Coping strategies and vulnerability to climate change of households in Mali

Supporting the vulnerable: Increasing the adaptive capacity of agro-pastoralists to climatic change in West and Southern Africa using a trans-disciplinary research approach

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Abstract

Variable and low rainfall patterns combined with increasing population pressure have led to natural resources degradation in the Mopti region of Mali. This has forced both agricultural and pastoral communities to transform their production systems and social relations. To assess the adaptive capacities of these agro-pastoral communities to climate change, a participatory survey was conducted in the region between February and May 2009. The survey covered in total 175 households, covering 60 households per agro-ecological zone (i.e. the zones Séno and Gourma), with 15 households per village. In the Delta zone, 55 households were available for the interview.

A multiple linear regression analysis was conducted to assess the relationship between household coping strategies and selected factors. The results showed that strategies adapted by agro-pastoral households to cope with climate change vary according to vulnerability factors such as the insufficiency of pastures for livestock, animals' diseases and death, crop failure caused by erratic rainfall, human sickness, lack of water supply for the livestock, conflicts related to resource use, and several others. The major coping strategies identified were the reduction in the number of animals, storage of crop residues and other gramineous species for livestock, and grain for the population as well as seeking external help. Some major factors were identified to influence strategies of households to cope with climate change. The multiple linear regression analysis showed significant relationship between these influencing factors and coping strategies.

Key words: coping strategies, climate change, pastoral communities, vulnerability factors, adaptive capacity, Africa.

CHAPTER 1: Introduction

1.1 Background

This report is one of the outputs of the BMZ funded project 'Supporting the vulnerable: Increasing the adaptive capacity of agro-pastoralists to climatic change in West and Southern Africa using a trans-disciplinary research approach'.

The goal of this trans-disciplinary project is to increase the adaptive capacity of agro-pastoralists, who are one of the most vulnerable groups in Africa, to climate variability and the expected effects of future climate change. The purpose of this project is to co-generate methods, information and solutions between local communities, local and international scientists, policy makers and other actors involved in climate change and adaptation programs, to develop coping mechanisms and adapting strategies to climate change and variability in West and Southern Africa, and more particularly in Mali and Mozambique.

The project aims to deliver five integrated outputs:

- Estimation and documentation of the effects of climate variability and change on the primary productivity of crops, rangelands and livestock, and associated livelihoods impacts.
- Inventory, documentation and dissemination of past, present and possible future agro-pastoralists coping mechanisms to deal with climate variability.
- Active learning mechanisms developed, and priority livestock-based technological adaptation options for improving food security, incomes and sustainability of agro-pastoralists co-identified with communities and other stakeholders and pilot tested.
- Policy entry points for supporting the implementation of priority livestock-based adaptation options in agro-pastoral systems identified and discussed with key stakeholders.
- Dissemination pathways identified and implemented at different levels, to increase awareness of the likely impacts of climate variability and change, and to provide information for making decisions in relation to adaptation options for different conditions.

1.2 Objectives of the study

Agro-pastoralists in Mali already face daunting challenges which are now compounded by the expected climate change and increasing climate variability. The planning and implementation of successful adaptation strategies are critical if agricultural growth in the region is to occur. In order to achieve food security and enhance households' livelihoods, we need to understand how households can respond to climate change. This response includes coping strategies, and in the longer term, adaptation (Kelly & Adger, 2000).

The vulnerability approach can help to contextualize how climate variability and change affects livelihoods. It also helps to emphasize that successful adaptation depends not only upon exposure and sensitivity to climate change, but also on an enabling institutional and policy environment and the inherent adaptive capacity of the system (Nelson et al., 2010; Adger, 2006; O’Brien et al., 2009).

As Heltberg et al. (2009) point out managing climate risk has traditionally been the responsibility of households, except in times of large extreme weather events and natural disasters. At the same time, the uncertainty associated with climate change demands for an approach that prepares people without relying on detailed climate projections. In this study, we therefore focus on the adaptive capacity of households.

Based on this, we developed a vulnerability index at the household level and validated the value of a variety of indicators often used in vulnerability assessments. We also investigated how these factors influence the choice of coping strategies. Our findings provide evidence confirming the likely efficacy of some common interventions for reducing vulnerability while questioning others.

1.3 Structure of the report

Chapter 2 describes the survey design and implementation. Chapter 3 then gives an overview of the main findings. This chapter is sub-divided in two sections. The first section discusses the results of the descriptive characteristics of surveyed households. We describe their assets and the main components of their farming systems. The second section discusses their vulnerability to climate change, and the factors influencing coping strategies and vulnerability. The report ends with a discussion and conclusions in Chapter 4.

CHAPTER 2: Survey design and implementation

2.1 General description of the study site

The Republic of Mali is a vast landlocked country located in West Africa (Figure 1). Annual rainfall varies less than 200 mm in the north to more than 1000 mm in the south. The country is characterized by a short rainy season between May and October and a long dry period from November to April. Rains are caused by the monsoon, a wind coming from the Gulf of Guinea and by the northern movement of the Inter-tropical Convergence Zone (Le Houerou, 1989).

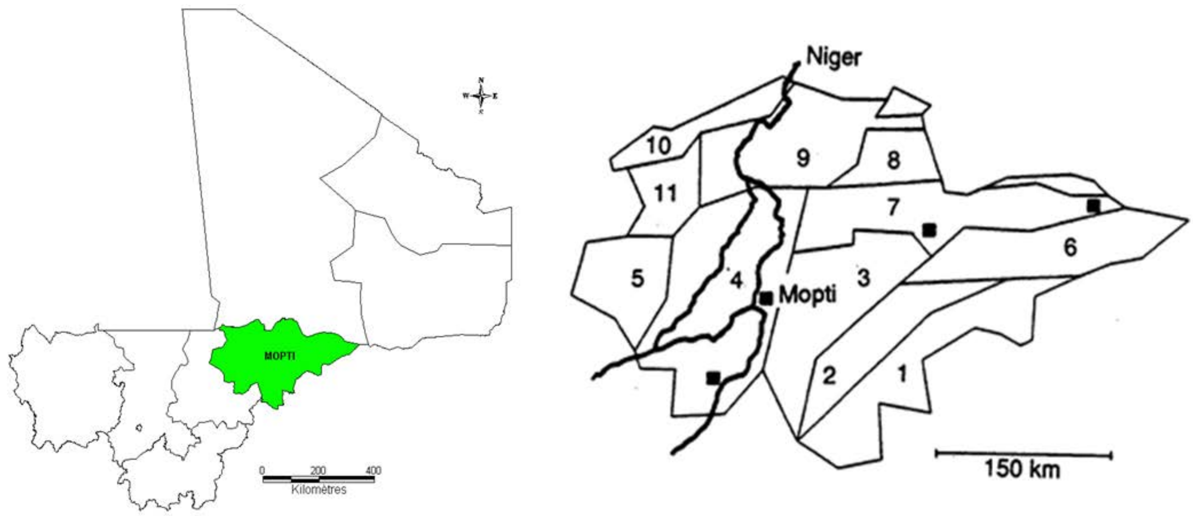
Figure 1: Map of Mali

Mali is a predominant agro-pastoral country. The rural sector occupies about 80% of the population and provides more than 80% of the internal primary product. Livestock production (i.e. cattle, sheep and goats) plays an important role. Livestock are a mean of subsistence for 30% of the population. They contribute 80% to the income of agro-pastoral communities and 11% to the gross domestic product per capita (DRSPR/Mopti, 1992). In the Mopti region, livestock husbandry accounts for nearly 22% of the cattle population at national level, 23% of sheep and 24% of goat numbers (DNSI, 1992).

Recent changes in population growth, increasing herd sizes and high levels of exploitation of woody resources have contributed to serious losses of plant biodiversity in the region. The erratic annual rainfall pattern limits grazing potential with respect to floristic composition, quality, and yield of forage. The decline of perennial herbaceous species and the woody vegetation, in some years, further limits the potential for animal production. The scarcity of pasture resources is so extreme in certain villages, that some locally owned sedentary and semi-transhumant herds leave the village for pastures in other areas or go on transhumance in other agro-ecological zones. After the millet harvest, these animals come back to the village and feed on crop residues, trees products such as pods of *Acacia albida* and whatever pastures remains. The lack of sufficient pastures sometimes causes herders to graze their livestock on crop and crops residues without owner's permission, and this has become a growing problem in the region and a major source of conflicts between farmers and herders (Samaké, 2003; Riddell, 1986).

The data for this study was collected in the Mopti region of Mali (Figure 2). This region covers 67,736 km^2 and includes the districts Bandiagara, Bankass, Djenné, Douentza, Koro, Mopti, Tennenkou and Youwarou. The region is dominated by the Central Delta of the river Niger with an area of 16,000 km^2 that is flooded annually in most years (Samaké, 2003). Eleven agro-ecological zones and are distinguished in the region (Cissé & Gosseye, 1990; Samaké, 2003) (Figure 2), agro-ecological zones 8−11 are not considered in this project. These agro-ecological zones are: Seno-Mango, Seno-Bankass, Sourou, Central Delta, Plateau, Méma-Dioura and Gourma.

Figure 2: Map of the location of Mopti region (left), and its 11 agro-ecological zones (right)



(Source: Van Duivenbooden & Veeneklaas, 1993)

The BMZ study was conducted in three zones namely Delta (number 4 in Figure 2), Gourma (number 7) and the Seno (number 2 and 6). Samaké (2003) describes these zones as follow:

- The Séno zones comprise the Séno-Bankass zone (i.e., Séno-Gondo) with 6,527 km^2 and the Séno-Mango zone with 9,300 km^2. Together, they represent about 23% of the total area of the region. Most soils are deep and loamy-sand to sandy-loam at the surface, with a low water holding capacity and a low fertility (van Duivenbooden & Veeneklass, 1993). Gravely clay represents 28% of the total area of the Séno-Mango and is used for pasture. This zone is suitable for cereal cropping and livestock husbandry. Millet is the main cereal in this zone. Sorghum is grown only in the valleys where soil fertility and moisture contents are high.

- The Central Delta is an alluvial plain along the River Niger with 16,079 km^2. Soils are clay-loam to silt-loam. This zone is suitable for arable cereal cropping (rice and sorghum), herding, fishing and forestry.
- The Gourma is a zone in the north of the Central Delta and north-east of the Plateau with altitudes varying between 250 and 400 m. Soils are moderately deep to shallow and sandy-loam at the surface with low to very low water holding capacity and low in fertility. Gravely loam soils are also found (34% of the area) and these are used for pasture.

In the region of Mopti, land use consists of arable cropping, animal husbandry, forestry and fishery. Farming systems always combine cropping and livestock systems. The region is characterized by the low productivity of animals associated to the insufficiency of forage during the dry season, the poor nutritional quality of pastures, the lack of genetic improvement and poor animal health care management. Moreover, the unfavourable climatic conditions lead to the reproduction and the dissemination of diseases and parasites, in particular ticks and worms.

2.2 Site selection and sampling

Due to the encompassing characteristics of the livelihood concept, research on rural livelihood must make difficult choices. This is because almost any aspect of the way people go about gaining a living is potentially legitimate to investigate, as a result, a mixture of qualitative and quantitative data collection has been gaining credence in the literature on development research methods in the recent times (Ellis & Freeman, 2004). For this report a quantitative household survey was carried out to assess assets, activities and incomes at the household level. With household, in this report, we refer to all individuals who live in the same residential unit, which may or may not be synonymous with family. Also the factors influencing a household vulnerability to the effects of climate change and the coping strategies used as adaptation measures were assessed.

The data used in this report came from a detailed household survey conducted between February and May 2009 in Mopti region in the Republic of Mali. The selection of twelve villages was made based on the two criteria:

- Choice of the agro-ecological zones
    - Distance of the zone from the river (close, intermediate, far),

- o Diversification of pasture management (burgu grass/graminea[1], crop residues)
- o Importance of herding in the zone
- o Presence of the waiting zones for transhumant herds.

- Choice of the villages
  - o Predominance of herding as the main activity of the village
  - o Distance of the village to a market
  - o Influence of the market on herding activities
  - o Accessibility of the village in all seasons.

On the basis of these criteria, the villages are distributed over three agro-ecological zones of Mopti region. The selected zones and villages are presented in Table 1 and Appendix 1.

Table 1. List of the agro-ecological zones and villages selected for the field surveys

Zones	Villages	Distance to river	Type of pasture	Market influence
Delta	Nérékoro	close	burgu	influenced
	Sindégué	close	burgu	less influenced
	Ouro-Modi	close	burgu	less influenced
	Yougonsiré	close	burgu	influenced
Gourma	Drimbè	intermediate	burgu, graminea and crop residues	influenced
	Douma	intermediate	graminea and crop residues	less influenced
	M'Boundou Koli	intermediate	graminea and crop residues	influenced
	Tannal	intermediate	graminea and crop residues	less influenced
Séno	Guéourou	far	crop residues	influenced
	Diallassagou	far	crop residues	influenced
	Baré-Dar-Salam	far	crop residues	less influenced
	Sadia-Peul	far	crop residues	less influenced

2.3 The questionnaire

A comprehensive dataset that comprised household demographic, household's livelihood, livestock ownership and other standard cattle related activities, were collected through a structured questionnaire. The questionnaire was divided into sections covering: household composition, livelihood strategies, and livestock assets; livestock ownership, herd dynamics and species; livestock feeding techniques, management, products and markets; welfare outcome (income, food consumption and health); and, vulnerability context (main concerns facing the households).

[1] Burgu is a Peul term for flooded pastures dominated by the perennial graminea species *Echinochloa stagnina*. The production can reach up to 20MT DM/ha. It is the most important and productive type of pasture in Mali.

2.4 Data collection

The questionnaires were completed through interviews with the household head or in his or her absence, the senior member available or the household member responsible for the management of farm and livestock. The surveys were based on 15 households per village representing 60 households per agro-ecological zone. In the Delta zone only 55 households were available for the interview, bringing the size of samples to 175 households for the region (Table 2). The surveys were conducted between 11 and 29 May 2009 in the prefecture of Bankass in the Seno agro-ecological zone, Mopti and Djenné in the Delta zone, and Douentza in the Gourma zone.

