Towards gender-informed adaptation planning in the Sudanian zone of Mali

Analysis of climate change vulnerability

Working Paper No. 310

CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

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RESEARCH PROGRAM ON
Climate Change, Agriculture and Food Security

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Abstract

Understanding the linkages between gender and vulnerability is crucial for proposing sustainable gender-responsive climate-smart solutions. This study compared the vulnerabilities of male (MHHH) and female household heads (FHHH) in the Sudanian zone of Mali using Cinzana in the Segou region as a case study. We used semi-structured questionnaire interviews and focus group discussions for data collection. The questionnaires were randomly administered to 233 household heads (23% women). The Livelihood Vulnerability Index (LVI) method was used to assess vulnerability to climate change. The results showed that livelihoods in the Sudanian zone of Mali are vulnerable to climate change. Female household heads (FHHH) were found to be more vulnerable. FHHH recorded higher values for six out of the eight LVI major components used in the vulnerability assessment: socio-demographic index, livelihood strategies index, social network index, food index, natural disasters and climate variability index and agricultural production system index. The study proposes a number of interventions for improving the adaptive capacity of FHHH to climate change and variability: improving access to financial resources, improving access to radio for receiving weather information, encouraging FHHHs involvement in farmer-based groups for peer-learning; and promoting the development of policy initiatives that ensure the mainstreaming of gender into agricultural development programs.

Keywords

Africa; Climate risk management; Food security; Livelihood analysis; Women

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Contents

1. Introduction 7
2. Methodology and study approach 9
   2.1. Study area 9
   2.2. Data sources and sampling method 10
   2.3. Vulnerability assessment 11
3. Results and discussion 22
   3.1. Overall livelihood vulerability index 22
4. Conclusion 30
References 31

1. Introduction

The economies and livelihoods of Africa largely depend on agriculture. However, the continent's agricultural systems are currently unable to meet the increasing demand for food for its growing population estimated to reach 2.4 billion by 2050 [1]. Recent projections under the international food assessment reports [2] indicate that without appropriate interventions, the present state of food insecurity in Africa will worsen in the next decade. The IPCC reports that climate change and variability will challenge efforts to boost food production and critically aggravate this situation [3, 4] due to changing rainfall distribution patterns, soaring temperatures, recurrent droughts, increasing flood frequency and intensity etc. In the literature, studies project yield of major food crops could reduce by 60% due to changing and varying climate [5]. Increasing climate variability may further complicate agricultural production and food security as recent studies have shown that nearly one third of the variability in yield is related to climate variability [6]. The high levels of rainfall dependence for agricultural sustainability in sub-Saharan Africa, combined with crop sensitivities observed at peak temperatures during the growing season, adds to the growing vulnerability of the agricultural sector to climatic variability [7].

The dry areas of Africa such as the Sudanian zone of Mali are among the most vulnerable to the adverse effects of climate change [8]. In these areas, rains are less frequent, temperatures are relatively higher and drought periods are longer. Declining yield of cereal crops (which constitute more than 50% of staple food crops) are also expected to be in the order of 20% to 50% by 2050 [9, 10]. With increased evidence from models and empirical historic data that future climate change and variability may have far-reaching consequences on food production systems and livelihoods, adaptation planning is considered an important strategy to appraising the capacity and suitability of present and planned agronomic practices, programs, policies, and infrastructure [11, 12] to accentuate implications on building adaptive capacity to plausible climate-related risks.

In the Sudanian zone of Mali, the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) is using its climate-smart village (CSV) projects in Cinzana to

test a number of climate-smart solutions for adaptation planning decisions [6]. However, for effective adaptation planning decision, the analysis of livelihoods and the understanding of how populations and agricultural systems are vulnerable to climate-related risks is considered an important step. Vulnerability is variously defined with the concept applied in several disciplines and themes such as public health, natural resources management, ecology, disaster risk management, development, livelihood security and famine, in sustainable development science, and in climate impact analysis [13-15]. Initially, the concept was based on two distinct areas of study [11]. The first was the human geography approach, used to describe a system's vulnerability to the adverse effects of a hazard [11]. The second approach was based on human ecology, seeking to understand who was vulnerable to hazards and why [11, 13]. As research on climate change developed, vulnerability assessment has become an integral component of adaptation planning [11]. In 2006, Adger [13] integrated the concepts of adaptive capacity and exposure and to the concept of vulnerability and defined vulnerability as being susceptible to damage from exposure to environmental stress and social change without the capacity to adapt. The Intergovernmental Panel on Climate Change (IPCC) in its fourth assessment report added sensitivity to the concepts of adaptive capacity and exposure [3] making the three concepts (sensitivity, adaptability and exposure) the pillars of vulnerability [16].

To assess vulnerability, several indices of measurement are proposed in the literature to estimate the relative levels of vulnerability based on scores [17]. These indices have been used in vulnerability assessments at the household, village/community, national and regional scales [18]. Some examples include the indexing and vulnerability profile method of Swain and Swain [19]; the aggregate vulnerability index of Gbetibouo and Ringler [20]; the social vulnerability index (SoVI), of Cutter et al. [21]; the environmental vulnerability index (EVI) of the South Pacific Commission for Applied Geosciences and the livelihood vulnerability index (LVI) method by Hahn et al. [22]. The LVI method of Hahn et al. [22] is particularly applicable in this study as it combines the IPCC vulnerability framework with the sustainable livelihoods approach. Datasets used in the LVI allows for the identification and prioritization of adaptation actions that can be mainstreamed into the development of robust local and national strategies for climate change adaptation. This notwithstanding, it has been limitedly applied in understanding the vulnerabilities of households from a gender perspective.

