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Local appropriation of socio-technical innovation: Case study of the shared mechanisation in Benin

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The paper explored different processes of appropriation that sustain experiences of shared mechanisation in Benin. It analyzed the links between groups' homogeneity, the member's representations of shared mechanisation and the processes of setting cost recovery rules for sustainable utilization of farm equipments. We identified some gaps between formal and applied rules in cooperatives and revealed that controlling socio-cultural homogeneity is an upstream strategy used by group leaders to ensure shared values and ease collective action rules making. The challenges faced by cooperatives can lead to the expression of latent heterogeneity factors, justifying a need for permanent rule negotiation.

Key words: Appropriation, Benin, collective action, group homogeneity, shared mechanisation, socio-technical innovation.

INTRODUCTION

The motorization of agriculture is still a challenge in many developing countries although this is required to promote large scale agricultural investments (Sanou et al., 2019). In Africa, up to 80% of lands are manually cultivated, 16% are cultivated with animal traction and only 4% are cultivated with motorized traction (van der Meijden, 1998). African agriculture is kept by smallholders practicing mainly subsistence farming and there is a potential for increasing cultivating lands. For instance in Benin, where smallholders cultivate on average 0.5 to 3 ha, only 37.6% of the agricultural land potential are used. The Government of Benin planned in 2006 to promote mechanisation. Subsequently, a National Council for Agricultural Mechanisation and a National Agency for the Promotion of Agricultural Mechanisation were created to lead the process of mechanisation of agriculture (MAEP, 2006). Especially in North Benin where large extents of lands are available, the mechanisation appeared as an appropriate solution. However, individual farmers can hardly afford a tractor. There was a need for the sustainable institutions, which can make it possible for small farmers to switch over to large scale agriculture. The organisational model of the farm machinery co-operative (CUMA: Coopérative d'Utilisation de Matériels Agricoles) was adopted to be generalised over the country. The CUMA is a form of collective property, organisation and utilisation of farm machineries in contrast with the individual form of property. CUMA is a cooperative which aims at providing its members with agricultural equipments services such as plough with farm machineries. The credo of CUMA is "Let us modernise together our agriculture through shared mechanisation". Shared mechanisation is the utilisation of farm machineries by a group of farmers gathered in

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cooperative at the possible lowest cost, according to the need of each member, through the “mutualization” of the charges (Baris and Grange, 2008, Balse et al., 2015).

The CUMA model was introduced in Benin first in 1995 with the support of AFDI (Agriculteurs Français et Développement International) Dordogne and the Dordogne Department Federation of CUMA of France. An experimental phase was conducted in Bembereke district (Borgou-Alibori Department) in the framework of the Program for the Professionalisation of Agriculture in Benin financed by French Development Cooperation. After many years, the suitable form of CUMA in North Benin was shaped. A CUMA should (i) be officially registered, (ii) operate in a delimited area, (iii) work exclusively for its members who must subscribe shares for five years renewable, and (iv) make decision according the principle of “one person, one vote”. The profile of CUMA adopted in Benin is the one with about 10 members cultivating altogether 100 ha per year and putting together a part of their resources to acquire and use farm machineries including one tractor, one plow and one trailer. The experience was successful and the number of CUMA has increased (Baris and Grange 2008).