Table 2. Data collection site in Mali

Zone	Villages	Household interviewed (n)
Delta	Yongocire	14
	Sindégué	13
	Ouro Modi	15
	Nerekoro	13
Gourma	Douma	15
	M'Oundoucoli	15
	Tanal	15
	Dirimbe	15
Séno	OuandianaPeul	15
	Sadia Peul	15
	Bare-Dar-salam	15
	Gueourou Peul	15
Total		175

2.5 Data reliability and validity

Enumerators were trained to prepare them for proper usage of the data collection tools and to harmonize sampling methods as well as the administration of questionnaires. This training was held in the conference room of the Regional Centre of Agricultural Research (CRRA) in Mopti between the 8 and 9 May 2009. Five modules were presented and discussed. A pre-test of the questionnaires was conducted on 10 May 2009 in the village of Nantaga located at about 3 km from Mopti city. Thereafter, the questionnaires of the different modules were adapted to the field realities.

CHAPTER 3: Results

3.1 Description of the farming system in the study area

The region belongs to the north Sahel-Soudanian bio-climatic zone. It is characterized by a short erratic rainy season from June to September and a long dry season from October to May with average rainfall of 500 mm. The length of the growing period is shorter in the North than in the South, mainly caused by an earlier end of the rainy season.

3.1.1 Characteristics of households

Tables 3 and 4 present socio-economic characteristics of households studied. The results in Table 3 show that show that the average age of the interviewed livestock herding households is about 67 years; the household size is 16 with a plot size of 5 ha.

Table 3. Summary of average household's characteristics in the region of Mopti

Parameters	Mean	Std. Dev.	Min	Max
Household age (Years)	58.6	13.47	22	89
Household size	10	4.22	1	32
Plot size (ha)	5	7	0	50
Off-farm income (CFA/year)	14,442	40,664	0	250,000
Crop income (CFA/year)	138,094	290,161	0	2,200,000,
Livestock income (CFA/year)	19,056	26,301	0	196,894
Household income (CFA/year)	171,593	294,895	0	2,287,500

Source: Author' survey (2009); n=175 households

Where:

CFA stands for Franc des Colonies Françaises d'Afrique (legal currency in Mali); 1 US$ = 510 CFA at the time of survey (February - May, 2009)

Ha stand for Hectares.

Table 4. Summary of gender of household heads in Mopti region

Gender	Frequency	Percentage (%)	Cumulative percentage (%)
Men	171	98	97.8
Women	4	2	100

A predominance of the male-headed households as opposed to females was observed during this survey (Table 5). Ninety eight cent of the households interviewed was male headed while only four per cent were female headed households. The age of household heads who were interviewed varied between 22 and 89 years with an average of 59 years (Table 5). Results also showed that education levels were low, with level of education ranging between 0 and 13 years and an average of only one year of education (Table 5).

Table 5. Summary of household's characteristics per agro-ecological zone

Zones	Sample size	Mean	Std. Dev.	Min	Max
Average household size					
Delta	55	10	4	3	16
Gourma	60	9	4	2	16
Seno	60	10	5	1	32
Average age (yrs.) of household head					
Delta	55	58	13	22	80
Gourma	60	57	12	30	86
Seno	60	61	16	23	89
Average Education (yrs.) of household head					
Delta	55	0,4	2	0	7
Gourma	60	1,9	4	0	13
Seno	60	0,1	1	0	7

Source: Author' survey (2009)

3.1.2 Household Assets

Household revenues are generated from off-farm, crop and livestock incomes (Table 3 and Table 6). Average income per year is 171,593 CFA, which includes crop, livestock and off-farm incomes (Table 3). Crop incomes constitute the main source of income generation for households followed by off-farm revenues (Table 6). The lower revenue was obtained with livestock resources.

The importance of the sources of incomes varies across the zones, but also within the zones. For example, for income from livestock the maximum income was observed in the Delta zone (Table 6). This can be attributed to the fact that the Delta continues to be the major area for herding and constitutes a zone of transhumance for animals coming from other areas of the region. As for crop revenues, the higher incomes were generated in the Gourma zone (Table 6). No important difference was observed for off-farm incomes coming from one zone to another (Table 6).

Table 6. Average income per household head by zone (in CFA)

Zones	Sample size	Mean	Std. Dev.	Min	Max
		Average off-farm income			
Delta	55	12,254	42,312	0	250,000
Gourma	60	17,554	18,686	0	98,500
Seno	60	12,754	44,136	0	230,000
		Average livestock income			
Delta	55	13,572	22,018	0	129,125
Gourma	60	16,100	18,697	0	98,500
Seno	60	9,273	12,816	0	87,500
		Average crop income			
Delta	52	34,163	36,544	0	196,895
Gourma	60	26,129	29,936	2,000	170,526
Seno	60	377,400	410,280	0	2,200,000
		Average total income			
Delta	55	59,998	58,970	0	285,146
Gourma	60	59,783	53,527	6,316	234,736
Seno	60	399,427	434,377	3,500	2,287,500

Source: Author's survey (2009)

3.1.3 Infrastructure and services

Table 7 shows information on village-access to infrastructure. The closest urban market in the region is 5 km from the surveyed households, while the farthest is at 160 km. As for livestock markets, the interviewed households are 2 to 40 km away. All villages are connected to both urban and livestock markets by the dirt tracts only, which make sale of animal products difficult.

No health centres, public telephone and electricity are available in the sampled villages. Drinking water is only available from wells. At the local level, lack of financial capital is a major constraint for infrastructural development. At the regional level, options for facilitating access to infrastructures such us market places, drinking water, health centres, are limited as investment capital is limited. Sinaba et al. (2009) indicated that difficulties in access to health centres, drinking water and school constitute some of the major vulnerability factors in the Delta zone.

Table 7. Average distances (km) of household to nearest infrastructures and services

	Average distances (km)											
	Delta				Gourma				Seno			
	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Urban Market	26[a]	24	2.5	60	20[ab]	13	5	40	93[c]	55	5	160
Livestock Market	11[a]	11	2.5	30	20[b]	13	5	40	5[c]	0.4	4	5
Portable water	2[a]	3	0	15	8[b]	6	0	15	1[ac]	3	0	5
Electricity	26[a]	24	2.5	60	20[b]	13	5	40	5[c]	0.5	4	5
Clinic / Hospital	2[a]	2	0.2	25	20[b]	13	5	40	5[c]	0.5	4	5
Public telephone	26[a]	24	2.5	60	20[b]	13	5	40	5[c]	0.5	4	5

NB: Means with the same letters are not significantly different from each other at 0.05 level

Source: Mali survey, 2009

3.1.4 Farm size and improvement

In the region of Mopti, households have an average plot size of 5.4 ha and household size of 10 persons per household (Table 5). Plot sizes vary from one agro-ecological zone to another. Maximum cultivated area per household head of 50 ha was observed in the Seno, the average plot size in this zone is 7.9 ha (Table 8). In the Delta and the Gourma zones, the average plot sizes are 4.3 and 4.1 ha respectively.

Table 8. Average cultivable plot size (ha) per Household head by Zone

Zones	Sample size	Mean	Std. Dev.	Min	Max
Delta	55	4.3	6	0	37
Gourma	60	4.1	4	0	20
Seno	60	7.9	8	1	50

In this study, 92% of the households said they owned their land without any title, 4% borrowed land with no payment, 2% rented the fields with payment in grain after harvest and 2% rented the land using cash payment (Figure 3). According to farmers, land is not sold but can be allocated for cultivation by external people (other households and migrants). They are not allowed to plant trees or to carry out other long-term management practices (e.g., construction of stone-lines for soil and water conservation) without prior authorization from landowners (Samaké, 2003). This result is confirmed by reports from this survey (Figure 4) in which 99% of the requested pastoral households expressed that they did not undertake any long-term practice of land improvement in their field whereas only 1% used fences.

Figure 3. Land ownership and land use in the region of Mopti

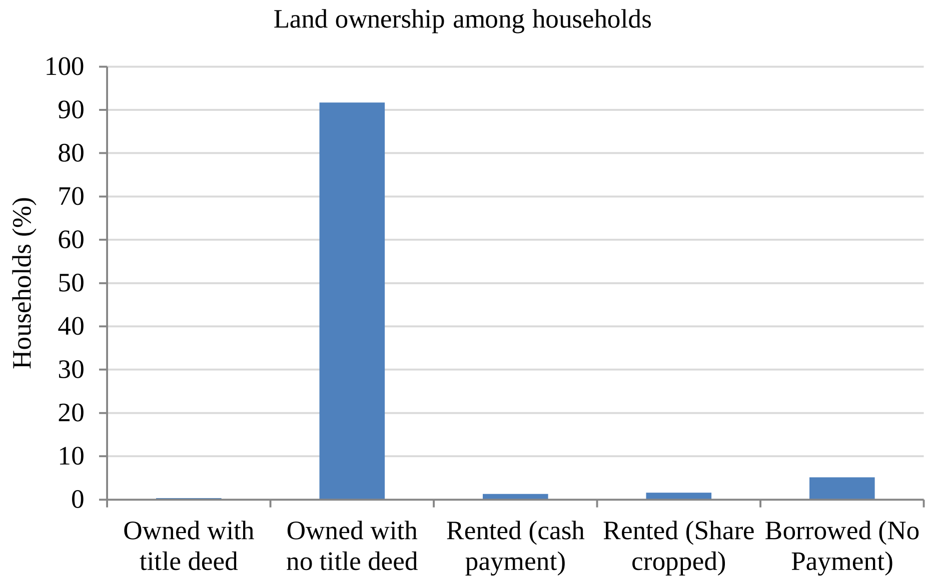
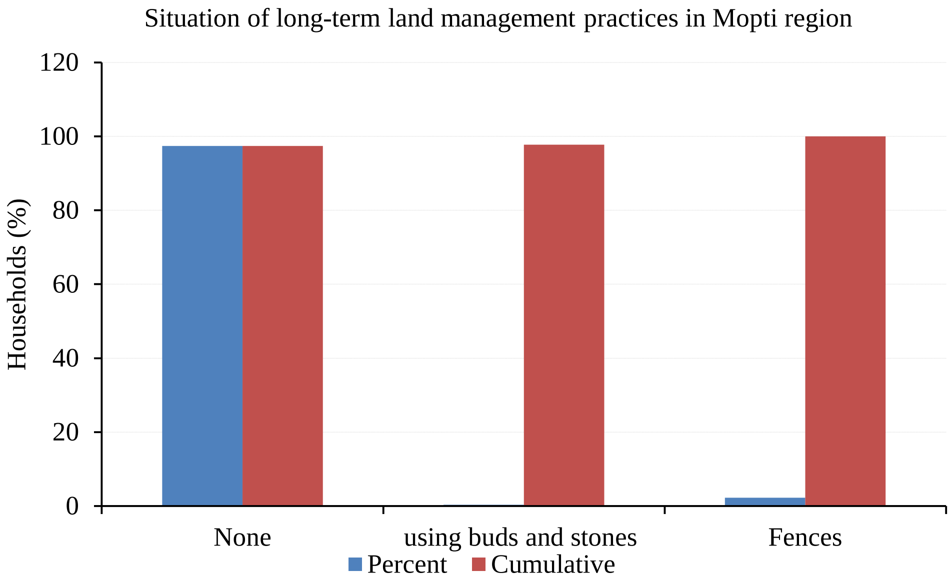


Figure 4. Situation of long-term land management practices in Mopti region



3.1.5 Livestock assets

In Mopti region, livestock activities are practiced in a very extensive way. They contribute to food security (meat, milk), animal traction, manure production and provide skin for households needs (clothing, containers, rope and many other valuable items). The results of the household survey showed that 87% of households raise cattle to produce milk for consumption, 86% for milk selling and only 5% for animal traction (Table 9). In many areas, the cattle kept by the Fulani herders provide manure to farmers. The animals graze on harvested stalks and manure the land to keep the fields fertile.

Table 9. Different uses of cattle keeping in Mopti region

Production parameter	Local breeds (n=175)
Households using milk for consumption (%)	87
Household selling milk (%)	86
Households using cattle for animal traction (%)	5

(n stands for the number of households)

The livestock consists predominantly out of indigenous breeds, and are raised in all zones using sedentary or transhumance systems. Average tropical livestock units (TLU) are 257 for cattle, 13 for sheep, 8 for goats and 2 for camels (Table 10).

Table 10. Tropical Livestock Unit (TLU) of local breed livestock in Mopti region

Livestock breeds	Mean	Std. Dev.	Min	Max
Cattle (n = 175)*	257	164	27	669
Goats (n = 170)	8	12	0	85
Sheep (n = 173)	13	12	0	54
Camel (n = 46)	2	2	1	8

** n stands for the number of households; TLU refer to Tropical Livestock Unit (1 TLU = 250 kg)*

3.1.6 Feed resources and feeding strategies

In the region, Samaké (2003) and Ballo and Ouattara (2005) indicated that after harvest, local herds of sedentary cattle graze on the remains of rice, millet and sorghum straw from November to the start of the first rains in June-July. In the rainy season, natural pastures are used as fodders. The herbaceous vegetation used as animal fodder includes some Graminea species, such as Burgu grass (*Echinochloa stagnina* and *Echinochloa pyramidalis*), *Vossia cuspidate and Andropogon gayanus*, and woody vegetation (like *Acacia albida* and *Ziziphus mauricia*) (Samaké, 2003; Ballo and Ouattara 2005).

Livestock feed varies over the years. Some livestock feeds were abundant 10 years ago but, absent today (Figure 5, Appendix 2). Some of these are forage species, including *Andropogon gayanus, Zornia glochidiata, Panicum sp* and *Cenchrus biflorus*. However, some livestock feeds were rare 10 years ago and abundant nowadays (Figure 6). The most important are cotton cakes and rice brans, *Zornia glochidiata*, crop residues (*Oryza barthii*) and *Chloris prieurii*.

