to a low digestibility and limited voluntary intake. Hence, most crop residues are cut and stacked or shocked, so as to reduce leaf loss from leaching or wind damage, and to improve the stored feed quality (Kossila, 1988). It is also speculated that in-situ grazing of crop residues can result to about 60% of straws being wasted due to trampling, termites and nutrient depletion by weathering (Savadogo et al., 2000). In crop residues, the nutritional quality of the leave may be considerably higher than that of the stem: however rice straw is an exceptional case where leaves are of lower quality than the stems (Kossila, 1988).

In Burkina-Faso, farmers deliberately opt for crop combinations and management practices that optimize residue production. These residues are harvested, stored and used for own animals or sale to other farmers during critical feed scarcity, often in the mid late dry season. It is said that some farmers obtain more than 25% of their annual cash income from trading crop residues (Renard and ICRISAT, 1997).

- **Sheep fattening**

In the West African Sahel, sheep fattening is an important economic activity, especially during the Islamic festival known as the Tabaski (Ayantunde et al., 2007). The strategy is to fatten young lean male sheep, either obtained from the farmer's own flock or purchased on the market from 2-3 months. Each farmer fattens between 1-5 heads, which are normally tethered or kept in a small sheltered enclosure at the homestead, fed and watered individually. Fattening is particularly attractive to poor farmers including women, because it requires low initial investment, with a rapid turnover, socially acceptable, and easy market access (Ayantunde et al., 2007).

2.5.2 Policy based adaptations

Households and communities in most developing countries have developed with time a number of adaptation strategies in response to extreme climate events, and these strategies differ among households and communities, depending on their social capacity and resource available (Orindi and Murray, 2005). Therefore, "incorporating indigenous knowledge into climate change policies can lead to the development of effective adaptation strategies that are cost-effective, participatory and sustainable" (Robinson and Herbert, 2001).

Stern and Treasury (2007) argued that, developing countries (mainly SSA and most South Asia countries) would suffer more the effect of climate change due to their exposure to an already fragile environment, their economic structure and low incomes which constrain their ability to adapt. Hence, the IPCC concluded there is little evidence that autonomous adaptation would be efficient and effective. Therefore intervention is necessary, in order to avoid maladaptation (Adger et al., 2003).

A couple of studies (Renard and ICRISAT, 1997; Simonsson, 2005; Orindi and Murray, 2005; IFAD, 2008; Kirkbride and Grahn, 2008; UNDP, 2009; Eriksen and Lind, 2009; Leten et al., 2010) on institutional response to climate change have been published. These studies suggested the following responses: technology transfer, economic diversification, provision of micro-credit to vulnerable groups, direct support to the agricultural sector by the provision of improved cultivar to the local communities, irrigation systems, early warning systems etc.

- **Agricultural support**

Provision of improved cultivar to the local communities

As drought periods are expected to increase in future, the identification of drought tolerant varieties should be provided to the local farming communities. However, this should be done in consultation with the local communities, to ensure their acceptability (Orindi and Murray, 2005). A couple of institutions such as the International Institute of Tropical Agriculture (Fernandez-Rivera, 2001), the International Livestock Research Institute (Thornton et al., 2008) and the Institut d'Economie Rurale (Yossi et al., 2008) are working in West Africa, to develop improved crop varieties with resistance to biotic and abiotic stresses, and a better nutritional attributes (Renard and ICRISAT, 1997). Regarding cowpea, they have developed several varieties with combined resistance to important diseases such as, aphid, bruchid, thrips and striga. These improved varieties have potential yields of over 2tha^{-1} of grains and 3tha^{-1} of fodder, in areas with 500mm or more annual rainfall, and over 1tha^{-1} of grain and 1tha^{-1} of fodder in very dry areas with less than 300mm annual rainfall.

- **Nature conservation**

Trees planting

In order to reverse the deforestation process, more actions such as environmental laws and direct support from governments are noticeable in SSA. In the Wajir district of Kenya for example, the district government included environmental issues in their work plans, and the district commissioner is required to plant 1000 trees each year (Kirkbride and Grahn, 2008). In order to reach this target, schools throughout the district were provided with drought tolerant Neem-tree seedlings, and expected to continued until deforestation would be reduced by 70% in the district (Kirkbride and Grahn, 2008). Another example is from the Kotido district of Uganda, where the local council passed by-laws that obliged every household to plant trees. Also in Mali, the government and NGO's initiated trees planting in regions that have experienced strong deforestation. Planted tree species where *Eucalyptus camaldulensis*, *Anacardium occidentale, Acacia albida, Balanites aegyptiaca* and *Acacia nilotica*, due to their short growing period, and their use in the society (Yossi et al., 2008).

- **Other supports**

Micro-credits

Access to credit is important because it encourages the adoption of various technologies that could enhance adaptation (Hassan and Nhemachena, 2008). With more finance and other resources at their disposal, Hassan and Nhemachena (2008) argued that farmers are able to make use of their available information to change their management practices, in response to changing climate and other conditions. With access to markets and financial resources, farmers would be able to buy new crop varieties, new irrigation technologies, fertilizers in times of need and other inputs they may need to change their practices, to suit the forecasted climate changes (Hassan and Nhemachena, 2008; UNDP, 2009).

Improved market accessibility

Hassan and Nhemachena (2008) argued that market access in an important factor affecting the adoption of agricultural technologies, because it provides an important platform for farmers to gather and share information. Two types of market access have been differentiated; input markets and output markets (Mano et al., 2003). Access to input markets allow farmers to acquire farm inputs such as different seeds varieties, fertilizers and irrigation technologies (Hassan and Nhemachena, 2008), while access to output markets provide producers with positive incentives to produce cash crops that can help improve their resource based, and their ability to respond to changes in climate (Mano et al., 2003; Hassan and Nhemachena, 2008).

Early warning systems

The UNDP (2009) argued that the current existence of uncertainties makes it difficult for affected communities to establish adaptation measures and technologies in a timely and effective manner, thus the need for early warning systems and improved climate information. They suggested that a security strategy for food and fodder needs to be developed, so as to allow a timely response to minimize death, suffering, and the undermining of pastoral livelihoods during and after droughts, as well as other disasters.

In Mali and most SSA countries, the USAID has established a Famine Early Warning Systems Network (FEWS NET), an information system designed to collect, analyse and distribute to decision-makers current information on flood situations and other climatic risks, so as to enable timely measures to prevent food-insecure circumstances (Simonsson, 2005).

2.5.2.1 Policy driven adaptation in Mali

Improvement of irrigation systems

Mali is crossed by two of the largest rivers in the African continent, the Senegal River with more than 900km long, and the Niger River with 1.600km long (IFAD, 2008). The Niger Delta in the area where most of the rice is cultivated in Mali, and this area is reported to loss between 40-50% of its water annually to evapotranspiration (Simonsson, 2005). Hence the government has carried major projects such as the construction of dams along the River Senegal and Niger, for continuous irrigation of croplands along these rivers (Leten et al., 2010). Such intervention encouraged floodplains agriculture in the Niger Delta. The construction of the Sélingué and Sotuba dams with improve irrigation has made it possible for farmers to cultivate two rice crops each year alongside these dams (Simonsson, 2005; Leten et al., 2010).

Others

Several projects have been undertaken by the government and stakeholders, in respond to climate change in Mali. These projects include the ODEM (l'Opération pour le Développement de l'Elevage dans la Région de Mopti), the PAAP (Projet Aménagement Agro-Pastoral), the CAT/GRN (Cellule Aménagement de Terroirs et Gestion des Ressources Naturelles) and the PNVA (Programme National de Vulgarisation Agricole) (Yossi et al., 2008).

Beside the above, Mali has developed a preliminary nation action plan on climate change (NAPA), which includes the following components:

- Teaching farmers how to make use of agro-meteorological information
- Building and maintenance of wells
- Developing new cropping systems
- Digging of canals to irrigate more land and cleaning of canals that have been filled with sand
- Provoking rainfall
- Increasing the use of improved varieties that are adapted to local conditions
- Using new agricultural technologies
- Diversification of agricultural production
- Strengthening early warning systems
- Establishing cereal banks
- Constructing new irrigation schemes based on water from the Niger and Boni rivers
- Strengthening fodder production (particularly of *bourgou* on the riverbeds)
- Improving access to credit for agricultural activities

Wood and charcoal are the main source of home energy in Mali, and due to the high pressure on these forest resources, the government has recently developed a strategy for domestic energy development (Aune, 2008). Important components of this strategy include:

- The use of improve stoves
- Promoting the use of gas for cooking
- Improving the efficient use of charcoal
- Establishing control of wood and charcoal market
- Improving management of forest, including replanting.

Some of the national adaptation programmes to climate change in the livestock sector in Mali are presented on the table below.

Table 6 National adaptation programme in livestock sector in Mali

Priority programmes	Action plans
1. National planning program and security of pastoral areas with options aiming at improving pastoral water, livestock feeding with cultivated fodder crops and research for specific forage plants in arid and semi arid areas.	- Pastoral Hydraulic: Strengthening of investment, management and building of infrastructures. - Animal feed: Strengthening fodder cropping, feed inputs and minerals during lean periods. - Animal feed: Support extension forage cultivation and action research on specific native plant species for feed in arid and semi-arid.
2. Program on animal health and public veterinary health, taking into account all aspects of vector-borne diseases and infectious diseases.	- Animal Health: Building capacity for prevention and treatment of animal diseases and epidemiological monitoring of emerging diseases and vector.
3. Program to support animal science and veterinary for the preservation of endemic species adapted to climatic rustic	- Veterinary and zootechnical research: Identification, preservation and dissemination of endemic species adapted to climate risks
4. Program to support marketing and promotion of industrial units in the livestock sector to de-stock and reduce the burden on pastoral rangelands	- Promotion and Enhancement of livestock: Design and implementation of industrial investment (slaughterhouses) to destocking of livestock and promote the export of meat.
5. Program of capacity building of stakeholders, including pastoral civil society, through information, education and communication for the implementation of local platforms, regional and national prevention and management of conflicts.	- Pastoral civil society: Strengthening of farmers and their socio-professional organizations. - Prevention and Conflict Management: Consolidation of traditional mechanisms and animation of platforms for the prevention and management of conflicts and pastoral land.

Source: Diakité (2010)

2.6 Identification and documentation of local innovations

This chapter gives an overview on how to identify and document farmer’s innovations. Some of the strategies used in previous studies are reviewed in this chapter, with eventual constraints, from both farmers and scientist site.

According to PROLINNOVA (2009), there is a clear difference between local innovation and local innovations with an S. Local innovation is regarded as: the process of developing new and better ways of doing things, whereas local innovations are the new ways of doing things, resulting from the innovation process.

Little is yet documented about farmers’ innovation in Africa (Reij and Waters-Bayer, 2001). Farmers innovation especially in Africa is described as endogenous agricultural innovation, which are new initiatives and processes of local groups or individuals (Sanginga et al., 2009). In Reij and Waters-Bayer (2001) literature, they defined a farmer innovator as: "someone who develops or tries out new ideas without having been requested by outsiders to do so". New farmer’s ideas in this context would mean starting in the farmer's lifetime and not inherited from parents. Assefa (2010) described Innovativeness as the capacities of individuals or groups, to look into given situations from different angles, in order to make new values out of them, without affecting the broader environment negatively.

Nevertheless, farming techniques in Africa are often transferred from one generation of farmer to another, and in the course of adoption of inherited techniques, adjustments can be made in order to meet certain realities such as changing environment, market demand and others. It is often hypothesized that most innovations occurring in Africa and other developing countries are merely adjustment of existing system, what Rice and Rogers (1980) called a reinvention of innovation. Reinvention itself is the degree to which an innovation is changed by the adopter, in the process of adoption or implementation it, after its original implementation (Rice and Rogers, 1980).

It is important to note that, “the term innovative farmer is not given to a certain social or economic group in the community, but to those farmers (regardless of their sex, wealth status or age), who are trying to add values to existing practices through creative engagement and experimentation, with a passion to seek changes that have economic, social and environmental significance” (Assefa, 2010).

2.6.1 Identification of local innovations

The identification of innovative farmers is not an easy task for several researchers. It requires a different approach than the traditional survey method which most researchers are familiar with. In complex systems such as in sub-Saharan Africa, the identification of local innovations requires time, patience and commitment to travel long distances, sometimes in a harsh environment (Assefa, 2010). It is even more difficult, given the fact that, most grassroots innovations systems in sub-Saharan African are both from endogenous and exogenous components (Sanginga et al., 2009). Nevertheless, in the process of local innovations identification, PROLINNOVA network members have developed different guidelines for what can be consider new (innovation). Some suggested, it should have been developed within the past 20 to 25 years, referring to one generation, others argued that it is acceptable if it was developed within the working lifetime of the farmer, therefore in the last 60 to 70 years (PROLINNOVA, 2009).

Local innovations are site-specific, hence can seldom be replicated exactly elsewhere. Consequently, the spread of innovations beyond localities particularly in Africa where smallholder farming is done under diverse conditions is not a good indicator of success. However, if shared, they can at least stimulate experimentation and innovation in other localities (Waters-Bayer et al., 2006).

Local innovation and indigenous knowledge are not valued by scientists, sometimes even by farmers themselves (Fenta and Assefa, 2009), that is why PROLINNOVA seeks to build partnerships among major stakeholders in agricultural research and development to enhance processes of farmer-led participatory innovation (Waters-Bayer et al., 2007).

Local innovations, traditional practices or invention?

A traditional practice differs from local innovations in the sense that, it is transfer from one generation to another. However, that stays as traditional practice if the next receiving generation do not change or modify the practice. Local innovations come about when farmers try to adapt the traditional practice, by replacing a component or ingredient of the practice that has become maybe scarce or out of stock. For example, when fertilizers become too expensive for crop farmers, they invite livestock keepers to camp on their farms, so as to manure it with their waste, PROLINNOVA (2009) argued that, this can be documented as traditional practices, but cannot be regarded as innovation. As a result, it is difficult to make a straightforward distinction whether something is an innovation or not, because the boundaries may be hazy. What differentiates an invention from local innovations and traditional practices is that, an invention is new in absolute terms; it can be a technique or technology that had never been discovered or developed anywhere else before (PROLINNOVA, 2009).

PROLINNOVA-Ethiopia adopted a schematic presentation to explain the conceptual framework of farmer innovation on figure 3 below. As shown on the figure, farmer's innovation can result either from the modification of both scientific and indigenous knowledge, through informal experimentations, driven by farmers' wisdom or simply occur by chance (Serendipity).

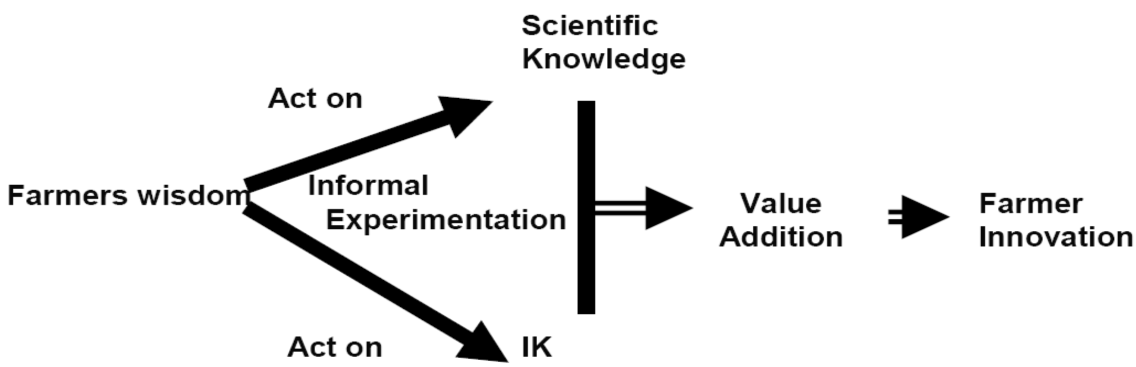


Figure 3 Processes leading to farmers' innovation

Source: Assefa (2010)

Methods used in identifying local innovations

Wettasinha et al. (2008) reviewed a number of methods that could be used in the process of identifying potential innovators.

a) Trough observation in farmer societies, in order to identify new practices.

b) By identifying key informants such as extension workers or local leaders, expecting these later could know or identify innovative farmers in their locality.

c) The use of the chain or snowball interviews, a method that can take place after the innovative farmers have been identified by key informants. This consists of identifying other innovative farmers, by asking those innovative farmers identified by key informant and so on.

d) Reconstructing innovation. This consists of asking a group of farmers to list some of the major agricultural innovations that took place in their areas, and adopted by most families. By identifying these major agricultural innovations, farmers that played important role in introducing, adopting or developing them are identified and interviewed.

e) Organising an innovation fair or workshop, where farmers could present the ideas they developed themselves or by others.

Researchers' perception and challenges in identifying local innovations

Assefa, (2010) argued that, most researchers nowadays still have the tendency to believe that resource poor farmers are unable to do research, because it is the exclusive mandate of formally established organizations and formally educated people. Therefore, the comfort zone for such researchers is behind closed doors or on stations, with peer groups.

