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Full Length Research Paper

Agricultural knowledge management: The case of cattle feed quality improvement in Bure district west Gojjam, Ethiopia

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The government of Ethiopia gives great attention to livestock development for the country's economy development. Having quality of animal feed is one of the pertinent components of livestock development. To improve the quality and quantity of animal feed in certain locality, farmers should be able to access and use appropriate knowledge for the particular problem at the right time and place. This research was conducted to assess agricultural knowledge management system in relation to improving the quality of animal feed in Bure district. To do so, the data were collected from primary and secondary sources. Multi stage sampling technique was used to select representative respondents. SPSS software (version 15) was also used to analysis the data. As survey result shows, crop residue (92.2%), attela (91.1%), natural pasture (65.6%), hay (62.2%) and birnt (30%) were the major feed sources for dairy producers in Bure district. To improve the quality of feed for their dairy cows, dairy producers had used supplementing non-conventional feeds (like attela and birnt) after grazing (92.1%), green hay making (65.2%), supplement concentrate after grazing (41.6%) and developing improved forage (20.2%) as the major mechanism. Agricultural officers (60.2%) and farmers' own experiences (52.3%) were the major sources of knowledge for dairy producers in order to improve the quality of cattle feed. Informal discussion (56.8%), experience sharing sessions (36.4%) and on-walk observation (26.1%) were also the major means to access such knowledge. On the other hand, dairy producers had transferred this knowledge into their neighbors (95.1%), friends (91.4%) and relative (63.0%). This study clearly shows that in the study area the mechanisms that were used for improving the quality of cattle feed, did not properly improved the quality of the feed as the dairy cow need. Therefore, efforts should be done to introduce improved and more productive fodder types. Improved mechanisms (like urea treatment, urea molasses block, micro effective) should also be introduced to improve the palatability of available crop residue. In addition, to enhance the adoption rate of all these technologies, all concerned bodies should understand the communities' knowledge system and approach them through their common knowledge sources and strengthen their means of knowledge accessing and sharing strategies.

Key words: Agricultural management, improved knowledge, cattle feed quality.

INTRODUCTION

The Government of Ethiopia gives high priority to agriculture and rural development as an engine of pro-poor growth and efforts to enhance agricultural productivity, increase the commercialization of smallholder surpluses and reduce rural poverty are cornerstones of the government's economic growth strategy, that is, Agriculture Development-Led Industrialization (Spielman et al., 2008). Agriculture is pivotal to Ethiopian economy. According to Teklu (2008) it contributes on average 46% of the real GDP and 85% of export earnings, and the sector employs about 85% of the population and about this 85% of the population lives in rural areas and practices subsistence agriculture and livestock production. Therefore, the development of Ethiopian agriculture will have direct impact on the overall development of the country.

The majority of smallholder farms depend on animals for draught power, cultivation and transport of goods. The sub-sector also makes significant contribution to the food supply in terms of meat and dairy products as well as to export in terms of hides and skins, which make up the second major export category. However, the productivity of the sub-sector is decreasing because of poor management systems, shortage of feed and inadequate healthcare services (Belay and Abebaw, 2004). To maximizing livestock production particularly dairy production, various improved technologies were imported into country (Azage et al., 2009). Besides, for a long period of time various research activities have been carried out on cattle feed and feeding practices in order to improve the availability of cattle feed and feeding system. These generated knowledge/technologies are mostly remained in the research centers rather than reaching to the end users. Among other resources, appropriate and relevant knowledge is an important resource to improve the quality of animal feed and minimizing freed grazing in cattle production system. Therefore, to bring development in animal feed production, have right knowledge at the right time for a particular problem is very crucial. It could have greet contribution in accelerating adoption of improved feed and feeding technologies and enhance cattle production and productivity. Therefore it is very important to understanding knowledge management system of a certain locality in order to generate appropriate feed and feeding technologies for a particular problems and locality and to enhance adoption rate of the generated technologies.

Objectives of the study

1. To identify the community's agricultural knowledge/practices that used for improving cattle feed quality.
2. To assess their sources and way of utilizing of new knowledge about improve cattle feed quality.
3. To identify means of knowledge acquiring and transferring among the major fodder producers

MATERIALS AND METHODS

Sampling technique

Multistage sampling design was used to select representative respondents. According to Adebabay (2009), in Bure woreda there are three milk production systems. These were rural, peri-urban and urban milk production system. This study was conducted based on these three milk production systems in order to understand how these dairy producers achieve the above objective. The list of milk producers of rural, peri-urban and urban milk production system were obtained from the district agricultural and rural development office. Therefore, from each subsystem, 30 farmers were selected purposively because of the accessibility and willingness of the respondents. To capture agro-climate various, rural sub system was further classified into three agro-climate zones. These were lowland, midland and highland. From each agro-climate zones, one kebele was selected purposively based on its dairy production potential and accessibility. Finally, because of the accessibility and willingness of the farmers, 10 farmers were selected purposively from each respective kebeles. Therefore, primary data were collected from 90 dairy producers in Bure districts.

Data collection and analysis

The study was conducted using qualitative and quantitative research design. By doing so, both qualitative and quantitative data were collected. Qualitative data sources were included participant observation (fieldwork), key informant discussion, focus group discussion, reviewing documents and texts. Quantitative data were sourced from farmers and agricultural experts. Semi structured questionnaire was used to collect this quantitative data. To ensure the validity of the questionnaire pre-testing was conducted. Finally, well appropriate semi-structured questionnaire was developed and then embark fieldwork.

Descriptive statistical tools such as frequency tables and percentages were used to describe the data. To test the difference among the subsystems on a certain variable, Pearson chi-square statistical test was used. To analysis the data, SPSS (version 15) software was used. For the data gained through key informant interview and unstructured interviews qualitative analysis was applied.

RESULTS AND DISCUSSION

Cattle feed sources

There were different cattle feed sources in any dairy production systems in the country. Dairy producers in *Bure* district had different cattle feed sources for their milking cows/ heifers. As Table 1 shows, crop residue (92.2%) and non-conventional feed (that is, *attela)* (91.1%) were the major feed sources for their dairy cattle in the study area, while in *Bahir Dar Zuria* district 4.45%) in Amhara and Dandi District (100%) in Oromia regions,

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Table 1. Main cattle feed sources.

The main animal feed sources	Subsystems						Total	
	Urban		Peri-urban		Rural			
	N	%	N	%	N	%	N	%
Natural pasture	14	46.7	23	76.7	22	73.3	59	65.6
Improved forage	7	23.3	5	16.7	5	16.7	17	18.9
Hay	25	83.3	12	40.0	19	63.3	56	62.2
Crop residue	23	76.7	30	100.0	30	100.0	83	92.2
Attela (byproduct of local beer)	27	90.0	27	90.0	28	93.3	82	91.1
Birnt (byproduct of local alcohol)	7	23.3	7	23.3	13	43.3	27	30.0
Total	30	33.3	30	33.3	30	33.3	90	100.0

Since the question has multiple responses, the sum of their percentages is more than hundred.

the major cattle feed source was natural pasture (Asaminew, 2007; Belay et al., 2012). In the district, natural pasture (65.6%), hay (62.2%) and *birnt* (30%) were also important sources of cattle feed. Only few respondents have used improved forage (18.9%) as source of feed for their cattle.

This finding has a negative implication on improved forage development and minimizing dependence of natural pasture. As the result, majorities of respondents were not able to get a benefit from improved forage. Therefore, some efforts should be taken by agricultural extension office and research institutes like awareness creation in developing productive improve forage and adequate supply of improved forage seed and plant materials to cattle producers in order to increase the availability of forage biomass for their cattle in the study area.

The major cattle feed sources in the urban subsystem were *Attela* (90%), hay (83.3%) and crop residue (76.7%). Whereas in both peri-urban and rural subsystems, crop residual and *attela* were consider as the major feed sources for their milking cows. Beside, natural pasture in both peri-urban and rural subsystems was also thirdly important cattle feed source.

Farmers' mechanism to improve cattle feed quality

Livestock feeds are the major inputs in any livestock production activity (Sintayehu et al., 2008; cited in Adebabay, 2009). As the result in different part of the country, farmers try to find different mechanisms to improve the quality of cattle feed to improve their milk production. As Table 2 shows, in the study area the major mechanisms to improve the quality of cattle feed was supplementing non-conventional feeds (like *Attela and Birnt*) after crop residue and/or grazing (92.1%) and followed by green hay making (65.2%), concentrate supplementation (41.6%) and developing improved forage (20.2%).

In urban dairy production subsystem, green hay making, supplementing non-conventional feed (like *attela and birnt*) and concentrate after grazing/ crop residue were the major mechanisms used to improve cattle feed quality. Whereas, in both peri-urban (93.1%) and rural (90.0%) dairy producers, supplementing non-conventional was the major mechanism to improve cattle feed quality so as to improve milk production.

In study the study area, supplementing concentrate after providing crop residues and/ grazing and hay making mechanisms show statistical highly significant difference across the subsystems at 1% of probability level. In the contrary, there was no statistically significant difference in both non-conventional feed supplementation and developing improved forage mechanisms to improve the quality of animal feed (Table 2). It implies that in all dairy production subsystems, farmers used non-conventional feed (*attela and birnt*) as a mechanism to improve cattle feed quality whereas in developing improved forage development majorities of dairy producers had not produced improved forage for their dairy production. Regarding concentrate supplementation and green hay making, dairy producers in urban subsystem highly used both mechanisms that the other two dairy subsystems to improved feed quality so as to improve their milk production.

This reveals that dairy producers in the study area use locally available materials to improve the quality of their cattle feeds (like supplementing non-conventional feed after grazing and green hay making). Concentrate animal feed and improved forage are not easily available in the study area. For instance, as a group discussion results indicate, in the study area there is no adequate agro-processing factories and concentrate animal feed makers. As the result the availability and supply of concentrate animal feed in the study area was very minimal. According the group discussion, the main problems to develop improved forage for their cattle were less awareness about improve forage, inadequate forage seed supply and shortage of cropland. Due to these and other reasons, dairy producers were not interested to provide piece of land for forage development to their livestock.

Table 2. Farmers' mechanisms in cattle feed quality improvement.

Variables		Sub systems			Total	Test value (X^2)	Sig.
		Urban	Peri-urban	Rural			
Developing improved forage	N	3	7	8	18	2.9	NS
	%	10.0	24.1	26.7	20.2		
Concentrate supplement on grazing/ crop residue	N	25	7	5	37	33.4	***
	%	83.3	24.1	16.7	41.6		
Non-conventional feed (like Attela, birnt) supplement on grazing/ crop residue	N	28	27	27	82	0.27	NS
	%	93.3	93.1	90.0	92.1		
Green hay making	N	30	14	14	58	24.8	***
	%	100	48.3	46.7	65.2		
Nothing done	N	0	1	0	1	2.0	NS
	%	0.0	3.4	0.0	1.1		
Total	N	30	29	30	89		
	%	33.7	32.6	33.7	100		

*** and ** represents as statistically significant at 1 and 5% probability level, respectively. NS = not statistically significant.