Many studies conducted on the mechanisation of agriculture in developing countries mainly dealt with the impact of mechanisation on the performance of agriculture, the reduction of the strenuousness of agricultural activities and the sustainability of agricultural systems. These studies revealed that the mechanisation of agriculture makes it possible (i) for farmers to save labor and increase their cultivated land and incomes (Clavel et al., 2008), and for men and women as well to invest the saved time in other activities (Persiguel, 1997; Faure, 1994; FAO, 2008). Beside these advantages, the mechanisation of agriculture can also threaten the natural resources (Persiguel, 1997; Pingali et al., 1987; Bigot and Raymond, 1991; Faure, 1994; Houmy, 2008; FAO, 2008). Emphasis was put on technical aspects of mechanisation. The shared mechanisation is a socio-technical package, suggesting a certain type of organisation in addition to the modern plowing technology. In a context where many new top-down agricultural technologies were rejected by farmers, the shared mechanisation which apart from being also top-down is more complex was successful. The paper aims at analysing different processes of appropriation leading to the sustainable use of the shared mechanisation. Specifically, the paper analyses the links between group homogeneity, the representations of shared mechanisation, the processes of setting rules within the CUMA and the achievements with regard to CUMA original objectives. We assumed that cooperative leaders try in different ways to control group heterogeneity to ensure the establishment of shared values, to ease rules crafting for sustainable utilisation of farm equipments. This paper contributes to understanding how social capital is enhancing innovation systems and processes. Strong support was found for the positive relationship between innovation and human capital (Dakhli and De Clercq, 2004) and social capital (Landry et al., 2002). Nevertheless, recent studies show that the influence of social capital on innovation is not as relevant as expected (Cáceres-Carrasco et al*.,* 2019).

THEORETICAL BACKGROUND

Debate on the issue of group heterogeneity in collective action is structured mainly by two questions. The first question is about which factors are worth being considered to establish heterogeneity, and the second is whether heterogeneity facilitates or impedes collective action? Heterogeneity can refer to variations in (i) political factors such as agreement on the legitimacy of leaders, (ii) socio-demographic factors such as sex, age, language, ethnicity, education, etc. or/and, (iii) economic factors directly associated with public good such as interest in it, resources available to contribute to its production, cost of those contributions, etc. (Oliver et al., 1985; Marwell et al., 1988; Velded, 2000; Adhikari and Lovett, 2006; Gehrig et al., 2019). These two sets of factors are related so that studies of the latter types of heterogeneity may enhance our understanding of the demographic factors (Heckathorn 1993). Therefore, instead of focusing on heterogeneity factors (wealth, locational differences, sociocultural differences) only, Varughese and Ostrom (2001) suggested to question how these variables are embedded in different situations to influence negotiation and sustaining agreements.

On the other hand, research findings diverge on the impact of group heterogeneity on collective action (Kölle, 2015). Beyond both competing thoughts - that emergence of cooperative behaviour is very difficult to get with highly heterogeneous agents (Seabright, 1993; Kant, 2000; Dayton-Johnson, 2000; Apparao et al., 2019) and that group heterogeneity is conducive to collective action (Olson, 1965; Udehn, 1993; Baland and Platteau, 1996) - came out some more shaded and more complex explanatory models (Oliver et al., 1985; Marwell et al., 1988; Heckathorn, 1993; Vedeld, 2000; Poteete and Ostrom, 2004; Gautam, 2007; Gehrig et al., 2019). For instance, Oliver et al. (1985) and Marwell et al. (1988) argued that heterogeneity of interest increases collective action, and heterogeneity of resources has a null effect or a positive effect on collective action while Heckathorn (1993) posited that, heterogeneity of interests can impede collective action under certain circumstances by polarising a group into opposing subgroups. Uler (2019) came with a more shaded point of view that heterogeneity can increase or reduce social cooperation depending on context: “*Heterogeneity augments collective action when that action's success is most problematic or the benefits of contributing are uncertain. (...)Increases in heterogeneity can promote social change in two ways: By* *weakening existing social power and by fostering the organisation of the powerless. It impedes social change when it strengthens existing power concentrations and further atomises the powerless*". For Varughese and Ostrom (2001), heterogeneity does not have any determinant impact on the success of collective action. Successful groups would "overcome stressful heterogeneities by crafting innovative institutional arrangements well-matched to their local circumstances". Adhikari and Lovett (2006) supported this finding that there is no clear-cut effect of group heterogeneity on collective action and reported that "forest user groups can create institutions for resource management according to their local context in order to avoid management problems created by inequalities among resource users." If the benefits of a change of rules are substantial for a leader or the majority of members, rules can change (Varughese and Ostrom, 2001). Thus, we can even expect discrepancies between formal cooperative rules and truly applied rules.