Despite of the above misconceptions which also implicate that, farmers are unable to solve their own problems or cope with their difficulties, there are growing numbers of researchers who regard farmers as partners with something to offer, and not just to receive. This set of researchers do appreciate the innovative capacity of smallholder farmers, therefore keen to work with them (Wettasinha et al., 2008; Assefa, 2010). However, this set of researchers may be confronted with practical challenges, because it is a new research domain, and requires a different survey approach without particular tools, as the normal methods which most researchers may be familiar with, and the data generated are difficult to use in the conventional statistical methods of analysis. Researching on local innovations is time consuming, therefore demands patience and commitment to travel long distances, sometimes in harsh environments (Assefa, 2010).

2.6.2 Documenting local innovations

Dimensions of an innovation

Several dimensions of an innovation need to be documented, in order to fully understand the implication of its practice. Gupta (1990) described some of those dimensions, which include:

a) The ecological context, which is related to the soil, climate, crop interactions etc.

b) The historical context, those are major events or exposures that lead to the development of the innovation, such as crop failure and others.

c) Economic and administrative context, this is the economic goals that lead to experimentation of new varieties or others regions for cultivation.

d) The serendipity, this explained if the innovation evolved by accident or not.

e) Who evolve or widespread the practice, an individual or group of farmers.

f) The name of the village and the farmer innovator are very important for documentation. There should also be a brief background of the farmers' family, to say if he or she is a native of the same village or emigrant, age, family composition and activities. The first trial period should be documented, and if it was shared or not.

g) A thorough description of the innovation, and what makes it different from other practices, preconditions for further trial, as well as site effects: positive or negative (Gupta, 1990).

Farmer-Led Documentation of innovation (FLD)

FLD of local innovation is an empowering process whereby, the local communities take the lead role in the documenting process (Rütter, 2008). Until recently, the documentation of local innovations was done by outsiders, and the result stored out of reach of the owners (farmers). That is why there has been a move towards Farmer-Led documentation, whereby farmers are key actors in the process, and the result is putted in a language being visual, spoken or written that they could understand. According to Rütter (2008), FLD enables the share of innovations, and also describe the process through which an innovation came to be. In FLD, community members are trained to use particular equipment such as cameras or audio recorder, and the outcome is presented to the community for discussion and validation. However, future perspective from development agents should emphasise on strengthening traditional methods of local knowledge sharing and documentation already used by local communities (Rüter, 2008).

Farmers' constraints in innovating

PROLINNOVA-Ethiopia identified a few factors that may hinder the innovative capacity of farmers. There is the limitation of resources, which is believed to hold farmer back from innovating. Most farmers are not eager to take risks and carry experiments with their scanty resources. Beets (1990) argued that: "one of the main features of subsistence farming is that, farmers produce in order to live. Hence, they often resist changing production methods since, when the change turn to be unproductive, their livelihood and survival are directly threatened". Among others is the dissuasion from the society; most people in local areas have the tendency to believe that, only the literate and intellectuals like extension workers could bring something new and important to the farmers, as a result no one in such societies would expect a poor farmer to be a source of innovation, that could potentially change lives (Assefa, 2010).

3 MATERIAL AND METHODS

3.1 Study area

This study was carried out in the Cercle[1] of Bankass, council of Deguessagou, located in Mopti region of Mali.

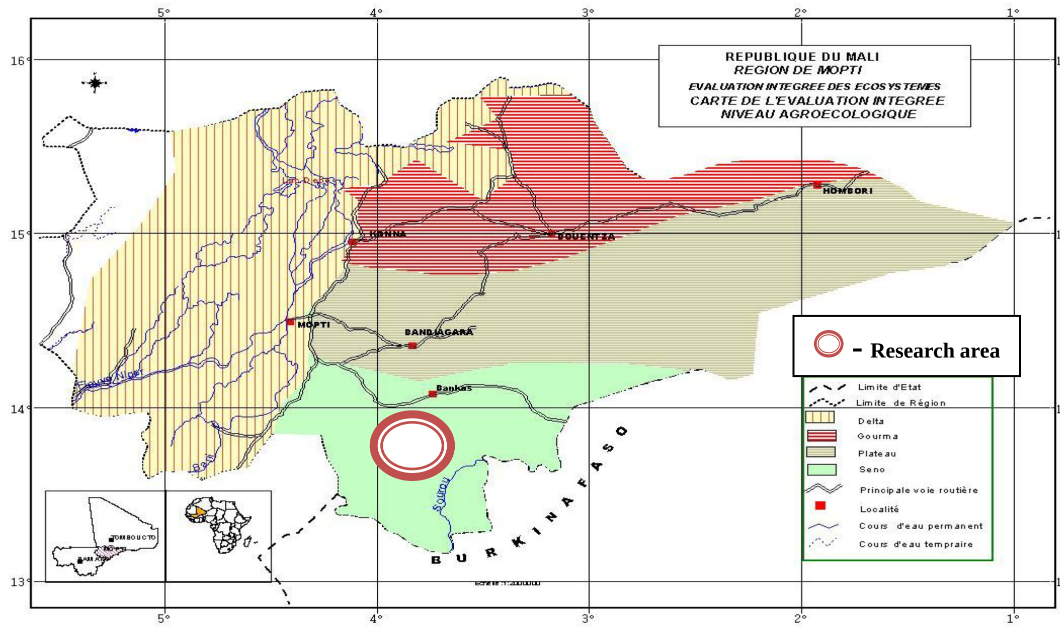


Figure 4 Mopti region, various agro-ecological zones and study location.

Source : (Ministère de l'environnement et de l'assainissement, 2009)

3.1.1 Location and climate

Mopti in known as the 5eme (Fifth) region, located at the central Mali. It lies between 15°45 and 13°45 latitude, and the meridians 5°30 to 6°45 west longitude, and covers an area of 79.0176km^2, which account for 6,34% of the national territory. Mopti has eight circles, four located at dry or exposed zone: Bandiagara, Bankass, Douentza and Koro, and four in flooded area: Djenne, Mopti, Tenenkou and Youvarou (PROMISAM, 2007; Ministère de l'environnement et de l'assainissement, 2009).

The region of Mopti is located halfway between the Sahelian zone (150-550mm isohyets) and the area Northern Sudanian zone (isohyets 550-750mm). The first zone is characterized by an arid to semiarid system, while the second it characterised by wet lands, mainly in the interior Delta of Niger, and cover only a small part of the region.

Rainfall in Mopti region is seasonal (June-September), with late July and early August the periods with highest precipitation. The annual precipitation in the Séno ranges between 200 to 400mm, with high variation in time and amount. The low precipitation in this zone is accompanied by high temperature, with absolute maximums reaching more than 45ºC in the

[1] Cercle is a division under a region (province): for example, the Cercle of Bankass is a division under the region of Mopti.

dry season. However, average daily means temperatures vary between 23^{o}C to 15^{o}C at night in the cold season (December-February). In the dry season (March-May), temperatures vary between 33^{o}C at night to up to 45^{o}C at day time (Werner, 2010). Strong winds occur from February to August, with maximum speed in June. Sunshine duration per year is estimated to 3200 hours (Simonsson, 2005; PROMISAM, 2007).

The graph below illustrates the variation in the number of days with rainfall in two Cercles of Mopti; Bankaas and Mopti, between the years 1998 to 2006. NB: Mopti is a region, but under this region there is also a Cercle called Mopti. Hence, Mopti in the figure below refers to the Cercle of Mopti, not the entire region.

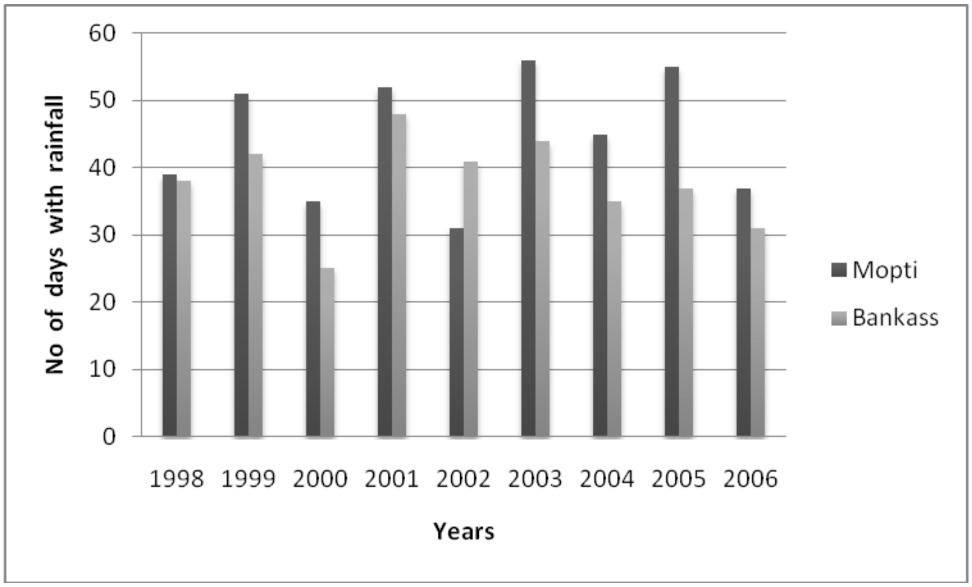


Figure 5 Number of days with rainfall in the Cercle of Mopti and Bankass

Source: Extracted from: Ministère de l'environnement et de l'assainissement (2009)

3.1.2 Natural resources

Land Resources

The Séno zone is divided in two zones: the Séno-Bankass, a vast plain of more than 6 527km^2, and the Séno-Mango zone, estimated to 9 300km^2 (Werner, 2010). The most common soils in the Séno are the sandy loamy and sandy-clay soils, often on shallow because of the extensive outcrops sandstone. According to the Ministère de l'environnement et de l'assainissement (2009), the arable land in the Séno covers about 33% of the total land area. The Seno is characterised by a very high pressure of land used by agriculture and mainly rain fed. This form of agriculture occupies about 65% of the area, mostly monoculture millet with few pasture lands. Studies conducted by SOS-Sahel observed that land distribution in the Séno was at a ratio of 1,3ha per capita in 1996, against 1,09ha in the year 2008, hence a decrease of 2,91% (Ministère de l'environnement et de l'assainissement, 2009).

Vegetation

The natural vegetation in the Séno-Bankass is dominated by grassland, described as a dwarf type of vegetation, sparse and difficult to reproduce. This dwarf vegetation is formed by a herbaceous cover, mostly annual grasses such as the *Cenchurus biflorsus, Schoenefeldia gracilis* and *Dactyloctenium aegypticum,* with dominant forbs *Zornia glochidiata and tribulus terrestris* (Turner 1998 cited in (Werner, 2010)). However on dunes and sandy areas, the *Aristida* species dominates (*Aristida mutabilis, Aristida pallida* and *Aristida papposa*). The most dominant tree species are in the Séno are the balanzan (*Faidherbia albida*), the wild plum (*Poupartia birrea*), the Kapok (*Bombax costatum*), the shea (*Vitelari paradoxa*), the tamarind (*Tamarindus indica*), the African locust (*Parkia biglobosa*), the wild dates (*Balanites aegyptiaca*) the baobab (*Andasonia digitata*) and neem (*azadirachta indica*) (Ministère de l'environnement et de l'assainissement, 2009).

Crop production

The Séno-Bankass is a vast plain of more than 10 000km^2, where rainfed crops occupy about 65% of the total area (Ministère de l'environnement et de l'assainissement, 2009). Agriculture is dominated by crops such as millet, fonio, cowpea, groundnuts, maize and beans. Table 7 below list the crops and area cultivated from 1999 to 2006 in the Cercle. It is important to note from this table that, from the year 1999 to 2005, there has been an increase of 20 000 hectares of cultivated area, giving a 32,2% increase in cultivated area within seven years, while the production has barely increased to 13% (Ministère de l'environnement et de l'assainissement, 2009).

Table 7 Crops and area cultivated in Bankass, from 1999-2006

Period	**Millet**	**Sorghum**	**Maize**	**Fonio**	**Beans**	**Groundnut**	**Area(ha)**
1999/2000	55 800	13 000	240	3 400	2 000	7 500	**89 440**
2000/2001	45 945	10 000	142	3 060	2 000	5 880	**73 587**
2001/2002	55 800	13 000	240	3 400	2 000	7 500	**89 440**
2002/2003	54 000	9 708	155	3 243	1 700	6 500	**82 306**
2003/2004	59 092	14 305	360	4 090	2 065	8 100	**96 862**
2004/2005	57 848	13 289	475	4 100	2 325	9 095	**96 272**
2005/2006	76 000	15 500	550	4 300	2 500	9 950	**117 650**

Source:(Ministère de l'environnement et de l'assainissement, 2009)

3.1.3 Human population

The population of Mopti in 2007 was around 1 865 297 inhabitants, according to Ministère de l'environnement et de l'assainissement (2009). However, PROMISAM (2007) forecasted for 2010, a population of 2 021 673 inhabitants, making it the second most populated region of the country, after Koulikoro. Moptis' population is predominantly rural (80%), divided in seven major ethnic groups: the Dogon (farmers, agro-pastoralists and artisans), the Fulani (livestock keepers and agro-pastoralists), Bambara (farmers, agro-pastoralists and artisans), Marka (farmers, agro-pastoralists and artisans), Bozo-Somono (fishermen and agro-Fishermen), Songhoi the (agro-pastoralists and small businesses), and a small minority of Bobo, which are generally farmers, agro-pastoralists and craftsmen (Ministère de l'environnement et de l'assainissement, 2009).

The data on table 8 below shows the projection in change of population in the region of Mopti. This table suggest that, the annual growth rate in Mopti since the census of 1998 is about 1,4%.

Table 8 Mopti human population from 2006 to 2010

Year	**Men**	**Women**	**Total**
2006	897 630	918 460	**1 816 090**
2007	921 951	943 346	**1 865 297**
2008	946 913	968 886	**1 915 799**
2009	972 668	995 239	**1 967 907**
2010	999 239	1 022 434	**2 021 673**

Source: PROMISAM (2007)

3.1.4 Livestock population

Mopti differs from other regions by its high potential in livestock keeping. Livestock found in this region are camels, cattle sheep and goats, distributed on a pastoral area estimated to 4,7 million hectares (PROMISAM, 2007; Leten et al., 2010). According to Werner (2010), most livestock in the region of Mopti are kept in a pastoral or agro-pastoral system, with seasonal transhumant movement patterns.

The livestock population in Mopti for the year 2007 is shown on the table below.

Table 9 Livestock population in the region of Mopti

Species	**Number**	**Percentage (%)**
Cattle	2 125 500	25,8
Sheep	2 480 620	30,1
Goats	3 304 500	40,1
Horses	151 120	1,8
Donkeys	153 520	1,9
Camels	5 780	0,1
Pigs	10 780	0,2
Total:	**823 1820**	**100**
Poultry	4 628 750	

Source: PROMISAM (2007)

3.2 Data collection

Data collection took place from March to May 2010 (8 weeks of field research). It focused on ten villages (2 host villages and 8 visited villages), two NGO's and three government services working in the field of adaption to climate change in the Séno. The research approach was qualitative, with a combination of several methods such as individual interviews, focus group discussion or group interviews, workshops and participants' observation. This combination of different research methods was purposefully for data triangulation.

The languages of communication in the research area was Fulfulde, hence the necessity to use a translator. Beside participants' observation and informal discussion periods, all the interviews were recorded with a digital recorder, and transferred into a field computer, and field pictures taken.

3.2.1 Selection of host villages

Host villages were Ouandiana and Deguessagou, selected during a group discussion in Bankass. Participants of this group decision were: Moussa Keita[2], Mamadou Bocum[3], Katja Flockau[4] and Roland Kuete[5]. Ouandiana was the first selected village, so as to continue the activities engaged by the previous research team, and Deguessagou was the second host village. The first selected village (Ouandiana) already fulfilled the selection criteria; therefore the emphasis was on the characteristics of the second village. Some of the key criteria for the selection of the second host village were:

- Importantly an agro-pastoral and Fulani village
- A non-conflicts village
- A village with less outside intervention from NGO's

Other important aspect taken into consideration by the researchers was the distance between the two host villages, due to the lack of transportation means and sharing of research materials. Consequently, the two villages were chosen about 5 kilometres away from each other.

3.2.2 Selections of neighbouring villages to host villages

Neighbouring villages were selected based on a regional map from the government officers in the council of Diallassagou. Information gathered from the key informants in host villages, were also taken into consideration, mainly regarding the working atmosphere in the selected villages. However the selection criteria used for the host villages were not of importance for this set of villages. Important aspects were the distances from the host villages and the village activities. Because of the heat at that period of the year and the available means of transport (a motorbike), villages within 5 to 15 kilometres distance from host villages were preferred. Visited villages around Ouandiana were: Dinto, Yalema, Bollé and Sankara, and those around Deguessagou were: Sokoro, Nema, Dianwely and Maga.

[2] Equipe systeme IER Mopti
[3] Animateur AMPRODE Sahel Bankass
[4] Student researcher
[5] Student researcher

3.2.3 Selection of NGO's and governmental services

Interviewed NGO’s were selected in the city of Bankass, the head quarter of the Cercle. Most NGO’s and Governmental services working in the region are established in Bankass. Those interviewed were: SahelEco Bankass, Caritas Bankass for the NGO’s, and servives d’élevage, d’ agriculture and eaux et forêts, for governmental services.