Table 3. Farmers' sources of knowledge for cattle feed quality improvement.

Farmers' source of knowledge for cattle feed quality improvement	Subsystems						Total		Test value (X^2)	Sig.
	Urban		Peri-urban		Rural					
	N	%	N	%	N	%	N	%		
Friends	4	13.3	4	13.3	8	28.6	16	18.2	2.43	NS
Relatives	3	10.0	2	6.7	9	32.1	14	15.9	7.27	**
Neighbors	8	26.7	8	26.7	12	42.9	28	31.8	1.66	NS
Community elders	3	10.0	1	3.3	7	25.0	11	12.5	5.80	*
My own	20	66.7	12	40.0	14	50.0	46	52.3	4.62	*
Research center	0	0.0	1	3.3	0	0.0	1	1.1	2.02	NS
BWARDO	13	43.3	19	63.3	21	75.0	53	60.2	4.77	*
NGOs	3	10.0	4	13.3	1	3.6	8	9.1	1.92	NS
TV	16	53.3	0	0.0	0	0.0	16	18.2	38.92	***
Radio	15	50.0	2	6.7	5	17.9	22	25.0	16.72	***
Agricultural College	1	3.3	1	3.3	0	0.0	2	2.3	1.02	NS
Reading Materials	5	16.7	0	0.0	0	0.0	5	5.7	10.59	***
Total	**30**	**34.1**	**30**	**34.1**	**28**	**31.8**	**88**	**100.0**		

***, ** and * represents as statistically significant at 1, 5 and 10% probability level, respectively, NS = not statistically significant.

Farmers' sources of knowledge for cattle feed quality improvement

Farmers could have various knowledge sources to tackle their agricultural production and marketing problems. As Table 3 shows, in the study area, Agricultural and Rural Development office (60.2%) and farmers' own experiences (52.3%) were the major sources of knowledge for dairy producers in order to improve the quality of their cattle feed. This finding is also agreed Jamal's finding (2010) in *Ada* district. The major knowledge and information source for *Ada's* women dairy farmers on improved feeding practices were Agricultural and development office of the district. Agricultural and Rural Development office and farmers' own experiences sources show statistically significant difference across subsystems at 10% of probability level. It implies that in peri-urban and rural subsystems, majority of the farmers used Agricultural and Rural Development office as a major source of knowledge whereas own experience and

Table 4. Farmers' means of access to knowledge on animal feed quality improvement.

Farmers' means access to knowledge	Subsystems						Total		Test value (x^2)	Sig.
	Urban		Peri-urban		Rural					
	N	%	N	%	N	%	N	%		
On-walk observation of the farmers' farm field	2	6.7	9	30.0	12	42.9	23	26.1	9.23	***
Informal discussion with other farmers	15	50.0	18	60.0	17	60.7	50	56.8	0.63	NS
Experience sharing sessions	7	23.3	13	43.3	12	42.9	32	36.4	3.00	NS
Demonstration session	1	3.3	4	13.3	11	39.3	16	18.2	12.01	***
Technology exhibition	1	3.3	0	0.0	0	0.0	1	1.1	2.02	NS
By try and error/ own experiences	8	26.7	9	30.0	7	25.0	24	27.3	0.34	NS
Listening radio	11	36.7	3	10.0	3	10.7	17	19.3	9.29	***
Watching TV	11	36.7	0	0.0	0	0.0	11	12.5	25.06	***
Reading	5	16.7	0	0.0	0	0.0	5	5.7	10.59	***
Formal education	3	10.0	0	0.0	0	0.0	3	3.4	6.21	**
Total	30	34.1	30	34.1	28	31.8	88	100.0		

*** and ** statistically significant difference at 1 and 5% of probability level. NS= not statistically significant difference.

mass medias (that is, TV and radio). There were also other knowledge sources for dairy producers on cattle feed quality improvement in the district such as neighbors (31.8%), radio (25.0%), TV (18.2%), friends (18.2%) and relatives (15.9%). Variation in neighbors as source of knowledge on cattle feed quality improvement across the subsystems is not statistically significant. Almost in all subsystems, neighbors are equally important as source of knowledge on cattle feed quality improvement.

In the study area, mass Medias has significant role in providing important knowledge/information on cattle feed quality improvement to dairy producers. The variation in mass Media usage as source of knowledge across the subsystems is highly statistically significant at 1% probability level. They are highly used at urban subsystem. TV was used totally by urban dairy producers, while 50% of radio in urban, 17.9% in rural and 6.7% in peri-urban subsystems was used.

Farmers' means of access to knowledge on cattle feed quality improvement

Dairy producers in the study area can access to knowledge through different means. As Table 4 shows, informal discussion with other farmers (56.8%), on-walk observation of the farmers' farm field (26.1%), experience sharing sessions (36.4%), demonstration session (18.2%) and listening to radio (19.3%) were major farmers' means of access to knowledge on animal feed quality improvements. In addition, few dairy producer respondents used other means, such as reading (5.7%), formal agricultural education (3.4%), watching TV (12.5%) and technology exhibition (1.1%).

Majorities of dairy producers in the urban subsystem access to knowledge on cattle feed quality improvement through informal discussion (50.0%), listening radio (36.7%) and watching TV (36.7%). In both peri-urban and rural subsystems, informal discussion and experience sharing sessions were the major means of access to knowledge on animal feed quality improvement (Table 4).

Knowledge utilization on cattle feed improvement

In rural parts of the country, farmers could get different kinds of agricultural knowledge from different sources to improve their agricultural production and productivity. However, not all the available knowledge may be relevant to solve agricultural production problems. Therefore, they were forced to modify the new knowledge in accordance with their own farming system and the natural of their particular agricultural problem. The modification of the new knowledge could be partially or totally based on the individuals' knowledge capacity, experience, the nature of farming system, type of the technology and the likes.

Farmers in *Bure* district were not special in modifying new knowledge on feed quality improvement. As Table 5 shows, majority farmers (50.6%) have used the new knowledge by partially modifying and the rest 40.2% of dairy producer used the new knowledge as it is. Only 11.5% of the respondents used the new knowledge by totally modifying based on their own farming system and nature of the problem.

Knowledge transferring and means of transferring

In the study area, almost all famers (92.2%) transferred their knowledge on cattle feed quality improvement to other farmers. As the Table 6 indicates, majorities of the

Table 5. Frequency distribution of the respondents on knowledge utilization**.**

Dairy production systems		Knowledge utilization			Total
		Knowledge utilization as it is	Partial modification	Totally modification	
Urban	N	10	16	4	29
	%	11.5	18.4	4.6	33.3
Peri-urban	N	13	14	3	30
	%	14.9	16.1	3.4	34.5
Rural	N	12	14	3	28
	%	13.8	16.1	3.4	32.2
Total	N	35	44	10	87
	%	40.2	50.6	11.5	100.0

Table 6. Frequency of distribution of knowledge transferring and to whom it transferred.

Variables		Subsystems						Total	
		Urban		Peri-urban		Rural			
		N	%	N	%	N	%	N	%
The respondent can share cattle feed quality improving knowledge to other farmers	Yes	26	28.9	30	33.3	27	30.0	83	92.2
	No	4	4.4	0	0.0	3	3.3	7	7.8
Respondents transfer their knowledge to	Son/daughter	7	26.9	9	30.0	14	56.0	30	37.0
	Relative	12	46.2	17	56.7	22	88.0	51	63.0
	Friends	22	84.6	28	93.3	24	96.0	74	91.4
	Neighbors	25	96.2	28	93.3	24	96.0	77	95.1
Total		26	32.1	30	37.0	25	30.9	81	100.0

N= number of frequency.

farmers have interested to transfer their knowledge to their neighbors (95.1%), close friends (91.4%), relative (63.0%) and children (37.0%). It implies that in the study area, there was a high tendency of knowledge diffusing among the animal feed producers.

In order to transfer such kinds of knowledge, farmers used different means. Majorities of the respondents (82.1%) transferred their knowledge to other farmers through informal discussion and followed by experience sharing (40.5%) and allowing farmers to visit their own farm (29.8%). Only few respondents (2.4%) transferred their knowledge through written materials (Table 7).

It implies that informal discussion was used as a major means of knowledge transfer among farmers across all the subsystems. As Table 7 shows, 80.8% urban, 83.3% peri-urban and 82.1% rural farmers have used informal discussion as a major means to transferring their knowledge to other farmers. Experience sharing in urban (38.5%), peri-urban (43.3%) and rural (39.3%) dairy subsystems was the second most important means of knowledge transferring mechanism. Transferring through written materials was lest mechanism to transfer knowledge to the other farmers. However, written material was the most important and easiest means transferring of knowledge and it also helps the end users to retrieve when they need the knowledge on other time. Therefore, it is important to encourage the farmers to record and document any new knowledge so as to use the new knowledge they need other time and to transfer to their neighbor and friend in safe way.

CONCLUSION AND RECOMMENDATION

In the study area, crop residue and non-conventional feed (that is, *attela)* were the major feed sources for their dairy cattle in the study area. To improve the quality of their cattle feed, supplementing non-conventional feeds (like *Attela and Birnt*) after crop residue and/or grazing and making green hay are the most important mechanisms. Supplementing concentrate and developing improved forage are less prior mechanisms to improve

Table 7. Farmers' means of knowledge transferring**.**

Means of knowledge transferring	Dairy subsystems						Total	
	Urban		Peri-urban		Rural			
	N	%	N	%	N	%	N	%
Informal discussion	21	80.8	25	83.3	23	82.1	69	82.1
Inviting farmers to visit their farm	6	23.1	8	26.7	11	39.3	25	29.8
Experience sharing	10	38.5	13	43.3	11	39.3	34	40.5
Using write materials	1	3.8	0	0.0	1	3.6	2	2.4
Total	26	31.0	30	35..7	28	33.7	84	100

the quality of dairy cattle feed.

In the study district, Agricultural and Rural Development office, their own experience and neighbor are the major sources of improve knowledge. Farmers have also accessed this knowledge through informal discussion, on-walk observation of the farmers' farm field and experience sharing sessions. Majority farmers have used this new knowledge by partially modifying in accordance with their farming system. Farmers in the study area could also transfer their knowledge to their neighbors, friends, relative and children via mainly through informal discussion, experience sharing and inviting other farmers to visit their own farm.