In the literature, climate change vulnerability has been confirmed to have a gender dimension [23, 24] with women often tagged the most vulnerable due to their roles and responsibilities in the household and their limited access to financial capital and farming resources [25, 26]. This has led to strong recommendations for women empowerment, the mainstreaming of gender in climate change adaptation planning and development of gender-responsive policies tailored to the needs of women in particular [27-29]. In the Sudanian zone of Mali, there is limited information on the gender dimension of climate change vulnerability while attempts to estimate vulnerability scores that will help guide the implementation and monitoring of climate-smart solutions for improved adaptive capacity are lacking. For effective planning of adaptation that meets gender-specific needs, a good understanding of the gender dimension of vulnerability in the area is crucial. Djoudi and Brockhaus [30] in their study on the gender perspectives of climate change adaptation in Mali recommended the establishment of the linkages between gender and vulnerability as a means to proposing sustainable gender-responsive solutions that help farmers reduce climate-related risks. This study therefore aimed to compare the climate change vulnerabilities of male and female household heads in the Sudanian zone of Mali using Cinzana in the Segou region as a case study. The study is based on the assumption that female-headed and male-headed households will have differences in climate change vulnerabilities due to differences in interrelated factors: socioeconomic characteristics, livelihood strategies as well as sensitivity and coping mechanisms to environmental hazards. The results of this study should contribute to the development of holistic and integrated approaches to improving the adaptive capacity of vulnerable communities in the study region.

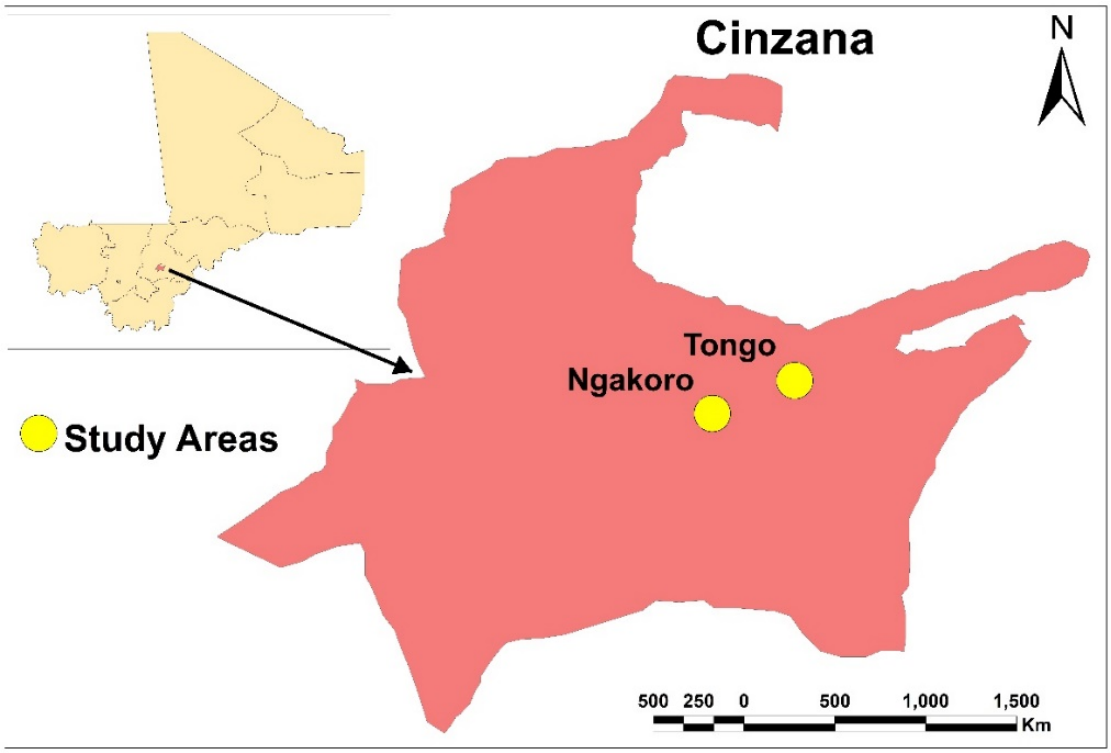
2. Methodology and study approach

2.1. Study area

The two villages (Tongo and Ngakoro) within the climate-smart village research for development site (Cinzana) of the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) in the Segou region of Mali (Figure 1) were used in this study. The study areas were chosen as they are characteristic of general situations in the Sudanian zone of Mali with a history of chronic food insecurity and malnutrition aggravated by climate change impacts. In addition, the study areas are of great interest to government agencies and

development experts due to increased contribution of the area to local food production. The villages selected for the study were 10 km apart and have the same agroecological characteristics. The study area falls within the Sudanian agroecological zone of Mali and can be located between latitude 13°15′10″N and longitude 5°57′55″W. The area has a uni-modal rainfall distribution pattern with the highest rainfall occurring between July and August. Mean annual rainfall and temperature are 680 mm and 36.8 ºC respectively [31]. Local climate generally feels hot most of the year while rainfalls are mostly sporadic with frequent dry spells. Agriculture is the dominant livelihood activity with sorghum and millet as major food crops. Cattle and sheep are the major livestock in the area and are reared solely or in some form of integration with crops. Soils in the study area are highly leached and classified as Alfisols according to the U.S. Soil Taxonomy [31].