The effectiveness of such a downstream reactions reported, for example, by Varughese and Ostrom (2001) and Adhikari and Lovett (2006) suggests that upstream avoidance of heterogeneity may be a way to decrease the requirement for innovative institutional arrangements, which are not always easy to construct. Because outside constitution of groups can make it difficult to establish accepted rules (Vollan, 2012), local group leaders may credit the upstream management of heterogeneity and therefore play with cooperative rules. This aspect of heterogeneity was not investigated enough in collective action research. There is still a strong need for understanding how institutional and cultural contexts affect collective action initiatives and how individuals can themselves influence structural variables such as heterogeneity so as to enhance the observance of norms (Ostrom, 2000). Cleaver (2002) argues that the nature, diversity and complexity of institutional crafting in common resource management need to be socially well informed. We did not focus on impact of heterogeneity on group performance. We considered apparently well-functioning cooperatives which had recorded nearly ten years of existence or more. And then we analysed the social processes of appropriation. This approach made it possible to highlight the links between group (farm machinery cooperative) members' representations of the CUMA/shared mechanisation (values, functions, etc.) and the processes of setting rules for the sustainable utilisation of equipments. We focused on value homogeneity and rules making with regard to cost recovery from members.

METHODOLOGY

Study area and selection of case studies

This research was conducted in Bembereke district (3,348 km², 77,354 inhabitants) in Northern Benin, where the shared mechanisation approach was mostly successful (Geay and Clarac, 2004). This area is struck by Soudano-Guinean climate (1000-1200 mm rainfall per year) and occupied principally by Batonou and Fulani ethnic groups. About 75% of people practice agriculture (farming and husbandry) as main occupation. Main crops are maize, bean, yam groundnut and, cotton which is the most important cash crop in Benin (Houngnihin, 2006). During a first exploratory phase conducted in Bembereke district, we surveyed 22 CUMA created between 1995 and 2010 in 10 villages. The size (number of members) of the CUMA varies between 6 and 20 people. We used a theoretical sampling process (Strauss and Corbin, 1990), to select one after the other three case studies. In this sampling process, we assumed that the way a CUMA was created, the cradle especially (church, family, quarter, etc.) would influence its pathway. We then selected respectively the CUMA *Nassara* in Guere village, *Besetindam* in Ina village and *Ankouamon* in Beroubouay village. The selected case studies were different with regard to their (i) working experiences, that is, creation dates, (ii) sizes, and (iii) equipment assets (types and numbers) (Table 1).

Sampling, data collection and analysis

Over two months, semi-structured interviews were conducted with (i) key informants which are 15 leaders of agricultural service organisations providing support to the CUMA, nine CUMA leaders (three leaders for each case study) and six focus groups (two focus groups for each case study) and 24 CUMA members (eight members for each case studies). Direct observation (Mettrick, 1994) was conducted to supplement these interviews. For the two first case studies, sampling of individual members was performed theoretically, that is, decisions on what data to collect and which farmers to interview next were based upon the review of the analyses of previous interviews. In general, after eight farmers in each case, additional interviews did not add new information.

The data collected on the structure and functioning of the CUMA include mainly the membership conditions, governance mechanisms, types of relationship between members, and different services provided by the CUMA to members. For each case study, we carried out systematic analyses at three focus points which are (i) the differences of representations of the CUMA among members, (ii) the negotiation processes of functioning principles leading to congruence or deviation with regard to standard cooperative principles, and (iii) the organisational stability and performance with regard to original objectives assigned to CUMA (evolution of the size of the CUMA, assurance of equipment maintenance, achievement of plowing for members). Cross-case studies analyses permit advancement of general conclusions.

RESULTS

General structure and functioning of farm machineries cooperatives

There are actually more than 150 CUMA in the Borgou-Alibori Department gathered in the Regional Union of CUMA. Although each of them has its own specificities, all the CUMA share in common some general structure and functioning principles mentioned in their constitution. Understanding this general structure and principles of functioning of the CUMA is important to assess the deviation or congruence between formal designs and

Table 1. Characteristics of the case studies.