To enhance the adoption rate of improved technology in relation to improving cattle feed quality and minimizing free grazing, all concerned bodies should understand the local knowledge and information following system of the society and approach them through the system. Various works should also be done on strengthening farmer-to-farmer interaction in regular and consistence manner in order to create mutual discussions and experience sharing among cattle produces in the study district.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

Constraints to the linkage between maize and livestock sub-systems in Ethiopian agriculture

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The study was conducted with the objective of assessing constraints to the linkage between maize and livestock subsystems in the Ethiopian agriculture system or practices. The linkage between the maize and livestock subsystems towards an integrated maize-livestock production system has been constrained by several factors. These factors affect resource flows between the two subsystems. These included socio economic, biophysical and institutional constraints, ever increasing population pressure which influences the availability of land for maize production and grazing; and large family size of households motivating farmers to cultivate more land dictated by the demand for enough grain, affecting the linkage. Feed shortage coupled with disease problems cause continuously declining livestock number and productivity constraining the contribution of livestock to the maize subsystem. Unbalanced research and extension focus between the maize and the livestock subsystems, difficulties in the process of technology popularization and inefficient and ineffective input, credit and veterinary services are the important institutional bottlenecks for integrating the maize and livestock subsystems to the desired level. Continuous extension education on natural resource conservation along with lessons on family planning is desirable to limit the effect of population pressure on the ecology and natural resource base. Moreover, research and extension support focusing on the generation and adoption of agricultural technologies that would help maximize output per unit of land from maize and livestock operations is required.

Key words: Ethiopian agriculture, extension, linkage, livestock production, maize sub-system research, production constraints.

INTRODUCTION

Agriculture is the backbone of Ethiopia's economy. It is dominated by a subsistence type mixed crop-livestock system where both crops and livestock are owned by smallholders. Mixed crop-livestock production system in Ethiopia has a long evolutionary history as sedentary agriculture. Currently, this is the most dominant land use

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system where the largest share of both crop and livestock products are derived (CSA, 2008). The potential of the system for achieving food self sufficiency, poverty reduction and establishing reliable material supply for industrial processes is immense provided a sustainable balance among the different components of the system is maintained and/or promoted in line with other efforts to improve the performance of agriculture. Within the agricultural sector, intensive cereal based growth offers the best prospects for sustained poverty reduction and economic growth (Dorward et al., 2004).

Maize production accounts for 16% of the total area under cereals and 27% of cereal grain production in the country (CSA, 2008). Livestock in the mixed crop-livestock system primarily serve as inputs for cereal agriculture. Maize production in the system supplies significant amounts of feed particularly in the major maize growing zones (Berhanu et al., 2007). Draught power supply for cultivation and for transporting maize produced to market is a crucial contribution of livestock to maize production. The magnitude of the interdependence is expected to increase in view of the ever declining size of land for grazing pushed by population growth. Thus, integrating the maize and livestock subsystems through innovations would be a viable option to achieve sustainable socioeconomic development. This could be materialized by establishing and maintaining functional linkages between the maize and livestock subsystems. Proper understanding of the mixed crop-livestock systems is critically important in order to devise appropriate technology transfers and institutional reforms for poverty alleviation, food security and sustainable resource management (Kristjanson and Thornton, 2004).
A study as a component of a larger project on ‘improving the utilization of maize as a food-feed crop’ came up with a set of constraints that limit the linkages between the maize and the livestock subsystems in the Ethiopian agriculture. This paper discusses the major constraints that limit the linkage between the maize and livestock subsystems, and suggests possible interventions.

METHODOLOGY

The study involved collection and analyses of both primary and secondary data. The secondary data sources were published and unpublished reports from Ministry of Agriculture and Rural Development offices and Research Institutes. The primary data were collected through focus group discussions, key informant interviews and household level surveys. The study areas were identified by combining and overlaying maps and information from International Center for Wheat and Maize Improvement (CIMMYT), International Food Policy Research Institute (IFPRI) and International Livestock Research Institute (ILRI). In the process of selecting the study sites, information related to maize cropping areas and mega environments, human population densities, livestock systems and livestock numbers were synthesized using GIS. The identified areas were Awassa, Bako and Ambo areas from which Awassa, Bako Tibe and Ambo districts were randomly selected for the household level study. The household level data were generated using a structured questionnaire involving a total sample size of 350 involving 90, 120 and 140 randomly selected households from Awassa, Bako Tibe and Ambo districts, respectively, from 11155, 14872 and 17351 farm households in that order.

RESULTS AND DISCUSSION

The constraints that limit the linkage between the maize and livestock systems assessed were broadly categorized into two sets namely; socioeconomic and biophysical constraints, and institutional constraints. The socioeconomic and biophysical subset of the constraints includes population pressure and large family size, and prevalence of diseases pests; whereas the institutional constraints encompass balance of research focus, and issues related to the extension services. The discussion follows this order.

Socioeconomic and biophysical constraints

Population pressure and large family size

Ethiopia has the second largest human population on the African continent (UNDP, 2009). Its population grows at a steady rate of 2.7% per annum (CSA, 2007). To feed this increasing human population, more land has been brought under cultivation. This is accompanied by extensive disturbance of the natural ecology through deforestation resulting in changes in the temperature and rainfall regimes of a given ecological system. Low amounts of rainfall and irregularity in its pattern cause crop failure due to moisture stress or confusions in planting calendar. A 10% drop in rainfall (below the long term national averages) resulted in an average drop of 4.2% in cereal yields in the country (Dagnachew, 2008). Land degradation is also one of the consequences of such a disturbance, affecting maize production and productivity due to decreasing soil fertility.

As a result of population pressure, land holding per family becomes smaller and smaller. For example, Byerlee et al. (2007) showed the magnitude of decrease in per capita land holding from 0.5 ha in the 1960s to only 0.2 ha by 2005 in Ethiopia. This impacts feed availability since farmers tend to cultivate more land available to them to produce enough food for their family at the expense of their grazing lands. With their perception of the urgency of securing grain as a result of large family sizes, farmers do not put feed related parameters as selection criteria for maize varieties.

In the current study, households were found to have large family size and the average family sizes per household were 6.5, 7.2 and 7.5 persons for Ambo, Bako and Awassa districts, respectively with the maximum ranging from 15 persons in Ambo to 24 persons in Bako, the figure in Awassa being 17 (Table 1). These figures

Table 1. Average family size and landholding per household and proportion of farmers who reported land shortage in the study districts.

District	n	Land ownership (ha)	Proportion of farmers facing land shortage (%)	Family size
Ambo	140	5.41	54	6.46
Bako Tibe	120	3.84	61	7.17
Awassa	90	1.72	79	7.54

n = number of respondents.

Table 2. Common livestock disease and parasite problems reported by district.

Disease/parasite reported	District		
	Ambo	Bako Tibe	Awassa
Black leg	*	*	**
Anthrax	**	*	*
Pasteurolosis	*	*	NR
Trypanosomiasis	**	***	*
Internal and external parasites	*	*	*
Mastitis	*	*	*

NR = Not reported. *the relative importance of the disease over sites where the number of asterisks increases with increasing importance of the disease.

indicate the magnitude of the burden for a household to produce enough grain to feed the large family. However, the average land holdings cultivated are virtually small ranging from one hectare in Awassa to three hectares in Ambo (Table 1). This was evidenced by the fact that 54, 61 and 79% of the sample farmers in Ambo, Bako and Awassa areas, respectively, reported that the land they owned was not sufficient to produce enough grain to feed their families (Table 1). In order to satisfy their demands for additional land, sharecropping and renting are the strategies employed. However, they do not get enough land to rent or share crop with. The shortage of land usually motivates them to cultivate more land accessible to them and the piece that is left for grazing is the immediate target which in turn aggravates feed shortage. Extended dry seasons and severe overgrazing make the carrying capacity of the piece of land that is left for grazing very low and unproductive by destroying the plant composition and depleting the regrowth potential of important species.

Prevalence of diseases and pests

Ethiopian agriculture is highly affected by the prevalence of diseases and pests of crops and livestock. Livestock diseases are among the constraints that affect the integration of maize and livestock subsystems in the major maize growing areas of the mixed crop-livestock system by causing high mortality rates of animals. For example, EARO (2001) estimates an annual loss of 2.4 to 3 million heads of cattle due to mortality. On the maize side, released varieties once believed to be resistant to certain diseases and pests go out of production due to disease and/or pest problems. This happens either because of the occurrence of new diseases or increased virulence of existing diseases as a result of ecological changes. The incidence of diseases and pests caused total crop failure or significant yield reductions both in maize grain, and stover which could be used to feed livestock

Diseases and parasites which affect livestock were reported by farmers in the study districts during focus group discussions supported by information from district offices of agriculture and rural development are indicated in Table 2. The situation is aggravated by the fact that livestock production is pushed to marshy areas where disease and parasite infestations are very high. Some of the diseases reported are anthrax, black leg and mastitis which are known to be diseases of intensification. Any effort towards an intensified maize-livestock system should take preventive, treatment and control strategies and their effective implementation as a crucial step. However, the situation in the study districts is constrained by several problems.

From the collected household level data, it was learnt that 58, 93 and 80% of the respondents with livestock in Ambo, Bako Tibe and Awassa districts, respectively, had access to veterinary services. Though the proportions of farmers who got veterinary services were not as low as

Table 3. Rank of major constraints associated with livestock production at each site as identified by farmers.

Constraint	Rank of constraints by district		
	Ambo	Bako Tibe	Awassa
Disease	3 (73)*	1 (92)	4 (42)
Feed shortage	2 (76)	3 (63)	1 (74)
Shortage of land for grazing	1 (89)	2 (81)	2 (60)
Lack of capital for initial investment	4 (35)	4 (23)	3 (55)

* Numbers in parenthesis refer to the number of farmers who reported the problem.

Table 4. Mean distance to market (km), and percentage of farmers who sell maize grain and their means of transport.

District	Distance to market	Sell maize (% of total respond ents)	Means of transport (as % of respondents who sell maize)						
			Pack animal	Human power	Pack animal + human power	Animal drawn cart	Vehicle	Pack animal + animal drawn carts	Animal drawn carts + vehicle
Ambo	8.2	22	79	6	15	0	0	0	0
Bako Tibe	4.8	70	44	1	6	38	2	8	1
Awassa	2.9	70	33	0	0	42	4	21	0

what would be expected, the quality of the services is highly affected by the technical inefficiency of veterinary personnel and lack of appropriate physical facilities for diagnosis and treatment of livestock diseases. For example, only one junior veterinary technician is assigned to supervise/attend to veterinary issues in three to five peasant associations in the study areas[1]. Besides their number, their technical capacity (education) limits them as they possessed diploma level of training. Vaccinations are practiced when national and/or regional campaigns were initiated. That is why repeated appeals by livestock owning farmers for the treatment of disease outbreaks did not get fast responses and appropriate measures. This was especially reported by farmers in the Bako area during the focus group discussions

Table 3 presents rank of key constraints to livestock production identified by farmers in the study districts. Feed shortage alone, as reported by farmers, ranked first in Awassa, second in Ambo and third in Bako Tibe. However, shortage of land for grazing is again to mean feed shortage. Therefore, overall feed shortage is the most critical livestock production problem in all of the study districts followed by diseases. Disease problem was reported with a much higher frequency in Bako Tibe than in Ambo and Awassa. This is because the Bako Tibe district is located in and around the Gibe Valley which is known for its high infestation rate with tsetse fly which transmits trypanosomiasis.