Figure 5. Various livestock feeds, which were present 10 years ago, but absent nowadays in Mopti region

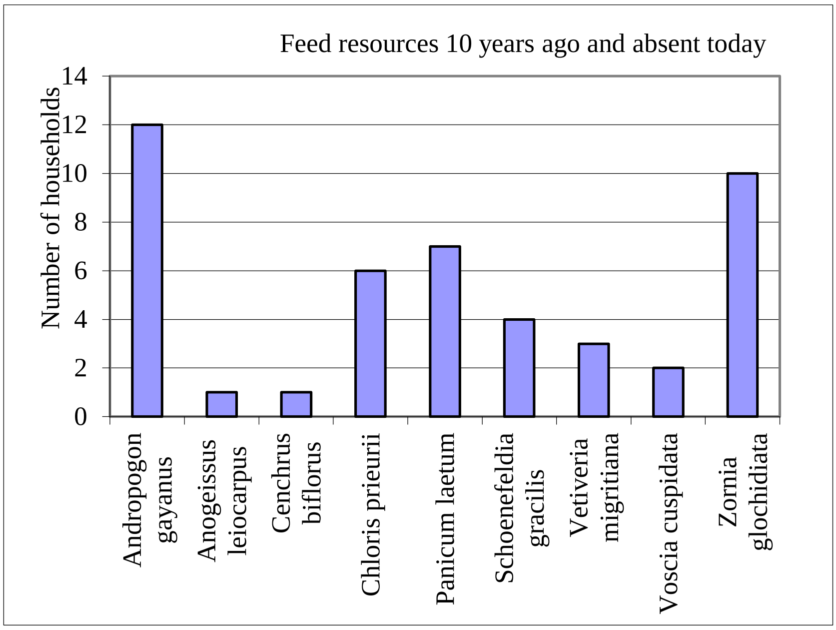
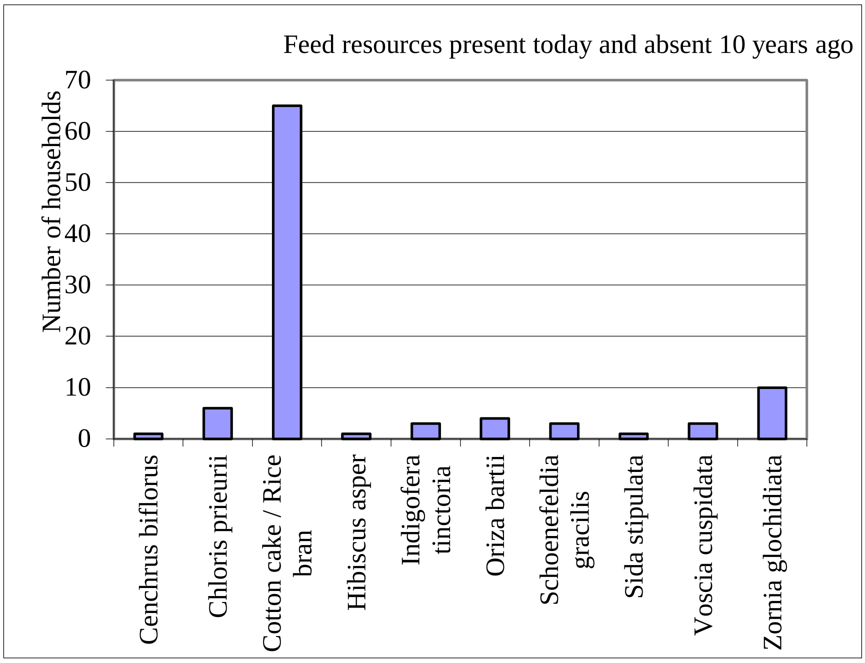


Figure 6. Various livestock feeds, which were absent 10 years ago, but present nowadays in Mopti region



Various types of crop residues are used for animals vary across agro-ecological zones. Residues of rice as well as sorghum, millet and cowpea are used as forage for animals in the Delta zone. In the upland zones of the Gourma and the Seno, residues of millet, sorghum and some leguminous crops (cowpea, groundnuts and Bambara groundnuts) are consumed by livestock after the harvest (Samaké, 2003).

Details of usage of crop residues among households are given in

Table 11. The results show that 30% of households use crop residues as fodders for cattle, whereas 29% leave them on the farm. Only 4% of the households use treated crop residues for cattle, and 2% use the crop residues for conservation agricultural. Similar results were found by a multidisciplinary farming research team of IER (DRPR/Mopti, 1992), which reported that crop residues constitute the major source of forage for cattle during the dry season in the Seno zone.

Table 11. The use of crop residues among livestock keeping households

Use of crop residues	Observations	Frequency (n)	Percentage (%)	Cumulative percentage (%)
Leave on the farm (as a mulch)	51	123	29	29
For cattle grazing	53	127	30	58
For goats grazing	33	83	19	78
Cut and carry for cattle	28	70	16	94
Treated for cattle	7	17	4	98
Used for conservation agriculture	4	2	2	100

Feed supplements are rarely given to livestock except for animals used for traction and those particularly used for fattening and milk production. These animals receive a wide range of feed resources, including groundnut and cowpea residues, ABH, cereal bran and kitchen wastes.

As for watering, animals are watered at the rivers and at wells during the dry seasons whereas in the rainy season, they drink on their own in temporary ponds existing in the grazed pastures, or at the rivers and wells.

3.1.7 Diseases: past and present, constraints for treatment

Results of this survey showed that certain diseases that were present 10 years ago (Figure 7) are almost nonexistent today (Figure 8), among those are contagious bovine pleuropneumonia (CBPP), Anthrax, pest, and Lumpy skin disease (LSD). However, some disease were rare 10 years ago, but abundant nowadays. Among these are foot and mouth disease (FMD), Distomatosis, Anthrax and CBPP. According to the farmers, livestock vaccination and treatment against internal and external parasites are limited, due to high prices and availability of veterinary inputs and lack of sanitary infrastructures, such as cattle inoculation centres.

Figure 7. Diseases present 10 years ago but absent today in Mopti region, based on 88 households

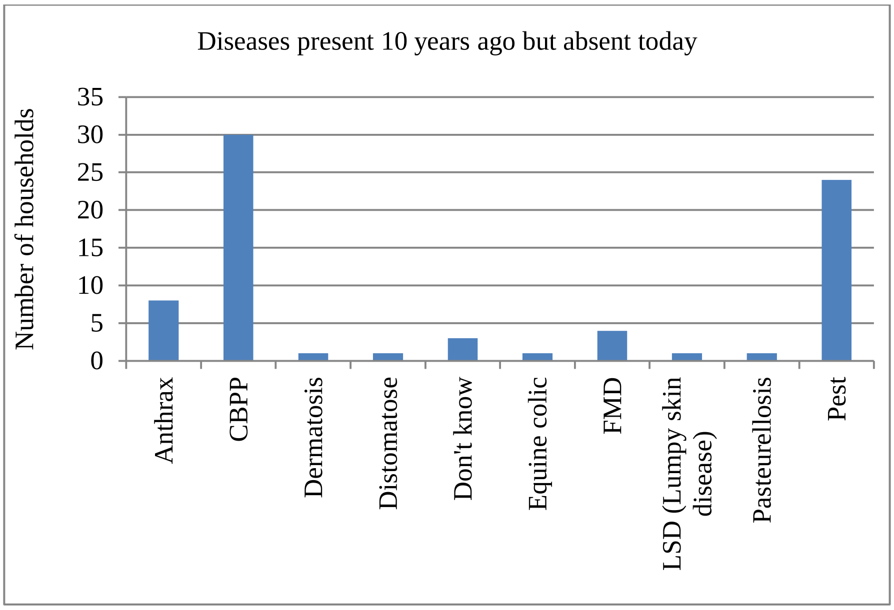
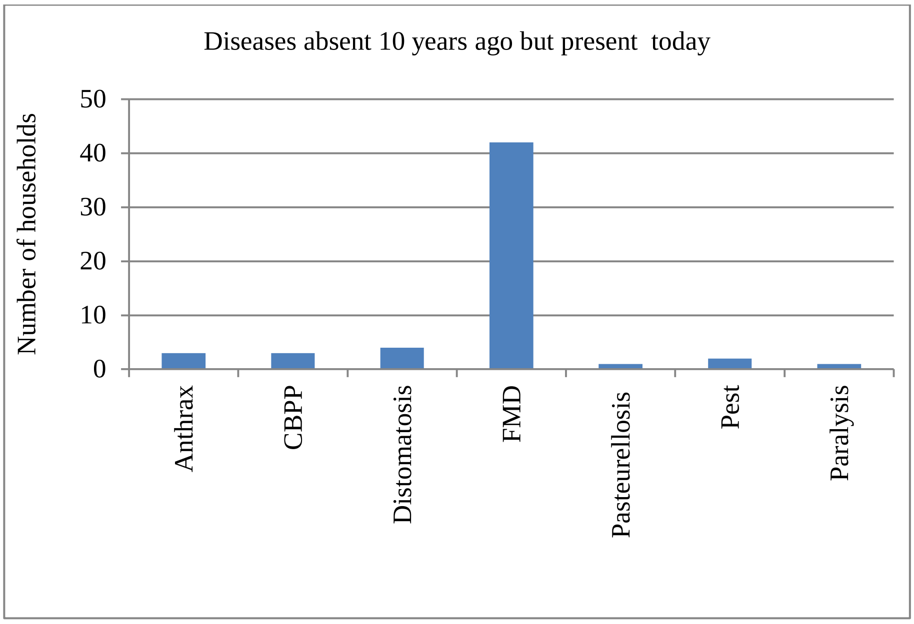


Figure 8.Diseases absent 10 years ago but abundant today in Mopti region based on 77 households



3.2 Vulnerability and coping strategies

3.2.1 Conceptual framework

Vulnerability is one of the key terms in the climate change literature. A wide variety of definitions and frameworks to assess vulnerability of households and ecosystems is used, described and applied throughout the scientific literature (see e.g. Alwang et al., 2001; Heitzmann et al., 2002; Turner et al., 2003; Lim and Spanger-Siegfried, 2004; Thornton et al., 2006; Adger, 2006; O'Brien et al., 2004; Brooks, 2003; Cutter, 1996; TzPPA., 2002/2003; Intergovernmental Panel on Climate Change (IPCC) 2001).

These different approaches each come with their own specific weaknesses, strengths and fields of application. None of them can be seen as superior, nor is there one that is most widely accepted. Their applicability depends on the context in which they are used and the scale at which they are applied. The definitions and frameworks combine hazard factors with social factors, i.e. they holistically merge external stressors with internal system capacity to resist and/or recover. It is precisely the interaction between these factors that defines the final outcome, impact or overall vulnerability of a system (e.g. Dilley et al., 2005; Lim & Spanger-Siegfried, 2004; Thornton et al., 2006; Alwang et al., 2001).

These components can be applied in various ways, depending on the stressors and the systems examined, the level of uncertainty of the stressors, whether the focus is broad or specific and on the direction and emphasis of the approach used (Notenbaert et al., 2010). Even though the semantics remain confusing, with many authors referring to risk for what we call vulnerability and to hazards for what we call risk, there seems to be a growing agreement that the vulnerability of any system is a function of three main components.

For the purpose of this paper, we will refer to (i) exposure to climate change impacts, (ii) sensitivity to those impacts and (iii) the capacity to cope with those impacts as the components of vulnerability.

Vulnerability is thus comprised of risks (or a chain of risky events) that people confront in pursuit of their livelihoods, the sensitivity of the livelihood to these risks, the risk response or the options that people have for managing these risks and finally the outcomes that describe the loss in well-being (Turner et al., 2003). The risk response or available options are in turn determined by livelihood assets, strategies and policy and institutional environments. Vulnerability, therefore, rests largely within the condition and dynamics of a coupled human–environment system exposed to climate variability and change. Vulnerability is thus conceptualized as the starting point of the analysis (Eriksen & Kelly, 2007), in which vulnerability depends not so exclusively on the precise nature of the hazard, but also on the latent characteristics of human–environment systems that enable them to cope with change in their current form, or undergo more transformative adaptation to maintain important functions (Folke et al., 2005; Nelson & Brown, 2007).

This definition of vulnerability is a useful concept for looking at climate change and adaptation. It is a dynamic and forward-looking concept that inherently deals with uncertainty and probabilities. The concept can be applied at many different and nested scales. Most importantly, vulnerability as a function of exposure and coping capacity explicitly links ecosystems with human welfare. It puts the people and their dependency on the natural and socio-economic environment at the centre of the analysis. This offers direct entry points for interventions on the resource, management and policy level. It is therefore applied in this study.

The starting point is to take a closer look at the main concerns and associated coping mechanisms of the surveyed households and investigate the factors influencing these. Households' coping strategies can potentially reduce damage associated with climate change by making tactical responses to these changes. Analysing factors influencing coping strategies adopted by households is therefore important for finding ways to help farmers in similar situations across Africa. It will also enhance our understanding on what factors are essential for designing incentives that could enhance the adaptive capacity of local farmers through appropriate coping strategies. We end the chapter by assessing the households' vulnerability and the determinants of this vulnerability.

3.2.2 Coping mechanisms and factors influencing them

Main concerns and associated coping strategies

Households were asked to state and rank the concerns which they were most afraid that could happen to them in the next 1 (one) year. Figure 9 indicates that the major concerns of the agro-pastoral communities, 34 and 32% of the 55 households interviewed respectively, are the insufficiency of pastures for livestock and food for the populations. Other important concerns were animals' diseases and death, crop failure, human sickness, lack of water for livestock, insecurity including conflict and violence, high prices of inputs, low market prices of the products and loss of goods (houses and lands) due to natural disasters. In their survey, Togola and Kéïta (1995) reported in the Delta zone that lack of natural pastures as well as water supply for the livestock in the dry season constitutes the major constraints to animal production in the zone.