Village	CUMA's name	Creation date	Number of members	Equipments
Guere	*Nassara*	2003	19	2 tractors, 2 plows, 1 trailer and 1 seed drill
Ina	*Besetindam*	2004	10	2 tractors and 2 plows
Beroubouay	*Ankouamon*	1995	13	1 tractor and 1 plow

Source: Own inquiry.

informal practices. The form of constitution of CUMAs is standard. In this form, only the name of the CUMA and the location village are to be completed. CUMA members are people who decided to gather part of their resources to acquire and manage farm machineries. After its establishment, the cooperative members must contribute about 20% of the cost of the materials they wish to acquire and incur a loan for the rest. The cooperative must manage to regularly pay some annuities. Other members could join the group after approval of the group and payment of their share. A general assembly gathers yearly all members, analyses the management report presented by the leaders, deals with organisational and technical concerns, elects new management committee members and makes decisions which should provide guidance to the leaders. Decision should be made democratically. CUMA are led by elected management committees whose size depends on the size of the CUMA itself. The committee ought to include the president, the secretary, the treasurer and the equipment manager. Tractor drivers are hired for part time. The role of the leading committee is to manage the resources of the organisation with obligation to yearly report on their management. The management committee organises one meeting at the beginning of each agricultural season to decide on the extent of land to plow for each member, according to which the order members' land will be plowed and how much each beneficiary should pay. The utilisation order of the machineries by members is determined primarily by negotiation between members and at random in case of lack of compromise. The tractor drivers implement the agreed plowing plan. The leaders are generally busy with their own farm activities and find it hard to measure the extent of land plowed in members' farm for control purposes. The plowing fees vary according to the need for maintenance and the status of the beneficiary (25,000 to 30,000 FCFA per ha for the members and 30,000 to 35,000 FCFA per ha for non members; 1 EUR = 655.95 FCFA). The fees are used to support fuel, maintenance, personnel (tractor drivers) charges and loan reimbursement. According to CUMA, specific (i) membership conditions setting the size boundaries of the CUMA, (ii) monitoring principles and machineries utilisation rules are implemented. These specific conditions, principles and rules, which can deviate from the original cooperative principles, subsequently determine the appropriation processes and performance of shared mechanisation.

Presentation of the three farm machineries cooperatives

The Nassara Cooperative

The members of *Nassara* CUMA are some members of Union of Benin Evangelical Churches in Bembereke district. The idea to create the CUMA emerged within the church under the responsibility of one leader of the Evangelical Hospital of Guere. Standing since the creation of the CUMA as president, the decisions made by this leader on behalf of the cooperative usually have unanimous support. The CUMA relies on religious ideology. The members share the same faith. Fraternity, solidarity and trust are supposed to be the foundations of the relationships among them and also the value of the CUMA. Most members assign a social function to the organisation.

The CUMA currently owns two tractors, two plows, one trailer and one seed drill. The equipments are used in turn to plough members' farms and to transport agricultural harvest from farms to home. The beneficiaries are expected to pay some fees for fuel, maintenance and loan reimbursement. The cost recovery strategy of the cooperative changed over time. Initially, the cooperative offered services only to members. Members paid their fees in two instalments. The first one is paid before the plough to support fuel cost, the salary of the tractor driver and for maintenance. The second half dedicated to bank credit reimbursement should be paid after harvest and commercialisation. However, some members, who are unable to pay fees for reasons such as illness and recent high expenditures for social events, get services free of charge. In addition, the leaders of the CUMA use collective funds to assist the members in the framework of the organisation of social events such as ceremonies as testified by a member: *"I've got a financial support from our cooperative when my child died. Before me, many members of the cooperative benefited from this help when they lost their mother, or wife."* Even in case of temporary physical incapacity for illness, the Nassara CUMA assisted its members: *"Last year when I was hospitalised, the CUMA ploughed my farm free of charge. I really appreciated this helpful support*". At the end of fruitful agricultural season, the CUMA leaders organised collective festivities to promote friendship and solidarity among members. The cooperative hardly paid off its debts fully. Decision was made to provide non-members with plough services. Non-members of the CUMA can take advantage of the equipment, but they must pay more fees.