Disease prevalence coupled with feed shortage reportedly influenced the number and productivity of livestock owned by households. A considerable proportion of the farmers in the study districts were without an ox for cultivation. Though there are established social norms and arrangements of sharing animals for power, those without oxen are liable to maize failure due to delayed planting as the priority in the arrangements goes for those who own the oxen. Almost all sample farmers in the study districts use animal power for transporting maize grain to market (Table 4). This is a strong evidence which shows the extent of farmers' dependence on animal power/livestock for household activities in addition to using them for cultivating their lands. Animals that are used for transporting maize grain to market are equines mainly donkeys. As shown in Table 8, farmers located far from market places tend to keep equines. It seems that the reason why 92 (66%) of the sample farmers in Ambo keep at least a donkey as compared to 26 (22%) in Bako Tibe and 21 (23%) in Awassa districts is distance to market centers. Obviously, manure is among the important resources from livestock that could be used for fertilizing maize plots. However, it was found that its use is very little in all of the study areas due to small livestock holdings. Even the amount obtained from households with larger livestock holdings is

[1] Peasant associations are the lowest administration units in rural Ethiopia. According to the Ethiopian Federal Democratic Republic administrative hierarchy, the regional states are divided into zones, districts and Peasant Associations (*kebeles* in urban areas), in that order.

Table 5. Annual capital budget share (in thousand Birr) allotted to crops and livestock research processes/Directorates for five years (2005-2009) in the Ethiopian Institute of Agricultural Research.

Program/Directorate	2005		2006		2007		2008		2009	
	Amount	% of total	Amount	% of total	Amount	% of total	Amount	% of total	Amount	% of total
Crops Research Process/Directorate	9495	5.32	10097	6.11	9970	8.94	9884	16.06	12483	13.83
Livestock Research Process/Directorate	4493	2.52	4459	2.70	4226	3.79	4804	7.80	8600	9.53

Source: Planning Office, Ethiopian Institute of Agricultural Research (personal communication).

confined to the use for backyard maize production.

Institutional constraints

Balance of the research focus and professional thinking

Agricultural research in Ethiopia is mainly focused on crops and related issues. This is reflected by the imbalance in staffing and financial resource allocation. The budget share allotted to crops and livestock research processes/Directorates for five years is shown in Table 5. In all of the years until 2009, the budget share for livestock research did not surpass half of the amount allotted for crops research. That difference in terms of percentage of the total budget is simple evidence that could show the imbalance. But the actual causes and picture go beyond that extent. Except in few, in most of the agricultural research centers, the primary mandate for their establishment goes for crop issues. This is linked to the motto of “food security” which has been echoed for several decades. Policy implementation has been considering livestock as a secondary enterprise (Habtemariam, 2003). Regardless of the importance of livestock in rural livelihoods, where farmers in the study areas state that “if there are no livestock, there is no life”, the focus of research seems to be more on crop production, maize as one of the commodity crops for food security, has got far better attention than livestock subsystem..

The maize research has been predominantly focusing on the development and release of maize genotypes that are adaptable to various climates and high yielding. The parameters considered through the process are all related to grain yield. Feed related traits were considered bad and negatively correlated with grain yield until very recently that maize breeders were convinced by evidence that informed the possibility of combining food and feed traits (Adugna, 2002; Devendra and Pezo, 2004; Singh et al., 2004). Nevertheless, the state of consensus among professionals on the way forward has not been determined yet. The absence of any involvement of livestock scientists in the maize breeding and selection programs in the Ethiopian Institute of Agricultural Research system could be an evidence to support the stated status.

Despite the global trend and professional thinking towards agricultural intensification through crop and livestock integration, the situation in Ethiopia in terms of research effort is below what could be expected. People view agricultural problems through their narrow professional perspective, being highly confined to discipline/enterprise specific activities. Regardless of the importance of livestock in the agricultural sector, even to the production of cereals like maize through the resources farmers get from, the research efforts to integrate maize and livestock are not up to the level the scenario demands. Feed shortage has been rated as the most important livestock production problem in Ethiopia. However, the conventional thinking to solve the problem has focused mainly on the improvement of grazing land productivity (which is almost non-existent on lands that are in the hands of smallholder farmers in the mixed crop - livestock system) and increase fodder availability through the dissemination of forage technologies to farming communities which is again constrained by shortage of land and seeds. Realizing the potential of crop residues for livestock feeding, research efforts on how to improve their utilizations were one of the areas of intervention that have been tried for many years (EARO, 2001). Attempts to improve maize stover utilization were employing different supplement strategies and treatment options. These strategies and options are labor and, more importantly, capital intensive which make them unaffordable to smallholders. Moreover, unavailability of feed resources for supplementation complicates the problem. Therefore, development of maize genotypes that could provide better quality and quantity feed should have presumably been the best option and focus of research towards an integrated and sustainable smallholder maize and livestock production in Ethiopia.

Table 6. Percentage distribution of household heads by education level (years of schooling).

District	Education level (years of schooling)				
	0	1-6	7-12	Mean	SD
Ambo(n=140)	44	30	26	3.64	3.904
Bako Tibe(n=120)	38	41	22	3.45	3.295
Awassa (n=90)	42	45	14	2.94	3.043

SD = Standard deviation; n = number of respondents.

Table 7. Number and proportion (%) of farmers who got their maize farm visited by extension agents at least once during the growing season.

District	Extension agent visit	
	n	%
Ambo (n=135)	23	17
Bako Tibe (n=118)	32	27
Awassa (n=88)	49	56

n = number of respondents.

The extension system and associated functions

In spite of the commendable magnitude of focus and efforts put forward to bringing success in agricultural development by the government through strengthening the agricultural extension system, there are still difficulties facing the system particularly when viewed from the angle of integrating the maize and the livestock sub-systems.

Issues related to technology popularization

For a successful adoption of a technology, popularization is a crucial step as it promotes better social inclusion in the use of the technology. This could be achieved through demonstrations and training. Organizing farmers' field days is one of the mechanisms to demonstrate a technology to end users. These are particularly important in the Ethiopian condition where the education level of farmers is considerably low. For example, 44, 38 and 42% of the sample farmers in Ambo, Bako Tibe and Awassa, respectively had no formal education (Table 6).

Teaching farmers on improved agricultural practices through frequent visits to farmers' fields, particularly in the growing season is an important extension activity to enhance the uptake of a technology at a larger and wider scale. However, as shown in Table 7, the percentage of farmers who got extension visits at least once during the growing season is markedly low in Ambo (17) and Bako Tibe (27) though the figure in Awassa (56) looks encouraging.

Moreover, the proportion of farmers who got training on improved agricultural practices is less than one third (Table 8) whereas participations in farmers' field days (Table 9) were limited to less than a quarter of the sample farmers in all of the study districts. Looking at those levels of participation in training and field days, it is evident that the focus is more on maize crop than livestock. A similarly low level of participation in livestock packages and training as compared to that of crops was reported by EEA/EEPRI (2006). Even the much higher figures of participation in both enterprises reported in the current study do not necessarily reflect the magnitude of efforts made to integrate maize and livestock sub-systems. Had it been like that, the practice of farmers in Ambo and Bako areas where maize stover is left to be consumed by animals and finished/spoiled in the field would have been processed to animal feed. Absence of extension education on how to integrate maize and livestock was reflected by the unchanged practice of not using collected and conserved maize stover in Ambo and Bako Tibe in spite of the reported severity of feed shortage particularly in the dry season.

The maize input system

A significant proportion of farmers used second generation seeds since they could not get seeds of their preference. As learned from farmers' experience, the use of second generation hybrid maize seeds causes yield reductions of up to 50%. The maize seed system suffers from a serious shortfall from the demand. Dawit et al. (2007) reported only a 53% success rate in 2004/05 cropping season in terms of satisfying the demand for improved maize seeds.

In addition to the overwhelmingly reported shortage of inputs in terms of quantity documented during focus group discussions, farmers ranked high price of inputs and their late supply as the most critical maize production problem in all of the study sites (Table 10). These are indications that the input system is inefficient and ineffective.

The credit system

The proportion of farmers who had access to credit

Table 8. Proportion of farmers who participated in training and the distribution by type of training.

District	Participation		Participation by type of training (as % of farmers participated)		
	n	%	Crops	Livestock	Both
Ambo (n=140)	24	17	12	4	84
Bako Tibe (n=120)	26	22	36	8	56
Awassa (n=90)	28	31	25	11	64

n = number of respondents.

Table 9. Distribution of sample respondents by their participation in farmers' field days by enterprise type and district.

District	Participation		% participation by enterprise		
	n	%	Maize	Livestock	Both
Ambo (n=140)	31	22	26	0	74
Bako Tibe (n=120)	26	22	19	0	81
Awassa (n=90)	22	24	50	0	50

n = number of respondents.

Table 10. Rank of key constraints in maize production as identified by sample respondents.

Constraint	District		
	Ambo (n=135)	Bako Tibe (n=118)	Awassa (n=88)
High price of inputs	1 (135)*	1 (118)	1 (88)
Late supply of inputs(seed and fertilizer)	2 (122)	2 (112)	2 (73)
Land shortage	4 (26)	3 (34)	3 (61)
Late onset of rain	3 (49)	4 (21)	4 (23)

* Numbers in parenthesis refer to the number of farmers who reported the problem. n = number of respondents.

Table 11. Proportion (%) of farmers who got credit facilities.

District	Credit service			
	Yes		No	
	n	%	N	%
Ambo (n=140)	117	84	22	16
Bako Tibe (n=120)	89	74	31	26
Awassa (n=90)	2	2.	89	98

n = number of respondents.

facilities in Ambo and Bako Tibe districts looks reasonably good and very much higher than that of Awassa where 98% of the sample farmers had no access to credit facilities (Table 11). However, those who had access to credit facilities reported problems about thecredit service they got. The widely stated problems included high interest rate, request to pay debt early in the dry season and down payment in order of importance

Request for debt repayment before the selling price of maize grain rises coupled with the stated high price of inputs creates a serious and devastating problem to farmers which forces them to sell livestock (including oxen) and other assets. Contracting out land was also reported as one of the practices. These all negatively affected the farmers' success rates in their engagements using both maize and livestock subsystems.