Figure 1: Map showing study areas in Cinzana in the Segou region of Mali



2.2. Data sources and sampling method

Primary and secondary data sources were used in this study. Primary data were collected through focus group discussions and semi-structured questionnaire interviews. We obtained informed consent from each participant of the surveys. Before starting each interview, all interviewees were informed about the context of the study and the anonymous nature of the survey. Permission was sought from participants of interviews. They all gave their consent

and did openly and freely answered all questions asked. In addition, this study was conducted in the framework of the Institute of Rural Economy's (IER) research activities; the mission of the institution being to conduct agricultural research in Mali with the aim of developing and introducing improved technologies that will enhance overall farm level productivity for improved livelihoods. Such research involves collecting perceptions of local stakeholders to help direct approaches.

The questionnaires were randomly administered to a total of 233 household heads (116 from Ngakoro and 117 from Tongo) to collect data on their socio-demographic profiles, production systems and livelihood strategies. The number of household heads used represent about 90% of those involved in the CCAFS climate-smart village project. There were 26 and 27 female household heads in Ngakoro and Tongo respectively involved in the questionnaire surveys and focus group discussions. The distribution of female-headed and male-headed households in the study area could only allow for the sample space used in the study. The interviews lasting between 20 minutes and one hour were done in the local language (Bambara), which is the most common language in the study area with responses recorded on tablets. We conducted four focus groups; two per village. Each focus group had 20 participants - ten men and ten women. The focus groups were conducted with one moderator and two team members serving as rapporteurs and contributing to further elaborations on questions. Responses in local dialect transcribed and analyzed in English. The discussions sought to complement data collected through the questionnaire interviews with probing questions that help understand pertinent issues regarding climate change perceptions and choice of adaptation strategies. Secondary data were weather information (1998 – 2013) obtained from the Mali Meteorological Agency.

2.3. Vulnerability assessment

This study used the Livelihood Vulnerability Index (LVI) method developed by Hahn et al. [22] to assess and compare the vulnerabilities of men and women to climate change. The LVI method emanates from the sustainable livelihoods approach described by Chambers and Conway [32]. This approach comprises seven flexible components: (1) food; (2) socio-demographic; (3) health; (4) water; (5) livelihood strategy; (6) natural disasters and climate variability; and (7) social networks. Several studies have employed this approach in assessing vulnerabilities to climate change under varying circumstances [16, 18, 33, 34]. Considering

livelihoods in the study area are tied to agriculture, we added an eighth component (agricultural production systems) in the vulnerability assessment. The LVI was calculated using primary and secondary sources of data collected. Data were used to estimate the indices of the eight components of the LVI: (1) socio-demographic; (2) food; (3) health; (4) water; (5) livelihood strategy; (6) social network; (7) natural disasters and climate variability; and (8) agricultural production systems. Each of the eight components of the LVI is composed of several indicators and sub-components. Using a balanced weighted average approach, each component and subcomponent contributes equally to the overall index. In Table 1, we provide a summary of how the sub-components were quantified. Information on the kind of questions used in obtaining responses from respondents, source of the questions and potential limitations where applicable.

Table 1: Major components and sub-components included in the LVI assessment

Major components	Sub-components	Explanation of sub-components	Survey question	Source	Potential limitations
Socio-demographic profile	Dependency ratio	Ratio of the population under 15 and over 65 years of age to the population between 19 and 64 years of age.	Give the sex and age of all the people in your household.	Hahn et al. (2009)	Confusion in the definition of the household. Big extended family systems
	Percent of household where head of household has not attended school	Percentage of households where the head of the household reports that they have attended 0 years of school.	What is your level of education?	Adapted from Hahn, 2009	
	Percent of household where incomes are below the minimum income	Percent of household where the sum of incomes is below the minimum income.	What are the activities that allow the household to have a source of income and how much per month? Do you receive national and / or international cash transfers? If yes, how much per month?	Developed for the purposes of this questionnaire	Difficult to have the exact monthly income by activity. Difficulty quantified income for activities performed by a different household member to investigate.
Livelihood strategies	Percent of households with a member working in a different community	Percentage of households that report at least 1 family member who works outside of the community for their primary work activity.	Are there people in your household who work in another community?	Hahn, 2009	Confusion on the terms "other community". Confusion at the level of who is a member of the household member or not.