At the end of each agricultural season, the leaders present a report on the utilisation of the common resources and the assistance to members. The members we met said to be satisfied with the management and achievements of their cooperative: "*Thanks to our CUMA I do not have to worry about ploughing my farms. My farms are generally ploughed on time. I'm proud and happy to be member of CUMA Nassara. Congratulations to our leaders*". After the cooperative has extended its services coverage to non CUMA members, some members complained for late service provision. Since 2004, the number of cooperative members is stable around 20 and the machineries are functional and well maintained. The extent of the lands cultivated by the members increased from 5.5 to 8 ha on average. The shared religious value and the subsequent representation of the CUMA as a structure with a strong social function is the pedestal of the sustainability of the cooperative.

The case of Besetindam Cooperative

The idea of the creation of the organisation developed within given ethnic group or clan, which shelters it. The members of *Besetindam* CUMA are connected by kin, marriage or close friend relationships. The CUMA owns two tractors and two plows. The leader, head of large family, is the main financial contributor for the acquisition of equipments. He stands as group leader and equipment manager and makes generally alone decisions on the utilisation of the equipments. He is responsible for the maintenance of the equipment. His leadership is not publicly criticised by the other members of the management committee, as he decides on people to be involved or to be excluded in/from the cooperative. The leader of the *Besetindam* CUMA, for instance, contracted bank credit in the framework of the creation the organisation and the acquisition of equipment. To be able to reimburse his debts and to support maintenance charges he gives priority to fee-based service provision to non members of the CUMA. The strategy adopted by the cooperative for cost recovery has been almost stable over time. Fee-based plough services are provided to members and non members. One member stated: "*As cooperative members, we paid 25000 FCFA/ha and non members paid 30000 FCFA/ha. We have been recently informed that we would have to pay yet 30000 FCFA/ha and non members 30000 FCFA/ha.*" Changes occurred in payment modalities as mentioned by the president of the cooperative: "*To help our members, we provided service on credit. Now we switched to cash payment because many people did not pay their debts. No cash, no plough! When the cooperative would not be able to reimburse its debts, I would be the one in trouble*". As the name of the CUMA stipulates it (*Besetindam* means in Batonou language "you should rely on your own craft"), kin relationships as value lost ground and the commoditisation partnership established.

The leader does not feel compelled to account for his management to the others. Such a CUMA functions as a private individual business and the cooperative aspect is used to have easier access to credit or machineries. Many members stated that the machineries are *"president's own investment".* The cooperative is organised around the personality of the president. Members feel indebted to him for having approved their membership. The president frequently receives some present from other members on the occasion of his family events such as baptism, weeding, death. He confirmed as follow: "*For good or sad events in my small family, the members of my cooperative frequently grant me support in cash or in kind (maize, rice, hens, etc.)*".

Since 2004, the number of members of the *Besetindam* Cooperative is stable around 10 and one of two tractors is functional and well maintained. The second tractor has broken down meaning that the performance of the cooperative is limited. This CUMA basically keeps on the original function assigned to CUMA which consists in facilitating access to plow service. However, the governance mechanism does not base on conventional cooperative principles and can lead to excluding or restricting its own members from taking advantage of equipments. The cooperative members adopted compliance behaviour with respect to the norms set by their leader. The extent of the lands cultivated by the members increased from 6 to 7.2 ha on average. The sustainability of the CUMA is ensured at the expense of the satisfaction of the members.