There is a high level of interdependence between the maize and livestock subsystems in the Ethiopian agricultural system. However, the resource and service flows between the subsystems in a manner that ensures sustainability has been constrained by heavy population pressure and accompanied land shortage; unbalanced research and extension focus; and, high prevalence of livestock diseases/ pests and limitations in veterinary and credit services. Therefore, in order to promote a sustainable integration of the maize and livestock subsystems, there is a need to make a parallel focus on both in terms of research and extension, and equitable share of required resources. Continuous extension education on natural resource conservation along with lessons on family planning is desirable to limit the effect of population pressure on the ecology and natural resource base. Moreover, research and extension support focusing on the generation and adoption of agricultural technologies that would help maximize output per unit of land from maize and livestock operations together is required.

Conflict of Interest

The authors have not declared any conflict of interest.

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Adapting to climate variability and change in smallholder farming communities: A case study from Burkina Faso, Chad and Niger (CVCADAPT)

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Climate variability and change is regarded as having major impacts on key sustainable socio-economic and environmental indicators in Sub-Saharan West Africa. Because of these concerns, we investigated smallholders knowledge, skills, and aspirations about managing climate change, and document adaptation strategies used in the semi-arid regions coming from Burkina Faso, Chad and Niger. We analyzed climate data from the 1950's to the present, including daily and aggregated rainfall and temperature variability, trends and extremes. We also examined farmer perceptions of climate, particularly with what was expected and what was actually observed. Field data was collected through: (i) a semi-structured survey administered to 478 head households; (ii) from focus groups through discussion and consultation with local stakeholders by using a risk matrix. The main agro-climatic risks for farmers in these countries are: Increasing maximum and minimum temperatures; high rainfall variability; and, extreme droughts and floods. We were able to work with communities to identify and prioritize authentic climate change adaptation measures that were deemed to be both strategic and complementary to prudent natural resource management and enhanced agricultural production. Identified innovative adaptation practices that may be up-scaled include: expanding irrigation systems, adjusting crop planting times to suit localized weather and climate forecasts, plant breeding to establish more heat-stress tolerant crops and associated agroforestry. In dryland rainfall systems, it was acknowledged there is a need for greater reliance on water-stress tolerant crops, better soil and water conservation techniques associated with broad catchment management and agroforestry, and improving soil management through prudent fertilizers in sorghum crops. To address climate change, such practices need immediate wider-scale implementation.

Key words: Climate variability and change, farmers perceptions, agro-climatic risk, adaptation, Sahel, Africa.

INTRODUCTION

Climate variability has historically affected West African society. This region has in our lifetime experienced severe droughts during the years 70 and 80s. This drought event has been described as one of the most severe in the world in duration and extent during that century (Hulme, 2001). In addition, other climate parameters such as dry spells, timing of the onset and end of the rainy season and length of growing period affect agricultural production significantly and hence food security. In most cases, crop failure in the semi-arid areas of Africa is mainly associated with a decrease in total rain, dry spells within the 'normal' crop growing season and a shorter length growing period (Araya and Stroosnijder, 2011). Climate change is likely to exacerbate these issues (IPCC, 2007).

A new pattern of rainfall variability has occurred post-90's in the Sahel West African region, characterized by a succession of much wetter and much drier years (Ali et al., 2011). However, the pattern of higher total precipitation coincides with increased mean intensity and accompanying floods. The end of the Sahelian drought post-1990s may have been premature (Ozer et al., 2003), and replaced with the realization of a new climate changed world for the peoples of this region. There has been a general warming trend throughout the region from 1960 to 2010, namely through a negative trend in the number of cool nights and more frequent warm days and warm spells (Ly et al., 2013). Observed temperatures have been increasing faster than global warming trends and expectations. The increase has fluctuated between 0.2 and 0.8°C from 1961 to 2010 (Ecowas-SWAC/OECD/CILSS, 2008). It is now inarguable that climate variability alongside climate change is now a major and permanent feature of semi-arid West Africa that needs to be confronted and appropriately dealt with (Akponikpè et al., 2010).

The agriculture sector in West Africa's includes livestock, fisheries and smallholder farming, and is a significant contributor to the economy. With less than 5% of agricultural land irrigated, rainfall variability and increasing temperature and evapotranspiration, have high socio-economic impacts on rainfed agricultural. All these challenges combine to add pressure to poverty (Mapfumo et al., 2008), natural resources depletion, diseases such as malaria and increase the vulnerability in the already vulnerable communities.

Numerous studies have already been undertaken in Africa on linking climate variability and change with farmer's perceptions and current coping strategies and applied adaptation measures (Macharia et al., 2012; Mtambanengwe et al., 2012; Henny et al., 2011; Moyo et al., 2012; Ouédraogo et al., 2010), but they have not been adequately targeted to suit west African agriculture and applied yet by extension practitioners (Mertz et al., 2011). Specific adaptation responses are important because the climate has already changed and these changes are likely to continue even if mitigation actions are enacted immediately (Cobon et al., 2009). However, the capacity of local farming communities and their institutions to respond accordingly to the new and emerging impacts of climate change is often constrained by lack of access to resources, information, and improved technologies (Mapfumo et al., 2013). A more thorough and comprehensive nationally coordinated approach is warranted, similar to the approach taken in Tanzania (MAFC, 2014). Furthermore, using tools and practices that help end-users identify adaptations that are 'location-specific' and 'knowledge-intensive' can accelerate roll-out of adaptation options for agriculture and water (George et al., 2014).

Understanding local farmer knowledge levels about climate and climate risk is a pre-requisite to mainstreaming climate adaptation into agricultural development strategies and plans. This paper examines local knowledge and experiences of farmers in Burkina Faso, Chad and Niger, about how they are managing climate variability and change - using elements of rainfall, temperature, and climate extremes events from 1960 to 2010. This data will highlight 'best management practices' and identify lessons learned for greater uptake and successes that can therefore help accelerate adaptation to climate change if adopted on a wider scale.

The first section of this paper examines farmer understanding of climate variability and change**.** The second section compares farmers' perceptions of climate change and variability in relation to climatological evidence. The last section presents data on the use of a risk management approach, which uses a multi criteria matrix analyses and participatory method that can then identify adaptation options to be implemented.

MATERIALS AND METHODS

Site description

The study was conducted in key semi arid cropping areas in the three countries in Burkina Faso, Chad and Niger. The survey was carried out (i) in Burkina Faso, in the northern community of Bogande, Mani in the East region, Safi and Koboure in the Central North; (ii) in Chad in the Chari department; and (iii) in the Western part of Niger in Tillabery, Filingue and Kollo (Table 1). In the 3 countries, the semi arid area is characterized by annual rainfall ranging from 600 to 350 mm and from 600 to more than 825 mm in the sudanian zone. The average length of growing period ranges from 75 to 140 days (Thornton et al., 2006). The average annual temperature ranged from minimum 21.3 to 22.9°C and maximum 34.7 to 36.7°C. Cropping systems are characterized by high rainfall variability and recurrence of droughts, poor soil fertility, high human pressure on the natural resources and consequently low productivity (Traoré et al., 2000). Millet, sorghum, cowpea are the main crop growing under rainfed agriculture. The economies of the region are built mainly on rainfed agriculture. Irrigated agriculture

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Table 1. Average annual minimal, maximal temperatures, rainfall and length of growing period (1961-1990) for the key stations in Burkina Faso, Niger and Chad.

Country	Weather station	Latitude °N	Longitude °	Elevation (mm)	Tmin °C	Tmax °C	Annual rainfall (mm)	LGP (days)
Burkina Faso	Bogandé	13	-0.1	250			584	114
	Boulsa	12..39	0.36	313			690	117
	FadaNgourma*	12.07	0.35	292	21.3	34.7	825	145
	Kaya	13.1	-1.1	313			670	121
Niger	Filingué	14.3	3.3	300			359	75
	Kollo	13.3	2.4	210			554	105
	Niamey*	13.28	2.1	222	22.4	36.1	539	103
	Tillabery*	14.2	1.45	209	22.9	36.7	399	80
Chad	Ndjaména*	12.1	15.1	294	20.9	35.8	520	95

*Weather stations with minimum and maximum temperature.

and fishing along the Niger River basin are also significant activities.

Survey data

The questionnaire was administered to a total of 478 household heads unequally distributed in the 3 countries according to the number of population and the importance of the rural activities. Random sampling was used to select the head of households for interview. This comprised 160 households in Burkina Faso, 196 in Chad, and 122 in Niger. Data was collected from January to March 2012 by Master degree students enrolled in a Climate Change and Sustainable Development Unit organized by AGRHYMET Regional Centre. A semi-structured household questionnaire was individually administered to the selected head of each household. Focus group discussions were also used to analyze and authenticate the impact of climate variability and change on farmer's livelihoods and environment (crop, water resource, soil, and other ecosystem services). The age of the respondents ranged approximately from 40 to 75 years. Data and information collected were focused on farmers' perceptions of climate variability and change, and the impact of climate variability and change on their livelihood including other data on crops, soils, water, vegetation and animals. Farmers' adaptation strategies to cope with climate variability and change were also featured. The survey also had focused questions on farmers' perceived climatic patterns to have stayed the same or changed before over the last 20 years.

Statistical tests and ensuring reliability of data

Quantitative data was analyzed using the Student t test. Qualitative data on impacts and adaptations was collected from the risk matrix (AGO, 2006; Cobon et al., 2009). To prioritize the adaptation measures identified, a variety of criteria have been used (Miller et al., 2006; USAID, 2007) to aggregate responses about: (i) the cost to implement adaptation options; (ii) the effectiveness in terms of benefits, damages mitigated, costs avoided, (iii) the ease of implementation including issues such as barriers to implementation and the need to adjust other policies to accommodate the adaptation, (iv) technical feasibility; (v) sociocultural feasibility, and the speed of implementation. For each criteria, a score from 1 to 3 was given (1 being poor performance and 3 high performance). To select the final set of adaptation measures and assigning or level of importance of each of them, consultations with decision-makers and stakeholders were done through the focus group survey with consensus being achieved on all options. Stakeholders included local farmers, Non-Governmental Organization local representatives of National Ministries and extension services. From these approaches, the adaptation measures with the highest score ranked most critical to implement.