3.3 Methods of data collection

Two weeks was the duration of stay in each of the host villages. However, the first week was for the interviews within the village, and the second week was to visit neighbouring villages.

Due to the importance of tee in these communities, interviews in both host and neighbouring villages were purposefully conducted around a cooking tee. It was shared with everybody present at the session, aimed at generating a convenient atmosphere for open discussions.

The table below shows the interviews done in host and neighbouring villages, as well as the types of interviews.

Table 10 Interviews carried out in host and neighbouring villages

Village	# of individual interviews[6]	# of focus group discussions or group interviews	Workshop
Host villages			
Ouandiana	4	4	1
Deguessagou	6	5	1
Neighbouring villages			
Sokoro	8	2	-
Dinto	-	1	-
Nema	2	-	-
Maga	1	-	-
Dianwely	5	1	-
Yaléma	-	1	-
Sankara	-	1	-
Bollé	-	1	-
Total: 10 villages	26	16	2

As shown on the table above, the workshops were organised only in the host villages, so as to help the villagers in setting the objectives of their future association.

3.3.1 Key informant interviews

Key informant interviews in NGO's and government services

Two NGO’s were interviewed and three governmental services, as shown on the table 12 below. Those were semi-structured interviews, using a preset questionnaire (see Annex 10.2), for both NGO’s and governmental services in the circle of Bankass.

[6] Individual interviews in host and neighbouring villages were done using different questionnaires

Innovations promoted or supported by both the NGO's and governmental services, regarding adaption to climate change.

- Getting their perception regarding climatic problems in the region, and impact on farmers.
- Strength and weaknesses of farmers in dealing with climatic problems
- Farmers' constraints in adopting innovations etc.

Table 11 Key informants in NGO's and Governmental services

Location of informants	Persons interviewed	# of interviews
NGO's		
SahelEco Bankaas	Housseini Sacko: Project coordinator	1
Caritas Bankaas	Issa Guindo: Development agent	1
Governmental services		
- Services d'Agriculture de Bankaas	Boubakar Diakité: Chief of sector	1
-Service d'élevage de Bankaas	Lassina Diallo: Chief of sector	1
-Services des eaux et forêts de Bankaas	Sidy Sofara: Chief of sector	1

Key informant interviews in villages

Those were the village chiefs, because they are the first contact persons in the village. However, in cases of prolonged absence, the chief may appoint a representative, for the duration of his absence. During interviews, village chiefs were often accompanied by their assistants, called Notables.

The first set of key informants' interviews was in the host villages, aimed at gathering information on the following issues:

- Information on various social groups, the population (number of families)
- Livelihood activities of the village.

The second set of informants was in the visited neighbouring villages: here the purpose of the interview was to get an overview on the village activities, and the identification of potential innovative farmers that were later interviewed. Among visited villages, the chief of the villages of Dinto, Yalema, Bollé and Sankara were not present in their village at the time of the visit. In these villages, the chiefs' representatives selected the innovative persons interviewed.

Key informants' interviews in host and neighbouring villages are shown on the table below.

Table 12 Informant interviews in host and visited villages

Location	**Persons interviewed**	**# of interviews**
Host Villages		
Deguessagou	Ali Diaguayeté: Village chief	1
Ouandiana Fulfudé	Bourbou Diagayeté: Village chief	1
Ouandiana Habé	Ousmani Guindo: Village chief	1
Neighbouring villages		
Sokoro	Essamba Karakodio: Village chief	1
Dianwely	Belko Oumaro Diagayeté: Village chief	1
Maga	Seidou Damango: Village chief	1
Nema	Ousmane Diagayeté: Village chief	1

3.3.2 Participant observation

Participant observation was part of the daily activities and took part often early in the morning or in the late afternoon. This because most village activities occurred at these periods of the day, due to the extreme heat occurring in the middle of the days. Participant observation was done by going round the village to see what activities the people were doing, and later asking them about activities they intended doing for the next day, so as to take part in the process. Those activities were in most cases the transportation and distribution of farm manure, the harvesting tree leaves for small ruminants etc. Young men were most often accompanied in their farm/herding activities, in view of the fact that the women were mainly engaged in the household activities such as pounding the millet, cooking, fetching of fuel wood and water from the well. Older men allocate the task to younger herders or farmers, as most field works were power demanding, such as transporting and distributing of compost.

The aim of participant observation was to understand the management practices of agro-pastoralists, thus covering the following aspects:

- How animals were kept, fed and sources of livestock feedstuffs.
- The type of work carried out on the fields, how it was organised and by who.
- Identify components of the farming system, so as to establish the relations between livelihood activities.

Living in the village, casual or informal discussions in the course of interacting with the people during tee or meals times have been other sources of data. Using this method of data collection, field notes and pictures were taken.

3.3.3 Individual interviews

Individual interviews in host villages

Most individual persons interviewed were those absent during the focus group discussion sessions, but whose names were mentioned as persons to meet for further information. For example in Ouandiana, two livestock keepers were interviewed based on the recommendation from other livestock keepers during a group interview. These persons were in most cases regarded as expert in given activities. As a result, six individual interviews were done in Deguessagou and four in Ouandiana, all using a questionnaire (see Annex 10.1). However, questions included the following:

- Farm history; that is how the livestock keepers or farmer acquired his/her herd or farm.
- An overview on farming activities
- Activities carried out beside main activities
- Climatic changes perceived by the livestock keeper or crop farmer for the past two decades
- How they are impacted by changes
- The coping strategies adopted or planned.

Individual interviews in neighbouring villages to host

Individual interviews in neighbouring villages were conducted with presumed innovative farmers, and entirely selected by the key informants (village chief). Selection criterions included the following characteristics:

- A crop farmer or livestock keeper from the village
- A farmer that was regarded as model by others in the village.
- A farmer frequently carrying experiment or trying new things on his farm.
- Most productive or experience farmers etc.

Once the farmers were identified, the interview was scheduled as follow:

- Self introduction from the farmer and researcher side, as well as the purpose of the research.
- The livelihood activities of the selected farmer, so as to know which activities they were involved.
- Type of experiment or innovations that the farmers were involved in, or more precisely regarding the adaptation to climate variability.

In case there was not a clear innovation from the farmers' side, the approach was changed and the following were compared:

- Regarding livestock's, the focus was on the difference in feeding options of livestock 10 to 15 years ago, as compare to their current situations. Hoping to identify novelties that occurred within livestock feeding.

- Regarding crop farmers, sources of farm inputs and farm management techniques of the past 10 to 15 years were compared to the current one, so to identify major adjustment in the farming practices.

The aim was to register innovations carried out by livestock keepers and farmers, which were potentially helpful for other communities, if possible within adaptation to climatic pressures.

3.3.4 Group interviews or focus group discussions

Group interviews in host villages

A group interview was done in major ethnic groups of the host villages, and each group interviewed in their various quarters. In case of limited time at the time of the interviews, further appointments were made for further discussions. Hence some ethnic groups were interviewed twice, like in Deguessagou.

Groups were between 5 to 10 participants, and in most cases aged between 30-81 years. However, participation was open for both women and men, old and young farmers within the ethnic group. Most group interviews were done with men, as women were most often occupied in their household activities. But, a group interview with women was done in Ouandiana, made up of women between 25 to 70 years of age, willingly gathered for an interview. Group discussions were designed to cover the following aspects:

- The livelihood activities of the villagers
- Climatic changes perceived for the last two decades in their locality, and problems such as high temperature, increase wind speed or unreliable rainfall etc. were pointed out
- The impacts of the listed changes on their livestock keeping and crops farming
- Adaption strategies to the listed impacts

Group interviews in neighbouring villages to host

In those villages, participants ranged between 6 to 10 farmers, often both livestock keepers and crops farmers that were regarded as most innovative in the society. They were selected by the village chiefs, with the same characteristic as with individual interviews in neighbouring villages.

The interview focused on the following aspects:

- Livelihood activities of the selected farmers
- Climatic problems they have been exposed to
- Adaption measures they have used to overcome such problems

In cases where no adaptation measures that were regarded as innovation were given, the following differences were asked:

- Regarding livestock's, the focus was on the difference in feeding options of livestock 10 to 15 years ago as compare to their current situations, so as to determine novelties in livestock feeding.

- Regarding crop farmers, sources of farm inputs of the past 10 to 15 years were compared to the current one, as well as major adjustment in the farming practices.

Every participant was given the chance for expression, so as to identify innovations that individuals or groups developed.

3.3.5 Workshop

Two workshops were organised in both villages, between 15 to 20 participants. Participation was open for all interested persons from all the social groups, men and women, young and elderly famers. They lasted for half a day, and during this period farmers were called to do some brainstorming in small groups of 4 to 5 persons. Topics of discussions were:

- First how their various domains of activities, being livestock keeping or crop farming were impacted by climatic changes.
- Second to that, they had to specify solutions they have adopted, taught or heard, vis à vis of the problems listed before.
- The third part consisted of looking at what was necessary for the accomplishment of the suggested solutions.

Participants had the choice to be identified as crop farmer or livestock keeper, because work was done in groups following that identity. In Deguessagou for example, participants were 15, with 10 livestock keepers and 5 farmers. Therefore 3 groups of 5 persons were formed, one group of crop farmers and two groups of livestock keepers. In Ouandiana the group was bigger and reached 20 participants. Farmers in this village acknowledged their full involvement in both livestock keeping and crop production, therefore needless to be divided as in the previous village. In that case, groups were formed by counting from 1 to 5 and each person with a number was asked to join persons with same number.

Farmers were asked to detach themselves from the other groups, in order to brainstorm on the issues mentioned above. The later outcomes were presented to others by a person from the group, chosen by other members of the groups. The brainstorming process lasted for about 10 minutes per group, and the outcome was presented to others, independent of the duration, and repeatedly on the above topics. Other group members were expected to comment on the outcome from other groups. Information was translated from Fulfulde and written down on flipchart papers on the wall, and this was repeatedly read to the participants, in order to generate discussion and reactions from other groups and members.

3.4 Data handling and analysis

Collected Data's were analysed following the figure below.

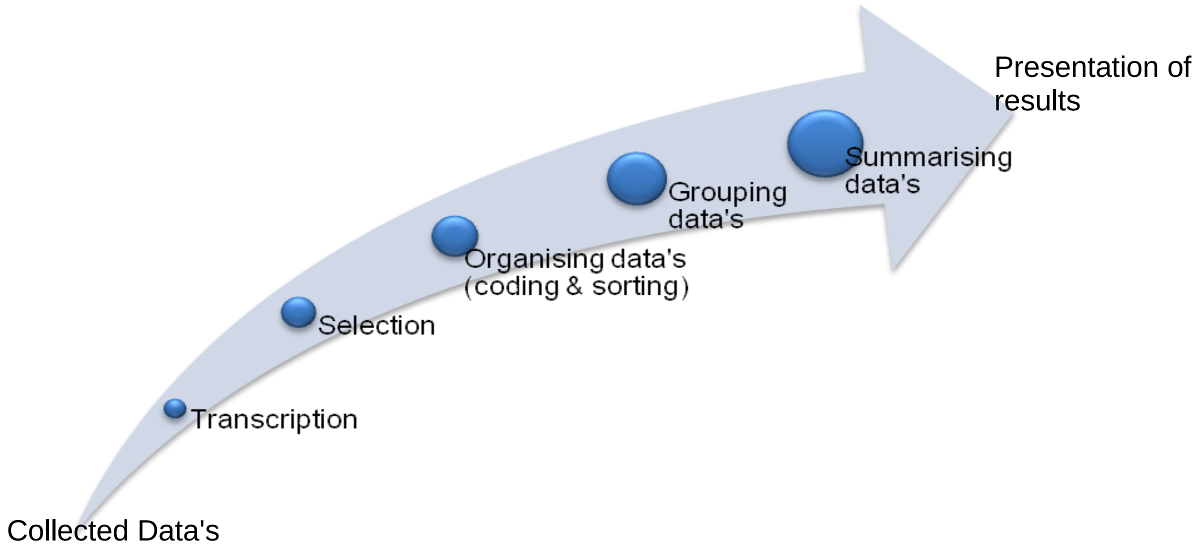


Figure 6 Data analysis steps

Source: own illustration

Beside the interviews carried out in NGO's and governmental institutions in French, all the interview in host and visited villages were done in the local language, therefore translated into French by a local translator. Those interviews were recorded and stored as audio files in a field computer. The audio files were further transcribed into written text, from French audio files into written English text, for further analysis.

In total, 31 individual interviews were carried out, including those from NGO's and governmental services, against 16 group interviews and two workshops in host villages. Among the 31 individual interviews, 12 interviews were selected for analysis, due to the quality of the information and their relevance to the research topic. Hence 19 individual interviews were not used, mostly for the following reasons: interviews were maybe too general, the information not triangulated, too much assumptions or information far from research topic. Among the 16 group interviews carried out, 9 were used for analysis, and 7 interviews discarded for similar reasons above.

Table 13 Used and non-used interviews

Interview type	Non-used interviews	Used interviews
Group interviews	GSO2, GD3, GDI, GD4, GD5, GW3, GW4,	GW1, GW2, GY, GB, GD2, GD3, GDO, GS, GSO1
Individual interviews	IW1, IN1, IM, ID3, ISO3, ISO4, ISO5, ISO6, IDI2, ID5, IDI4, IDI3, ISO7, IDI1, IDI5, ID1, ID2, IW2, IN2	ID6, IW3, IW4, ISO1, ISO2, ISO8, ID4,
NGO's and Government services	-	5 interviews
Total:	26 non-used interviews	21 used interviews

Code used: GDO; group interview Dinto, GW1; group interview Ouandiana (number 1), GS; group interview Sankara, GD; group interview Deguessagou, GSO; group interview Sokoro, GB; group interview Bollé, GY; group interview Yaléma, GDI; group interview Dianwely. ISO; individual interview Sokoro, IW; individual interview Ouandiana, ID; individual interview Deguessagou, IN; individual interview Néma, IM; individual interview Maga, IDI; individual interview Dianwely.

Selected interviews for content analysis were cross checked, in order to look at how individuals or groups responded to questions. Data's were further organised by key questions, so as to look across all respondents and their answers. By doing so, consistencies and differences were identified, and all data's from each question putted together. The answers from various questions were later summarized, and key topics identified.

4 RESULTS

The results of this case study will be presented as follow: first an overview of the two host villages will be presented, followed by results from selected interviews in both host and other visited villages. Results from the later will focus on climatic problems as expressed by agro-pastoralists, and the perceive impacts on their activities. Other observed changes that were repeatedly mentioned during interviews will also be presented, although their direct link with the climate may be debatable. Adaptation strategies in use in these communities will be presented, with a focus on innovations. Climatic changes and impacts observed by NGO's and the governmental services will be presented as well, and their domain of intervention in the research area.

4.1 General information on study area

This section gives a general overview on the two main research villages and their livelihood activities. This does not include other visited villages because of the little time spend there.

Ouandiana and Deguessagou are two neighbouring villages distant of about 5km. These are two villages with a common history, since the population of Deguessagou originated from Ouandiana 80 years ago, according to their village chiefs. As shown on table 14 below, major activities in both villages are livestock keeping and crop farming, as the villages are made up of both farmer tribes (Dogon and Rimaibés) and livestock keeper tribe (Fulani's).

Table 14 Basic information on host villages

Characteristics	**Villages**	
	Ouandiana	**Deguessagou**
First settlement	- Since around 118 years in 2010	- Since around 80 years in 2010
Population	- 647 inhabitants	- 1641 inhabitants (Including Hamaux)
Number of families	- 35 families	- 33 families in main (Deguessagou) - 38 families in Hamaux
Major activities	- Livestock and crop farming	- Livestock and crop farming
Tribes	- Dogon - Fulani - Rimaibés - Moussi	- Dogon - Fulani - Rimaibés
Number of Hamaux	- None	- Naidé - Bollé - Mora - Wouro-Cikary

Source: Key informants interviews in Ouandiana (07.04.2010) and Deguessagou (23.03.2010)

4.1.1 Livelihood activities

Livelihood activities here are basic activities carried out by the communities, in order to meet a certain objective. In host villages, livelihood activities include both farm and off-farm activities. The main farm activities were livestock keeping and crop farming. Those are two integrated activities which Fulani (pastoralists) and the Dogon and Rimaibés (crop farmers) acknowledged to combine at the present time. Although every tribe in these communities was involved in one way or another in crop farming and livestock keeping, during interviews sessions, various tribes identified themselves by their original activities. The Fulani for example presented themselves as livestock keepers and were interviewed as such, while the Dogon and Rimaibés regarded themselves as crop farmers. Regarding this implication of all tribes in both agriculture and livestock keeping a key informant in Bankass argued that: "De nos jours tout Peulh est un agriculteur et tout cultivateur est un éleveur" (Housseini Sacko).

Despite this combination of activities, calculation based on interviews and casual discussions revealed that, an average Fulani household owns about 19 big ruminants and 24 small ruminants, with an average farm size of 2 hectares. Crop farmers owned less livestock as compared to the Fulani's, with an average of 3 livestock per household and mainly small ruminants, tethered or kept in a small sheltered enclosure. The farm sizes within crop farmer tribes were three times larger than those of Fulani livestock keepers, with farm sizes ranging between 3 to about 6 hectares.