The case of Ankouamon Cooperative

The idea to create the *Ankouamon* CUMA came from young farmers living in the same quarter, with some support of their parents. The membership criterion was the living area. Members are not systematically connected by kin or confessional relationships. The CUMA actually owns one tractor and one plow. The *Ankouamon* CUMA has implemented many times cost recovery strategies, one after the other. At the beginning, the leaders of cooperative calculated all the charges for using the machineries (fuel, maintenance, salaries and loan reimbursement) that each member was expected to pay at once before getting his farm ploughed. Most members could not cope with these costs. Distinction was made between fix charges as contribution to loan reimbursement and charges associated with the extent of

Table 2. Comparison of the three types of CUMA with regard to values.

Types of CUMA	Homogeneity criteria	Initial values	Value changes	Rule-making processes
Ideological CUMA - *Nassara*	Religion	Trust	-	More democratic decision making and monitoring but highly influenced by the president and the equipment manager
Patriarchal CUMA - *Besetindam*	Kinship and friendship	Respect to authority Low of primogeniture	Economic rationality	More autocratic decision making and monitoring by the head of the household who is also the president
Bipolar CUMA *Ankouamon*	Residence area	-	Rationality vs. Collectivism	Decisions are sometimes deals between both groups and sometimes imposed by one of both groups

Source: Own inquiry.

ploughed area. People disbursed the ploughing charges because this was condition for getting services. Loan recovery was not effective at the end of the agricultural campaign. The leaders of the CUMA decided that each member should pay half of his contribution to loan reimbursement together with ploughing costs before service provision. Cash payment of all contribution prior to service provision and service provision to non-members were decided to ensure the survival of the CUMA. Few people were able to afford such possibility but expect ploughing services. Although the CUMA constantly adjusted its cost recovery strategy, the cooperative hardly faced its financial liabilities. At present, when the machineries have a breakdown, some "rich" members pay for the reparation, on credit to the cooperative. The machineries are then put at their disposal until complete reimbursement of the reparation expenses. This practice, specific to this CUMA, fits with its name *Ankouamon* which means in Batonou language "you get what you do".

The lack of a shared value at the outset permits the expression of any kind of heterogeneity. The CUMA *Ankouamon* clearly appears to be heterogeneous with regard to the age or generation of the members. Different age groups of people coexist in the same cooperative. They are supposed to have the same rights in a socio-cultural context characterised by a strong intergenerational gap made of respect. This contrast between modern cooperative principles and local socio-cultural principles raises another challenge. Two groups of members, young and older people, are torn between the social and the technical functions of their CUMA. For young people, only people who are members of the CUMA or who accept to pay additional fees should benefit from the equipment of the organisation. Older people found this position too individualist and posit a more collectivist representation of the CUMA. According to the latter, only people who do not have relatives in the CUMA can be called non-members of the CUMA. To put it another way, once somebody is a member of the CUMA, his relatives and friends should be allowed to use the equipment of this CUMA.

One of them complained: *"I was disappointed because I definitively think that one cannot be looking for money everywhere and causing people's suffering. Our young people do not listen anymore to our views and advices".* The two groups are torn and each of them attempts to control the decision within the CUMA: *"Our so-called wise people do not care about the debts we need to reimburse. They do not like paying their share and would like that we supply service to non members free of charge. They request that we plough for free to their relatives"*

The leaders of the CUMA yearly report on their management to the members. This CUMA face challenge of establishing operational boundaries recognised or acceptable by all the members. Since 2004, the number of cooperative members is stable around 12 and the equipment is functional and well maintained. The extent of the lands cultivated by the members increased from 6.5 to 10 ha on average. The functioning dynamic and the sustainability of the *Ankouamon* CUMA rely on permanent negotiation and compromises between both groups with antagonist representations of the CUMA.

Comparative analysis of how CUMA is shaped by representations of members

According to their features, we distinguished ideological (Nassara Cooperative), patriarchal (Besetindam Cooperative) and bipolar (Ankouamon Cooperative) CUMA. Table 2 presents a comparison of the three types of CUMA with regard to their homogeneity factors, the core values and the rule-making processes. The homogeneity factor targeted upstream by group leaders or creators suggests the core value of the cooperative. The value inspires the rule making processes applied in the CUMA. Where the initial value did not exist (Ankouamon Cooperative) or did not led to shared rules (Besetindam), values and rule making process changed over time, until the establishment of equilibrium.