Figure 9. Factors related to vulnerability of agro-pastoralists in Mopti region

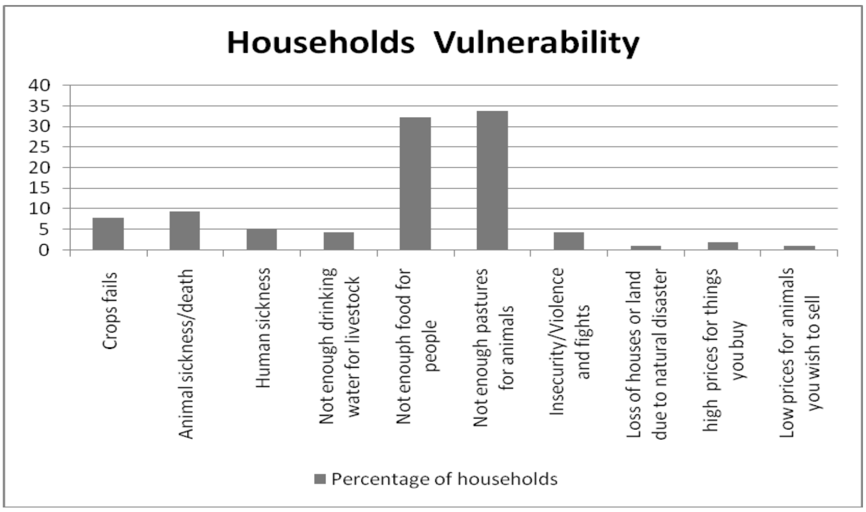
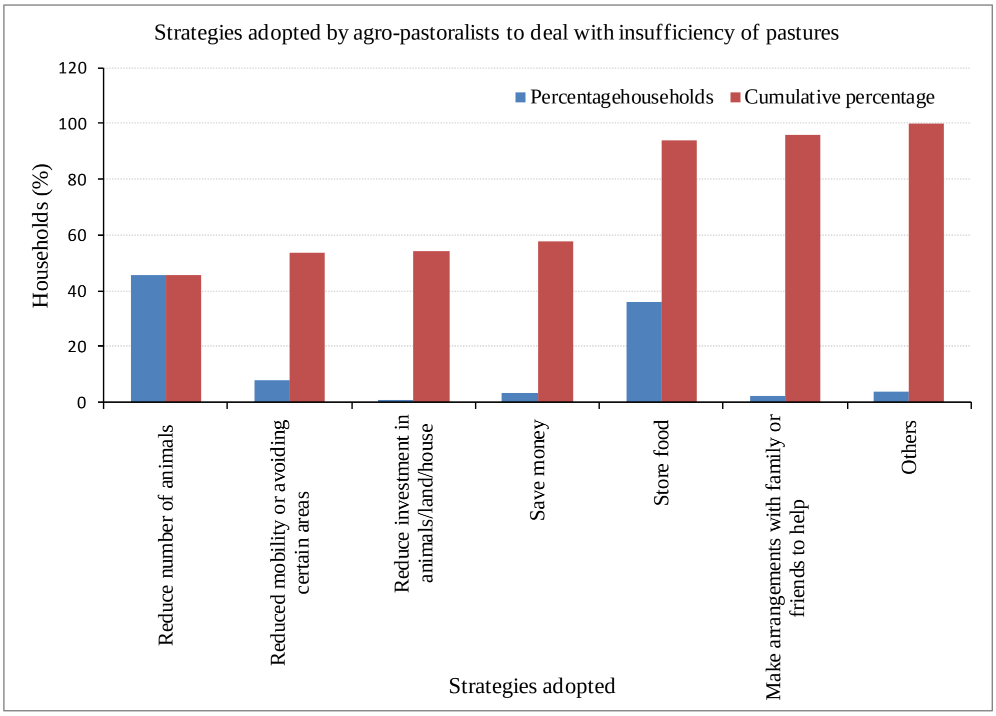


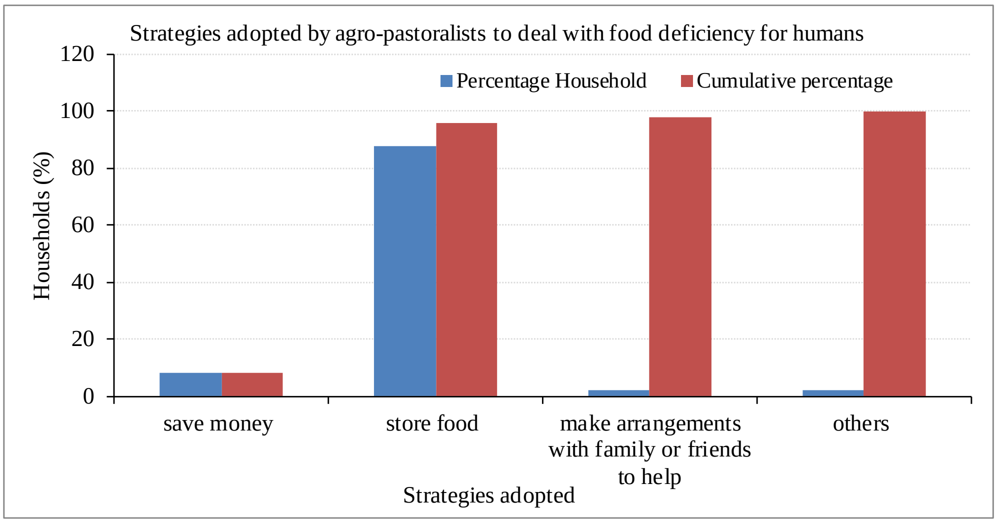
Figure 10 and Appendix 3 show actions adopted by the households to solve problems related to insufficiency of pastures. The most important strategy was reducing the number of animals. To solve feed deficiency problems during the dry period, households indicated that they collect and store animal feed such as crop residues, burgu grass or other herbaceous forages, and fruits of *Acacia albida* and *Acacia nilotica*. About 8% of the households adopted strategies aimed at reduced morbidity of the herd or avoiding certain areas.

Figure 10. Strategies adopted by agro-pastoralists to deal with insufficiency of pastures



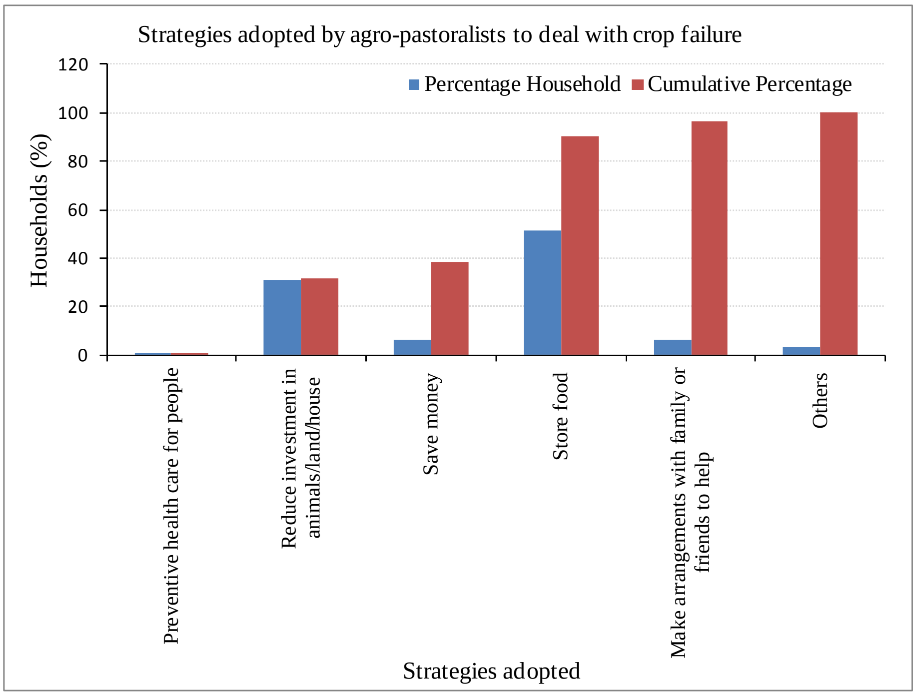
With regard to vulnerability factors related to food insufficiency for humans, 88% of the households mentioned collecting and storage of cereal grains at harvest, during successful years, the best preventive action to deal with food scarcity (Figure 11, Appendix 3). Other strategies were saving money and making arrangements for help with families or friends.

Figure 11. Strategies adopted by agro-pastoralists to deal with food deficiency for humans



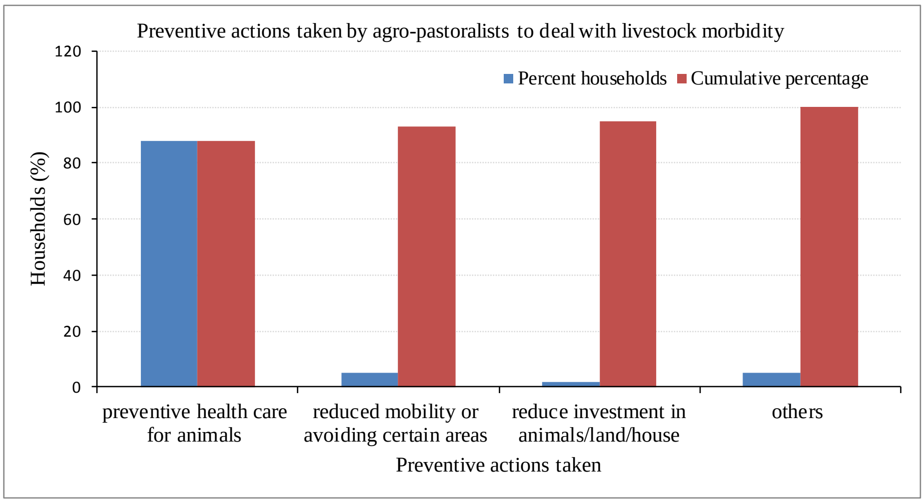
Crop failure caused by biotic (i.e. pest, weed, diseases and grain eating birds) and/or biophysical constraints (i.e. erratic rainfall and unfavourable physical and chemical conditions of soils) result in food deficiency during the critical periods of the year, mainly in the rainy season. To prevent this, about 52% of the 55 samples of household interviewed chose to store food, whereas 31% opted to reduce investment in animals, lands and houses (Figure 12, Appendix 3). The main difference between Figure 11 and 12 is that households considered crops not only a source of food but also income. Therefore, income that could have been realised if crop failure does not occur was also implicit in the strategies adopted.

Figure 12. Preventive actions taken by agro-pastoralists to deal with crop failure



The results in Figure 13 and Appendix 3 show farmers consider preventive health care (i.e. vaccination of livestock against animal diseases) an appropriate action to prevent loss of livestock. A minority of households mentioned the reduction of morbidity by avoiding certain infested areas or reducing animal herd sizes would be a good strategy to cope with the effects of climate variability.

Figure 13. Preventive actions taken by agro-pastoralists to deal with livestock morbidity



Although not mentioned during this survey, Moore et al. (2005) reported that famine relief actions in the Delta zone of Mopti region, like in other areas in the Sahel, consists out of providing food to pastoralists who lost their livestock or farmers who lost their crop after drought or any other natural desaster. In this situation, food is freely distributed to needed households.

The inland valley and the upland zones of the region are transitioning from traditional to intensified agriculture and animal husbandry production. These dominant sectors serve as the engines of sustainable economic development that provide food security and alleviate poverty in the region. However, uncertain, variable and low rainfall patterns and increasing population pressure leading to natural resources degradation have forced both agricultural and pastoral communities to transform their production systems and social relations on which they relied on. The results of this study showed that preventive actions, adapted by farmers dealing with climate variability, are related to factors that determine vulnerability as indicated in Figure 9.

The factors influencing the coping mechanisms

Adaptation measures help farmers guard against losses associated with climate change. The analysis presented next identifies some of the factors influencing coping strategies utilized by households, in order to provide policy information such as which factors to target and how, so that farmers are encouraged to increase their use of different adaptation measures.

The analytical approach that is commonly used in the investigation of factors influencing an adoption or the utilization of a specific coping strategy among farmers is logit regression. The computation burden of the logit regression is made easier by the likelihood function, which is globally concave (Hausman & McFadden, 1984). Logit analysis also produces statistically sound results. By allowing the transformation of a dichotomous dependent variable to a continuous variable ranging from -∞ to + ∞ the problem of out of range estimates is avoided. Moreover, the logit regression provides results which can be easily interpreted; the method is simple and gives parameter estimates which are asymptotically consistent, efficient and normal, so that the analogue of the regression t-test can be applied.

The logit model for the factors influencing the coping strategies among agro-pastoralist households is as presented in the equation below:

$$Logit\ (y_1=1) = f(\beta_0+\beta_1 X_1+ \beta_2 X_2+\beta_3 X_3,\ +\beta_4 X+ \beta_5 X_5+,\ldots,+ \beta_{32} X_{32}+ \beta_{33} X_{33})$$

With: $f = \frac{e^x}{1+e^x}$

Where X_1, X_2... X_{33} stands for the variables as described in Table 12

Table 12. Summary of the explanatory variables used in the regression model

Variable	Variable definition	Measures
dist~nmarket	Distance to the urban market	Km
distanceto~d	Distance to the paved road	Km
dist~lmarket	Distance to the local market	Km
dist~kmarket	Distance to the livestock market	Km
distanceto~r	Distance to potable water	Km
distanceto~y	Distance to the nearest electricity	Km
disttothen~r	Distance to the nearest health centers	Km
disttothen~e	Distance to the nearest public telephone	Km
dailyavail~r	Daily potable water availability	1=yes and 0 =no
hhgenderd~0f	Household gender	1=Male and 0 =Female
yrsspenton~n	Years spent on education by HH head	Years
hhage	Age of the household head	Years
Plot size	Plot size (ha)	Hectare (Ha)
incomefrom~k	Proportion of income from livestock	Percentage (%)
cropvaluep~a	Crop value per hectare	Mts (1US$ =27Mts)
numberofna~e	Number of natural resources accessed	Count
accesstora~r	Access to rangeland	1=yes and 0 =no
accesstofo~s	Access to forest	1=yes and 0 =no
accesstow~10	Access to water resources	1=yes and 0 =no
freepaidra~s	Free/paid ratio to access resources	Ratio
incomedive~s	Income diversification indices	Index
livestockd~s	Livestock diversification indices	Index
cropdivers~s	Crop diversification indices	Index
orgcommuni~e	Membership to organization	1=yes and 0 =no
grouppatic~r	Membership to a group	1=yes and 0 =no
numberofco~d	Number of constrains listed	Count
savingsdum~e	Saving undertaken in the last 1 year	1=yes and 0 =no
emergencyd~e	Emergency needed in the last 1 year	1=yes and 0 =no
hhsizeadul~t	Herd size	TLU
hhsizeadul~t	Household size (AE)	Adult equivalent (AE)
lengthofil~s	Length of illness	Months
hhdepenenc~o	Household dependent Ratio	Ratio
	Maximum temperature	^{0}C
	Minimum temperature	^{0}C
	Annual rainfall	Mm
	Rainfall variability	Index
	NDVI	Index

NB: The expected sign could not be assigned because of the large number of coping strategies in consideration

To assess the factors influencing a specific coping strategy, the respondents that utilized this coping strategy were given the value of 1 and 0 otherwise. The analysis was done with 33 independent variables comprising geographical, demographic and socio-economic variables. The coping strategies or dependent variables (Y) in the model comprised of: storing of food, saving money, preventive health care for animals, preventive health care for humans, introduction of irrigation, and increasing water storage capacities. They were given a binary value of 1 or 0. Each of these dependent variables was regressed against the 33 independent variables.

Our choice of explanatory variables is dictated by theoretical behavioural hypotheses, empirical literature and data availability. The explanatory variables considered in this study consist of seasonal climate variables, geographical, demographic and socioeconomic factors.

Resource limitation coupled with household' characteristics and poor infrastructure limit the ability of most farmers to adapt certain coping strategies amidst changing climate (Kandlinkar & Risbey, 2000). Table 12 summarizes the explanatory variables used for empirical estimation.