Analyses of observed climate data

Daily rainfall, minimal and maximal temperature were collected from the AGRHYMET Regional Centre data basis completed by the National Meteorological Services of the 3 countries. Because of the high spatial rainfall variability, we selected the closest weather station to the village. Climate data rainfall, maximum and minimum temperature from 1960 to 2010, were collected and digitized (Table 1). The data were quality controlled using Rclimdex package (Zhang and Yang, 2004). Minimum and maximum temperatures and rainfall anomalies were computed with respect to the reference period 1961 to 1990. Other rain season parameters such as onset, cessation of rainy season and length of growing period were also computed (Stern et al., 2006). Several definitions are adopted for the onset and the cessation date of the rainy season (Stern et al., 1981; Sivakumar, 1988; Traoré et al., 2000). In this study, the criteria used to determine onset date is a cumulated rainfall of 20 mm or more over three consecutive days after the first day of May with no dry spell greater than 20 days in the next 30 days. The end of the season was defined as the date after the first day of September when available soil water content dropped approximately to 0.05 mm due to crop evapotranspiration. The length of growing period was calculated as a difference between the onset and the cessation dates. The Student's t-test at the 95% level of significance for the comparison of two means for the time series before 1990 and after 1990s, were applied for annual rainfall, onset date and length of growing period (Arlery et al., 1973).

RESULTS AND DISCUSSION

Farmers' understanding of climate change

Within our sample in our study countries, > 90% of farmers from Burkina Faso and Chad consider total rainfall decrease is the greatest challenge to overcome

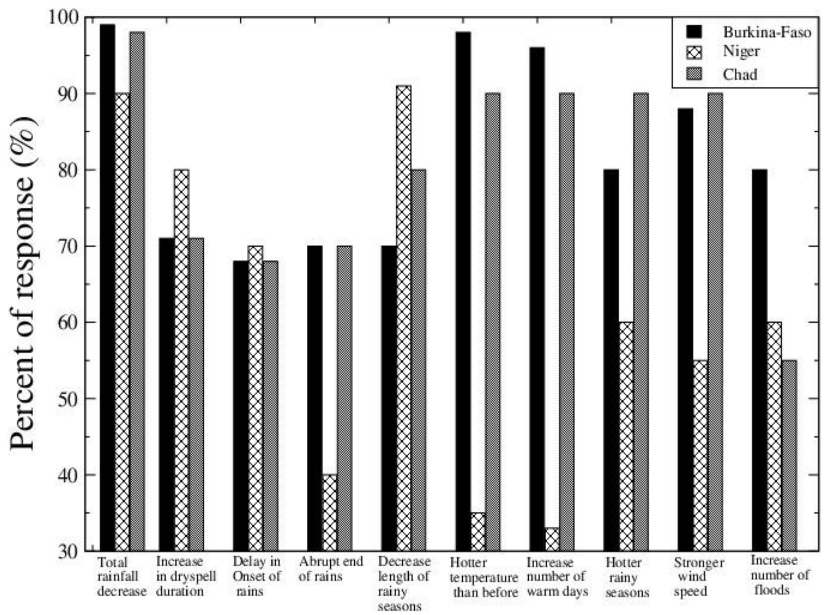

Figure 1. Farmers (n=478) considerations of greatest climate challenges to overcome in farming - from Burkina Faso (n=160), Chad (n=196) and Niger (n=122).

(Figure 1). Those from Niger considered the greatest challenge to be a shorter rainy season. In addition, >70% reported that the dry spell duration has increased over the last 20 years and drought became more severe particularly in Tillabery in semi arid Niger. An observed delay in the onset of rains was also reported by 65% of the farmers along with an abrupt end of rains by 70%. About 70% of the farmers in Burkina Faso, 90% in Niger and almost 100% in Chad reported a decrease of the length of the rainy season. In the same time, 40% of farmers indicated a rise in the number of heavy rain in the region of Tillabery. In addition, 60% of respondents in the region of Tillabery, 80% in Burkina Faso and Chad mentioned that flood increased during these last decades.

More than 90% of farmers observed increasing temperature over the last 20 years in Burkina Faso and Chad (Figure 1). Farmers mentioned that warmer days and nights have increased during the last 2 decades. However, only a third of respondents reported that temperature has increased significantly in Tillabery, Niger.

The farmers' perception of a decline in rainfall may be related to the lower moisture availability for plant growth resulted from soil fertility decline and soil erosion (Adimassu, 2014). However, Van de Giesen et al. (2010) show that farmers in the Volta region have experienced shifts in the onset of the rainy season later in the year, from April towards May. These farmers now sow 10 to 20 days later than their parents. While, Diouf et al. (2000) show spatial heterogeneity of response from LGP to climate variability and change over the Sahel region.

Observed climate data: Trends and variability

Rainfall

Statistically, annual rainfall has not changed in the past 20 years compared to period before, particularly from the year 60' to the present period (Figure 2). The evolution of total annual rainfall has been characterized by a succession of wet years from 1950 to 1969, followed by a period with the persistence of dry years from 1970 to 1993 (L'hote et al., 2002; Ali et al., 2008). This has resulted in a southward movement of isohyets by about 200 km (Diouf et al., 2000). While the present period experienced receiving long-term 'average' rainfall throughout the 1990s.

For most stations, the amounts of annual rainfall during the period before and after 90 are not significantly different according to Student's t-test at 5% probability level. Only a few number of selected stations such as Kaya (Burkina Faso) show a significant decrease of the amount of rainfall during the past 20 years (Table 2). From the beginning of the 90s, another mode of variability, characterized by a succession between wet and dry years seems to have started in the region (Ali, 2011). This high rainfall variability could be probably due to climate change during the past 20 years. In the same period, the maximum day precipitation amount have increase in general in the semi arid West Africa region (Gachon et al., 2007). In addition, the average number of flood events have increased from less than 2 per year before 1990 to more than 8 to 12 per year during the 2000s (Sarr, 2012). The years 2000, particularly 2007,

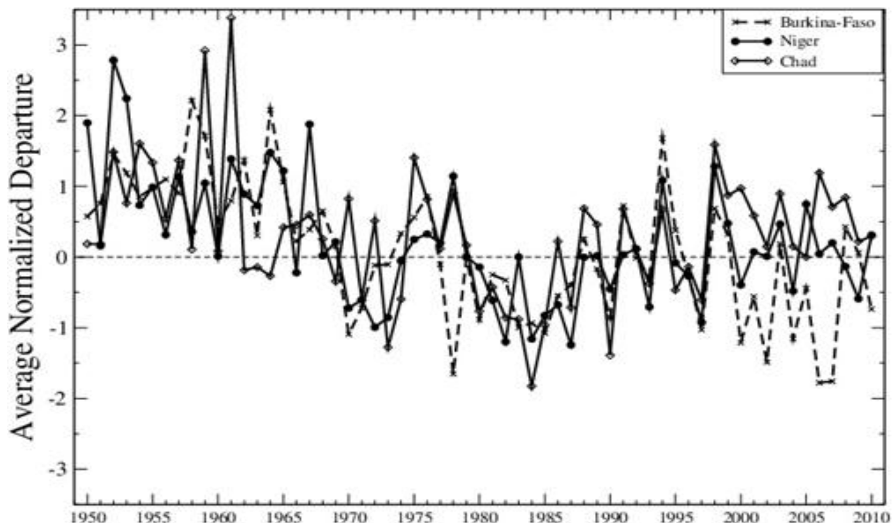

Figure 2. Average annual rainfall normalized departure from 1950 to 2010 in the studied weather stations in Burkina Faso, Niger and Chad.

Table 2. Mean comparison of annual rainfall before and after 1990 (before and after the past 20 years), (significant if observed Student t test > critical Student test = 2.001).

	Annual rainfall (mm				
Weather station	**Before 1990**	**After 1990**	**Difference before and after 1990**	**Confidence interval at 95 % level around the mean difference**	**Observed t**
Tillabéry	442	420	-22.4	[-90.2 ; 45.4]	0.66
Niamey	564	545	-19.23	[-94.6 ; 56.2]	0.5
Kollo	568	521	-46.58	[-127.7 ; 34.6]	1.14
Filingué	418	387	-31.1	[-109.8 ; 47.6]	0.79
FadaNgourma	883	853	-29.51	[-113.7 ; 54.7]	0.7
Kaya	692	587	-105.01	[-198.8 ; 11.2]	**2.24**
Bogandé	634	629	5.2	[-68.5 ; 79.01]	0.142
Ndjaména	561	587	25.31	[-57.1 ; 107.7]	0.61

2008 and 2009, have experienced several cases of floods in West Africa with severe destruction of infrastructure and significant crop losses (Sarr and Lona, 2009). The impacts of these events were probably amplified by the land change affecting runoff.

Onset and length of growing period

In this region, agricultural farmers system is highly vulnerable to the rainfall component such as onset, and length of growing period variability (Dodd and Joliffe, 2001). Onset date occurs according to the station, from the second decade of May to third decade of June (Table 3). The observed length of growing period (Table 4) ranges between 80 days in the northern part of the region (Tillabery) and 150 days in the south of Burkina Faso (Fada Ngourma). The onset date, the length of growing period during the past two decades and the period before did not show significant difference according to the Student's t test (Tables 3 and 4). Only the station of Kollo in Niger shows a significant late onset date during the present period. Alhassane et al. (2013) showed that the agro-climatic risks of the recent period (1991 to 2010) are still the same as those in the historical drought period of 1970 to 1990. Onset dates of the cropping season show a quasi-stationary trend from 1970 to 2010. In addition, the succession of wet and dry periods recorded from 1990s does not seem to favor the extension of length of growing period.

Temperature

From 1990 to 2010, a clear trend of increase is observed for the minimal and maximal temperatures (Figure 3a and

Table 3. Mean comparison of onset date before and after 1990, (significant if observed Student t test > critical Student test = 2.001).

Onset date					
Weather station	**Onset date before 1990 (mm)**	**Onset date after 1990 (mm)**	**Difference before and after (mm)**	**Confidence interval at 95% level around the mean difference**	**Observed t**
Tillabery	24 June	20 June	-5	[-16.1; 6.7]	0.82
Niamey	04 June	03 June	-1	[-13.1; 11.1]	0.17
Kollo	31 May	14 June	13	[-2.8; 23.4]	**2.50**
Filingue	23 June	18 June	-5	[-17.5; 6.9]	0.80
FadaNgourma	11 May	11 May	0	[-11; 10]	0.05
Kaya	28 May	26 May	-2	[-12.9; 8.5]	0.40
Bogandé	24 May	29 May	-5	[-17; 7.7]	0.77
Ndjaména	16 June	17 June	2	[-11.5; 14.8]	0.26

Table 4. Mean comparison of annual length of growing season before and after (significant if observed Student t test > critical Student test = 2.001).