	Percentage of households dependent solely on agriculture as a source of income	Percentage of households reporting only farming activities as a source of income	What are the activities that allow the household to have a source of income and how much per month?	Hahn, 2009	The respondent tends not to mention the activities he considers of minimal importance and / or the activities he does not practice directly.
	Average of the agricultural diversity index	The inverse of the (number of agricultural activities + 1) reported by a household.	What areas of agricultural activity are practiced in your household?	Hahn, 2009	The respondent tends not to mention the agricultural activities that he considers to be of minimal importance and/or the agricultural activities that he does not practice directly.
	Inverse of average number of adaptation strategies implemented in the household at the crop level	The inverse of average number of climate change adaptation and climate variability strategies implemented by households at the crop level.	Can you tell me if you are using any of the following practices to deal with rainfall and climate hazard?	Developed for the purposes of this questionnaire	
	Inverse of average number of adaptation strategies implemented in the household at the livestock level	Inverse of average number of climate change and climate variability adaptation strategies implemented by households at the livestock level.	Can you tell me if you are using any of the following practices to deal with rainfall and climate hazard?	Developed for the purposes of this questionnaire	

	Percentage of households not receiving a cash transfer	Percentage of households that do not receive national and / or international cash transfers.	Do you receive national / international transfers?	Developed for the purposes of this questionnaire	
Social networks	Average ratio received / given	Ratio of assistance received in a household during the last 12 months to assistance given by the household to someone else in the last 12 months.	During the past 12 months did your household receive help from family, friends or acquaintances? During the past 12 months did your household provide any assistance to someone outside the household?	Adapted from Hahn, 2009	Consideration of financial assistance only.
	Average borrowed / loaned	Ratio between borrowing by the household and loans made to the household during the last 12 months. If the household borrowed money but did not lend it, the ratio is 2/1 or 2; if the household lent money but did not borrow the ratio is ½ or 0.5	During the last 12 months did you borrow money? During the past 12 months have you lent money to a friend, family member or acquaintance?	Hahn, 2009	The notion of time is subjective.
	Percentage of households that did not go to the government for help or assistance	Percentage of households reporting that they have not asked the local government for help in the last 12 months.	During the past 12 months have you asked for help from the local government / local chieftaincy?	Hahn, 2009	The notion of time is subjective.

	Percentage of households belonging to a producer organization	Percentage of households with at least one member in a producer organization.	In your household is there a person who is part of a producer organization?	Developed for the purposes of this questionnaire	Surveys may neglect the specification of farm organization and take into account all kinds of organizations.
	Percentage of households with a radio	Percentage of households with radio available	In your household do you have a radio?	Developed for the purposes of this questionnaire	
	Percentage of head of household with mobile phone	Percentage of head of household with a mobile phone.	Do you have a mobile phone?	Developed for the purposes of this questionnaire	
Health	Average km to reach a health center	Average kilometers between households in the nearest health center.	How far in km is the nearest health center?	Adapted from Hahn, 2009	Subjective estimate of the distance.
	Percentage of households where at least one of the members had to miss work due to illness	Percentage of households with at least one member of the household who had to miss work or school because of their state of health during the last 12 months.	In the last 12 months, was there a household member who had to miss work or school because of illness?	Adapted from Hahn, 2009	The notion of time is subjective.
	Average exposure to malaria * prevention index	Number of months exposed to malaria * Have at least one mosquito net (have a net = 0.5 and do not have a net = 1). If the respondent answers that malaria is frequent in April and	What are the months of the year when malaria is very present? Your household has how much mosquito net?	Hahn, 2009	

		May, and that he has no mosquito net: the index is the following: 2 * 1 = 2			
Food	Percentage of households mainly dependent on family farming for their food	Percentage of households whose main source of food is agriculture	What is the main source of food?	Hahn, 2009	The term "principal" is subjective.
	Percentage of households with insufficient food throughout the year	Percentage of households reporting not eating enough at one time of the year	Does your household have enough food all year round?	Hahn, 2009	May not reflect the general trend of food deficiency (specific to the current year).
	Percentage of households that do not save harvest	Percentage of households that do not maintain a harvest for another time of the year.	Do you save crops for another time of the year?	Hahn, 2009	May not reflect the general trend.
	Percentage of households that do not save seeds	Percentage of households that do not save seeds for the next crop year.	Do you save seeds for the next year?	Hahn, 2009	No specification of the yearl.
Water	Percentage of household reporting	Percentage of households having a conflict around the water.	Have you ever had a water dispute in your community?	Adapted from Hahn, 2009	Remembrance of only violent conflicts.

	conflict around water				
	Percentage of households using a natural source of water	Percentage of households reporting as a primary source of water a natural source such as the well, the marigot, the river.	What is your main source of water?	Hahn, 2009	The term "principal" is subjective.
	Average km to reach the water source	Average kilometers traveled by households to reach their main source of water.	How far in km is your water source?	Adapted from Hahn, 2009	Subjective estimate of the distance.
	Percentage of households reporting that water is not available year-round at their main source	Percentage of households reporting that water is not available year-round at their main water source.	Is water available every month of the year at this spring?	Hahn, 2009	May not reflect the general trend. No specification at the year level.
Natural disasters and climate variability	Average number of floods	Average number of floods reported by households during the last 6 years.	How much flood episode have you experienced since 2012?	Hahn, 2009	Bias of memorization. May not remember the exact number on different years.
	Average number of droughts	Average number of droughts reported by households during the last 6 years.	How much drought has you experienced since 2012?	Hahn, 2009	Bias of memorization. May not remember the exact number on different years.
	Percentage of households unaware of	Percentage of households not informed by the occurrence of extreme natural events during the last 6 years.	Have you been warned by the arrival of floods and / or droughts?	Adapted from Hahn, 2009	The word "warn" is subjective.

	arrivals of floods and droughts				
	Percentage of households with members injured during natural disasters	Percentage of households with at least one household member during extreme events in the last 6 years.	Has anyone in your household been ill, injured because of floods or droughts?	Adapted from Hahn, 2009	Bias of memorization. The most serious injuries are those that we remember most.
	Mean standard deviation of mean maximum daily temperature per month	Mean standard deviation of the mean of the maximum daily temperature per month over the last 15 years available	From the meteorological data.		
	Mean standard deviation of average minimum daily temperature per month	Mean standard deviation of average minimum daily temperature per month over the last 15 years available	From the meteorological data.		
	Average standard deviation of monthly precipitation	Average standard deviation of average monthly precipitation over the last 15 years available	From the meteorological data.		
Agricultural production system	Crop diversity index	The opposite (of the number of crops in the household's production system + 1).	What are the crops grown in your household?	Hahn, 2009	The respondent tends not to cite crops he considers of minimal importance and / or crops on which he does not work directly.