Seasonal climate variables: Seasonal temperature and precipitation influence households' choice of coping strategies. Empirical studies on economic impact of climate change on agriculture in Africa have shown that climate attributes (temperature and precipitation) significantly affect the net farm revenue and such impact can be significantly reduced through coping strategies (Seo & Mendelsohn, 2006; Benhin, 2006). Kurukulasuriya & Mendelsohn (2006) have also shown that choice of crop and livestock species are sensitive to seasonal climate variables. These studies show the importance of seasonal climate variables in influencing the choice of coping strategies adopted by households. It is our hypothesis that drier and warmer climates favour livestock production and irrigation and are a contributor to crop failure.

Socio economic attributes: In adoption literature *household size* has been shown to have mixed influences on adoption of technologies related to agriculture (Birungi, 2007). Large households might be forced to divert part of their labor force into non-farm activities, in order for example to generate more income (Tizale, 2007). Nevertheless, opportunity cost of labour might be low amongst most households. For others, coping strategies such as irrigation which is more labour intensive, we hypothesize household size to have a positive influence on the adoption of such coping strategies.

Also the influence of *household head age* has been mixed in literature. For example Nyangena (2007) and Anley et al. (2007), found that age is significantly and negatively related to a farmer's decision to adopt coping strategies related to water. On the other hand, Bayard et al. (2007) found age to be positively related to coping strategies associated with conservation measures. The *gender of the household head* has been found as an important variable affecting adoption decisions. For example, Bayard et al. (2007) found female households to be more likely to adopt coping strategies related to natural resources management and conservation practices. Accordingly, Clay et al. (1998) found that *education* was a significant determinant of coping strategies adopted, while Gould et al. (1989) found that education was negatively correlated with such decisions. We expect that households with more education have some information about climate change and coping strategies that they can use in response.

Farm asset and wealth factors: empirical studies have found mixed effects of *farm sizes* on adoption of coping strategies. For example, a study in South Africa showed that farm size was not a significant adoption factor (Anim, 1999) while in Nigeria, it was farmers with large farms that were found to allocate more land for constructing bunds (Anley et al., 2007). In this study it is hypothesized that farmers with small farms would adopt coping strategies that require small areas of land, such as diversification.

Several studies have shown that *access to emergency loan/cash aid* is an important factor influencing the adoption of various technologies (Kandlinkar & Risbey, 2000; Tizale, 2007). With more financial and other resources at their disposal, farmers are able to make use of all the available information to change their management practices in response to changing climatic and other conditions. For instance, with financial resources and access to markets, farmers are able to buy new crop varieties, new irrigation technologies and other important inputs they may need to change their practices to suit the forecasted climate changes.

Market access is another important factor influencing coping strategies (Feder et al., 1985). Input markets allow farmers to acquire the inputs they need such as different seed varieties, fertilizers and irrigation equipment. At the other end, access to output markets provides farmers with positive incentives to produce cash crops that can help improve their resource base and hence their ability to respond to changes in climate (Mano et al., 2003).

Maddison (2006) observed that long distances to markets decreased the probability of farm coping ability in Africa and that markets provide an important platform for farmers to gather and share information. Access to *electricity* was found to be an important factor explaining crop choice (Kurukulasuriya & Mendelsohn, 2006) and livestock choice (Seo & Mendelsohn, 2006). Household access to electricity may reflect either higher levels of market access or both. Farmers with better access to public infrastructure therefore are expected to be able to take up coping strategies measures that enable them to cope better.

Econometric analysis with cross sectional data is normally associated with problems of heteroscedasticity and multicollinearity. Multicollinearity among explanatory variables can lead to imprecise parameter estimates. To explore the potential multicollinearity among explanatory variables, we calculated the correlation between continuous independent variables as shown in Table 13.

Table 13. The Pearson correlation co-efficient on factor influencing coping strategies across households in Mopti region of Mali

	urbanm~t	localm~t	portab~r	neares~y	near~lic	gender	levelo~n	age	oflive~e	cropva~e
Urbanmarket	1									
Localmarket	-0.2649	1								
portablewa~r	-0.1219	-0.1636	1							
nearestele~y	-0.0626	0.3393	0.1867	1						
nearestpub~c	-0.0626	0.3393	0.1867	1	1					
Gender	0.0261	-0.0724	0.0438	-0.0832	-0.0832	1				
levelofedu~n	-0.1443	0.2526	-0.0731	0.0215	0.0215	-0.0456	1			
Age	0.2363	0.0219	-0.2208	-0.1755	-0.1755	-0.1115	0.0331	1		
oflivestoc~e	0.1281	0.1018	-0.0071	0.6543	0.6543	-0.0625	-0.0606	-0.2457	1	
cropvaluep~e	-0.1259	0.0461	0.0516	0.0177	0.0177	-0.0846	0.194	0.044	-0.1766	1
numberofna~b	-0.4239	0.2843	0.0887	0.3743	0.3743	-0.111	0.0525	-0.1564	0.1975	0.0246
accesstora~d	-0.2298	0.0711	0.4755	0.0926	0.0926	-0.051	0.2219	-0.1191	-0.0162	0.0291
accesstofo~t	-0.3522	0.208	-0.1115	0.2014	0.2014	-0.1115	-0.0103	-0.0745	0.0681	0.0227
accesstowa~e	-0.1258	0.2007	-0.2364	0.3391	0.3391	-0.0231	-0.1337	-0.0666	0.2865	-0.0117
incomedive~x	-0.0933	-0.0171	0.0773	-0.0623	-0.0623	0.0525	0.0382	0.0732	-0.1443	0.1158
livediveri~x	0.106	-0.2138	0.0562	-0.0819	-0.0819	0.003	-0.0291	-0.2629	-0.0188	0.0703
cropdiveri~x	0.1497	0.1411	-0.2317	-0.1152	-0.1152	0.0139	0.0264	0.0879	-0.0976	0.2955
memberofco~m	0.0269	-0.1919	0.1493	-0.1531	-0.1531	0.0228	0.0551	0.0174	0.004	0.214
groupmembe~i	0.0121	-0.0421	-0.1681	-0.1343	-0.1343	-0.0267	-0.0116	-0.0578	-0.1218	0.0397
paidfreera~o	-0.0424	0.1165	-0.0597	0.0141	0.0141	-0.0118	-0.0226	-0.0801	-0.0706	0.1847
savemoneyy~e	-0.3381	0.1728	-0.1303	0.2025	0.2025	-0.0547	-0.0584	-0.0788	0.1367	0.0578
dependentr~o	-0.2716	0.2265	-0.0766	0.1619	0.1619	-0.05	0.1387	0.0463	-0.0214	0.1794
dealtwithe~e	-0.0138	-0.018	0.1185	-0.0686	-0.0686	0.089	0.0369	0.0658	-0.1614	0.125
Ndvi	0.4714	0.068	-0.3847	0.2081	0.2081	-0.0322	-0.1983	0.0764	0.3645	-0.16
Plotsize	0.2344	0.1033	-0.1421	-0.1669	-0.1669	-0.0409	-0.0706	0.208	-0.1607	0.0985

Table 13. The Pearson correlation co-efficient on factor influencing coping strategies across households in Mopti region of Mali – continuation

	number~b	access~d	access~t	access~e	income~x	livedi~x	cropdi~x	member~m	groupm~i	paidfr~o
numberofna~b	1									
accesstora~d	0.2604	1								
accesstofo~t	0.7893	-0.183	1							
accesstowa~e	0.6366	-0.4229	0.5287	1						
incomedive~x	0.0386	0.1492	0.0395	-0.1315	1					
livediveri~x	-0.1244	0.0681	-0.1506	-0.132	-0.0527	1				
cropdiveri~x	0.0037	-0.2152	0.1541	0.0766	-0.0048	0.1135	1			
memberofco~m	-0.1014	0.0113	-0.0722	-0.1125	0.0218	0.1497	0.1419	1		
groupmembe~i	-0.0202	-0.214	0.0637	0.1264	-0.1657	0.1045	0.1696	0.0961	1	
paidfreera~o	-0.0072	0.0912	-0.0553	-0.0524	-0.0418	0.0484	-0.0325	-0.0373	-0.0538	1
savemoneyy~e	0.4448	-0.251	0.5388	0.4792	0.0353	-0.1566	-0.008	0.0266	0.1109	-0.0604
dependentr~o	0.3241	-0.0295	0.324	0.2572	-0.0479	-0.0287	0.1289	0.0145	0.194	0.0478
dealtwithe~e	-0.0807	-0.008	-0.0497	-0.0794	-0.0227	0.0112	0.2244	0.0064	0.1326	-0.0236
Ndvi	-0.0442	-0.5179	0.1102	0.3587	-0.1179	-0.0033	0.2558	-0.0851	0.2117	-0.0827
plotsize	-0.1227	-0.1323	0.0114	-0.0824	-0.0021	0.0247	0.5887	0.0243	0.1151	0.0184

	savemo~e	depend~o	dealtw~e	ndvi	plotsize
savemoneyy~e	1				
dependentr~o	0.2797	1			
dealtwithe~e	-0.0288	-0.0297	1		
ndvi	0.1861	0.0542	-0.0054	1	
plotsize	-0.1323	-0.0757	0.4	0.1538	1

The results of the correlation analysis indicated that distances to the nearest electricity, nearest public telephone and health centre were highly correlated and we had therefore to combine the three distances to public facilities. For dummy variables we used the chi-square test for independence to determine the dependencies between variables. The variance inflation factor results in Table 14, for all included variables was less than 10, which indicate that multi-collinearity is not a serious problem in the reduced model.

Table 14. Variance Inflation Factor (VIF) test for multicollinearity among variables included in the analysis of factor influencing the coping strategies

Variable	VIF	1/VIF
accesstowa~e	5.92	0.169041
motorabler~d	5.78	0.173109
numberofna~b	5.55	0.180341
accesstora~d	4.25	0.235498
nearestele~y	3.57	0.279841
ndvi	2.9	0.34427
oflivestoc~e	2.66	0.376035
cropdiveri~x	2.15	0.466144
plotsize	2.04	0.489826
portablewa~r	2.04	0.490782
localmarket	1.83	0.54549
savemoneyy~e	1.8	0.555849
cropvaluep~e	1.48	0.674396
levelofedu~n	1.47	0.679599
age	1.42	0.702438
dependentr~o	1.35	0.73827
dealtwithe~e	1.34	0.74872
livediveri~x	1.32	0.760406
memberofco~m	1.3	0.770586
groupmembe~i	1.28	0.778436
paidfreera~o	1.17	0.851481
incomedive~x	1.14	0.878613
gender	1.11	0.903287
Mean VIF	2.39	

To address the possibilities of heteroscedasticity in the model, we estimated a robust model that computes variance estimator based on a variable list of equation-level scores and a covariance matrix (StataCorp, 2005). Table 15 presents the estimated effect of different variables to the coping strategies utilized by households. The results show that most of the explanatory variables are statistically significant at 10 or lower and the signs on most variables were as expected except for a few. The chi square results show likelihood ratio statistics were highly significant (P<0001) suggesting the models had a strong explanatory power.

Table 15. Logistic regression results on factor influencing the coping strategies in Mopti, region of Mali

	Store food (CS1)	Save money (CS2)	Preventive animal health care (CS3)	Preventive human health care (CS4)	Reduce livestock morbidity (CS5)
Dist-Urban Mkt	-.0020	-.0423***	.0132**	.0065	.0098
Dist-motorable road	.0341	.1673	-.0659	-.0589	-.0408
Dist_local_Market	-.0261	-.0529	.0103	-.0720**	-.0489
Portable water	-.0006	-.0198	-.0834	-.0473	-.0192
Dist-to electicity	.0077	. -.0484	.0560**	.0409	.0553*
Gender	.3943	-.3790	-.3974	-.7106	1.3522
Level of education	-.1736	-.0630	-.0039	-.1432	-.0201
Age	-.0443**	.0179	-.0008	-.0352**	-.0005
% livestock income	-.0274**	.0046	-.0108	.0002	-.0113
Crop vale per hectare	-2.56	.0001	-.0000	-.0000	-.0000
Number of natural resources	2.3121***	2.6407***	-.2914	.6982	1.2043
Access to rangelands	-2.2819***	-4.8449***	-.4082	-1.4029*	-2.0795**
Access to forest	-1.7159**	-1.2461	1.9610**	.3105	-.4483
Income diversification index	.9516	2.6847	.0972	1.8196	-5.4256
Livestock diversification index	-.8230	-.5875	-1.4295	-1.0992	-1.6634
Crop diversification index	2.3896	-1.0831	1.4756	3.2617**	-.6601
Number of community organisation	-.2015	.2724	.4590	-.0128	-.5042
Group membership	-.2091	1.1625	2.0198***	1.9295***	.8968
Save money	.2744		-.4313	.1200	-.3106
Dependence ratio	-.5283	-.9326	-.8058	-.8184	3.1441
Dealt with emergence	-1.3695	.7659	-.0171	-.8443	1.1055
Plot size	.0216	-.0529	-.0465	.0080	-.0367
NDVI	4.3738***	20.6797**	-2.9464	-9.3106**	-1.4085
Rainfall	-.0252**	-.0381**	.0007	.0142	.0029
Constant	8.4930*	10.0724	1.8402	-1.2076	.4078
Log likelihood	-76.77	-47.47	-83.74	-82.12	-82.42
No of observation	171	172	171	171	171
LR chi^2	82.52	140.13	61.50	72.75	70.51
Prob>chi^2	0.0000	0.0000	0.0000	0.0000	0.0000
Pseudo R^2	0.3496	0.5961	0.2686	0.3070	0.2996

Significant at 10%, ** significant at 5%, and* significant at 1%.*

The result suggests that a long distance to the urban market promotes preventive health care of the animals as a coping strategy against climate change and variability. The distance to the urban market is, as expected, a negative and positive influence (at 5% level of significance) on the use of saving and preventive health care for animals respectively. This implies that, when distances to a point /places where the banking facilities are situated are far, it becomes costly for farmers who are already resource constrained to access such services, consequently as the results shows a household in such situation is more likely invest on improving the animal health as an form of insurance (Binswanger and McIntire, 1987; Ng'ang'a, 2011). Similarly, the results shows that long distances to the local market has a negative and significant (P<0.05) effect on the use of preventive health care for household member as a coping strategy. This could be due to high cost involved when accessing preventive health care services. Under condition of resource constrain condition household must make decision in such a way that the available resources are allocate optimally among the competing needs such as food for the households, livestock treatment etc. in most cases local market are much closer to the household and therefore an advantage because services such as preventive health care services are closer and cheaper, therefore if the local market are far away household are forced to spend much more time, labor and money hence the negative effect.