Length of growing season (LGP)					
Weather station	**LGP 1990 (day)**	**LGP after 1990 (day)**	**Difference before and after (day)**	**Confidence interval at 95 % level around the mean difference**	**Observed t**
Tillabéry	80	80	0	[-12.3 ; 12.06]	0.02
Niamey	105	109	4	[-9.9 ; 17.9]	0.57
Kollo	108	96	-12	[-26.0 ; 0.57]	1.91
Filingue	80	84	4	[-9.3 ; 17.24]	0.60
FadaNgourma	149	144	-5	[-17.15; 6.7]	0.87
Kaya	121	123	2	[-10.5 ; 14.2]	0.29
Bogandé	120	116	-6	[-20.4 ; 9.2]	0.7
Ndjaména	99	99	0	[-12.8 ; 14.5]	0.1

b). All the stations showed an increase of annual mean minimum and maximum temperatures from the years 90 compared to the period before. The value appears to be increasing at a faster rate for the minimum than for themaximum. Before the 90' and the past two decades, minimum temperature increased significantly from 1.3 to 1.1°C for all the weather stations (Table 5 and Figure 4a and b). In the same time, the maximum temperature showed a significant increase from 0.75 to 1°C. Over the two periods, the average increase of temperature in this region was 1.04°C. Indeed, Caesar et al. (2006) show that minimum temperature has increased faster than maximum temperature, thus contributing to narrow the diurnal temperature range. According to IPCC (2013), the globally averaged combined land and ocean surface temperatures showed a warming of 0.85 [0.65 to 1.06]°C over the period 1880 to 2012. In addition, Ly et al. (2013) showed a general warming trend in the entire region from 1960 to 2010 with a negative trend in the number of cool nights and more frequent warm days and warm spells. Over the same period, the occurrence of extreme hot days and nights has increased by 8.2 and 8.6 days / decade, respectively (New et al., 2006). This warming is projected to continue and will likely be accompanied by more extreme climate events (Vincent et al., 2005).

Farmers' perceptions compared to observed meteorological data

The survey showed that farmers perceived climate to have changed in the past 20 years. In general, farmers (more than 90% in Burkina Faso and Chad) felt that temperature had increased over the past 20 years. Farmers reported that present temperatures have been increasing faster than the period before the 1990s. Observed temperature data showed a clear signal of general warming trend throughout the region during the period from 1960 to 2010.

During the past 20 years, succession of wet and dry years has been noted. Since the mid-1990s, rainfall measurements did not show a downward trend in rainfall amount. Closer normal to above average rainfall amounts have predominantly been noted. Then, the perceived change in rainfall reported by farmers differed with the observations. Therefore, farmers still remember the

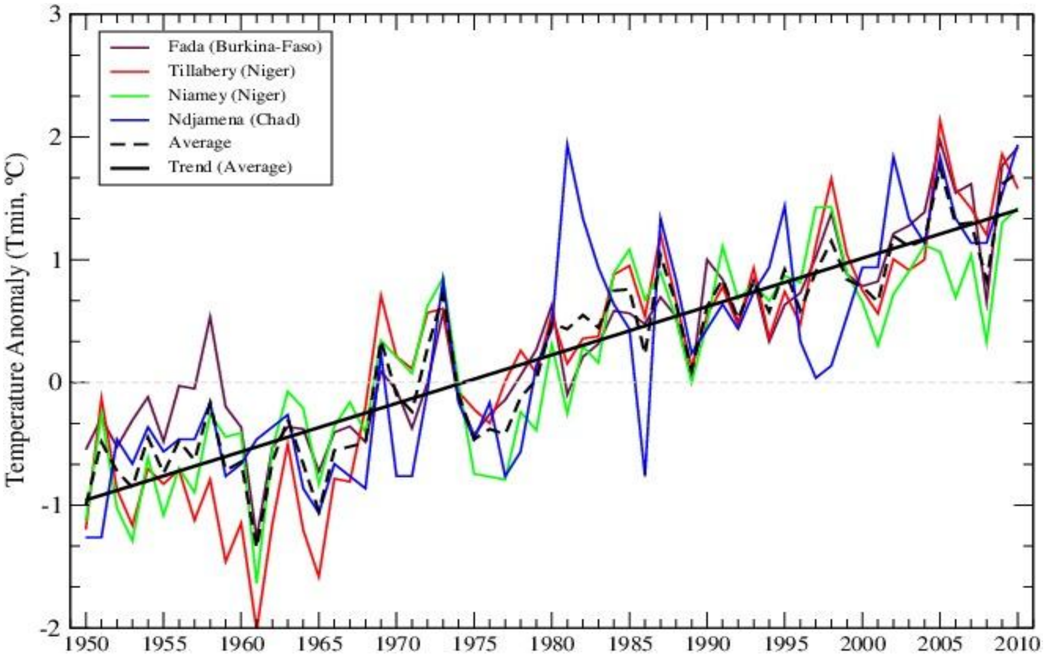

Figure 3a. Minimum temperature anomalies relative to 1961-1990 average in the four reference weather stations.

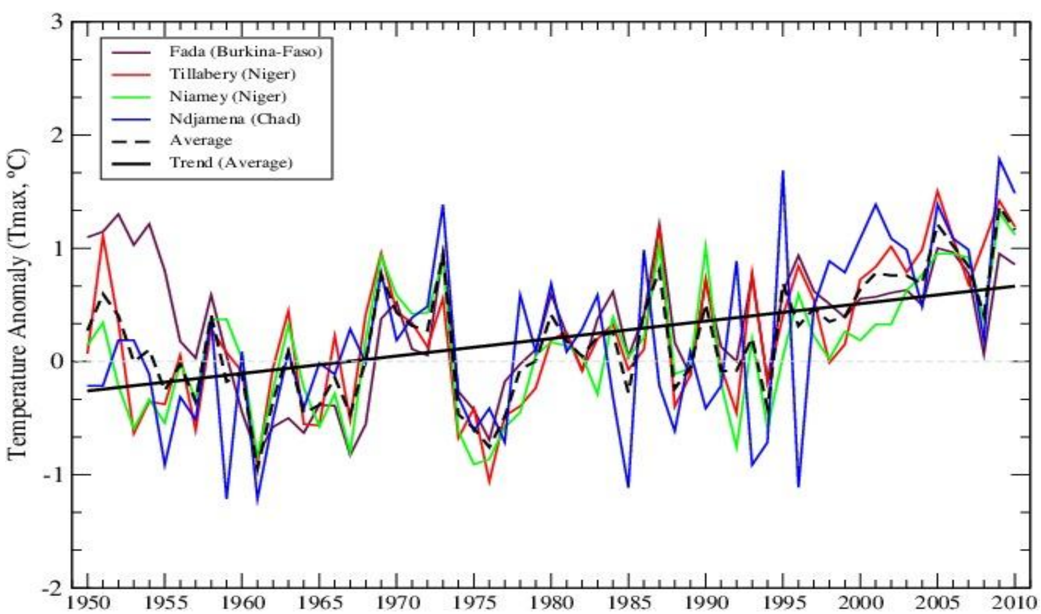

Figure 3b. Maximum air temperature anomalies relative to 1961-1990 average in the four reference weather stations.

severe droughts of the 70s and 80s but have not captured well the return to better rainfall conditions since the beginning of the 90s which is also accompanied with high rainfall variability. This is probably related to the high inter annual variability of rainfall which is perceived by farmers as a period of rainfall decrease.

Over the past 20 years, a delay in the onset of the rainy season or early cessation greater than the period before was not observed. Alhassane et al. (2013) has shown that present agro-climatic risks remained similar to the historic drought from 1970 to 1990. However, it still probably differed from the wet period of the 50s and

Table 5. Mean comparison of minimal and maximal temperature before and after 1990, (significant at 95 % level if observed Student's t test > critical Student test = 2.001)

Weather station	Minimal temperature			Maximal temperature		
	Difference before and after 1990°C	Confidence interval at 95% level around the mean difference	Observed t- test	Difference before and after 1990°C	Confidence interval at 95% level around the mean difference	Observed t-test
Tillabery	1.3	[0.9; 1.71]	**6.8**	0.7	[0.38 ; 0.95]	**4.66**
Niamey	1.1	[0.8; 1.41]	**7.2**	0.4	[0. 12; 0.68]	**2.81**
FadaNgourma	1.2	[0.9; 1.41]	**9.08**	0.4	[0. 09; 0.69]	**2.67**
Ndjaména	1.2	[0.8; 1.53]	**6.23**	0.74	[0. 37; 1.12]	**4.03**

60s.The number of floods were perceived to have increased by a higher proportion of farmers in Burkina Faso and Chad (80%), and Niger (60%). Afterwards during the 90s, more extreme event occurrences and the number of flood events have increased in West Africa compared to the period from 1966 to the early 1980s. In the same time, (Gachon et al., 2007) showed a positive trend of the 90th percentile of daily total rainfall and the number of days with precipitation exceeding the 90th percentile with respect to 1961–1990.

Climate change impact and innovative farmer's adaptation strategies

From farmers' perceptions and agroclimatic trends
analysis with 50 years of daily rainfall and temperature data observations, the main climate risks in the region can be summarized in decreasing order of importance as: (i) increasing maximum and minimum temperatures; (ii) high rainfall variability; and, (iii) extreme droughts and floods.

In Burkina Faso, Chad and Niger, farmers have attributed a decrease in yield to climate variability and change. According to focus group discussions, another impact of climate change is also manifested, by a decline in soil fertility, because farmers have had to repeatedly replant crops, and abandon longer-cycle varieties (Table 6). Indirect effects also include the increase in plant health problems (diseases and attacks on crops). One of the main impacts of climate change is the loss of surrounding biodiversity. In terms of water resources, the results varied according to country. In Burkina Faso, farmers recorded a depletion of ponds and water points while in Niger, cases of disappearance of ponds and formation of new ponds that did not exist before were reported. Higher rainfall variability and increase in heavy rains in some parts of the Sahel would explain some of these observations. Concerning the irrigated cropping system in Niger, negative impacts of climate change, particularly include temperature increases in accelerating maturation of seedlings in nurseries of lettuce, cabbage and onion. At transplanting, increased abortion rates of all vegetable crops was also noted by farmers, particularly cabbage and tomato. Finally, the increased evaporation, combined with the decline of water resources translate into lower crop yields are considered as the major climate change impacts on production.

To manage rainfall variability, communities in the region have already implemented a wide range of adaptive measures such as micro water harvesting (Zaï) techniques, stone lines (60%), conservation of sorghum residues and organic matter (Barbier et al., 2008). With regard to present climate risk and possible amplification due to climate change, farmers expressed and prioritized new needs in term of adapting agriculture to climate variability and change.