The functioning of CUMA was expected to align with common principles of cooperative governance structures.

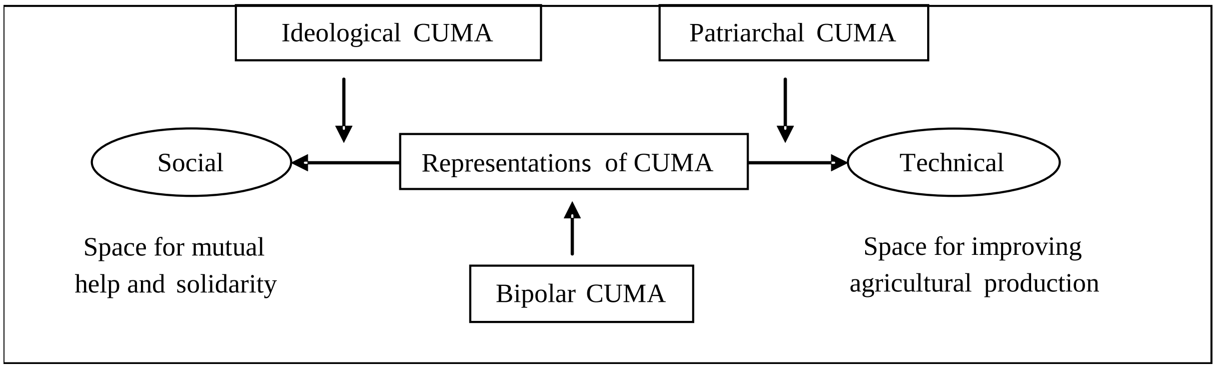

Figure 1. Different representations of the function of CUMA.
Source: Own inquiry.

However, the negotiations of norms and principles take place within CUMA, based on the values and CUMA representations of the members. While some people emphasize the social function of CUMA, other people stress the technical function of CUMA (Figure 1). Accordingly, the cooperative is seen as a sphere of mutual help and solidarity by the ones and as a space for improving agricultural production by the others. Between both extreme representations of CUMA, there is a large range of possibilities. The bipolar CUMA represents the in-between case where both sides of CUMA are perceived at best. In this CUMA, the boundaries, for instance, are usually challenged by its own members divided into subgroups according to their representations of the CUMA, that is, social solidarity or economic rationality.

DISCUSSION

According to Ostrom (1990) and Dietz et al. (2003), the governance structure of farm machineries should follow some principles to be successful: (1) the boundaries, that is, the number of members of CUMA and the numbers of equipments should be clearly defined; (2) the machineries utilisation rules restricting time and land units should be suitable to local farming conditions; (3) the members should have the rights to devise their own institutions and the members affected by the operational rules should participate in making or modifying these rules; (4) CUMA leaders should be accountable to the members; (5) the members who violate operational rules should be likely to be assessed graduated sanctions by other members; (6) the members and leaders should set up operational conflict resolution mechanisms. Our results confirm some principles and illustrate that they are interlinked, but also provide some evidence for shading some of them. Group homogeneity contributes to set up cooperative boundaries (principle 1). Boundaries are defined such as to ease not only the construction of shared rules (principle 2) but also their observance, confirming that beyond the existence of rules, the intern capacity of cooperatives to ensure the observance of rules is important to sustain collective action (Ostrom, 2000). The gap between the operational rules we observed and the theoretical cooperative rules especially those associated with participation of members in decision making (principle 3), accountability (principle 4), and sanction (principle 5) revealed the limit of normative organisational development. For instance, accepted "autocratic" leadership may be favorable to collective action. Such a leadership, based on political or economic heterogeneity (Velded, 2000), can benefit from the complicity or the trust of members who show compliance behavior. In complex conditions, applying this kind of leadership style seems to be for collective action leaders one of the simplest ways to ease the construction and the observance of rules.