As expected the distance to electricity, had a positive and significant (P< 001) effect on the use of preventive health care for animals and reduction of livestock morbidity. In this study good access to electricity had a positive influence on the ability of the households to use preventive health care for animals and reduction in livestock morbidity. This could be due to technology required to provide proper health care for animals becoming more accessible to households. In their study, Kurukulasuriya and Mendelssohn (2006) found that access to electricity was an important factor explaining households' access to technology. In addition, proper health care for animals is also likely to reduce livestock morbidity.

As expected, as the age of the household had a negative and significant (P<0.05) influence on the storing of food and preventive health care for human beings as a coping strategies. The negative effect of age of household head on preventive health care as a coping strategy, could be due fact that as household head become old, their body becomes weak and as such cannot very actively engage in income generating activities efficiently. This in a way compromises their ability to generate sufficient income to provide quality healthcare to their family members. Similarly, the proportion of income derived from livestock had a negative and significant effect on storing food as a coping strategy across households. The negative effect of livestock diversification indices could be due to the fact that diverse forms of livestock household that were derives a high income from livestock thereby acting as a disincentive for storing of crops as a coping strategy.

The number of natural resources accessed and used by the households had a positive and significant (P<0.001) influence on households ability to storing of food and saving money as coping strategies. Natural resources contribute vegetables and fruits (i.e., forest fruits) that the households depend on for food. The positive influence of the number of natural resources could be attributed to their strategic use by the households when the weather is favourable, while conserving their food in stores for use in bad times (i.e. when the environment is unfavourable). The use of natural resources also reduces the need to use money by the household for purchasing food and instead they save the money. The saved money could then be used during bad times (i.e. when the weather is unfavourable for food (crop and livestock) production for the households.

The group membership had a positive and significant (P<0.001) effect on the use of preventive healthcare for animals and preventive healthcare for human beings. These results are in line with the expectation of the study because in group meeting and associations, the members tend to pass important information to their colleagues when in group meeting. This information could be related for example to presence of livestock diseases in particular grazing areas or how to treat certain diseases, to understand certain symptoms thereby facilitating seeking of treatment on time. Community organizations are an example of social capital in that households facing a particular difficulty can always turn to friends for financial or material support. In a community different households are endowed differently in terms of assets, and their entitlements. An organization in a community also enhances sharing of information about the available opportunities for even critical information such as disease prevention.

The natural vegetation index had a positive and significant (P<0.05) influence on use of food storage and saving of money as a coping strategy across households. This could be attributed to the availability of pasture for the animals, thereby enhancing livestock productivity. High livestock productivity implies that household can consume product such as milk produced from livestock (such as milk) and which cannot be stored for a long compared to crop products such as grains (i.e., millet and sorghum). The availability of pastures also reduces the expenses for example that could have been used in purchasing of feeds. At the same time a well fed animals have lower chances of contracting diseases of going down due to infections, thereby saving money that could have otherwise be used in purchasing of veterinary treatment drugs.

However, in most cases an area where natural vegetation index is highest most corresponds to areas with favourable environment in terms of vegetative growth. In region such as Mopti, this area is most often close to a forest and river. Due to the need for household to reduce the morbidity associated with livestock death due pasture, the households move with the livestock to such areas. Moving to such areas tend to increase the distances to the health facilities, which again tend to increase the time and cost associated with accessing such facilities, hence the negative influence on preventive healthcare for human beings.

Rainfall had a negative and significant ($P<0.05$) influence on the storage of food and saving money as coping strategies. These results are in line with the expectation because when household receive a lot of rainfall or as the rainfall become more reliable, household do not foresee lack of food as an immediate concern. As a result they do not resort to storing of food as a coping strategy to climate change and variability associated risks. Similarly, because of lack of concern on food shortage as rainfall increases implies that households are not motivated to save money for bad (i.e., when the environment is unfavourable for crop and livestock production) times. This could be explained by fact that as the environment becomes dryer and lack of food becomes a frequent phenomenon, households are more likely to be motivated to look for other alternatives to ensure food availability in bad times, however, if the environment is conducive/favourable, the vice reverse is likely to happen. That is, as the environment becomes favourable for crop and livestock production (i.e., as rainfall increases) household need to save money as a coping strategy declines. This observation might also be attributed to the fact that in period low rainfall, water shortage is also likely to become an issue, consequently, households have to spend money purchasing water for consumption hence the need to save money.

3.2.3 Determinants of the households' vulnerability

The households were not only asked to list and rank their concerns and associated coping mechanisms but also to compare with other households (in the same village) the extent to which they have been coping. For each of the concerns they were facing, they were asked if they had been coping either better than, worse than or similar to other households in their village. This information allowed us to come up with a household-level vulnerability index, assessing the degree of a households' vulnerability to climate change and variability in relation to other households in the same village.

For each of the concerns a household listed, an impact factor (I_i) was established. This impact factor takes the value of +1 if the household considered itself coping less well than the other households, -1 if it was doing better and 0 if they assessed themselves similar to the other households in the village. The rationale was that households that are coping less than others are more vulnerable, while the ones that are doing better than other households have a lower vulnerability. The concerns listed are not all of equal importance. To correct, we established a weight for each of the concerns based on the rank they were assigned across all the sampled households. If a household reported 'n' concerns, the vulnerability of a household was then calculated following formula:

$$V = \sum_{\boldsymbol{i}=1}^{\boldsymbol{n}} w_i I_i$$

Where:

N Number of concerns

Wi Weight of concerns

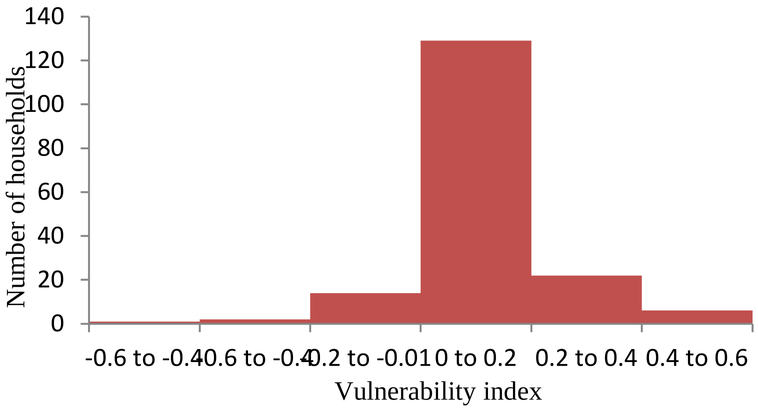
Ii Impact (+1: worse than/ 0: same/ -1: better).

As households compare their vulnerability to households in the same villages, the exposure to climate change and variability can be assumed to be equal. The vulnerability assessment the households make therefore reflects the internal capacity only, i.e. differences in sensitivity and coping capacity. This capacity is profoundly influenced by external policy and institutional context. As with the exposure, we assume these are equal for all households in the same village.

This vulnerability index provides a directly observable proxy for vulnerability and enables us to determine which factors influence households' vulnerability to climate change. To this end, correlation and regression analysis was used to determine the factors influencing the household's vulnerability based on the vulnerability index developed.

The frequency histogram of the vulnerability index is somehow shifted to the left Figure 14. This indicates the general tendency of the households to perceive the problems they face as worse or their own coping capacity as lower than their neighbours'. This is in accordance to the social psychology literature on the worse-than-average effect (e.g. Kruger, 1999; Moore & Small, 2005), which describes the human tendency to underestimate one's achievements and capabilities in relation to others, especially in difficult situations or when the chances of success are perceived to be low.

Figure 14. Frequency histogram of the vulnerability index



The computed final vulnerability index was correlated with the factors hypothesized to influence the vulnerability using spearman correlation. These included a combination of demographic, socioeconomic and geographic factors, including the numbers of coping mechanisms practiced by each of the households. In addition, analysis was done using STATA for windows, version 10 SE to help determine the combined effect of the different hypothesized factors on households' vulnerability regression. Both the correlation and regression analysis used a 0.01 to 0.05 level of significance.

Table 16 presents the significant factors associated with household vulnerability based on spearman correlation analysis considering the vulnerability index developed by the authors. Several demographic, socioeconomic and geographic factors were found to have considerable correlation with the vulnerability. They include: farm distance to the market, farm distance to clinic and public telephone, proportion of household income derived from livestock, crop value per hectare, number of natural resources accessible to households, crop diversification index, household ability to save, access to emergency cash loan and food aid over the last one (1) year.

In addition, income diversification index, livestock diversification index, and crop diversification index were calculated. The income diversification index was computed using Simpson diversity index (Ijaiya et al., 2009):

$$Di = \{[\Sigma\, n\, (n-1)] \,/\, [N\, (N-1)]\}$$

Where:

D_i Income diversity index of the household I, ranged from 0 to 1

n Total income from the different sources that contributes to households i’s to overall income such as crop, livestock, off-farm (i.e. harvesting of forest products such as charcoal), remittances and employment.

N Overall household income.

Table 16. Summary of factors hypothesized to influence household vulnerability to climate

Variable definition	Units of measurement	Mean	Std dev
Geographical variables			
Distance to the urban market	Km	46.7	48.7
Distance to the paved road	Km	32.1	29.5
Distance to the motorable roads	Km	4.4	7.4
Distance to the local market	Km	7.7	8.3
Distance to the livestock market	Km	11.9	11.7
Distance to portable water	Km	3.7	4.7
Distance to the nearest electricity	Km	16.7	17.6
Distance to the nearest health centres	Km	9.1	11
Distance to the nearest public telephone	Km	16.7	17.6
Access to forest	Dummy:1=Yes and 0, otherwise	0.4	0.5
Access to water resources	Dummy:1=Yes and 0, otherwise	0.3	0.5
Access to rangeland	Dummy:1=Yes and 0, otherwise	0.4	0.5
Number of natural resources accessed	Count	1	0.8
Free/paid ratio to access resources	Ratio	0.01	0.08
Rainfall	mm	523	78.9
Demographic factors			
Household gender	Dummy:1=Male, 0, otherwise	1	0.2
Years spent on education by HH head	Years	0.9	2.9
Age of the household head	Years	58.9	13.1
Household dependent Ratio	Ratio	0.1	0.1
Preventive health care for human	Dummy:1=Yes and 0, otherwise	0.5	0.5
Length of illness	Months	3	18
Household size	Adult equivalent (AE)	14.5	2.3
Household dependence	Adult equivalent (AE)	1.4	1.3
Income variables			
Proportion of income from livestock	Percentage (%)	37.9	34.7
Crop value per hectare	CFA (1US$ =500 CFA)	10455	10601
Income diversification indices	Index	0.3	0.1
Livestock diversification indices	Index	0.7	0.2
Crop diversification indices	Index	0.4	0.2
Membership to organisation	Dummy:1=Yes and 0, otherwise	0.2	0.4
Membership to a group	Dummy:1=Yes and 0, otherwise	0.3	0.5
Saving undertaken in the last 1 year	Dummy:1=Yes and 0, otherwise	0.1	0.3
Emergency needed in the last 1 year	Dummy:1=Yes and 0, otherwise	0.09	0.3
Saved money	Dummy:1=Yes and 0, otherwise	0.5	0.6
Stored food	Dummy:1=Yes and 0, otherwise	0.5	0.5
Livestock variables			
Herd size	Tropical Livestock Unit (TLU)	55.7	51.3
Reduced investment on animals	Dummy:1=Yes and 0, otherwise	0.4	0.5
Preventive health care for animals	Dummy:1=Yes and 0, otherwise	0.6	0.5
Reduce number of animals	Dummy:1=Yes and 0, otherwise	0.4	0.5
Reduce livestock mobility	Dummy:1=Yes and 0, otherwise	0.6	0.5

With this index, 0 represent infinite diversity and 1 represent no diversity. This means that the bigger the value of D_i, the lower the diversity. However, because this is neither intuitive nor logical, to get over this problem, D was subtracted from 1 to give diversity index of $1 - D_i$.

The livestock diversification index was computed using the Shannon diversity index (Begossi, 1996):

$$L_i = \sum_{i=1}^{s} -(P_i \ * \ \ln P_i)$$

Where:

Li Livestock diversity index

Pi Proportion of entire population of livestock in a homestead made up of species i

S Numbers of species encountered in each homestead, but which are owned and managed by the household

∑ Sum from species 1 to species S.

High values of L_i are representative of more diverse livestock across the households. Households with only one species of livestock would have a L_i value of 0, as P_i would equal 1 and be multiplied by the natural logarithm (ln) of P_i, which would be equal to zero. In Mopti, the species of livestock kept by the households ranges from one to six, i.e. cattle, sheep, goat, chicken, pigs and camels.

The crop diversification index was computed, using the following formula:

$$C_i = \sum_{i=1}^{s} -(P_i \ * \ \ln P_i)$$

Where:

C_i Crop diversity index

Pi Proportion of the entire population of crops made up of species i (in this case a plot was picked at random in for each interviewed household)

S Numbers of crop species encountered in the selected plot

∑ Sum from crop species 1 to species S.

High values of C_i represent crop diversity in a certain plot. A plot with only one species of crop would have a C_i value of 0, the C_i value is high in a plot with many crop species.

Among the 39 variables that had been hypothesized to influence household vulnerability, 24 variables were quantitative while 15 were qualitative variables (Table 16). The correlation results of quantitative variables (geographical, demographic, income and livestock), revealed that 12 of them were significantly (at $p<0.05$) correlated (Table 17), implying that multicollinearity may emerge if such variables were to be included in one regression model. Therefore, the 12 correlated quantitative variables were dropped, and would not be included in the regression analysis. The correlation coefficient of the remaining 12 quantitative variables ranged between $\rho=-0.366$ and $\rho=0.28$, suggesting that each of the variable picks up something that was "distinct" are presented in Table 18.

The correlation result out of the 15 qualitative variables done using χ^2 showed that 5 of them were significantly (at $p<0.05$) correlated as shown in Table 19. These 5 qualitative variables (group membership, access to water, access to forest, storage of food and making arrangements with the family) were thus dropped, since multicollinearity may emerge if such variables were to be included in one regression model, implying that only 10 qualitative variables were distinct (Table 20). Therefore, only a total of 22 factors were used in the ordinary least squares (OLS) regression to determine what factors influence household level vulnerability, That is, 12 and 10 quantitative and qualitative variables respectively.