	Animal diversity index	The inverse (of the number of types of animals in the household production system + 1).	What are the animals raise in your household?	Developed for the purposes of this questionnaire	The respondent tends not to mention the livestock he considers to be of minimal importance and / or the animals he does not care for.
	Percentage of households not owning farmland	Percentage of households that farm on land that does not belong to them.	What is your land situation?	Developed for the purposes of this questionnaire	The term "owner" is subjective.
	Percentage of households exclusively feeding animals from farm resources	Percentage of households feeding animals raised exclusively by farm resources.	How do you feed animals?	Developed for the purposes of this questionnaire	The terms "external resources" are subjective.
	Average number of equipment and draft animals available	Inverse number of farm equipment and number of available draft animals in the household	What are the different agricultural equipment and draft animals that you have available?	Developed for the purposes of this questionnaire	Interpretation of "having available" by not necessarily owning the equipment or the animal.

The calculation of the LVI was done to allow for the comparison between MHHH and FHHH. Considering each subcomponent has its own measurable unit, the sub-components were first standardized as an index using the relation:

$$Index_s = \frac{S - S_{min}}{S_{max} - S_{min}} \quad (1)$$

Where s is the main subcomponent and s_{min} and s_{max} are the minimum and maximum sub-component values respectively at the community level (Hahn et al. 2009)

Following standardization of the subcomponents, they were averaged using Equation 2 to calculate the value of each major component:

$$M = \frac{\sum_{i=1}^{n} index_{si}}{n} \quad (2)$$

"Where M is one of the eight major components for the community (Social Networks; Natural Disasters and Climate Variability; Socio-Demographic Profile, Livelihood Strategies, Health, Food, Water or Agricultural Production System), $index_{si}$ represents the sub-components, indexed by i, that make up each major component, and n is the number of sub-components in each major component. Once values for each of the eight major components were calculated, they were averaged using Equation 3 to obtain the LVI" (Hahn et al. 2009).

$$LVI = \frac{\sum_{i=1}^{8} w_{M_i} M_i}{\sum_{i=1}^{8} w_{M_i}} \quad (3)$$

"Where LVI is the Livelihood Vulnerability Index which is equal to the weighted average of the eight major components. The weights of each major component, w_{Mi}, are determined by the number of sub-components that make up each major component and are included to ensure that all sub-components contribute equally to the overall LVI" [22, 35]. In this study, the LVI is scaled from 0 (least vulnerable) to 0.7 (most vulnerable).

3. Results and discussion

The goal of this study is to contribute to the development of gender-responsive solutions that improve the adaptive capacity of vulnerable farmers in the Sudanian zone of Mali. To achieve that we conducted this study as part of baseline assessment and situational analysis of vulnerabilities of female-headed and male-headed households to allow for the identification of adaptation needs and the implementation of climate-smart interventions with a gender focus. The adopted approach was a slight addition to datasets used in vulnerability assessment by Hahn et al. [22] who combined the IPCC vulnerability framework with the sustainable livelihoods approach.

3.1. Overall livelihood vulerability index

Table 2 shows the values of the LVI sub-components for male household heads (MHHH) and female household heads (FHHH) in the community. The minimum and maximum values of the sub-components are also provided. The values of the major components are shown in Table 3.

Table 2: Values of the LVI sub-components for female and male-headed households in Cinzana in the Segou region of Mali

Major components	Indicators	FHHH	MHHH	Minimum	Maximum
Socio-demographic profile	Dependency ratio	1.545	1.645	0.000	9.000
	Percent of household where head of household has not attended school	84.300	88.600	0.000	100.000
	Percent of household where incomes are below the minimum income	100.000	81.319	0.000	100.000
Livelihood strategies	Percent of households with a member working in a different community	82.353	82.418	0.000	100.000
	Percentage of households dependent solely on agriculture as a source of income	80.400	85.200	0.000	100.000
	Average of the agricultural diversity index	0.258	0.233	0.090	0.500
	Inverse of average number of adaptation strategies implemented in the household at the crop level	0.249	0.246	0.130	1.000
	Inverse of average number of adaptation strategies implemented in the household at the livestock level	0.592	0.443	0.200	1.000
	Percentage of households not receiving a cash transfer	84.314	76.923	0.000	100.000
	Average ratio received / given	0.971	0.940	0.500	2.000