Livestock keeping

- **Big ruminants**

During interviews, livestock keepers identified one breed of cattle common in the Séno; the *Nai Poulipouli* (Fulani's cattle) breed. They regarded this breed a regional breed, inherited from forefathers and used already for several generations. The *Bodorodgi* was another breed identified, but occurred only in few parts of Séno. This later was described as a big animal with very tall horns, most common in the north east part of Mopti, in the area of Douentza.

- **Small ruminants**

Livestock keepers listed three breeds of small ruminants that are kept in the Séno: the *Balbab*, the *Ketedji* and the *Pedjigarou* or Métis. The breed *Pedjigarou* as described by livestock keepers is a crossbreed of *Balbab* and *Ketedji*. The pictures below show the identified breeds.

Balbab

Pedjigarou

Ketedji

Picture 5 Sheep breeds identified by livestock keepers

Source: Own pictures

Livestock keepers differentiated the above breeds by factors such as the feed demands, growth rate, tail and ear sizes, market price, the adaptability which they related to the origin of the breed and others, as shown on table 15 below.

Table 15 Comparative characteristics of identified sheep breeds

Sheep (breeds)	Origin	Growth rate	Legs	Tail size	Ear size	Market price	Feed demand	Adaptability
BalBab	Niger	faster	v. tall	v. long	v. long & large	high	v. high	not adapted
Ketedji	Mali	slow	short	short	short	v. high	average	v. adapted
Pedjigarou	N+M	fast	tall	long	large	cheap	high	adapted

V = very

Source: ISO1, GDO, ISO2 and casual discussions

Cultivated crops

Among cultivated crops, pearl millet (*Pennisetum glaucum* R.Br) was the most common crop cultivated by all tribal groups in studied villages. Other cultivated crops were: beans *(Phaseolus vulgaris)*, fonio (*Digitaria exilis*), groundnut (*Arachis hypogaea* L.), sorghum (*Sorghum bicolour (L.)*Moench), maize (*Zea mays* L.), *dah (Fulani* name*)* or roselle (*Hibiscus sabdariffa*) and soybean (*Glycine max*). According to farmers, beans and peanuts were grown purposefully for the leaves, which they regarded very nutritive for livestock, and used to sustain livestock during the dry season period when fodder scarcity is high. Few farmers grow cotton as well, mainly for making ropes that are sold on the local market and used in tethering small ruminants.

Off-farm activities

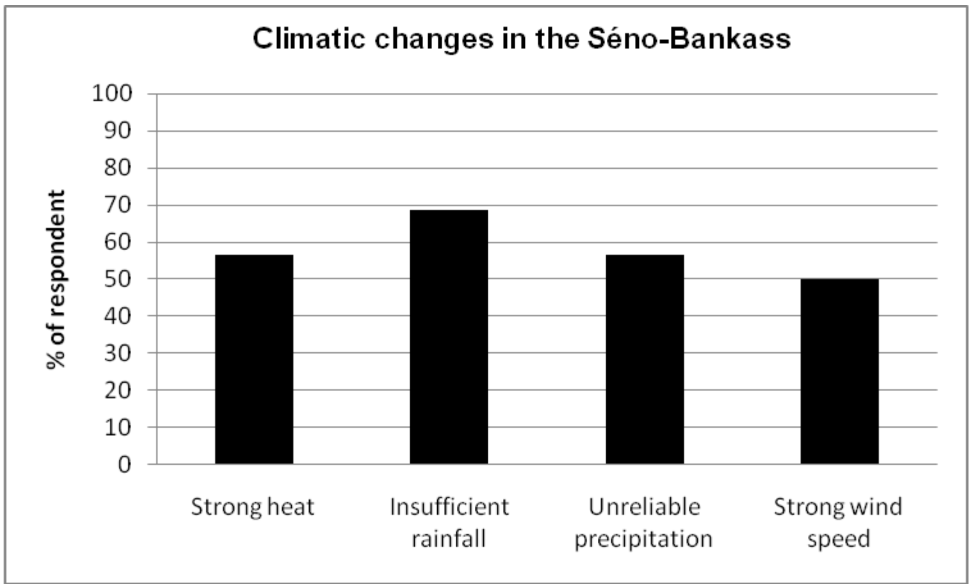
Off-farm activities in both crop farming and livestock keeping tribes included: the manufacturing of mat, roof, fan, bricks, calabash, home maintenance and plastering. Most of these activities were carried out during the dry season period, when there was less field work to be done.

4.2 Climatic changes and impacts observed by agro-pastoralists

Regarding farmers' perceptions of climatic changes, a key informant in Bankass argued that, " Concernant les changements climatiques, tous le monde y compris les paysans constatent ces changements, même s'ils ne sont pas à mesure de donner des explications parce qu'ils n'ont pas eu la chance d'aller à l'école. Ils se plaignent par exemple en disant qu'il fait trop chaud de nos jours, c'est parce qu'ils font la comparaison avec les années passer qu'ils font cette remarque" (Lassina Diallo).

Taking into consideration the above statement, farmers are able to observe climatic changes, even though they do not have formal equipment to monitor the changes they experience. However, they expressed changes based on the observed impacts on their farm productivity.

This section presents the climatic changes observed by ago-pastoralists, and how their activities are affected by observed changes. For this section, 16 interviews (3 individual interviews: ID6, IW3, ID4 and 8 group interviews: GW1, GD2, GS, GSO1, GB, GW2, GDI, GD3) and 5 interviews from NGO’s and governmental services were selected. Just 15 interviews are considered because: these are interviews in which interviewed persons were directly asked if they have experienced climatic changes for the past decades. Farmers expressed their remarks differently, for example some farmers begun by enumerating changes they have observed whereas other simply confirmed they have experienced changes. These later were further asked to specify changes they have observed. Despite of the differences in expression, interviewed persons experienced various changes. From the selected 16 interviews, 8 (50%) observed an increase in wind speed, which they expressed as strong wind speed. 11 (68,5%) said to have witnessed a change in the amount of rainfall or precipitation, 9 (56,5%) mentioned the strong heat and the unreliable rainfall respectively.



n=16

Figure 7 Climatic changes observed by agro-pastoralist

Source: Own calculation

- **Strong wind speed (forte vitesse de vent)**

Most farmers and livestock keepers observed changes through various impacts on their farm activities. They described these changes by pointing at the impacts on their production. They were expressed as follow:

- "Le vent souffle tellement fort de nos jours qu'une fois qu'on ait semé, ca amène le sable couvrir les semences qui auront du mal à pousser" (GB).
- "Il n'est pas facile de semer en début d'hivernage, à cause de la forte vitesse de vent qui couvre les bions ou on doit semer" (GSO1).
- "Une fois que tu as semé et qu'il ne pleut pas, le vent transporte le sable pour enterrer d'avantage les semences et une fois que la pluie recommence, les grains on du mal a poussé" (IW3).

- “Le vent souffle trop fort et ca transporte tout sur son passage dans les champs, même le compost que tu mets dans ton champ. En fin de compte, ton champ n’est plus fertilisé” (GS).
- ”Il leurs arrive parfois de semer après la première pluie et lorsqu’il ya interruption entre cette première pluie et la deuxième, le vent transporte du sable pour couvrir les semences et de ce fet ils doivent semer a plusieurs reprise, pour pouvoir récolter” (ID6).
- “Le vent est tellement for que ca fait tomber le mil et ca casse les branches d’arbres qui détruisent les récoltes et nos maisons” (GD3).

From the above statements, respondent’s observations were based on the impacts of strong wind speed. This was in most cases at the beginning of the growing season, and at this period, the wind carries sand to cover the seeds deep, and they observed that even when the rain returns, seeds have difficulties in shooting from the soil. In some cases they carry several sowing because previous seeds did not finally germinate. One group of farmers observed the impacts of the “Forte vitesse de vent” as they call it, though logging of trees branches, which destroy cereals crops and damage homes.

A livestock keeper in Deguessagou observed that the strong wind speed impacts on his animals especially during the dry season. He explained that, because it's a sandy area, when livestock are lying down, this wind carries particles of sand that would stick to the body of the animal. He believes this negatively impact the growth of the animal, because the body becomes too strong and not flexible, hence the animal stays skeletal (ID6).

- **Strong heat (Forte chaleur)**

Although few persons pointed out that the “forte chaleur” as they called it, is one major problem which they are confronted with, most did not clearly state how their activities were affected by it. From own measurements, temperature moved from 25-30^{0}C in the early morning to reach 45^{0}C between 11 am to 15 pm, hence no field activities was possible during this period of the day, as the soils temperature (mostly sandy soil) was hotter than the air temperature.

Regarding the impacts of this strong heat on various farm activities, farmers in Deguessagou discussed that the heat enables a better growth of the millet and other crops, because they have noticed that without the heat and a high humidity, seeds would not produce (GD3). Other farmers still in Deguessagou argued that, when there is intensive radiation on their fields and later there is rain, it is easier for them to make good harvest, but when suddenly cold and heat fluctuates, or if it stays cold all through the rainy season, they may not expect good harvests (GD2). Without further explanations, other farmers speculated that hot sun reduces the power of their soils (GW2).

- **Unreliable precipitation**

Most interviewed farmers and herders observed a decrease in the coming and duration of the rainy season. During a group interview in the village of Dinto, a farmer voiced that, "En ce qui concerne la pluviométrie, les choses deviennent catastrophiques et chaque année nous apprécions plus l'année précédente, ce qui nous donne un sentiment de peur" (GDO). According to this farmer, the rain is reducing with each passing year, and each year they appreciate more the previous year.

Most remarks regarding the unreliable precipitation were the following:

- "Parfois après les premières pluies, les gens pensent que c'est le début de l'hivernage et ils commencent à semer. Quelques semaines après, il y a interruption et les plantes commencent à sécher avec des impacts sur les récoltes" (GW2).
- "Ils ont remarqué aujourd'hui que, il peut arriver parfois qu'ils aillent dans leurs champs pour semer alors que les Fulfuldes qui vivent moins d'un kilomètre d'eux sont toujours assis à la maison parce qu'il n'y a pas de pluie dans leurs champs. Donc leur remarque est que la pluie ne se fait pas seulement rare mais ne viens pas sur les mêmes champs au même moment" (GW2).
- "Le problème avec la pluie de nos jours c'est en début d'hivernage et vers la fin de l'hivernage. Mais parfois au bon milieu de l'hivernage il ya interruption et bien sur les récoltes seront très mauvaises" (GD2)
- "Parfois au milieu de l'hivernage il ya des interruptions de pluies qui dure jusqu'a 20 jours ou même 1 mois" (GD3).

Other observations were that, there experiencing a delay in the coming of the rainy season and the early return of the dry season (GD, GSO1).

Regarding the impacts of the unreliable rainfall on farming activities, most interviewed persons speculated that it is difficult for them to make good harvests because when there is interruption, crops dry up. In Deguessagou, farmers explained they normally seed after the first rains and wait for germination to start cultivating, and when there is interruption in the rainfall, they have difficulties in cultivating the soil because the fields are too dry, and they can wait for several weeks before the rain returns. When this occur, they have a delay in their farm activities because a farm they would normally cultivate in 5 days, may end up taking 20 days (GD2).

- **Insufficient rainfall**

Regarding the amount of rainfall, most observations were the following:

- "Nous avons constaté des changements en ce qui concerne la quantité de la pluviométrie. Il y a des moments ou il ne pleut que 1 mois ou 1 mois et demi et pendant ce temps le mil n'est pas mûr et la pluie disparaît. Le résultat c'est la famine partout" (GDO).
- "De nos jours il pleut de moins en moins, voila pourquoi l'agriculture n'est plus rentable" (GS).

For the observed impacts of insufficient rainfall, some farmers said "it causes uncertainties in the sowing period, for example if there is rain, they would seed and hope it continues, when it does not continue and the seed do not germinate they repeat the sowing and so on.

Sometimes that continue until they are late in their sowing and that would have a negative impact on their harvest. Therefore with less rainfall, they invest more in their field like sowing 3 to 4 times before they can hope to harvest, and all that is wastage for them" (GW2).

Regarding the way in which livestock is affected by the insufficient rainfall, a livestock keeper in Bollé argued that, to talk about grass there must be rain, and when there is no rain of course there is no grass for livestock (GB). Another livestock keeper said "Quand il ya pas assez de pluie, forcement il ya moins d'herbes et les animaux sont très maigre. Un animal maigre soit refuse l'accouplement où cette animale a du mal à mettre bas" (ID6). Livestock keepers' observations are that, the reduction in the amount of rainfall has an impact on livestock because there is less fodder, livestock are dry, and dry animal either refuse mating or have difficulties in calving.

Another livestock keeper correlated the availability of fodder to the amount of rainfall and said to remember that when they had enough rain, there was an abundance of fodder and they had always calves. But today his remark is that, due to the reduction of livestock fodder, even if a cow would calve today, the young calves do not grow fast anymore, whereas in the past, once an animal would calve, within three years they would normally expect the new one to calve as well. According to them, the situation at present days is that, they have to count at least five or six year before the new calve would calve as well (IW4). In the village of Sokoro, a livestock keeper said they grew beans before mainly for the leaves that they use in feeding their animals, and since the amount of rain has reduced it is very difficult for them to make serious harvests of these residues (GSO1).

However, there was an exception regarding the amount of rainfall. During a group interview with crop farmers in Deguessagou, one farmer argued that there is always rainfall in their area, maybe not so much or too much but they have enough rain, and the problem may be that, the soils are poor. Still within this group interview, another farmer added that, before the rain would come too much and even carry away crops but it is not more the case today. For them, when there is little rain, it is at the right time and they have to know how to take advantage of it (GD3).

Table 16 Summary of observed climatic changes and perceived impacts

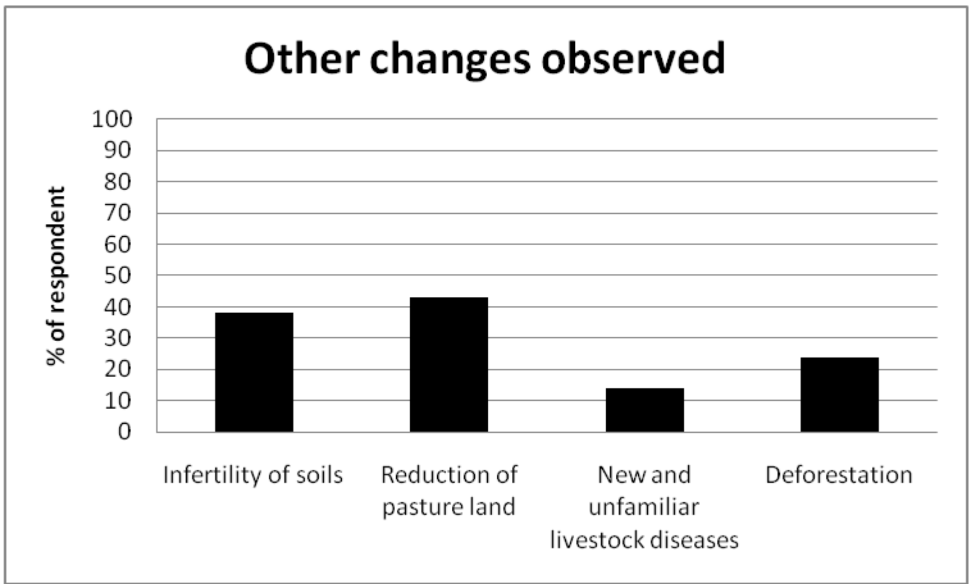
Changes identified	**Impacts**	**Source**
a. Strong wind speed	-Logging of cereals -Logging of tree branches -Dispersion of compost - Burying of seeds	GD2, GW2, IW3, ID6, GS
b. Strong heat	- Favour plant growth - Reduces the power of the soil	GD3, GD2, GW2
c. Unreliable precipitation	- Delay in farming activities - Poor harvest	GD2, GW2
d. Insufficient rainfall	- Poor harvest: crops and residues - Multi-seeding - Uncertainties in seeding periods - Slow growth of crops - Less fodder - Longer calving interval	GDO, GW2, GSO1, GB, ID6

4.3 Other changes observed by agro-pastoralists

This section is mainly for those changes which agro-pastoralists either associated to climatic problems or simply those changes they have experienced in their production systems. Some of the changes listed may just be speculation, or based on their observations. However, it is very difficult to differentiate between statements based on speculations or experiences.

Since these statements were repeatedly mentioned, they need some consideration. All the selected 21 interviews were used, because some of these problems were raised at random during interviews.

From the selected 21 interviews, 8 (38%) mentioned the infertility of the soils, 9 (43%) the reduction of pasture lands, 3 (14%) new and unfamiliar livestock diseases and 5 (24%) deforestation.



n=21

Figure 8 Other changes observed by agro-pastoralist

Source: Own calculation

- **New and unfamiliar livestock diseases**

Regarding the new and unfamiliar livestock diseases, there were mixed statements. On one side some livestock keepers said there have been emerging unfamiliar diseases, whereas others argued that there are fewer livestock diseases in the present days as compare to the past.