Table 17. Pearson correlation results for the quantitative variables

	Paved road	Motorable road	Local market	Urban market	Livestock market	Portable water	Nearest electricity	Nearest clinic	Nearest Public telephone	Number of natural resources	Paid/Free resources	Rainfall	Level of education	Age	Dependent Ratio	Length of illness	HH size	Income diversification index	Crop diversification	Livestock diversification	Herd Size	Livestock income	Crop value	HH dependence
Paved road	1																							
Motorable road	-0.36*	1																						
Local market	-0.21**	0.27*	1																					
Urban market	0.70**	-0.27**	0.26**	1																				
Livestock market	-0.113	0.63**	-0.65**	-0.19**	1																			
Portable water	-0.16*	-0.48*	-0.16*	0.12	0.45*	1																		
Nearest electricity	0.18*	0.27**	0.34**	-0.06	0.50**	0.19*	1																	
Nearest clinic	-0.14	0.81**	0.12	-0.15	0.75**	0.50**	0.28**	1																
Nearest Public telephone	0.18*	0.27**	0.34**	-0.06	0.50**	0.19*	1.00**	0.28**	1															
Number of natural resources	-0.34**	0.14	0.29**	-0.43**	0.19*	0.09	0.37*	-0.02	0.37**	1														
Paid/Free resources	-0.08	0.16*	0.11	-0.04	0.05	-0.06	0.02	0.08	0.02	-0.01	1													
Rainfall	0.35**	0.19*	-0.33**	0.47**	-0.1	0.1	-0.46*	0.26**	-0.46**	-0.67**	0.03	1												
Level of education	-0.24**	0.38**	0.24**	-0.14	0.15	-0.08	0.02	0.20**	0.02	0.05	-0.02	0.03	1											
Age	0.1	-0.15*	0.05*	0.23**	-0.08	-0.22**	-0.17*	-0.1	-0.17	-0.14	-0.08	0.11	0.03	1										
Dependent Ratio	-0.35**	0.05	0.22**	-0.27**	0.03	-0.07	0.16*	-0.11	0.16*	0.32**	0.05	-0.43**	0.14	0.05	1									
Length of illness	0.04	-0.06	0.17*	0.14	0.09	0.01	0.03	-0.08	0.03	0.06	-0.01	-0.08	-0.05	0.17	-0.002	1								
HH size	0.15	-0.13	-0.1	0.32**	-0.14	-0.14	-0.14	-0.08	-0.14	-024**	-0.03	0.23**	-0.11	0.04	-0.39**	0.03	1							
Income diversification index	-0.21**	0.09	0.03	-0.09	0.02	0.08	-0.05	0.04	-0.04	0.05	-0.04	0.06	0.03	0.10	-0.05	0.22	-0.22	1						
Crop diversification	0.02	-0.19*	0.13	0.14	-0.09	-0.24**	-0.12	-0.25**	-0.19	0.01	-0.03	-0.04	0.03	0.09	0.13	0.04	0.26**	-0.09	1					
Livestock diversification	-0.38**	0.36**	0.15*	-0.51	0.29	0.29**	0.31**	0.26**	0.31**	0.41**	0.07	-0.37	0.11	-0.32	0.33**	0.03	-0.28**	0.002	-0.06	1				
Herd size	-0.03	0.03	0.14	-0.11	0.18	0.03	0.27**	0.08	0.27**	0.19*	-0.06	-0.32	0.02	-0.04	0.20**	0.17	0.11	-0.06	-0.05	0.21	1			
Livestock income	0.34**	0.07	0.1	0.13	0.08	0.02	0.66**	-0.09	0.66**	0.19*	-0.07	-0.2	-0.06	-0.25	-0.02	0.02	-0.05	-0.14	-0.1	0.08	0.18	1		
Crop value	-0.21**	0.18	0.04	-0.12	0.03	0.05	0.02	0.07	0.02	0.02	0.19	-0.06	0.20	0.04	0.18*	-0.03	0.09	0.11	0.30**	0.12	0.12	-0.18*	1	
HH dependence	-0.35**	0.03	0.21**	-0.25**	0.02	-0.07	0.13	-0.12	0.13	0.32**	0.05	-0.42**	0.12	0.05	0.97**	0.01	-0.26**	-0.06	0.18*	0.34*	0.21**	-0.04	0.18*	1

*** Correlation is significant at the 0.01 level (2 tailed).*

** Correlation is significant at the 0.05 level (2 tailed).*

Table 18. Correlation results for quantitative factors hypothesized to determine vulnerability index

	Livestock market	Education level	Age	% of livestock income	Crop value per hectare	Paid /Free Ratio	Income diversification index	Crop diversification index	Livestock diversification index	Herd size (TLU)	length of illness (months)	Rainfall (mm)
Livestock market	1											
Education level	0.153	1										
Age	-0.081	0.029	1									
Proportion of livestock income	0.077	-0.059	-0.25	1								
Crop value per hectare	0.027	0.195	0.04	-0.176	1							
Paid/Free access to resources	0.053	-0.022	-0.08	-0.071	0.185	1						
Income diversification index	0.018	0.033	0.097	-0.137	0.108	-0.042	1					
Crop diversification index	-0.09	0.025	0.088	-0.1	0.296	-0.034	-0.009	1				
Livestock diversification index	0.287	0.106	-0.32	0.076	0.121	0.067	0.002	-0.066	1			
Herd size (TLU)	0.183	0.015	-0.04	0.176	0.12	-0.057	-0.058	0.048	0.213	1		
Length of illness (months)	0.091	-0.047	0.173	0.018	-0.033	-0.01	0.22	0.036	0.03	0.169	1	
Rainfall (mm)	-0.099	0.029	0.11	-0.2	-0.059	0.027	0.061	-0.039	-0.366	-0.315	-0.076	1

Table 19. Correlation between qualitative variables (chi-square results)

chi-square results	Access to water resources	Access to forest	Access to rangeland	Dealt with emergency in the last 1 year	Group membership	Membership to a community organisation	Gender	Saving	Store food	Make arrangement with the family
Preventive health care for human beings	9.419**	5.6**	17.35	0.073	18.69***	0.000	0	0.065	10.18**	4.4**
Preventive health care for animals	11.572***	12.45**	20.32	0.006	21.28***	0.013	0.205	0.035	5.68**	9.42**
Reduce investment on animals	62.85***	48.34***	27.14	0.28	11.23***	1.09		0.007	36.205***	24.63***
Reduce the number of animals	96.49***	72.74***	41.34	0.508	9.77**	0.59	0.182	1.1	47.35***	25.84***
Reduce livestock mobility	26.54***	7.7**	23.85	0.96	7.96**	4.5*	0.687	0.777	12.92***	6.535**

****, **, *, significance at 1, 5 and 10 per cent respectively*

Table 20. Correlation between qualitative variables (chi-square results) that were later used in ordinary least squares (OLS) regression model

	Access to rangeland	Dealt with emergency in the last 1 year	Membership to a community organisation	Gender	Saving
Preventive health care for human beings	17.35	0.073	0	0	0.065
Preventive health care for animals	20.32	0.006	0.013	0.205	0.035
Reduce investment on animals	27.14	0.28	1.09		0.007
Reduce the number of animals	41.34	0.508	0.59	0.182	1.1
Reduce livestock mobility	23.85	0.96	4.5*	0.687	0.777

Table 21 presents the results of Pearson's correlation analysis for variables associated with vulnerability among a sample of 174 households. The results show that three factors were significantly correlated with household vulnerability index at $p<0.05$ and $p<0.1$ level of significance. These were: access to rangelands, exposure to emergency situation in the last one year and reduction of livestock mobility. As expected reduced livestock mobility was positively and significantly (at $p<0.05$) correlated with household level vulnerability, implying that households whose livestock movement was constrained were more vulnerable to the effects associated with climate change and variability. The positive and significant (at $p<0.01$) correlation of emergency situation that households had encountered in the last one year with household level vulnerability, was as expected, suggesting that households who had dealt with emergencies situations during the last 12 months were more vulnerable than those who had not. Finally, the results also showed that access to rangeland had a negative and significant (at $p<0.05$) correlation with vulnerability, implying that households with ease of access to the rangelands for their livestock grazing were less vulnerable to effects associated with climate change and variability.

Table 21. Correlation results of vulnerability index and the distinct hypothesized variables

Geography variables	Vulnerability Index (VI)
Rainfall	0.062
Free/paid ratio to access resources	-0.039
Access to rangelands	-0.296**
Distance to the livestock market	-0.138
Demographic variables	
Gender of the household head	0.047
Years spent on education by the household head	-0.187
Age of the household head	-0.003
Preventive health care for human	0.112
Length of illness	0.11
Income variables	
Proportion of income from livestock	0.04
Crop value per hectare	-0.002
Income diversification index	0.011
Livestock diversification indices	0.125
Crop diversification indices	0.081
Membership to community organisation	-0.088
Saving undertaken in the last 1 year	0.111
Dealt with emergency in the last 1 year	0.156*
Livestock variables	
Herd size	0.136
Reduced investment on animals	0.118
Preventive health care on animals	0.134
Reduce number of animals	0.019
Reduce livestock mobility	0.196**

*** Correlation is significant at the 0.01 level (2 tailed).*

** Correlation is significant at the 0.05 level (2 tailed).*

Finally a robust OLS regression analysis was run to find out what factors were important in determining household level vulnerability to climate change and variability (Table 22). The regression was implemented in steps. The first step was to regress the vulnerability index with geographic and demographic variables in OLS 1 and then proceed by combining vulnerability index, geographic and demographic factors with region control variables (OLS 2). Later in OLS 3, we combined geographic, demographic, region control variables and income variables. OLS 4 is similar to OLS 3 but without regional control dummy variables. Finally in OLS 5, geographic, demographic, income, livestock and region control variables were all combined and regressed hence making it the complete regression model.

The ability by the household to save some income is significant (at $p<0.1$) and negatively influencing household vulnerability as shown in Table 22, column 5 (OLS 4). Savings enable household to smooth consumption during times when cropping fails or when livestock production is below the levels required to sufficiently cater for household consumption and income. Climate change and variability especially following droughts is associated with decline in crop production as well as livestock deaths. At such times, households rely on accumulated resources in form of savings. Thus, the ability to save cash for use in the future lowers household vulnerability level. Implying that more savings have the potential to help farmers meet shortfalls for example through purchasing of food following a period of crop failure due to drought. To our surprise the results showed that when we modelled the control for regions (Column 6 or OLS 5), saving is no longer important. This could be explained by the loss in variation which comes along when the regional control enters the model.

Table 22. Ordinary least squares (OLS) results of factor influencing household vulnerability

		OLS 1	OLS 2	OLS 3	OLS 4	OLS 5
Geography variables	Rainfall (mm)	0.001** (-0.001)	0.001 (0.000)	0.001 (-0.0001)	0.0001** (-0.0001)	0.001 (0.000)
	Paid/Free access to resources	-0.033 (-0.142)	-0.038 (-0.143)	-0.04 (-0.145)	-0.007 (-0.142)	-0.009 (-0.141)
	Access to Rangeland	-0.107*** (-0.027)	-0.127*** (-0.033)	-0.124*** (-0.033)	-0.088** (-0.029)	-0.118*** (-0.032)
	Distance to the livestock markets	0.0001 (-0.001)	0.001 (-0.001)	0.0001 (-0.001)	0.0001 (-0.001)	0.0001 (-0.001)
	Demographic variables					
	Gender of the household head	0.004 (-0.073)	0.001 (-0.073)	-0.005 (-0.073)	-0.021 (-0.072)	-0.002 (-0.073)
	Years spent on education by HH	0.0001 (-0.004)	-0.001 (-0.004)	-0.001 (-0.004)	-0.001 (-0.004)	-0.002 -(0.004)
	Age of the household head	-0.001 (-0.001)	-0.001 (-0.001)	-0.001 (-0.001)	-0.001 (-0.001)	-0.001 (-0.001)
	Preventive health care for human beings	0.006 (-0.024)	0.013 (-0.024)	0.008 (-0.024)	0.018 (-0.025)	0.01 (-0.025)
	Length of illness	0.001 (-0.001)	0.001 (-0.001)	0.001 (-0.001)	0.001 (-0.001)	0.001 (-0.001)
Income variables	Proportion of income from livestock			0.001 (-0.001)	0.001 (-0.001)	0.001 (-0.001)
	Crop value per hectare			0.003 (-0.001)	0.005 (-0.001)	0.003 (-0.001)
	Income diversification			0.075 (-0.178)	0.148 (-0.175)	0.102 (-0.176)
	Livestock diversification index			-0.103* (-0.061)	-0.089* (-0.06)	-0.104* (-0.061)
	Crop diversification index			-0.012 (-0.06)	-0.039 (-0.059)	-0.016 (-0.059)
	Member of a community organisation			-0.047* (-0.028)	-0.042 (-0.028)	-0.047* (-0.028)
	Saving undertaken in the last 1 year			-0.14 (-0.103)	-0.176* (-0.099)	-0.136 (-0.100)
	Dealt with emergency in the last 1 year			0.221** (-0.11)	0.243** (-0.106)	0.196** (-0.107)
Livestock variables	Herd size (TLU)				-0.001* (-0.001)	-0.001* (-0.001)
	Reduce investment on animals				0.084** (-0.037)	0.096** (-0.37)
	Preventive healthcare for animals				0.019 (-0.024)	0.016 (-0.024)
	Reduce number of animals				-0.009 (-0.055)	0.034 (-0.06)
	Reduce livestock mobility				0.029 (-0.025)	0.035 (-0.025)
Regional control variables	Delta: dummy=1, 0 otherwise		-0.216 (-0.204)	-0.143 (-0.185)		-0.186 (-0.140)
	Gourma: Dummy =1, 0 Otherwise		-0.327 (-0.268)	-0.239 (-0.248)		-0.075 (-0.187)
	Constant	0.121 (-0.101)	0.119 (-0.101)	-0.013 (-0.127)	-0.144 (-0.138)	-0.197 (-0.244)
	R squared	0.131	0.142	0.213	0.26	0.281
	Adjusted R-Square	0.086	0.084	0.116	0.153	0.165
	Observation	174	174	174	174	174

[a] *Robust standard errors in parenthesis. *p<0.1, ** p<0.05, p<0.01;* [b] *Dependent variable: Vulnerability index*

In the complete model (OLS 5), when the regional dummy variables enter the model, the variable rainfall becomes insignificant. This could be due to the fact that when undertaking the present study, households were asked to compare themselves against households in the same villages. In theory, this implies that rainfall coefficient should be similar across the different villages. In general therefore in our complete model, only six variables were significant in determining household vulnerability across the studied households. Both the correlation and regression analyses agree on three factors. These were: access to rangelands, dealing with emergency and reduction of livestock mobility. The regression analysis results showed that four variables had the a priori expected signs, they include: access to rangelands, membership to community organisation, dealt with emergencies in the last 1 year and reducing investment on animals.