In response to perceived and observed changes in weather patterns, local stakeholders' priorities for adaptations focused in shifting the times of planting dates and relying more on heat stress tolerant crops. They also now have associated agroforestry and forage production crops plus wind breaks to lessen effects of higher temperatures (Niger, irrigated system). In rainfall systems, the main adaptation strategies are targeting more rapidly maturing crops, supplemental irrigation, improving soil fertility management combined with agroforestry (Table 6). According to Traoré et al. (2014), crop management practices based on adjusting the planting date and choices of improved variety are the adaptation strategies most readily available to farmers to deal with the effects of climate variability. However, investment in equipment to manage land is also required to ensure adequate and supportive governance for food security (Mati, 2011). In addition, policies to encourage farmers to use irrigation systems and raise cropping intensity for irrigated area are needed (Valipour, 2014).The effects of different agroforestry techniques in enhancing the resilience of agricultural systems against adverse impacts of rainfall variability, increased temperature; reduced water availability, soil erosion as well as pests, diseases and weeds are accepted by farmers. Agroforestry systems play an important role in terms of increasing carbon stocks in the terrestrial biosphere and then offer opportunities for linking adaptation and mitigation (Albrecht and Kandji, 2003;

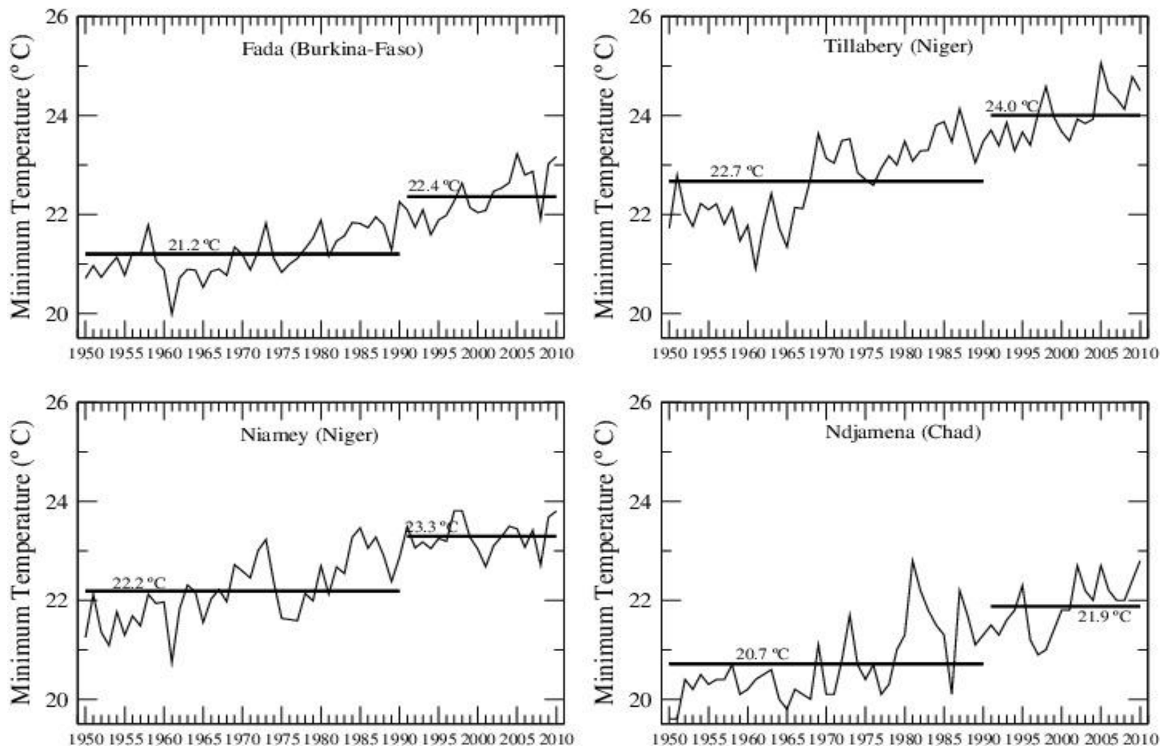

Figure 4a. Average pre- and post-1990 minimum air temperature at four reference stations in West Africa.

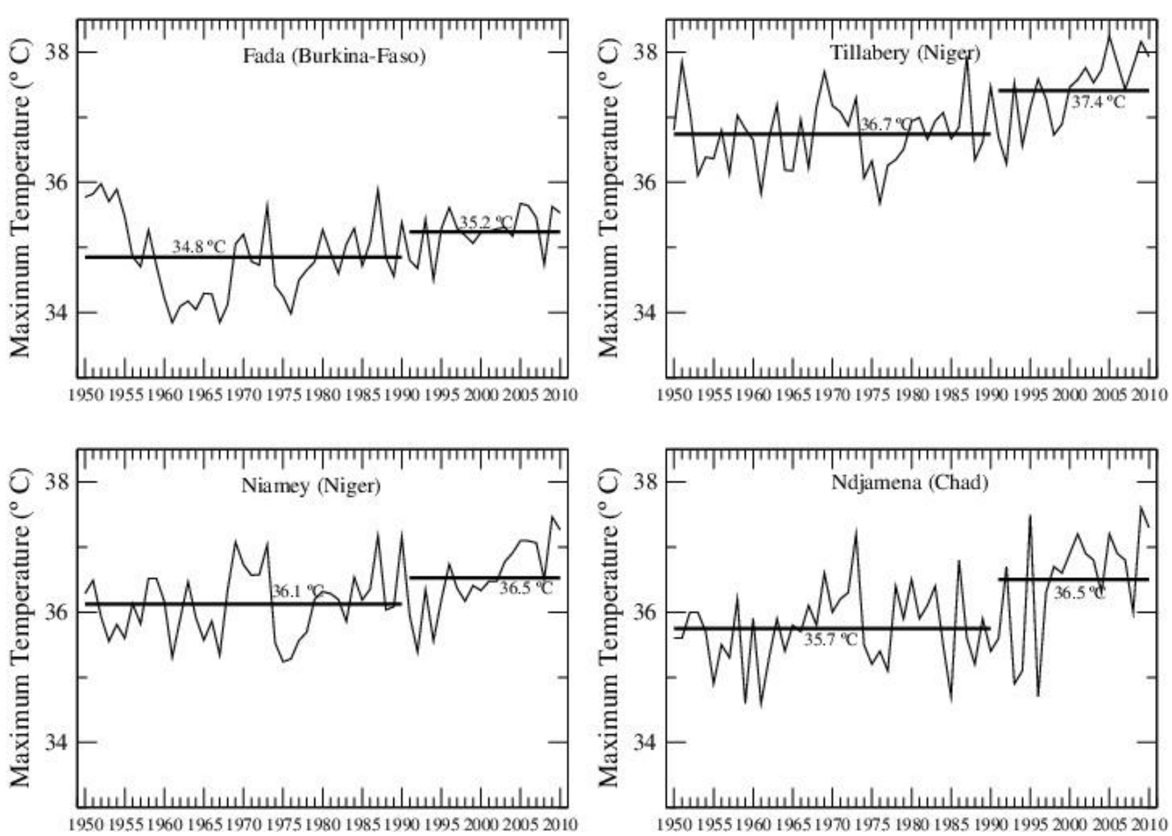

Figure 4b. Average pre- and post-1990 maximum air temperature at four reference weather stations in West Africa.

Table 6. Matrix of specific climate change impacts and innovative adaptation measures.

Country	Department /area Agro ecological zone and cropping system	Main perceived and observed climate risk	Climate impact issues	Farmers' priorities adaptations measures	Rank
Niger	Region of Tillabery 350 -500 mm Irrigated system across the Niger river (irrigated vegetable crop)	Temperature increase Rainfall variability	Increase of abortion rates of all vegetable crop (nurseries and planting stage) Reduced water availability Decrease in crop yield(water stress)	Shift of planting dates and to heat stress tolerant crops associated to agroforestry to cope with high temperature : development of Sahelian farmland with a wide variety of tree species (Moringa oleifera, Bauhinia rufiscens, Accacias trees, Lawsonia inermis, Eucalyptus sp, Ziziphus mauritania) for windbreaks and production of air animal feed	1
				Research on crop calendar, particularly on early planting vegetables crop	2
	Region of Tillabery 350 -500 mm Rainfed system	High rainfall and rainfall component variability, drought, Heavy precipitation and flood events	Abandonment of long-cycle varieties, Increase of frequency or replanting Decrease in crop yield	Supplemental irrigation associated with early rapidly maturing crop, tillage before planting and use of fertilizer	1
Chad	Region of Chari-Baguirmi (Department of Chari) Soudano Sahelian zone 400 to 700 mm	Dought, rainfall variability, Shortened LGP , Heavy precipitation and floods events.	Reduced flood recession sorghum areas Decrease in crop yield and production	Use of improved soil and water conservation management practices, crop diversification, and better soil and fertilizer management in sorghum flood recession cropping	1
				Use of seasonal rainfall forecast in rainfall cropping system	2
Burkina Faso	Region East and Central North Soudanian zone 600 -800 mm Rainfed system	Rainfall decrease drought, reduction of LGP	Yield decrease	Use of crop water stress tolerant Better soil and water conservation techniques	1
		Flood events	Crop losses by waterlogging	Management of lowland and improved drainage	2

Atela, 2012).

In Chad, the use of improved soil and fertilizer management practices, crop diversification is favored. These fertile land flood recession, which retain moisture, have higher potential compared to rainfed land. Intensification of this flood -prone land is attractive because it has so far been more profitable in the recent past. Considering the large geographical extent of these land systems in Chad (Salamat, Guera, Batha), the positive contribution this could make to satisfy food security and address climate change in Chad is worth further investigation. In fact, diversifying crops and cultivars, staggering planting date and managing soil fertility were identified as the major adaptation options to stabilize production against increased rainfall variability (Rurinda et al., 2014).

In Burkina Faso, stakeholders favored the use of drought tolerant varieties, and better agricultural water and land management to address drought. Improving the management of lowland grown crops, are also required. The use of the seasonal climate forecasts are already helping farmers and could help farmers even more to manage climate risk mainly rainfall, onset and cessation date variability if such forecasts were more timely and targeted (Roncoli et al., 2002).

Conclusion

This work revealed that farmers from Burkina

Faso, Chad and Niger are keen observers of climate variability and change and use this information in risk-averse approaches. Farmers are aware of increased temperature, greater rainfall variability and changes to the crop growing period. Furthermore, they have a clear perception of the increasing frequency of extreme events such as hotter temperatures and flooding. These changes are corroborated by observed temperature and rainfall trends. Farmers perceive the major climate risks to manage in agriculture remain as: increased temperature; higher rainfall variability; droughts; and floods. A matrix of innovative adaptations measures were identified to help manage agriculture and water in rainfed and irrigated cropping systems. These adaptations measures focused on heat stress or water stress tolerant crops associated with complementary agroforestry; early maturing crops; supplemental irrigation; the use of improved soil and fertilizer management practices; and the use of the seasonal climate forecasts. These adaptation options, if adopted on a larger scale, will enhance management of the impacts of climate change in the region and assist in climate change mitigation. Resourcing these 'location-specific' and 'knowledge-intensive' practices and accelerating the uptake of such techniques given the scenario and timeline of the changing climate will be the next challenge (OCDE, 2009).

Conflict of Interest

The authors have not declared any conflict of interest.

ACKNOWLEDGEMENTS

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