Some arguments for this statement were that, “Aujourd’hui il ya des maladies animal dont ils ne peuvent pas dire de quoi l’animal soufre. Parfois ils pensent que c’est la maladie Doudé, mais en fin de compte ce n’est pas ca et même pas la fièvre” (GY). Another livestock keeper argued that, “avant il y’avait pas de problèmes avec les maladies, mais aujourd’hui il ya des maladies dont ils sont incapable de dire de quoi l’animal souffre. Parfois ils sont dans la brousse et subitement un animal tombe et ils restent là troublé, ils appellent même les vétérinaires mais ces derniers seront eu aussi confuse” (IW4).

However, another livestock keeper in Sokoro argued that, they cannot really talk of livestock diseases these days, because they are far less than before. He suggested that, the main livestock problem in the present days might be hunger, because there is no serious grass growing on pastures anymore, hence animals are always feverish and can be exposed to lot of things (GSO1).

- **Reduction of pasture land.**

In most cases, the reduction of the pasture land as explained by livestock keepers occurs due to the fact that, more pasture land is converted to farm land. Regarding this, a livestock keeper in Yaléma said: “Il arrive parfois que vous conduisez votre troupeau dans un pâturage et après quelques temps vous constatez que ce pâturage a été cultivé et vous n’avez plus accès à ce lieu” (GY). In Dinto, livestock keepers said there are no more grazing areas because people are cultivating almost everywhere and it very difficult for them to keep the entire herd at home, so they are forced to take their herds out to the highlands.

Livestock keepers in Sankara observed there has been a reduction in their pasture lands, and they attribute that to the way villages are settling around them. They remarked that they had few villages in the past, and all households had enough farm land and grazing area. But today the situation is very much different, because they cannot travel a distance of 3 to 5km without seeing a new village, and it is on the pasture areas and farm lands they formerly cultivated that new villages come to settle, and cultivate (GS). Livestock keepers in Yaléma and sokoro argued that, the population increase is the main reason behind the reduction in grazing area.

Regarding the impact of this of this reduction of pasture land, a livestock keeper in the village of Yalema said they have never experienced feeding animal at home until now. Before they needed just to take them to the bush were they could graze themselves and eat additionally tree leaves. But today they have to go to the market and buy feed for their livestock. Within the same group, another livestock keeper voiced that, “Avant les animaux leurs faisaient vivre, mais aujourd’hui c’est eux qui font vivre les animaux” (GY).

- **Deforestation**

More detailed explanation was given on the rate of deforestation in the villages of Sokoro and Ouandiana. Interviewed persons in these villages revealed that there has been a shift in trees and species distribution, because some trees have disappeared in favour of others. In Ouandiana for example, farmers said they have realised that all trees are dead, except the thorn trees, known as the wild date (*Balanites aegyptiaca*). They further argued that this tree was in countable number in the past, but in the present days, it is growing everywhere. Whenever they see a new tree growing in the bush, they have no doubt that it can be the wild date, because that is the only tree that seems to be more adapted to the situation they are facing today (GW1). Regarding trees species that disappeared in their region, farmers named the tamarind (*Tamarindus indica*) and the shea (*Vitelari paradoxa*). They also argued that, their village was once surrounded with baobabs (*Andasonia digitata*), and today just a few can be counted (GW1). In Sokoro, the same remark was made, regarding the lost of tree species and the increase occurrence of the wild date. In addition to the above trees listed in Ouandiana, farmers in Sokoro said to have witness the lost of the Kapok (*Bombax costatum*), and the same remarks for the baobab, which they believed it is at risk of extinction (GSO1).

Regarding the impacts of the lost of these species on the production systems, most livestock keepers said the leaves and fruits of these trees were additional source of livestock feeding.

- **Soil infertility**

The problem of soil infertility appeared to be a common problem to both livestock keepers and crop farmers. In Ouandiana, a farmer said he noticed that their soils are poor because, every year the same fields are cultivated and they do not do that much fallow, so that the soil can recover. His conclusion was that, when you cultivate the same soil every year, it gets poorer and poorer (GW2). During a group interview in Deguessagou, some farmers also argued that their fields are tired (referring to its infertility), because they have noticed that after cultivating a field for three years, it is tired and they have only compost and animal waste to give back to it (GD3).

Talking about compost, farmers' referred to the household waste or animal faeces. The household waste was dump on one specific area, and transported to the crop fields at the beginning of the cropping season. Animals waste is what they assembled either in sheltered enclosure where home animals (sheep and goats) are kept, or gathered under trees at the home premises, where these animals are tethered.

Farmers in Bollé and Ouandiana used specific weed species as indicators for erosion. They argued that the amount this "bad" weed increases on crop fields with the increase in soil infertility. According to farmers, these are weeds that normally grow on poor soils. The identified weeds were *Do* and *Yara wouah* in Fulfulde. *Do* particularly grows between millet plants as observed by farmers, and once it is removed, new shoots are again coming up.

Below on picture 6 are *Do* and *Yara wouah,* taken at the middle of the dry season in Bollé and Ouandiana.

Yara wouah

Do

Picture 6 Weed species used as indicator of poor soils

Source: own pictures

These weeds were also reported badly for livestock, because in the village of Sankara livestock keepers said they have realised that there is a type of insects that feeds on *Do*, and once livestock eat this weed regularly it becomes sick and they believe those insects may be the cause. Concerning the weed *Do*, crop farmers in Ouandiana said it serves for two medicinal purposes:

- The first use was: when an animal was suffering from diarrhea, grinded dried leaves were mix with water and given to the animal to drink, in order to stop the diarrhea.
- The second use was: when an animal had a growing stomach (bloat) because it has eaten too much beans for example, they can still grind the dry leaves and mix with water that they pump in the animal rectum, so as to push it (GW2).

Despite those therapeutic uses of *Do* as claimed by those farmers, they said it is helpful only for livestock keepers: therefore they do not need this weed on their farms and would like to eradicate it.

According to farmers, increase soil infertility impacted negatively on crop production and fodder availability on pastures.

Crop farmers in Sokoro argued that, soils are so poor in such a way that harvests at the present time are barely a third of what they harvested about ten years ago. In Sokoro, a farmer said he noticed that: “Avant sur un hectare de terrain tu pouvais récolter même 20 sacs de mil, aujourd’hui tu es incapable de récolter 10 sacs, voila pourquoi les gens augmente les superficies de champs” (GSO1). Still regarding the poor harvest resulting from soil infertility, other farmers in Yaléma said their harvest are reduced in such a way that, if someone had two storages for harvested cereals before, today that person needs just one, and if someone had half of a storage, today that person needs a quarter (GY).

Most livestock keepers believed the reduction of grass on pasture is the result of the increase soils infertility. Some even argued that soils are so poor today that even if people would give out more land for pasture, it may not make a difference because, most soils have been eroded, and no serious grass can grow on them anymore. Some livestock keepers even argued that fodder species that livestock normally eat has disappeared, and it is only until recently that they started eating the weed *Do* (GW1).

Table 17 Summary of other observed changes and perceived impacts

Changes identified	**Impacts**	**Source**
a- New and unfamiliar livestock diseases	- Feverish livestock	GSO1, GY, IW4
b- Reduction of pasture land	- Favourable for plant growth - Reduces the power of the soil	GD3, GD2, GW2
c- Deforestation	- Less feeding options for livestock - Lost of tree species	GB, GW2, GSO1
d- Soil infertility	- Poor harvest: crops and residues - Poor pastures - Increase in farm sizes - Increase occurrence of weeds: *Do* and *Yara wouah*	GDI, GW2, GSO1, GB, GY

4.4 Climatic changes observed by key informants in NGO's and governmental services

The interviewed persons in NGO's and governmental services said to have observed changes such as: the change in the coming of dry and hot periods, changes in the amount and time of precipitation.

- **A change in the coming of dry and hot periods**

Interviewed persons said to have observed a change in temperature as compare to 10 years back, however no direct impacts on agro-pastoral activities were given. Remarks were the following:

- "Nous sommes maintenant en Mars et depuis le mois de Février on commence à sentir une très grande chaleur, normalement cette grande chaleur c'est a partir du mois d'Avril et Mai. Ceci veut dire donc que le climat à changer, et la saison sèche est devenue très longue" (SahelEco).

- "De par le passé on avait la période de chaleur, mais de nos jours cette période de soudure qui est caractérisé par la forte chaleur commence très tôt et se prolonge dans la période d'hivernage" (Services d'élevage).

The above observations suggest that, there is a shift in the periods with high temperatures in the region, which is prolonging into the rainy season. According to the key informant in the service des eaux et forêts, the hot periods in the Cercle of Bankass start normally between the months of April and May, but since about 10 years ago, they are experiencing hot temperature reaching 40^0C already in February, which he regarded as changes. The key informant from SahelEco observed similar changes as in the service des eaux et forêts, regarding the shift in the coming of dry season and hot period.

- **Changes in the amount and time of precipitation**

Observations regarding the change in precipitation were that:

- "Il ne pleut pas abondamment, et les marres d'eaux ne dure plus longtemps. Avant on voyait les marres d'eau encore avec de l'eau en début d'hivernage mais de nos jours, après les récoltes entre Octobre et Décembre, tous les marres sont déjà a sec" (SahelEco).

- "Parfois il ya des pluies qui causent des dégâts et des moments ou il y a absolument rien, on dirait que l'hivernage se déplace parce l'année dernière jusqu'au mois d'Août il y avait pas de pluie, mais au mois de Septembre ou il pleut d'habitude moins, ont a eu beaucoup de pluie jusqu'en Octobre. Nous percevons vraiment les changements climatique maintenant, soit ce sont des grosses pluies ou la rareté de pluie" (Caritas).

- "Normalement partir du mois de Mai les paysans attendent la pluie, mais de nos jours le mois de Mai fini et ils amorcent le mois de Juin sans pour autant avoir la pluie. Donc les changements climatiques se présentent au niveau de l'installation de l'hivernage, de plus en plus tardive" (Service d'élevage).

The above statements suggest that there has been a shift in the return period of the rainy season and a change in the amount of rainfall. This is in a way that, either they experience heavy rainfall that causes lot of damages or they have almost no rain, like in the year 2009, according to the key informant in the service d' élevage.

Regarding the impacts of the change in rainfall on livestock, the key informant in the service d'élevage argued that, "Les impacts sont tangibles sur l'élevage, les pâturages sont vides, les résidus de récoltes sont ramassés des champs et les animaux n'ont presque rien à manger. A un certain niveau les animaux n'en peuvent plus, ils sont vaccinés mais ils meurent parce qu'ils n'ont rien à manger ni à boire, comme l'année dernière (2009) les bovins mourraient come ca". Other impacts are on water ponds, and key informant observed that few decades back, water ponds lasted until the beginning of the rainy season, but at the present time, they have observed that between October to December all water ponds are dried, and families in some areas are forced to travel long distance of up to 10 kilometres to fetch for water. Regarding crop farming, most key informants said the above changes have negative impacts on crop yields in the region.

4.5 Autonomous adaption strategies to perceived climatic changes

This section outlines the adaptation strategies currently used by agro-pastoralist in the Séno. From this study, it is clear that farmers in this region have adjusted their production systems, in response to their changing environment. This section presents the innovations that have recently been developed in the study area. These are either new adaption strategies in absolute term, or re-adaptation of existing adaption strategies. Adaption strategies that already cited in literatures are briefly highlighted. Detailed explanations will be given to those adaption strategies that are considered new or modified.

The results obtained will be presented in two parts, starting with the autonomous adaptations gathered in farming communities, followed by supported adaptation from the government and NGO's.

4.5.1 Adaptation strategies used by livestock keepers

Adaption to feed scarcity

Livestock keepers said to experience a reduction in the amount of fodder and area allocated to grazing lands. In response to this increase scarcity of feedstuff, livestock keepers adopted series of measures such as:

- Seasonal or permanent migration to better grazing areas
- Harvesting and stocking of dried fodder and crop residues
- Supplementing feedstuff with wild fruits
- Selecting adapted breeds
- Selling of livestock in order to buy feedstuff for the rest of the herd
- Fattening
- Buying of additional feedstuff (eg. cotton cake)
- The reduction of herd size.

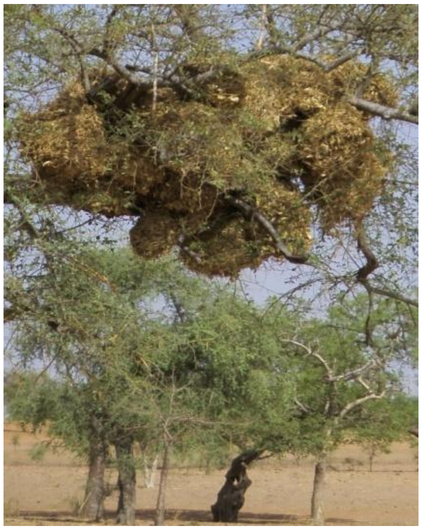
Just the area of feed supplementation will be given detailed explanation, since the other strategies are similar to those that have already been analysed in the literature review. Feed supplementing to be discussed entails crop residues and wild fruits.

- **Supplementing feedstuff with harvested crop residues.**

Although the harvesting and storing of crop residues has been cited in literature, attention is given to it mainly because of various conservation methods used. It is noticeable in the Séno that, crops residues are potential sources of livestock feedstuff in the dry season period, known as "période de soudure". In this study, crop residues are harvested after the main crops have been harvested. The most used crops residues were millet stems, beans and groundnut leaves. Beans and groundnut leaves were described as highly nutritive for livestock, and grown purposefully for their leaves. A livestock keeper in Sokoro argued that "Les feuilles de haricot et d'arachides on un effet curatif sur l'animal. Ca facilite la digestion et empêche la constipation parce que un animal constiper maigris" (ISO1).

Based on own observation, residues were stored either on the field (in-situ) as shown on picture 7, or harvested and stored at the home premises (ex-situ), as on picture 8.

Regarding in situ conservation, groundnuts and beans leaves were in most cases tied in small bundles and putted on the trees branches, due the roaming number of livestock on fields.



Picture 7 Stored beans & groundnut leaves

Source: own picture

Beans and groundnut leaves were harvested immediately after the harvesting of major crops. The harvesting of these residues occurred between the months of October and November in most cases, and were stored until May or even June according to some livestock keepers, whereas others argued they could store them as long as it did not rain on them.

Most of these residues were used for own livestock and also sold on the local market. Other crop residues sold on the local markets were the leaves of *dah* (Hibiscus sabdariffa), and this crop was gowned exclusively by non-Fulani tribes. The flowers were used for making traditional drink commonly known as *bissap.* The leaves of *dah* were also used for feeding livestock, and sold on the market as well.

Ex-situ conservation of crop residues was principally done for the millet stems, as shown on picture 8 below. However, during informal discussion with farmers, it was obvious that several factors influenced the conservation methods (in-situ or ex-situ). These methods vary from one farmer to another, depending on the available labour within the family, the amount of residues and the use of the residues; that is whether they are to be sold or stored for own use.

As shown on picture 8, the storage of millet stems is done in such a way that a certain degree of moisture is maintained and less damage from roaming livestock. Heaps are then putted round in such a ways that edible parts of the stems are all turned into the centre.

Picture 8 Stored millet stems

Source: Own picture

Supplementing feedstuff with wild fruits

Regarding the use of wild fruits for supplementing livestock feeding in the dry season, three varieties of fruits was identified by livestock keepers. Those were the fruits of balanzan tree (*Acacia albida*), *kohic* (*prosopis africana*) and *barkehi (Piliostigma thonningii).*

- The balanzan fruits.

It is a fruit yellowish in colour, and harvested toward the beginning of the rainy season, between March-April. This tree is very common in the council of Laguassagou, according to Adama Karakodjio, a livestock keeper in Sokoro. The raw fruit was from livestock keepers' own harvest or afforded on the local market. The fruit was given to livestock in two forms. Most livestock keepers said they pounded it and gave directly to livestock, whereas a livestock keeper in Sokoro said he mixes the pounded fruits with cooked *dah* seeds.

Both *dah* grains and the balanzan fruits are shown on picture 9 below.

Dah grains Balanzan fruits

Picture 9 Balanzan and *dah* grains

Source: own pictures

Dah seeds were available on the market or within the village, but grown exclusively by non-Fulani tribes like the Dogon or Rimaibés. The balanzan fruit was either harvested or bought on the local market. Regarding the prices of balanzan and *dah* on the market, a bags of 100kg of balanzan ranged between 2000– 2500fcfa, whereas 100kg of *dah* was sold at 10 000fcfa (ISO8) or 65fcfa/litre, according to livestock keepers in Dinto.

Concerning the mixture of *dah* and the fruits of balanzan, Adama Karakodjio who is currently trying this combination said the grains of *dah* must be cooked until they are soft. These cooked grains are further mixed with pounded fruits of balanzan. For the mixture, he uses two times more balanzan than the grains of *dah*. He estimated a mixture fraction of 20 litres of balanzan against 10 litres of cooked grains of *dah.* However, this livestock keeper said neither the balanzan fruits nor the grains of *dah* have any side effects on livestock, in case of too much ingestion: hence the percentage of each in the overall mixture is simply a personal decision.