The variables reducing investment on animals and dealt with emergency in the last one year, had a positive and significant (at $p<0.05$) sign, implying that households who had dealt with an emergency situation during the last one year as well as those who had reduced investment on animals were more predisposed to vulnerability. At the same time membership to a community organisation and the size of the herd, had negative and significant (at $p<0.01$) signs, implying that households whose herd sizes were large, and those who were members to community organisations were less predisposed to the vulnerability associated with climate change and variability. Similarly, access to rangelands by livestock had a negative and significant (at $p<0.001$) influence on household vulnerability as hypothesized. This implied that households whose livestock species could access the rangelands easily were less vulnerable to climate change and variability.

The results showed that herd size had negative and significant (at $p<0.01$) influence on household vulnerability to climate change and variability. Livestock are assets, in that they contribute immensely to household livelihoods through marketed (milk and meat) and non-marketed (financing, insurance dowry payment and social prestige) benefits (Ng'ang'a, 2011). In addition, in arid and semi-arid areas, due to high covariant risk in crop production (Binswanger and McIntyre, 1987), households must find other sources of insurance; in such cases livestock plays an important insurance role. These imply that households who are in a position to increase their herd size, in some way boost their insurance, income and food base, hence lowering their vulnerability.

The results also showed reduction on livestock investment to be positively and significantly (at $p<0.05$) associated with household vulnerability to climate change and variability. Just like other capital or income generating asset such as machinery up on which wear and tear lead to depreciation in value, as well as reduced efficiency in performance, infestation of livestock by disease causing organisms could lead to weakening of their body within a short period of time. The effect and impact of diseases on livestock are more pronounced during drought periods due to reduced water and pasture availability.

Decline in water is also often associated with slow regeneration of the vegetative part of plants, which livestock browse or graze on. To survive, animals have to trek for long distances in search of water and pastures. Hence among households, where investment (such as purchase of commercial feeds, vaccination and treatments) on animals are on a decline, it could easily lead to livestock succumbing to climate change and variability related effects quickly leading to large losses within a short period. This would make the households more vulnerable.

This finding corroborates similar observation in rural development literature (see for example Dercon & Krishna, 1996; Little et al., 2001; Little, 1992) that investment in livestock particularly in rural areas, is by far the most preferred by households even as they seek to diversify their income sources. This is because of the important role of livestock as a form of saving and insurance.

The positive and significant influence by the variable 'dealt with emergency in the last one year' in determining household vulnerability implies that, that household, which has been previously predisposed to an emergency situation, was more vulnerable. The reason for this could be that, any emergency situations calls for households to mobilize their assets and their entitlements. In land abundant arid and semi-arid areas (Binswanger & Rosenzweig, 1986), livestock such as cattle, goat and sheep serves as the main assets that households could dispose of quickly to offset any emergency needs that could arise.

Livestock reproduction makes livestock favourable as a form of saving and insurance, however reproduction takes time (Ng'ang'a, 2011). This means that, households who had in the last one year dealt with an emergency are more likely to have reduced livestock numbers or even other assets when coping with the emergency situation. This leaves them more vulnerable compared to households that experienced no emergency situations during the same period.

Access to rangeland had a negative and significant influence on household vulnerability. This was as expected because at ceteris paribus, in arid and semi-arid areas, most households own livestock, which are also a major form of asset. The importance of livestock as an asset has been shown to increase with decrease in rainfall (Binswanger & McIntyre, 1987). At the same time, it is known that arid regions are characterised by low and erratic rainfall leading to low agricultural crop productivity. Consequently, households living in these areas keep searching for pastures and water for their livestock, to sustain their livelihoods, hence their high mobility (Bekure et al., 1991). One of the major sources of pastures for livestock is the common access rangelands, where animals could graze without causing damage or creating conflicts. This could explain why access to rangeland has negative effect on household vulnerability.

As expected the result showed that livestock diversification which was hypothesized to exert a negative effect on household vulnerability had a negative and significant effect on household vulnerability. Livestock diversification instigates a diversity of species for example camel, goat, sheep and cattle to cope with climate change and variability related hazards such as drought (Mc Cabe, 1996). Literature on rural development in general and agro-pastoral in particular (Dercon & Krishna, 1996; Little, 1992; Nkedianye et al., 2009) posit that diversification of incomes has the potential of lowering household vulnerability.

According to our results, however, if a household choose to keep all their assets in different form of livestock, then their vulnerability level is reduced. That is households who had diversified by keeping a mixture or variety of livestock species are less vulnerable to effects associated with climate change and variability. Different species of livestock succumb to climate change and variability related effects differently. For example in most cases, as it get drier, goats have a higher survival rate than cattle. This is because as it get drier most often the grasses dries up faster than trees and shrubs, and since goats are browsers, they could survive on twigs and pod from leguminous trees, hence a high survival rate. This could explain why in their study, Little et al., (2001) found that despite high severity and correlation of livestock losses in East African rangelands, livestock diversification was still more pronounced among pastoral communities.

Membership of community organisations among households as expected had a negative and significant (at $p<0.1$) influence on household vulnerability to climate change and variability. Community organisation is an example of social capital in that households facing a particular difficulty can always turn to friends for financial or material support. In a community, different households are endowed differently in terms of assets, and their entitlements. Community organisations are forms of social networks and in regions that share similar experiences and covariant risks which are common in ASALs (Binswanger and McIntyre, 1987; Binswanger and Rosenzweig, 1986), they act as think tanks through sharing of knowledge among the households (Pfeifer, 2011).

Organisation in a community also enhances sharing of information about the available opportunities elsewhere, for instance in both pastoral and agro-pastoral areas, households gather information about areas where pastures for grazing their livestock is available. This information is then passed quite easily through relatives and friends whom they associate with. Moreover, the difference in endowment among households provides an opportunity for those who are less endowed. For instance during drought some farmers, especially those who are financially endowed, endeavour to transport water using trucks to faraway places where their livestock are being grazed. During such times, the less endowed households, but who associate through a community organisation with the more endowed households, might get an opportunity to transport water to their livestock too at a lower cost. Therefore, by being a member of a community organisation, the household vulnerability to climate change and variability is lower compared to that of non-members.

CHAPTER 4: Conclusions and policy recommendations

This study analysed actual coping strategies used by agro-pastoralists based on a household survey of approximately 175 households in Mopti region of Mail. The results permitted a better comprehension on the adaptive capacity of the agro-pastoralist communities to climate variability and change.

The major concerns faced by the agro-pastoral communities in the region are the insufficiency of pastures for livestock and crop failure caused by erratic rainfall, resulting in food deficiency. Other factors influencing vulnerability are animals' diseases and death, human sickness, lack of water supply for livestock, high prices of inputs and low market prices of outputs.

The results of this study indicated that pastoralist communities have adopted many strategies to reduce their vulnerability. The best options to face the consequences of climate variability and change were listed as reducing the number of animals, collection and storage of feed for animals and grain for the populations, reducing investment on animals and houses, vaccination of livestock against animals diseases and avoiding infested areas, and making arrangement with families or friends to help.

Agro-pastoralists in Mali already face daunting challenges which are now compounded by the expected climate change and increasing climate variability. This condition is further worsened by a complex interaction of multiple stressors occurring at various levels such as geography, market access, household and socio-economic characteristics and the low adaptive capacity. For example income, assets and access to social services are unequally distributed (Akoon, 2010; World Bank, 2005). This research aims at contributing to the debate, by focusing into a number of components which, in our view, could shed some lights on important determinants of household vulnerability to climate variability and change, of how in seeking solutions of increasing adaptive capacity to climate change, an integral approach which involves focusing on risks and vulnerabilities is important.

In general our results from the Mopti region of Mali, provide some evidence for the view that geography is important in determining household vulnerability to climate change and variability. In addition, our evidence identifies a number of income and livestock variables that seem to attribute to household vulnerability. Our main results indicate that most of the geographical variables do not to a large extent determine household vulnerability. This could be due to the relatively little spatial variation of our geographical variables. For example most of the households interviewed were most often living in villages. Consequently the distances from each of the interviewed households in the sampled villages to most of the social services such as clinic, water sources, to road and market were more or less the same, hence dropping of these variables due to high correlation. However, this could change if a larger sample size is used.

In the literature, temperature and rainfall are two variables that have been identified as important measures with regard to food production systems (IPCC, 2001). This is because any variation for example between the low and high values as well as frequency to which these extremes occurs, matters to a large extent in determining food production and supplies. In most of sub-Saharan African countries, reliance on rain fed agriculture is high in that only less than 5 five per cent is irrigated (ibid). Therefore, the a priori expectation for our results was that more rain could impact negatively on household vulnerability. At first the indication from our results was that rainfall was an important factor in influencing household vulnerability. At first sight, these results appear to conflict with the evidence provided in the cross-country studies identifying rainfall as a long term driver in reducing household vulnerability to climate change and variability. However, when we controlled for the regions, where households were comparing themselves with others in the same village, the impact of the rain fizzled away.

The results from this study have shown that for reduction of vulnerability to climate change, for better or improved adaptive capacity there is need to evaluate factors which are important in different areas for the purpose of targeting (say for sustainable development). On one hand, for example the results have shown that access to rangeland, increasing the herd size and membership to a community organisation are important in reducing household vulnerability to climate change. On the other hand, the result indicates that cutting down investment on livestock could predispose the household to higher vulnerability. Although our findings clearly show the importance of different factors in determining household vulnerability, the OLS results of factors influencing household vulnerability showed that the model could only explain 28% of the variation and this implies that there are other factors were not include in the model that have greater effect on household vulnerability. There is thus a need for an in-depth study for other additional factors which makes households vulnerable to the effect associated with climate change and variability.

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Appendices

APPENDIX 1. Distances (km) of the villages in three zones to various infrastructures and services

	Gourma				Seno				Delta			
Distance (km) to nearest	Dirimbé	Douma	M'Boundou Koli	Tanal	Guéourou	Diallassagou	Baré-Dar-Salam	Sadia-Peul	Nérékoro	Sindégué	Ouro-Modi	Yougonsiré
Paved road	0	1	5	40	70	90	40	40	2	1	60	30
Motorway	0	20	15	15	0	0	0	0	0	0	0	0
Local market	5	20	1	10	5	0	4	5	3	6	7	15
Urban market	5	20	15	40	5	160	100	101	130	45	60	30
Livestock market	5	20	15	40	5	5	4	5	3	6	7	30
Streaming water	5	0	15	10	0	5	0	0	3	3	0	0
Electricity	5	20	15	40	5	5	4	5	3	6	60	30
Health centre	5	20	15	40	5	5	4	5	3	6	0	0
Public telephone	5	20	15	40	5	5	4	5	3	6	60	30

APPENDIX 2. Dynamic of forage during years

APPENDIX 2a. Forage present 10 years ago, but absent now

Feed	Count	Feed	Count	Feed	Count
Acacia Albida	2	Goudoubal	1	Oriza bartii	1
Wuludéré	1	Gourdial	5	Panicum sp	4
Anogeissus leiocarpus	1	Guingal	1	Yama	1
Aristida sp	6	Guirigal	2	Parkia biblobosa	1
Bagoni	1	Hudo poudjiho	1	Pennisetum pedicelatum	7
Baou	1	Indigofera tinctoria	1	Ptérocarpus sp	1
Békoé	1	Ipomea verticillata	1	Sadiè	2
Boubal	1	Irigolmadji	1	Sakatère	1
Boudouda	1	Kaccamadji	2	Samba n'béréwo	3
Bougnari	1	Kelbi	2	Schoenefeldia gracilis	11
Bouwal	1	Kiessou	1	Sclerocaria birrea	1
Brachiaria ramosa	1	Kudel kolade	1	Selbere	3
Bulogo	1	Laïdi	1	Sewoko	2
Cenchrus biflorus	12	Lannea	2	Sinkaré	1
Chloris sp	12	Laouni	1	Soybow	1
Cymbopogon giganteus	1	Loudetia	1	Tadial	1
Dadial	1	M'Badojè	1	Takabal	1
Dandiou	1	N'badaou	1	Takabal	2
Dhira	1	Nbadoré	9	Takalpoli	1
Diabol	1	N'bougnari	2	Tamaridus indica	1
Dialanèlaye	1	N'bouwa	1	Taxobal	1
Didere	1	Ndaae	1	Tegelé	1
Diligol	1	N'dayal	1	Tiaobol	1
Dioborou	4	N'deguery	1	Vetiveria nigritiana	11
Dioloubedié	1	N'dilichou	1	Voscia cuspidata	3
Echinochloa stagnina	4	N'diriri	1	Votacie	1
Falladé	3	N'gnèlo	2	Walwaldi	1
Fayekabodje	1	N'gologo	1	Wotaré	1
Galakoye	1	Niala	1	Wouldere	1
Gobedolo	1	N'Libilabawo	1	Wulogo	1
Andropogon sp	82	Zornia glochidiata	19	-	-

APPENDIX 2b. Forage absent 10 years ago, but present nowadays

Feed	Count
Zornia glochidiata	10
Voscia (rizière)	3
Tourteaux de coton	62
Son de riz	4
Singare	2
Sinakré	1
Sida sp	1
Oriza bartii	4
Schoenefeldia gracilis	3
Saroho	2
Saboudé	1
Aliment bétail	5
Nianerio	1
Cenchrus biflorus	1
Indigofera tinctoria	3
Huderewo	4
Gotoro	3
Dingemène	1
Déba	1
Dah (blanc)	1
Chloris prieurii	4
Boula	1

APPENDIX 3. Prevention actions

Preventions action against	Percentage of households (%)	Cumulative percentage (%)
	lack of pastures	
Reduced number of animals	46	46
Reduced mobility or avoiding certain areas	8	54
Reduced investment in animals/land/house	1	54
Save money	3	57
Store food	36	94
Make arrangements with family or friends for help	2	96
Others	4	100
	lack of food for human	
Save money	8	8
Store food	88	96
Make arrangements with family or friends for help	2	98
Others	2	100
	crop failure	
Preventive health care for people	1	1
Reduced investment in animals/land/house	31	32
Save money	7	38
Store food	52	90
Make arrangements with family or friends for help	7	97
Others	3	100
	animal sickness/death	
Preventive health care for animals	88	88
Reduced mobility or avoiding certain areas	5	93
Reduced investment in animals/land/house	2	95
Others	5	100