Social networks	Average borrowed / loaned	1.226	1.063	0.500	2.000
	Percentage of households that did not go to the government for help or assistance	92.157	90.659	0.000	100.000
	Percentage of households belonging to a producer organization	45.100	35.714	0.000	100.000
	Percentage of households with a radio	41.176	37.363	0.000	100.000
	Percentage of head of household with mobile phone	45.098	13.187	0.000	100.000
Health	Average km to reach a health center	9.471	10.280	0.000	50.000
	Percentage of households where at least one of the members had to miss work due to illness	27.451	32.418	0.000	100.000
	Average exposure to malaria * prevention index	1.343	1.341	0.000	1.500
Food	Percentage of households mainly dependent on family farming for their food	76.500	54.900	0.000	100.000
	Percentage of households with insufficient food throughout the year	19.608	20.879	0.000	100.000
	Percentage of households that do not save harvest	17.647	30.726	0.000	100.000
	Percentage of households that do not save seeds	3.922	4.468	0.000	100.000
Water	Percentage of household reporting conflict around water	21.600	14.835	0.000	100.000
	Percentage of households using a natural source of water	100.000	100.000	0.000	100.000
	Average km to reach the water source	0.233	0.235	0.000	1.000
	Percentage of households reporting that water is not available year-round at their main source	3.900	9.890	0.000	100.000
Natural disasters and climate variability	Average number of floods	2.590	2.250	0.000	7.000
	Average number of droughts	2.860	2.390	0.000	7.000
	Percentage of households unaware of arrivals of floods and droughts	56.863	67.033	0.000	100.000
	Percentage of households with members injured during natural disasters	17.647	8.791	0.000	100.000
	Mean standard deviation of mean maximum daily temperature per month	3.376	3.376	2.793	3.809
	Mean standard deviation of average minimum daily temperature per month	3.458	3.458	2.976	3.458
	Average standard deviation of monthly precipitation	82.190	82.190	50.583	126.415
Agricultural production system	Crop diversity index	0.280	0.200	0.090	0.500
	Animal diversity index	0.300	0.250	0.170	0.500
	Percentage of households not owning farmland	7.900	17.300	0.000	100.000
	Percentage of households exclusively feeding animals from farm resources	52.400	52.800	0.000	100.000
	Average number of equipment and draft animals available	0.380	0.304	0.170	1.000

FHHH = female-headed household, MHHH = male-headed household

Table 3. Indexed sub-components, major components and overall LVI for community, female-headed households and male-headed households at Cinzana in the Segou region of Mali

Major components	Indicators	FHHH index	MHHH index
Socio-demographic profile	Dependency ratio	0.172	0.183
	Percent of household where head of household has not attended school	0.843	0.886
	Percent of household where incomes are below the minimum income	1.000	0.813
	SDI	*0.672*	*0.627*
Livelihood strategies	Percent of households with a member working in a different community	0.824	0.824
	Percentage of households dependent solely on agriculture as a source of income	0.804	0.852
	Average of the agricultural diversity index	0.41	0.35
	Inverse of average number of adaptation strategies implemented in the household at the crop level	0.111	0.089
	Inverse of average number of adaptation strategies implemented in the household at the livestock level	0.430	0.302
	Percentage of households not receiving a cash transfer	0.843	0.769
	LSI	*0.570*	*0.531*
Social networks	Average ratio received / given	0.314	0.293
	Average borrowed / loaned	0.484	0.375
	Percentage of households that did not go to the government for help or assistance	0.922	0.907
	Percentage of households belonging to a producer organization	0.451	0.357
	Percentage of households with a radio	0.412	0.374
	Percentage of head of household with mobile phone	0.451	0.132
	SNI	*0.506*	*0.406*
Health	Average km to reach a health center	0.316	0.333
	Percentage of households where at least one of the members had to miss work due to illness	0.275	0.324
	Average exposure to malaria * prevention index	0.895	0.894
	HI	*0.495*	*0.517*
Food	Percentage of households mainly dependent on family farming for their food	0.765	0.549
	Percentage of households with insufficient food throughout the year	0.196	0.209
	Percentage of households that do not save harvest	0.176	0.307

	Percentage of households that do not save seeds	0.039	0.045
	FI	*0.294*	*0.278*
Water	Percentage of household reporting conflict around water	0.216	0.148
	Percentage of households using a natural source of water	1.000	1.000
	Average km to reach the water source	0.233	0.235
	Percentage of households reporting that water is not available year-round at their main source	0.039	0.099
	WI	*0.372*	*0.371*
Natural disasters and climate variability	Average number of floods	0.37	0.321
	Average number of droughts	0.409	0.341
	Percentage of households unaware of arrivals of floods and droughts	0.569	0.67
	Percentage of households with members injured during natural disasters	0.176	0.088
	Mean standard deviation of mean maximum daily temperature per month	0.574	0.574
	Mean standard deviation of average minimum daily temperature per month	1.000	1.000
	Average standard deviation of monthly precipitation	0.417	0.417
	NDCVI	*0.502*	*0.487*
Agricultural production system	Crop diversity index	0.463	0.268
	Animal diversity index	0.394	0.242
	Percentage of households not owning farmland	0.079	0.173
	Percentage of households exclusively feeding animals from farm resources	0.524	0.528
	Average number of equipment and draft animals available	0.253	0.162
	APSI	*0.343*	*0.275*
Overall LVI		*0.470*	*0.432*

SDI = socio-demographic index, LSI = livelihood strategy index, SNI = social network index, HI = Health index, FI = food index, WI = water index, NDCVI = natural disasters and climate variability index, APSI = agricultural production system index, FHHH = female-headed household, MHHH = male-headed household. Index of the major components and the overall LVI are in bold and italics.