- *kohic* (*Prosopis africana*) fruit

Kinqueteladji as shown on picture 10 below was according to most livestock keepers' not good for their livestock. However, they said their animals have understood that there is not much left for them to eat. Regarding the effect of this fruit, most livestock keepers feeding this fruit to their livestock said they see no positive impact on the animal. Livestock keepers in Yaléma for example said they fed this fruit to their livestock because when there is nothing for them to eat around the bush; they are all at the homestead bleating.

Picture 10 *Kohic* fruit (*kinqueteladji*)

Source: own picture

Like other wild fruits, *Kinqueteladji* was given to livestock in two forms. It was pounded and combines with millet chaff according to some livestock keepers, or added a bit of salt according to others.

Regarding this fruit, livestock keepers in Bollé said ten years back, their livestock did not eat this fruit. Even at the present days, if given to livestock without mixing with salt or millet chaff, they are sure that livestock will not still eat.

- *Barkehi (Piliostigma thonningii)* fruit

Barkehi was used by several livestock keepers, same as *kinqueteladji,* because they were available around the villages. Most users said they relied on their own harvest, because it was not really food for livestock and no one could see it on the market. Livestock keepers feeding this fruit to their livestock said it was one of the few things that are available for their livestock. For this reason, a livestock keeper said: "un enfant qui n'a pas de maman se contente du lait de sa grand-mère" (GDO). That was to say livestock at present days do not have much choice regarding feedstuff.

Picture 11 *Barkehi (Piliostigma thonningii)*

Source: Own picture

This fruit was described as bitter in taste and most livestock keepers said if given to livestock without additional mixture they might not eat. Therefore, the fruit was pounded in order to reduce it into smaller pieces or almost powder, and further mixed with millet chaff. Regarding the proportion of the fruit and the millet chaff in the mixture, a livestock keeper that is currently feeding this combination to his livestock said 10 litres of pounded *barkehi* fruits against 5 litres of millet chaff was adequate (IW4).

Table 18 below shows other supplementing feedstuffs sources used by livestock keepers in the study area. This table is a summary of the registered feed sources, prices and properties as described by livestock keepers. Crop residues of millet, groundnuts and beans were also important in the dry season period.

Table 18 Recorded complementary sources of livestock feedstuff

Feed supplement sources	Properties	Price	Source
Dah (*Hibiscus sabdariffa*)	Fatten up	65fcfa[7]/litre or 10000fcfa/ 100 kg	GY, GDO, ISO8
Cotton cake	Fatten up	6500fcfa/50 kg	ISO8, IW3, IW4, GDI, GS, GSO1
Balanzan (*Adansonia digitata*)	Fortify	2000-2500fcfa/100 kg or own harvest	ISO8, GY, GS, GB
Dry grass (Not specified)	Sustain	3000-5000fcfa/load of donkey or own harvest	ID6, IW3, IW4, ISO8, GS
Kinqueteladji (*Prosopis africana*)	Sustain	Own harvest	GB, GY
Barkehi *(Piliostigma thonningii)*	Sustain	Own harvest	GB, IW4

Adaption to rain scarcity

No specific new adaption strategies were mentioned. However, in periods of prolonged dry season or delay in rainfall, most livestock keepers said this was the will of God. During such moments, they carry prayer session in the Mosque in order to call for the rain. Some said they believe in the powers of Marabou. For this reason, free will money is collected from around the village, and given to these persons that have additional power to call for the rain. On the other hand, most livestock keepers acknowledged that sometimes it does

[7]FCFA: Franc Communauté Financière Africaine; 1 Euro = ~655 FCFA

work, sometimes not. In any case, the money given to these persons is non-refundable they said.

4.5.2 Adaption strategies used by crop farmers

Adaption to rain scarcity

In respond to the increase scarcity of water, crop farmers in the Séno implemented series of measures, which enabled them to ensure harvests. These measures include:

- Diversification of crop varieties
- Multi-sowing
- Rituals

These strategies have been used by other communities, as already discussed in the literature review. However, the diversification of crop varieties will be presented in detail.

- Diversification of crop varieties (the case of pearl millet)

Insufficient and unreliable precipitation result to water deficit in studied villages, hence farmers adjusted by diversifying their crop varieties. This was done by using both the long cycle variety called *Gaouri* in Fulani, and the short cycle variety known as *Gaouri gnaoundi*, in the case of pearl millet.

The long cycle variety and the short cycle varieties were in some cases cultivated together, because farmers said they were not sure to have rainfall through the entire rainy season. In Dinto for example, a farmer argued that “nous cultivons les deux variétés parce qu’on n’est pas sur d’avoir assez de pluie pendant l’hivernage. Même avec moins de pluie on est sur de récolter la variété a court cycle” (GDO).

In some villages, farmers did not grow both varieties together, but selected the variety to be seeded depending on the starting period of rainy season. In Bollé for example, crop farmers said if the coming of the rain is delayed until August, they will be forced to plant the short cycle variety. But if there is already enough rainfall between June and July, they can sow the long cycle variety.

Table 19 Comparative characteristics of the long cycle and short cycle varieties of millet

Variety	**Growth**	**G. length**	**Panicle size**	**Yield**	**grains**	**High**
Gaouri	Slow	4-5 months	Long	High	Big/heavy	3-4m
Gaouri gnaoundi	Fast	3-4 months	Short	Low	Small/light	About 2m

G= Growth

Source: GDO, IW3, Informal discussions

The picture below shows the two varieties of millet, as identified by crop famers.

Picture 12 *Gaouri* and *Gaouri gnaoundi*

Source: Own picture

The long cycle variety was the peoples own variety, whereas the short cycle was regarded as an outside variety. Regarding the source of the outside variety (*Gaouri gnaoundi*), farmers pointed at two sources: some farmers said their seeds were from the highlands of Bandiagara, and others from the council of Laguassagou. Farmers using the variety from the highlands of Bandiagara said there was a clear difference between the two varieties, in terms of yield, grain sizes, and amount of residues. But farmers using the short cycle variety from the council of Laguassagou said there was no big difference between the two varieties.

Farmers using the short cycle variety from the council of Laguassagou said they noticed that, from the first year of sowing this variety, everything may appear good, but the cycle is slowed after about 3 years and it slowly become a long cycle variety.

Regarding the variety from the highlands of Bandiagara, farmers highlighted the following advantages and disadvantages, as shown on table 20 below.

Table 20 Advantages and disadvantages of cultivated varieties of millet

Variety	Advantages	Disadvantages
Short cycle variety: *(Gaouri gnaoundi)*	- Secured harvest during periods with less rainfall - Short growing period - Less water needed - Single sowing possible	- Short panicle - Small grains - Low yields - Less residues - Attract birds - Small stems - Less resistant to strong wind
Long cycle variety: *(Gaouri)*	- Long panicle - Big grains - Higher yield - Bigger stems - More resistant to strong wind - More residues	- Highly water demanding - Multi-sowing - Longer growing period

Source: GB, GDO, IW3 and informal discussions

Some farmers said they were not willing to use the short cycle varieties because they encountered few problems with this variety. Problems encountered were: the low yields of harvest, residues and migrant birds that will devastate the crops. A farmer in Ouandiana argued that “Ils utilisent encore leurs semences ordinaires parce que, lorsqu’ils utilisent la variété a court cycle, ca mûrit très vite, et hors mis le fait que ca donne des petits épis, une fois que c’est prêt a récolter et que votre champs est le seul avec les récoltes mûrs, les oiseaux vont dévaster ton champs et tout détruire, car ils ne verront que ton champs” (GW2).

Therefore, due to their bad experiences with migrant birds and the low yields, farmers in Ouandiana and Deguessagou were rather skeptical about the short cycle variety of millet. However, some farmers said a joint choice of this variety by all farmers at the village level may be a solution. Other farmers argued that it can only be a solution if neighbouring villages are also included, because farmlands from their villages and neighbouring villages are today much closed to each other.

Despite the problems facing other farmers with this new millet variety, farmers in Dinto acknowledged they use both varieties together, by dividing their fields in two parts: one part for the short cycle variety and the other part for their normal seed. The reason behind growing both varieties was that, the short cycle variety yields are very little, the grains very small. Therefore, they do not really want to get rate of their own seeds.

In order to use the short cycle variety and avoid crop loss due to migrant birds, farmers in Bollé said they make a calculation regarding the sowing period. Hence, their advice to other farmers facing this problem was: “when there is rain, do not rush to sow with those that have the long cycle variety, wait until they have seeded and you make a calculation to see when you can plant. If you have to sow with others, it should be the same variety. When you make good calculation, the high of all the varieties will be the same and birds will not differentiate between plants anymore” (GB).

Adaptation to strong wind speed

In order to reduce the amount of damage caused by the strong wind speed (la forte vitesse de vent), most crop farmers and livestock keepers said trees planting was for them the ultimate solution. In order to reduce logging in cereals by the strong wind, some farmers in Deguessagou said they tied the millet plants together, so as to allow free circulation of the wind through the crop field.

- **Tying of millet plant**

This method was used by crop farmers in Deguessagou, and consisted of tying the millet plants together in bunches at the flowering stage. This was done by using the leaves of the same millet plants. This was to allow the circulation of wind through the entire field. Nevertheless, farmers argued that some plants are always destroyed, and those are harvested and dried at home if matured, to prevent it from getting rotten on the field.

- **Tree planting**

Most livestock keepers and crop farmers said trees planting can solve most the problems they are facing. During a focus group discussion in the village of Sankara, a farmer highlighted the following, in support of his idea about trees planting: "La solution qu'ils ont trouvée pour les problèmes auxquels ils sont confrontés comme: problème d'eau, herbes a bétails et forte vitesse de vent, c’est le reboisement. Parce que si il arrive qu'ils plantent suffisamment d'arbres sur leurs champs, cela peut ralentir la vitesse du vent et de réduire la quantité de mauvaises herbes dans leurs champs, parce qu'il y aura l’ombre, et quand il ya l'ombre le sol se repose, les feuilles vont tombés pour enrichir les sols et ils redeviendront plus productifs. Même un puits qui se sèche, pour eux quand il ya plus d'arbres, l'eau vient quand il n'ya plus d'ombre" (GS).

According to most interviewed persons in the research area, tree planting is the solution for most of the problems they are facing such as high wind speed, water problem and soil infertility.

Due to the supposed important of trees in those communities, future objectives of farmer groups included trees planting. During focus group discussion in Ouandiana and Deguessagou, agro-pastoralists identified tree species they intended to plant in their communities. Agro-pastoralists based their selection criterion on: the possible importance of each tree and the age at first use, as presented on table 21.

Table 21 Selected tree species for community trees planting

Trees specie	**Age at 1st use**	**Use of the tree**
Baobab (*Adansonia digitata*)	2-3 years	- Leaves are used for soup - Fruit are used for crème with millet - Tree skin used for ropes - Shelter for resting - Leaves and rotten branches serve as field compost
Shea (*Vitelari paradoxa*)	3 yeas	- Leaves used for livestock feeding - Fruit are eatable - Seeds are used to make Shea butter
Kohic (*Prosopis africana*)	5-10 years	- Leaves and fruits used for livestock feeding - Leaves cure stomach problems and cough
Balanzan *(Faidherbia albida)*	3 years	- Fruit are used for livestock feeding - Leaves can serve as field compost
Eucalyptus *(Eucalyptus leucoxylon)*	6 years	- Leaves are used for curing malaria - Branches used for home construction
Neem *(Azadirachta indica)*	3 years	- Resting place - Leaves for animal feeding - Branches used for home construction
Ronier (*Borassus flabellifer* L.)	5-10 years	- Edible fruits - Branches used for home construction - Leaves are used for fan and braid making

Source: Focus group discussions in Ouandiana and Deguessagou

4.6 Supported adaptation from NGO's and the Malian government

4.6.1 Supported adaptation from NGO's

SahelEco and Caritas were NGO's with activities that aimed at strengthening the adaptive capacity of agro-pastoralists to climate variability's in the Cercle of Bankaas. The first focused on trees planting, and the later on water, hygiene and sanitation. Their zones of intervention were in all the twelve councils of the Cercle of Bankaas, namely Bankass, Baye, Diallassagou, Dimbal Habbe, Kani-Bonzoni, Koulogon Habe, Lessagou Habe, Ouonkoro, Segue, Sokoura, Soubala and Tori.

The activities carried out by both NGO's, as explained by interviewed key informants are shown on table 22 below.

Table 22 NGO's activities in the Cercle of Bankaas

NGO	Domains of intervention	Informant
SahelEco	- Supporting local initiatives in tree planting - Diffusion of good management of trees - Elaboration of local agreements for the good management of trees - Diffusion of good agricultural practices - Financial support to those that spared at least 50 trees/ha on their farm land	**Housseini Sacko:** Project coordinator; SahelEco - Bankass
Caritas	- Supply of drinking water in villages - Digging of large diameter wells for humans and animals - Encourages sustainable agriculture Through PAMPAID[8] - Sensitization of communities for the proper use of hydraulic infrastructures	**Issa Guindo:** Community development officer; Caritas - Bankaas

4.6.2 Supported adaptation from governmental services

Those governmental services working in the Cercle of Bankaas included the service of livestock keeping, focusing mainly on livestock health and the control of dairy products, the agricultural service in charge of the documentation of agricultural activities in the Cercle and the realisation of state projects. The water and forest service was in charge of the implementation of the national policy, according to interviewed key informant.

These services worked under their ministries, focusing on activities listed and presented on the table below.

[8] PAMPAID: Programme d'accompagnement du monde paysan à l'agriculture durable

Table 23 Governmental services and domain of activities

Service	Domains of intervention	Informant
Service d'élevage de Bankaas	- Improvement of animal health through vaccination - Control an inspection of dairy products - Treatment of infectious diseases - Conservation of forage resources	**Lassina Diallo** Chief of veterinary sector - Bankaas
Services d'agriculture de Bankaas	- Documentation of agricultural activities in the Cercle - Realisation of state projects - Supervision of villages activities - Moral and technical support regarding food growing and storage - Fulfilling farmers' need in term of farm equipments - Provision of short cycle seeds to 100 farmers in each village every year - Provision of fertilizers to farmers - Buying of harvest at higher prices - Sensitization of farmers on the use and importance of compost	**Boubakar Diakité** Chief of agricultural sector - Bankaas
Services des eaux et forêts de Bankaas	- Implementation of national policy - Preservation of wildlife and forest areas - Sensitization of the population - Advisory services - Submission of operators to logging tittles - Restoration of degraded areas through tree planting - Maintenance of biodiversity	**Sidy Sofana** Forester chief of Bankaas

5 DISCUSSION

This research was done in an agro-pastoral community, where there is an integration of crop farming and livestock breeding. This crop-livestock integration has been described as one of the most significant innovations that occurred in the Sahel for the last decades. Even though the integration of crop–livestock farming is regarded as innovation by some authors, others argued that this combination of crop–livestock may have negative implications on property rights, equity, and risk management within farming communities concern (Harris, 1999; Williams et al., 2000; Perret, 2008).

Despite this combination of farm activities, it was observed that, Fulani which are traditionally pastoralists still prioritize cattle rearing. Other tribes such as the Dogon and Rimaibés gave more priority to crop farming, and identified themselves as crop farmers.

Even though most agro-pastoralist in this study still identify themselves by their original activities, Harris (1999) argued that, this traditional division between nomadic pastoralists and sedentary farmers has diminished, as both groups are nowadays engage in livestock rearing and crop farming.

5.1 Discussion of method

5.1.1 Data collection

The data collection was done between March and May 2010, a dry season period in the Séno-Bankass. At this period of the year, daily temperatures were very high, and could easily reach 45^{0}C at the middle of the day. This period also had the highest occurrence of the harmathan, which brings into the region the dry winds from the Sahara Desert, and a thick haze of dust, thick enough to obscure the sun and affect visibility for couple of days.

Selection of key informants in NGO’s and governmental services

Initially, just NGO’s were to be interviewed, but due to their limited number in the Cercle, governmental services based in the Cercle were also interviewed. The selected key informants were in the city of Bankaas, the head quarter of the Cercle. The purpose of interviewing those key persons was to gather innovation they supported in agro-pastoral systems of the Séno. Initially, it has been planned to interview at least ten NGO’s working in the region. In that sense, a list of NGO’s working in Mopti was made, with the help of the local supervisor in IER-Mopti.

From this list of active NGO’s, only a few acknowledged they have been working on improving or supporting farmers initiatives in adapting to climate variability’s. However, most attempt through phone calls for possible meetings for interviews failed, as most persons that were supposed to be in charge of such activities were either on seminars, vacations or out of office. Nevertheless, there were positive responses as well, within which some said to have stopped activities since few years back, due to budget constraint. Finally, two of those NGO’s were reached, and with this reduced number, it was interesting to look at policy driven adaptations from the Malian government.

5.1.2 Methods used in data collection

Participant observation

This was scheduled to be carried with young and old agro-pastoralist, both men and women, spending with each person in those categories at least a day. This research method is regarded by Bouchard (1976) as advantageous in the sense that: it focuses the attention of the researcher on behaviour of the target farmers, rather than relying simply on the verbal interviews. It brings the researcher to look at the whole farmer and environment in an integrated way, and put the researcher in the context of discovery what Merton (1949) cited in Bouchard (1976) called the serendipity pattern of social research. However, this method is also known for its time consuming, and difficult to know when to break off from further observation (Waddington, 2004).

Participant's observation in this study was hindered by limited field activities and the extreme weather conditions (high temperatures) during the study period. Therefore, data generated may be too weak to give a full picture of the management strategies of agro-pastoralists in this region. The best possible time for field work and participant's observation in this region is between the months of November to January, a period with more field activities.

Interview of key informants

The interview of the key informants in NGO's and governmental services was done using a questionnaire. Most of these key informants insisted to see the content of this questionnaire. This was an uncomfortable situation, because the interviewees knew already the structure of the questionnaire. All interviews, including key informants interviews from NGO's, governmental services and in villages were recorded and sometimes notes taken, so as to come back on important issues mentioned. This was to avoid interrupting of the interviewees. However, Bouchard (1976) argued that, taking notes distracts the interviewer from the careful observation of the informants' visual behaviour or intonation, and can slow the interviewee down as well.

Identification and interviewing of innovative farmers

This part of the research consisted of identifying innovative farmers, and gathering innovations they developed. These were done in neighbouring villages to host villages, and were to be introduced in the host villages. However, thinking of sharing and up scaling those practices (innovations), there is the fact that local innovations are site-specific, hence can be seldom replicated elsewhere. On the other hand if introduced elsewhere they can at least stimulate experimentation and innovation in those localities (Waters-Bayer et al., 2006). That is why the host and neighbouring villages where selected in one ecological zone, so as to increase the chances of environmental compatibility with the gathered innovations.

Because the gathered innovations were to be introduced in other villages, this was preceded by one week of individual and group interviews in each of the host villages. The aim was to learn about the current climatic problems experiencing agro-pastorals in those villages, as well as the innovation they have developed. This strategy was used in other to avoid the assumption that, farmers do not adopt innovations because it addresses the wrong problem (Fujisaka, 1994).

Challenges faced in identifying and interviewing of potential innovators

- **Reliability on key informants for the selection of innovators**

The interviewed farmers in the neighbouring villages were to be innovative farmers in those villages, hence to be selected based on their distinctive works. However, the selection of those persons was entirely carried out by the key informants (village chief), sometimes with the assistance of his "notables". This method of identification of farmer innovator is suggested by Wettasinha et al. (2008). Due to the social structure and hierarchy in those villages, the key informants are the first contact persons, and they naturally take these responsibilities to select the innovative persons in their villages. This is also a means for these village chiefs to show their authority in the community.

However, the selection criterion and characteristics of an innovator was clearly explained to the key informants, as found in sessions 3.3.3 and 3.3.4. However, during the interview sessions, selected persons were asked about possible reasons, why they are privileged, or which innovations they have carried out that kept the chief thinking about them. Most interviewees acknowledged it was perhaps due to their courage, their active participation in social works, or their loyalty to the village chief. From those statements, it was clear that the selection criterion proposed was not applied. As pointed from literature, this method of identification of local innovators may be subjected to biases (Wettasinha et al., 2008). Due to time and resources constraints, other methods such as observation or organizing an innovation fair or workshop were not tried.

Using the key informants in the visited villages was a key constraint to reaching potential innovators; nevertheless, the selected persons were in general active persons.

- **Confusions for what can be an innovation**

The concept of farmers' innovation was something completely new to me, hence my full dependence on scanty literature on the topic. Regarding what can be called innovation, some authors suggested that, it should have been developed within the past 20 to 25 years, this referring to one generation. Others argued that it is acceptable if it was developed within the working lifetime of the farmer, therefore in the last 60 to 70 years (PROLINNOVA, 2009). Faced to those two options, it was difficult to mark a clear cut to which extend the research could be deepen.

Farmers' difficulties in sharing innovations

- **Under-estimation of innovation**

The sharing of innovation from farmers' side did not depend on the effective use of the identification method, rather on farmers' understanding of what was an innovation. Farmers' inability to share innovations in this study does not imply that they were less innovative. This was maybe due to the fact that they do not value their actions. Nevertheless, Beet (1990) and Assefa (2010) argued that it is possible that, resource limitation forces farmers in such environment to stick to their normal practices, in order to avoid failure, which may have direct consequences on their food availability.

- **Over-valued of intervention**

It is obvious that, most interviewed persons did not believe in their innovative potentials. During interviews, some farmers clearly stated that: only we (the research) can bring those solutions or advice them on what to do. With this belief, it is clear that no one in the community expects a poor farmer to be the source of an innovation that others in the community can profit from. This belief is supported by a study from Ethiopia, where a farmer stated that, "many people in his society have the tendency to believe that, it is only the literate and intellectual people (like the extension workers) who could bring something new and important to the farmers" (Assefa, 2010). The problem is that, those active persons are sometimes rejected in the society. In Ouandiana for example, a farmer engaged in tree plantings acknowledged that, people often look at him as a mad person, because he travels a lot to find trees he could plant around his village. With this feeling of been regarded low in the society, it is difficult for such persons to share what they know or have been experimenting.

5.2 Discussion of results

Results are from different villages, and complement each other to give an overview on the agro-pastoral system in the Séno-Bankaas. Although the study area is in the Sahel region, those results cannot be representative of the entire Sahel regions, for several reasons: first because the production systems in Sahelian countries depend strongly on rainfall, which varies in time, space and location. Secondly the soil type which determines the types and varieties of crops to be produced is predominantly sandy in the Séno. Those factors may be different in other Sahel regions, even within the same country.

5.2.1 Agro-pastoral system in the research area

The results found on session 4.1 gives an overview on the livestock keeping and crop farming in the research area, without going in details into those systems, because more time would have been needed, and the use of PRA tools such as the seasonal calendar for example. For this reason, the results presented on this session may not be representative of the livelihood in the Séno-Bankass. However, it gives an overview on the functioning of the agro-pastoral system in the study site.

5.2.2 Climatic changes observed by agro-pastoralists

The climatic problems observed by agro-pastoralists in the research included; the increase wind speed, unreliable precipitation, insufficient rainfall and extreme heat. These climatic changes have been cited in some literature (Hulme and Viner, 1998; Patz et al., 2000; Hulme et al., 2001; Butt et al., 2005; Simonsson, 2005; Nyong et al., 2007; Ministere de l'environnement et de l'assainissement, 2009; Kotir, 2010).

Other changes which agro-pastoralists associated to climate change they have experienced were; the infertility of the soils, the reduction of pasture land, new and unfamiliar livestock diseases and deforestation. It should be noted that, farmers and herders often expressed the problems they are facing through the impacts on their activities. Nevertheless, there is no direct link between the climate and some of the problems mentioned. The reduction of pasture land as understood from livestock keepers' explanations result from the expansion of agricultural area, due to population increase and the increase in soil infertility which drives farmers to cultivate more land in order to compensate the poor harvest.

Deforestation is not a climatic problem, rather a result of human interventions, such as fuel wood extraction or shifting cultivars', driven by population increase and poverty (Lambin et al., 2001), hence population increase is a driving factor of deforestation.

Regarding the scarcity of grass on pastures, it is obvious that pasture areas have a carrying capacity for livestock, and if exceeded this causes degradation, hence climate cannot be singled out as responsible of that change (Lambin et al., 2001). Nicholson et al (1998) argued that, the roots of this problem are population increase, the sedentarization of indigenous nomadic people, deforestation, overgrazing and the growing of livestock number.

Soil infertility as identified by agro-pastoralists is not directly caused by climatic variability´s, however may be worsened or initiated by it (Simonsson, 2005). As observed in this study, land degradation or increase in soil infertility is much more of a human induced problem than climatic. This is based on the following reasons:

Multiple use of crop residues: from own observation, most crop residues in the studied villages are not incorporated back to the soil, at least not directly. Nyong et al. (2007) argued that, mulching which moderates the soil temperature, suppresses diseases, harmful pests and conserve soil moisture is very common in the Sahel. This was not observed in this study. Instead, most crop residues such as beans and groundnuts leaves for example, were regarded as very nutritive for livestock, therefore taken out of the fields and store for livestock feeding, in some cases even sold on the local markets.

From observation, most sorghum and millet stover were often burned as fuel wood, used for fencing, thatching (building material from plant) or fed to livestock. This multi-purpose use of sorghum and millet stover is also observed in several semi-arid areas in Africa (Rai, 1999). Of course feeding crop residues to livestock, one may argued that the faeces will be later transported to the field as farm inputs. On the other hand, just by feeding those residues to livestock, there are nutrients looses such as nitrogen. Bationo and Mokwunye (1991) estimated that, the retention of nitrogen for example in livestock body is between 4-10% in beef, and between 13-28% in dairy cattle.

Burning of crop residues as observed do not only expose the cultivated field to direct sun radiation or wind erosion, but also lead to a good amount carbon and nutrients losses such as sulphur and nitrogen through burning (Bationo and Mokwunye, 1991). The above practices lead to an unbalance between farm off take and farm inputs, described as soil mining, and typical of farmers in the Sahel (Powell et al., 1993).

Increase use of dried animal faeces as fuel wood: dried cattle faeces are growing source of cooking fuel wood in this area. As observed in this study, young women go out early in the morning or late in the evening to collect dried faeces that they use for cooking.

Over exploitation of farm lands: according Mazzucato et al. (2001), poverty leads to more land degradation, because farmers are unable to postpone production in order to practice land enhancing measures. Livelihoods in such dry areas depend strongly on agriculture, resulting therefore in over cultivation. The situation in this study is that, families depend strongly on farming and livestock keeping for subsistence. In most villages farmers reported that for the past decades family sizes have increased, whereas the farm sizes allocated to each family did not changed that much. As a result, families are obliged to cultivate the same fields every year, with limited or non-existing fallow, so as to meet their household demand.

Nevertheless, the conservation of carbon through a minimum tilling during cultivation was observed in this study, and is believed to be typical of the farmers in the Sahel (Nyong et al., 2007). But, the increase use of animal draft-power for cultivation reserved to wealthy farmers is becoming gradually important and common, as some farmers argued it is important for them to own this, so as to cultivate more areas of land in future.

Regarding the use of animal draft-power, farmers in this study had conflicting opinions about its use. Some farmers argued it is very important for them in future, whereas others believed they started witnessing the increase degradation of their soils since its introduction and increase use. The later is somewhat supported by literature, which suggests that tillage using animal draft-power can result in environmental degradation, as its use is directly linked with soil erosion and accelerated decomposition of organic matter (Adesina, 1992). This study also argued that ploughing using draft-power can as well lead to an increase in yields, ranging from 22-25% increase in millet, sorghum and groundnuts, to even up to 50% increase for maize, depending on water availability.

5.2.3 Impacts of observed changes on activities

The increase in temperature and decline in rainfall as already experienced by agro-pastorals in this study eventually cause ecological stresses. Nyong et al. (2007) believe such changes will “impair the functioning of ecological systems particularly in terms of plant growth and development”.

Agro-pastoralists in this study observed several climatic impacts on their production systems, resulting in most cases from unreliable or insufficient rainfall. However some studies argued that, if rainfall increases there will be a reduction in livestock net income in drylands. This was based on the assumptions that livestock keepers will switch from livestock keeping to crop farming, grass lands may grow to become forest, hence reduce the quality of pastures, and there will be an increase incident of livestock diseases (Seo and Mendelsohn, 2007).

Crop farmers in Deguessagou believed they have an increase in millet yields as temperature increases. This is also supported by literature in the sense that, as the concentration of CO_2 in the atmosphere increases, plants usually close their stomata, depending on their energy demand. This is to reduce the conductance of CO_2, and the transpiration rate of the plant. By so doing plants increase their water use efficiency by avoiding losses. This adjustment mechanism in plants can lead to higher yields in both C3 and C4 plants, even in environments with mild water stress (Rötter and van de Geijn, 1999).

Although deforestation is not a climatic problem as expressed by agro-pastoralists, as trees and shrubs are removed to produce fuel wood, charcoal, or for agricultural land, the land becomes increasingly impacted by wind and water erosion. Those later leads to soils infertility, as the soils’ texture, organic matter and nutrients contents are eroded (Nicholson et al., 1998).

5.2.4 Adaptation strategies

The purpose of adaptation is to reduce vulnerability. However, Stern and Treasury (2007) argued that “there are limits to what adaptation can achieve”. They also believe that, as the magnitude and speed of climatic changes increases, the relative effectiveness of adaptation in those communities living already at the edge of survival is expected to reduce. Nevertheless, agro-pastorals in this study have invested in a range of adaptation, even though constrained by resource availability.

Autonomous adaptation

The identification and documentation of autonomous adaptation strategies in the Séno-Bankass was initially the bigger part of this study. However, most of the adaptation strategies pointed out by the agro-pastorals in this study were already in practice, as reviewed in some literatures (Mortimore and Adams, 2001; Orindi and Murray, 2005; Butt et al., 2005; Benhin, 2006; Amsalu and de Graaff, 2006; IPCC, 2007; Siebert et al., 2008; Roncoli et al., 2009; Speranza et al., 2009).

- **Adaptation within livestock keeping**

Regarding innovations in the area of livestock, just the area of feed supplementation was given more focus. The reason is that, adaption strategies such as mobility, the selection of adapted breeds and others were already mentioned in some literatures.

Nevertheless, mobility as cited in literatures and also practice in the study area was constrained by the expansion of crop lands to grazing areas. Food security is an important concern to the Malian government, and there are efforts towards achieving it. This is done through direct support to crop farmers, by giving them incentives to increase farm sizes. With the increase in cultivated area, most livestock corridors to those grazing areas are completely closed down. By doing so, herders are forced to intrude on the new agricultural fields, resulting in conflicts between farmers and herders, sometimes deadly.

Although the harvesting of wild fruits and trees branches to sustain livestock during the dry season was regarded a new way of feeding livestock in the study area, most livestock keepers acknowledged it was a risky strategy for them. This because it was prohibited by law to harvest tree branches or fruits, no matter the reason. This was a government regulation to slow the deforestation rate in this region. Therefore victims were subjected to financial sanctions from the forest agents, working in collaboration with the village chiefs.

Crop residues were potential source of livestock feeding during the dry season. The entire beans and groundnuts leaves in visited villages were completely taken off the field and stored at home or even sold on the local market. During the study period, the amount of millet stems found on the fields after harvest somewhat differ from one village to another, depending on the village size. For example in large villages such as Ouandiana or Deguessagou, fewer millet stems were found on the field at the period of the study, as compare to smaller villages such Maga or Dinto. Consequently, one can conclude that the village size and population, also correlated to the amount of livestock kept by the population, is a strong determinant whether crop residues such as millet stems are left on the field or simply harvested and store at the home premises.

- **Adaptation within crop farming**

Millet in the studied villages was the most common food crop and the most cultivated as well. Hence, most farmers' discussions about cultivated crops where referred to millet. As presented in section 4.5.2, farmers diversified their millet varieties in order to secure harvest under harsh environmental conditions. According to some key informants, the research institute IER, working under the ministry of agriculture is providing short varieties seeds to farmers in the region. But, most farmers using these varieties acknowledged these varieties were from other farmers in different regions. Although short cycle varieties seed were made available to farmers, a key informant from the ministry of agriculture said most farmers are very reluctant in taking these varieties from the research. However, he also said those farmers using these varieties from the research were encouraged to share these varieties. It is possible that these varieties that farmers said were from the highlands of Bandiagara and from the council of Laguassagou were from the research, because the key informant said they donate each year those short cycle varieties to 100 farmers in selected villages.

More important is the remark of farmers in the village of Bollé, regarding the short cycle varieties obtained from the council of Laguassagou. These farmers said they observed some changes after three years of using this short cycle varieties, and it gradually become like their normal long cycle variety. This change in the cycle of pearl millet can be explained by the fact that, this crop is predominantly cross-pollinated, with 75-80% out crossing (Rai, 1999). Because farmers used both long cycle varieties and short cycle varieties, there are high probabilities of cross-pollination between these two varieties, with impacts observed on the growing length of the crossed varieties.

Regarding the increase in soil infertility, most farmers depended on the household waste and livestock faeces. Few farmers used additional fertilizers purchased on the local market, often in small quantity.

Deforestation is a growing phenomenon in the Séno-Bankass, and agro-pastoralists are very much aware of the consequences. That is why most villages have engaged in tree planting, some under the care of NGO's as in Sokoro, or from individual initiatives such as in Ouandiana. Engaged persons arguments were based on the conviction that, trees can slow the wind speed blowing through their villages, reduce the amount of dangerous weed on their fields, provide shadow and when there is shadow, they believe the soil can rest, leaves will fall to bring inputs to the soils and these soils will again be productive, and even a well that is drying out, at their knowledge water comes when there is more shadow. This statement is equally supported by literature, and suggest that trees actually improve the soils physical properties, increase the SOM, reduce nutrients loss by erosion or leaching, increase the uptake of nutrients to reach the root zone, biological N_2 fixation and water storage (Buresh and Tian, 1997).