The results provide clear indications that FHHH in the Sudanian zone of Mali are more vulnerable to the effects of climate change and variability. The results of the LVI showed a score of 0.470 for FHHH and 0.432 for MHHH. This agrees with the growing assertion that women farmers in Sub-Saharan Africa are more vulnerable to climate change and greatly affected by its impacts [26]. In addition, our results are in line with the study conducted by

Shah et al. [35] in Trinidad and Tobago where FHHH were found to be more vulnerable than MHHH. The higher LVI of FHHH can be attributed to interplay of factors. The important differences in vulnerability are in terms of social relations (+/- 0.099), the agricultural production system (+/- 0.068), the socio-demographic profile (+/- 0.044) and livelihood strategies (+/- 0.039). From Table 3, it was evident that FHHH recorded higher values for six out of the eight major components used in the LVI estimation - socio-demographic index (SDI), livelihood strategies index (LSI), social network index (SNI), food index (FI), natural disasters and climate variability index (NDCVI) and agricultural production system index (APSI). Below we discuss the contributions of the LVI sub-components.

3.1.1. Socio-demographic index (SDI)

In particular, SDI contributed the most to the vulnerability of FHHH (Table 3). Among the SDI subcomponents, household income was found to be the most important indicator of vulnerability. From the results, FHHH were found to be low on incomes earning below the national minimum wage (31 047 XOF Francs per month) of Mali [36]. The low level of income of FHHH increased their overall SDI (0.672) by 50%. While the SDI results showed, MHHH had higher dependency ratio (0.183) and higher illiteracy level than FHHH, this could not increase their SDI index beyond that of their female counterparts. The relatively higher incomes of MHHH may have suppressed the impact of such indicators on the SDI.

Income as paramount among other factors leading to the increased vulnerabilities of women has repercussions on access to water, access to food, access to health, adoption of livelihood strategies and social network characteristics which were also used in the LVI estimation. The importance of household income on adaptive capacity to climate change is not new in the global literature [23]. Adoption of climate-resilient soil and water conservation technologies, rainwater harvesting, crop diversification, climate information and improved animal breeds are known to be influenced by income [8]. Generally, smallholder farmers in Africa are resource-poor and receive limited financial resources to expand and increase production [23, 37]. The role of culture, social norms and responsibilities of women even make their situations worse constraining their abilities to manage the limited household financial resources. By creating opportunities that help women acquire more financial resources and diversify production, they will be equipped with important safety nets to avert risks posed by climate change and variability. In Mali, agricultural development banks and microfinance

companies established to support farmers are now shifting to urban areas limiting access of rural farmers to credit facilities [38]. Even with the limited financial facilities, the disparities between men and women are very evident. Due to the limited market-orientation of women's agricultural activities, they get limited funding due to their inability to pay back loans. Implementing policies that foster innovative financial schemes such as farmer self-help groups, cooperatives, provision of subsidies and capacity building programs that can help women diversify their income-generating activities are important for bridging the income gap and improving the resilience of rural livelihoods. Several studies recording lower levels of incomes for FHHH [e.g. 39, 40] have also advocated for women empowerment through the financial schemes aforementioned and the implementation of gender-informed policy initiatives that help women unearth their entrepreneurial skills to improve their financial standing [41-43].

3.1.2. Livelihood strategy index (LSI)

Similar to SDI, LSI was higher for FHHH (0.570) than MHHH (0.531) which implies FHHH are more vulnerable to climate change in relation to livelihood strategies. MHHH households were found to be more dependent on agricultural income (85.20%) than FHHH (80.4%). MHHHs also had a greater diversity of agricultural activities such as crops, livestock and gardening than FHHHs. A number of factors contributed to the higher LSI for FHHH. Among the six indicators used in the LSI estimation, FHHH recorded higher values for four: agricultural diversity index (0.41), inverse of average number of adaptation strategies implemented in the household at the crop (0.111), livestock (0.4330) levels and percentage of households not receiving a cash transfer (0.843) (Table 3). With agriculture being the mainstay of livelihoods in the community, diversifying agricultural production and opting for new income streams is one major opportunity for reducing climate-related risks. At the survey location, mixed farming systems were found to be more common among MHHH than FHHH. Women farmers plant monocrops of sorghum or millet. Only a small percentage are involved in horticulture or livestock. In addition, MHHHs tend to adopt more cultural practices and breeding programs that allow the optimization of production than FHHHs. This also explains why the agricultural production systems index was lower for MHHH than FHHH. Other production factors like land accessibility had significant impact in the LVI estimation. Comparatively, MHHH were found to have on average more than twice the size of

agricultural land owned by FHHHs (11.2 ha against 5.1 ha). With a significant proportion (40-60%) of African FHHH involved in agriculture, improving their adaptive capacity to climate change is crucial as part of efforts to boost food security in Africa [44].