Supported adaptation from NGO's and governmental services

Regarding the NGO's activities in the Séno, Caritas until 2009 intervened in 4 villages, and extended to 28 villages as from 2009. SahelEco said it was present in all the villages in the Cercle, estimated to 282 villages. However, almost all visited villages in the council of Diallassagou at the period of the research said they did not profit from the support of these NGO's. Farmers in Sokoro said trees' planting was initiated in their village by SOS-Sahel, a British NGO transformed into the present SahelEco.

The livestock keeping services operating under the ministry of livestock keeping is one of the most active on the field, regarding livestock vaccination. The key informant said they have eradicated most livestock diseases in the Séno, through compulsory vaccination. However, there are upcoming challenges regarding livestock diseases, as most livestock keepers said *doudé* and *gougnè* were emerging livestock diseases.

The water and forest services in the study area ensured that deforestation is reduced, this by giving financial sanctions to culprits. Livestock keepers feeding their animals with additional tree leaves and wild fruits reported this service was very active in the region. However, logging for fuel wood or for feeding small ruminants around the village premises persisted. Perhaps a better solution will be to give more power to the village chiefs and assistants (Notables) to control the forest resources, since they are permanent in their villages and highly respected.

A couple of adaption strategies were mentioned out by the agricultural agent in Bankass, as shown on table 23. Those strategies if properly implemented could facilitate the adaptation process in these communities where farmers are struggling to cope with their meagre resources. Few farmers acknowledged to have received the training in how to make compost from extension workers, and hope they will soon profit from other support like the provision of farm equipment. Although the agricultural service in Bankass said they buy harvest in villages at higher prices than on the market, farmers in Ouandiana and Deguessagou were eager to build community storages for their harvest, and planned buying cereals from farmers after harvest, as most farmers are in need of cash at that period of the year when prices seems to be low. During periods of scarcity like at the end of the dry season or at the beginning of the sowing periods, they can sell these grains in the village, at lower prices than on the local market, so that most families will be able to afford.

6 CONCLUSION

The results of this study show that, agro-pastorals in the drylands of Mopti observed climatic changes occurring within their region, although they do not have formal monitoring tools that may enable them to observe the progression of such changes. However, regardless of the change in the period and amount of rainfall, which farmers in this study were relatively sure to have observed, other changes they did mentioned were simply speculation, since they hardly explained how much change they have observed.

Despite the difficulties in explaining how much changes has occurred in their production environment, farmers were very much sure of the impacts of the perceived changes on their production system, due to the direct effects on crop yields, availability of grass on pasture etc.

Regarding crop farming, results of this study showed that farmers autonomously implement a series of measures, which enables them to reduce their vulnerability to climatic stresses. These measures include the choice of crop varieties that matches the prevailing climatic conditions. This selection of crop varieties coupled with other strategies such as more farm input and others enabled farmers to guarantee harvest under hash environmental conditions. In most cases, farmers owned two varieties of crops (the case of pearl millet) the short cycle variety which they regard as outside variety, and their own variety, often distinguished by its long growing period and the higher demands in water, as compare to the short cycle variety.

Regarding livestock keeping, the main challenge for livestock keepers was to sustain their livestock through the hash nine months dry season per year. Regarding the strategies suggested, mobility will be hampered in future by population increase and the extension of agricultural areas into pasture lands and livestock corridors.

It can also be concluded from this study that, the problems facing agro-pastoralists in the Séno-Bankass such as: land degradation, reduction of fodder and others, are not only caused by climate change and variability, but in combination with other pressures such as population increase, continuous cultivation of crop lands etc.

In agro-pastoral systems such as in this study, crop residues are important sources of livestock feedstuff during the long dry season period. The growing use of crop residues for feeding livestock and other purposes increases the vulnerability of arable lands to extreme weather events.

Regarding policy driven adaptation, governmental services and NGO's have initiated several projects, designed to support farmer communities in the Séno-Bankass. However, this study also found that farmers in drylands of Mopti have sufficient knowledge in how to cope with adverse impacts of climate change in their region. But, some adaptation options may not be sustainable. For example, when feedstuff becomes scares in the dry season periods, livestock keepers react by adopting alternative feedstuff such as harvesting tree branches and feeding tree leaves to livestock. It is clear that feeding livestock with tree leaves from harvested tree branches only reinforces deforestation in these areas. That is why the IPCC (2007) already concluded there is little evidence that autonomous adaptation will be efficient and effective. Hence, effective intervention that takes into consideration farmers' interest is needed, in order to avoid unsustainable adaptations.

7 SUMMARY

Agriculture is an important sector in the Sahelian countries, due to its multiple roles in food security, employment and contribution to national GDP's. Inhabitants of the Sahel regions depend mainly on rain fed agriculture and livestock. Production in Sahelian countries is hindered by the low use of external inputs, absence of mechanisation, poor linkages to markets and climate variability's. Climate variability's is not a new phenomenon in the West African Sahel, and farmers through their indigenous knowledge systems have developed and implemented adaptation strategies that have enabled them to survive hash drought periods, such as those that occurred in the 1970’s and 1980’s.

The objective of this study was in three-folds: 1) - to gather adaption strategies promoted or supported by NGO's and governmental services in the study area, 2) - to identify climatic problems observed by agro-pastoralists and the impacts of observed changes on their production systems, and 3) - the identification and documentation of innovations, regarding agro-pastorals adaption strategies to climate variability’s and changes, in the drylands of Mopti region in Mali.

Field data collection took place from March to May 2010, and focuses on a total of ten villages in the Séno-Bankass, two NGO’s and three governmental services based in Bankass, the head quarter of the Cercle. Data collection was qualitative, with a combination of methods such as individual interviews, focus group discussion or group interviews, participants' observation and workshops. Interviews were semi-structured, with preset questionnaires for each target group. The language of communication in the research area was Fulfulde, but interviews were translated into French by a local translator. These interviews were recorded, and later transcribed in English, for content analysis.

The result of this study shows that, diversification in livestock and crop farming characterises the agricultural system in the Séno. However, two major tribes can still be differentiated in the Séno, based on their prioritized activity. Those were predominant crop farmers or livestock keepers. Agro-pastorals in drylands of the Séno-Bankass observed climatic changes occurring in their localities, those changes include: the strong heat, strong wind speed, insufficient and unreliable rainfall. Other changes observed were: the infertility of soils, the reduction of pasture lands, new and unfamiliar livestock diseases and deforestation. Regarding the impacts of speculated changes on farm activities, they observed a reduction of crop yields and residues, increase in lands degradation, delay in farming activities, reduction of livestock fodder, uncertainties in farming activities, longer calving interval of livestock etc.

Faced to these problems, agro-pastorals in the Séno like in other drylands areas of Sahel developed a series of measures, so as to reduce their vulnerability. Regarding livestock keeping, adaption strategies to expected changes include: the seasonal migration to better grazing areas, harvesting and stocking of dried fodder and crop residues, selection of adapted breeds, selling livestock in order to buy feedstuff for the rest of the herd, fattening, rituals, trees planting, reduction of herd sizes and the supplementation of feedstuff with several wild fruits varieties. Regarding crop farming, adaption strategies include: the diversification of crop varieties, multi-sowing, rituals, tree planting and more farm inputs. Policy driven adaptation from the governmental services and NGO's include: the restoration of degraded areas through trees planting, provision of ameliorated crop varieties to the farming communities, the conservation of forage resources, the treatment of livestock diseases, the provision of farm equipment etc.

Conclusions of this study are that: agro-pastoralists in the Séno have adopted strategies that enable them to reduce their vulnerability to climatic pressure and other changes. However, there are limit to what autonomous adaption can achieve. That is why more policy driven adaption is needed to support and guide indigenous adaptation, so as to avoid maladaptation.

8 RÉSUMÉ

L'agriculture est un secteur important dans les pays du Sahel, en raison de ses rôles multiples dans la sécurité alimentaire, l'emploi et la contribution au PIB national. Les habitants des régions du Sahel dépendent principalement de l'agriculture pluviale et l'élevage. La production dans les pays sahéliens est entravée par la faible utilisation d'intrants, l'absence de mécanisation, l'inaccessibilité des marchés et la variabilité du climat. La variabilité du climat n'est pas un phénomène nouveau dans le Sahel Ouest-Africain, et les agriculteurs grâce à leurs systèmes de savoirs autochtones ont élaboré et mis en œuvre des stratégies d'adaptation qui leur ont permis de survivre à des périodes de forte sécheresse, tels que ceux qui ont eu lieu dans les années 1970 et 1980.

L'objectif de cette étude était en trois volets: 1) - recueillir des stratégies d'adaptation promus ou soutenus par les ONG et les services gouvernementaux dans la zone d'étude, 2) - identifier les problèmes climatiques observés par les agro-pasteurs et les impacts des changements observés sur leurs systèmes de production, et 3) - l'identification et la documentation des innovations, concernant les stratégies d'adaptation agro-pastorales à la variabilité et des changements climatiques, dans les zones arides de la région de Mopti au Mali.

La collecte de données a eu lieu de Mars à Mai 2010, et se concentre sur un total de dix villages dans le Séno-Bankass, deux ONG et trois services gouvernementaux basés à Bankass, le chef-lieu du Cercle. La collecte des données a été qualitative, avec une combinaison de méthodes telles que des entretiens individuels et en groupes, des entrevues en discussion de groupe, l'observation des participants et les ateliers. Les entrevues étaient semi-structurées, avec des questionnaires prédéfinis pour chaque groupe cible. La langue de communication dans le domaine de la recherche a été le Fulfulde, mais les entretiens on été traduits en français par un traducteur local. Ces entrevues ont été enregistrées, puis transcrites en anglais, pour l'analyse de contenu.

Le résultat de cette étude montre que, la diversification dans l'élevage et la culture des plantes caractérise le système agricole dans le Séno. Toutefois, deux grandes tribus peuvent encore être différenciées dans le Séno, en fonction de leurs activités prioritaires. Ce sont les producteurs soit spécialiser dans la culture des plantes ou spécialiser dans l'élevage. Les agro-pasteurs dans les zones arides du Séno-Bankass observent des changements climatiques qui surviennent dans leurs localités, ces changements comprennent entre autre: la forte chaleur, la forte vitesse du vent, les pluies insuffisantes et peu fiables. D'autres changements observés sont: l'infertilité des sols, la réduction des pâturages, les nouvelles maladies du bétail et la déforestation. En ce qui concerne les impacts des changements spéculé sur les activités agricoles, ils ont observé une réduction des rendements des cultures et des résidus, l'augmentation de la dégradation des terres, le retard dans les activités agricoles, la réduction de fourrage pour le bétail, les incertitudes dans les activités agricoles, plus l'intervalle entre vêlages etc.

Face à ces problèmes, les agro-pasteurs du Séno comme dans d'autres zones arides du Sahel ont élaboré une série de mesures, de manière à réduire leur vulnérabilité. En ce qui concerne les stratégies d'adaptation dans le secteur de l'élevage, des hypothèses suivantes ont été recensés: la migration saisonnière vers de meilleurs pâturages, la récolte et le stockage des fourrages séchés et les résidus de récolte, la sélection de races adaptées, la vente du bétail pour acheter des aliments pour le reste du troupeau, l'engraissement, les rituels, la plantation d'arbres, la réduction de la taille des troupeaux et la supplémentassions de l'aliment avec plusieurs variétés de fruits sauvages. En ce qui

concerne les cultures agricoles, les stratégies d'adaptation comprennent: la diversification des variétés de cultures, multi-semis, les rituels, la plantation d'arbres et plus d'intrants agricoles. Les politiques d'adaptation entraînés par les services gouvernementaux et les ONG comprennent : la restauration des zones dégradées par la plantation d'arbres, la fourniture de variétés de cultures améliorées aux communautés agricoles, la conservation des ressources fourragères, le traitement des maladies animales, la fourniture de matériel agricole etc.

Les conclusions de cette étude sont que, les agro-pasteurs du Séno ont adopté des stratégies qui leur permettent de réduire leur vulnérabilité aux pressions climatiques et autres changements. Cependant, il ya des limites à ce que l'adaptation autonome peut atteindre. C'est pourquoi l'adaptation plus guidée par les politiques est nécessaire pour soutenir et guider l'adaptation autochtone, afin d'éviter certains maladaptation.

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10 ANNEX

10.1 Farmers' questionnaires

Nom de l'agriculteur ou Berger	
Age:	
Composition Familiale	
Nom du Village	
Superficie du champ/ nombre d'animaux	
Source de revenue	
Date:	
Heure:	

A. Questions Génerale.

I will like to learn about the history of your farm, can you please tell me something about that/parlez moi de l'histoire de votre champ, c'est-á- dire comment vous l'avez eu et combien de temps vous exercez déjà dans ce domaine d'activité?
Can you give me an introduction into your farm/ Donnez moi une idée générale de vos activités?
Are you carrying out activities besides farming (that are sources of livelihood)/Entreprenez-vous d'autres activités en dehors de vos travaux de champs, si oui, quoi?

B. Do you encounter changes with the climate here in the past 10 – 15 – 20 years? If yes, which changes/ Avez-vous constaté des changements avec le climat, pendant les 10- 15 ou 20 dernières années? Si oui, quels changements?

C. How does it affect the crop/agriculture or livestock system/quelle est l'impact de ses changements dans vos activités de champs/bétail?

D. How do you cope with these changes? Describe these coping strategies/comment faites-vous face à tous ces changements? Quelles stratégies utilisez-vous?

E. Are you currently working with other farmers to overcome to climate problems? / Travaillez-vous avec d'autres agriculteur/éleveur pendant ces moments difficiles?

10.2 Key informants questionnaires (NGO's and Governmental services)

Nom & address de l'ONG	
Nom & poste du personnel	
Domaine d'intervention	
village d'intervention	
Activities de l'ONG	
Date:	
Time:	

A. Questions génerale.

Introduction about the organisation (history)/ parlez-moi de votre organisation

Current activities/ quels sont vos activités récentes?

Activities in crop and livestock (emphasis on innovations)/ quels sont les activités que vous faites dans le domaine de l'agriculture ou d'élevage?

Activities relate to change in climate (emphasis on innovations)/ quelles sont les activités qui ont pour but de lutter/atténuer les effets de changement climatique?

B. With regard to innovations in crop and livestock (and if applicable in change in climate):

Which of these innovations are from outside and which are from local farmers/ quelles sont les stratégies d'adaptations qui viennent de vous, et ceux qui viennent des agriculteurs?

Which are adopted (easily, slowly – explain also why, success stories or difficult)/ quels sont les mieux adopter?

Which are short term long term/ lequels sont lont et court termes?

Are farmers participating well. Is farmers participation encouraged and how/est-ce-que les paysans prennent part activement dans vos activités? et comment encouragez-vous leurs participations?

What are the problems with regard to adoption of (some of) these innovations/quels sont les problems qui surviennent, en ce qui concerne l'adoption des stratégies adaptation?

What from your opinion/experience are strength and weakness with regard to adoption of innovations/ par rapport a vos experinces sur le terrain, quels sont leurs forces to leurs faiblesses à adopter des récents stratégies d'adaptation?

C. Opinion of NGO on change in climate

Can climate change be observed and how/ Selon vous, est-il possible d'observer les changements climatique, si oui, comment est-ce possible?

How is it affecting farmers (which ones, which activities etc)/quels sont les impacts sur les activités des agro-pastoraux?

How are farmers reacting? / Comment est-ce que ces agriculteurs réagissent-ils?

What are their strength and weaknesses in dealing with climate problems/ d'après vous, quels sont leurs forces et faiblesse, a pouvoir vaincre les problèmes du au changement climatique?

10.3 Form for documenting identified innovations

Nom de l'agriculteur ou Berger	
Age:	
Composition familiale	
Village	
Nom du groupe d'agriculteur	
Nombre d'agriculteur	
Activités	
Date:	
Heure:	

What is the innovation about/ En quoi consiste l'innovation?

Which problem does solve/ Quel problem sert-il a resoudre?

What is its purpose/ Quel est son but?

What is its goodness/ C'est quoi le bienfait de cette innovation?

Where did the idea come from/ D'ou viens l'idée/ l'origine?

When did you invent it/ quand l'avez-vous inventé?

Who else was involved/ Qui d'autre était impliqué dans la mise en œuvre de l'innovation?

Which resources are needed for the innovation/ Quels sont les resources nécessaires pour la mise en pratique votre innovation?

Is it replicable and under which conditions/ Est- il replicable? Quels sont les conditions nécessaires pour sa mise en pratique?

Is it difficult or simple to take over/ est-il facile ou difficile a refaire ou reproduire?

Are the materials needed available locally/ est-ce-que le matériel nécessaire pour sa réalisation est disponible dans votre localité?

Have you shared it/ L'avez -vous partager?

Do other farmers use it? Did others found it difficult/D'autres personnes l'ont-ils utilisé, si oui, comment l'ont-ils trouvé? C'est-á-dire, difficile ou facile

Who uses it (you can interview them later)/ Connaissez-vous d'autres gens qui l'ont utilisé ou adopter?

Does it help to save money or labour, does it create income, is it economical/ l'innovation aide à épargner de l'argent, la main d'œuvre ou il est juste Economique?

Declaration

I, the undersigned, hereby declare that this thesis is a personal work. I also guarantee that, this work has never been used in the past for any examination intended for a university degree.

Witzenhausen 21st March 2011

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Roland Kuete Tagnigue