3.1.3. Social network index (SNI)

At the level of social relations, FHHH (0.505) were found to be more vulnerable than MHHH (0.406). The difference was due to the lack of access of FHHHs to communication tools such as radio and mobile phones; low involvement in cooperatives and low membership in farmer-based organizations. In terms of gadgets, MHHH were more equipped than FHHH. About 41.8% and 37.34% of FHHHs did not have radio and telephone respectively against 15.1% and 13.19% of MHHHs for the same gadgets. The limited access of FHHHs to household gadgets such as radio, TV and communication devices like mobile phones in developing countries is highly documented in the literature. Despite increased mobile phone usage in Africa, studies report women are about 21% unlikely to access and use them [e.g. 45, 46]. In Northern Ghana, Partey et al. [23] found that compared to men, women farmers had limited access to mobile phones to receive seasonal weather information. With absence of radio and telephone devices among FHHHs in the study area, they are likely to lose vital information, including climate information that is broadcast over the radio or telephone. Agricultural information services are valuable assets for vulnerable populations in Africa therefore the lack of access to devices that can help farmers receive such information may make it difficult for them to be aware of technologies that help improve their adaptation [23]. In addition, the study found FHHH members are less involved in cooperatives than MHHH members which constrain their ability to access local or community funds. Generally, households in Ngakoro and Tongo give, on average, more financial help outside the community than they receive. The ratio between the aid received per household and the aid given per household is 0.971 for FHHH and 0.940 for MHHH. Moreover, in terms of the ratio between borrowing and lending, on average, households in the study area borrow more than they lend. Indeed, the ratio is 1.226 for FHHH and 1.063 for MHHH. About 56.9% of FHHHs borrowed in the 12 months preceding the survey, compared to 30.2% of MHHH. Moreover 92.2% of FHHHs and 90.7% of MHHHs reported they have not approached their local government for help in recent months. There are limited farmer-based organizations in the study area. About two-thirds of MHHHs have at least one member in a producer organization. Meanwhile 45.1% of FHHHs

have no members in this type of organization. Participation in farmer-based organizations or groups is highly recommended due to opportunities for farm technology transfer and sharing of up-to-date agricultural information.

3.1.4. Health, food and water indices

With a health vulnerability score of 0.517, MHHHs were more vulnerable in this respect than FHHHs (0.495). The average distance to the health center was higher for MHHH (around 800 meters) than FHHHs in the villages of Ngakoro and Tongo. The results showed that MHHHs have a higher proportion of members who have not been able to perform their activities (work, schooling) because of health problems. In fact, 32.4% of MHHHs have at least one member who had to miss work or school due to health problems compared to 27.45% in FHHHs. The exposure index for malaria was almost the same for both household groups (1.343 for FHHH and 1.341 for MHHH). Households generally report more to health centers within the three rainy month (July, August and September) when malaria is mostly prevalent. This notwithstanding, the impact of HI on the overall LVI of MHHH was not significant. Conversely, FHHHs were more vulnerable than MHHH (0.294 versus 0.277) in terms of diet. About 76.5% of FHHHs had an exclusive source of food from agriculture compared to 54.9% of MHHH. The results showed that one-fifth of households had limited food all-year-round. Food insufficiency on average takes two months out of 12. Comparatively, more (30.7%) MHHH had storage facilities for harvested farm produce compared with FHHH (17.7%). In this regard, it becomes crucial for stakeholders in the agricultural sector of Mali to improve farmers' access to storage facilities for improved food availability. Similarly, to diets, FHHHs were slightly more vulnerable than MHHH in terms of water with a water index score of 0.372 against 0.370 for MHHH. FHHHs had a higher percentage of conflict around water (21.6%) than MHHH (14.84%). In the community, women are the ones who deal with household water management, which may explain the gap between the two groups. All households in both villages depend on water from hand-dug wells or rainwater for the household activities. The distance between households' homes and wells is around 0.2 km for both types of households. Wells are often located close to habitats. In our sample, the farthest distance of a household from the well was about 1 km.

3.1.5. Natural disasters and climate variability index

In terms of exposure and impact of natural disasters and climate variability, FHHHs were found to be more vulnerable to natural disasters and climate variability. While all may have similar level of exposure, MHHH as revealed by the results of the livelihood strategy index have a better adaptive capacity due to increased income, diversification of production systems, more easily access to farm resources, access to radio, mobile phones which are crucial for emergency preparedness. In the focus group discussions and questionnaire interviews, it was revealed that 33% of MHHH were more informed about extreme weather events like floods and droughts compared with 43% of FHHH due to limited access to radios and limited involvement in the activities of farmer-based groups.

4. Conclusion

The results of the study provide clear indications that livelihoods and agricultural production systems in the Sudanian agroecological zone of Mali are vulnerable to climate change. Comparatively, female household heads (FHHH) were more vulnerable with vulnerability index scores higher than male household heads (MHHH) households. A number of factors such as income, number of dependents, choice of agricultural production systems, social networks etc. used in computing the eight major components of the livelihood vulnerability index (LVI) contributed to the increased vulnerability of FHHH. It was evident that FHHH recorded higher values for six out of the eight major components used in the LVI estimation - socio-demographic index (SDI), livelihood strategies index (LSI), social network index (SNI), food index (FI), natural disasters and climate variability index (NDCVI) and agricultural production system index (APSI). The study provides some recommendations deemed as crucial entry points for improving the adaptive capacity of FHHHs to climate change – (1) improvement of FHHH's access to financial resources and opportunities for generating more income, (2) improving FHHH's access to radio for receiving weather information, (3) encouraging FHHHs involvement in farmer-based groups for peer-learning and sharing of agricultural information and (4) policy initiatives that ensure the mainstreaming of gender into agricultural development programs, plans and strategies.

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