Many studies posit that the existence of clear rules is required for collective action to be successful (Beyene, 2009; Kruijssen et al., 2009; Barham and Chitemi, 2009). We showed that to a given homogeneity factor is associated specific values and subsequent rule-making processes. Beside the main formal criteria for membership which are the residence area and the payment of share, other factors such as religion (cultural homogeneity), kinship and friendship (social homogeneity) and residential area (geographic homogeneity) were used upstream by CUMA leaders to ensure common representations, accepted values in order to control rules setting processes within CUMA. This strategy seems to have been successful in *Nassara* Cooperative, showing that group homogeneity can be favorable to collective action as mentioned by Seabright (1993), Kant (2000), Dayton-Johnson (2000) and Flanery et al. (2019). On the contrary, the more problematic results obtained in the other cooperatives are evidence that group leaders can also base on group heterogeneity to sustain collective action, where group homogeneity failed to foster common representation of interest and shared rules. The changes of cost recovery strategies over time (providing services to non-members, requiring cash payment before service provision) are the reflection of the non-effectiveness of the upstream homogeneity setting strategy, meaning the existence of important heterogeneity factors. The expression of these hidden heterogeneity factors (age in *Ankouamon*, economic power in *Besetindam)* required rule re-negotiations in the CUMA, basing on the subsequent values (individualism vs. collectivism in *Ankouamon*, commoditisation principle in *Besetindam*). We can thus agree with Udehn (1993) and Baland and Platteau (1996) that in both cases, group heterogeneity has been the pedestal of collective action sustainability strategy. To sum up, group heterogeneity can be conducive or impede collective action (Oliver et al., 1985; Marwell et al., 1988; Heckathorn, 1993; Vedeld, 2000; Poteete and Ostrom, 2004; Gautam, 2007; Gehrig et al., 2019), depending on context. In opposite to Cáceres-Carrasco et al*.* (2019) who found that social capital does not influence innovation, our results show that farmers are capable of using social capital to develop local institutions that serve their purposes; supporting therefore Landry et al. (2002) on the existence of positive relationship between social capital and innovation.

Conclusion

This paper presents the general structure, principles of functioning of the CUMA and the specificities of three case studies from Bembereke district in Northern Benin. We highlighted the links between groups' (farm machinery cooperative) heterogeneity, the representations of the CUMA/shared mechanisation (values, functions, etc.) and the processes of setting rules for the sustainable utilisation of equipments, especially those related to cost recovery. This perspective made it possible to explore how group homogeneity influences the success of collective action through the promotion of shared rules in the group. The three CUMA we investigated are different with regards to members' representations of share mechanisation, subsequent values and the processes of rule setting. We showed that setting groups with demographic/socio-cultural homogeneity can be an upstream strategy for ensuring shared values and rules in three different contexts. Since a group can never be totally homogeneous, the challenges faced by cooperatives let emerge some latent heterogeneity factors. The dynamic of heterogeneity factors justifies the need for permanent rules negotiation in collective action.

The cooperative is seen as a sphere of mutual help and solidarity by the ones and as a space giving opportunity to improve agricultural production by the others. Between both extreme representations of CUMA, there is a large range of possibilities. Prescribed cooperative principles are then considered as suggestions by the stakeholders. Rules and principles of cooperatives, far from being gained in advance, are permanently negotiated within the cooperatives to make collective action successful. The real and practical principles which are applied result from the confrontation between modern cooperative rules and local socio-cultural norms. The confrontation of members' representations patterns the scheme of CUMA. There is a gap between theoretical and applied rules of the cooperatives. The equilibrium point is found out of the common normative guidelines that should govern the functioning of a cooperative. The acceptance of the equilibrium situation, regardless of its compliance to formal principles, determine or underpin the appropriation model, the performance and sustainability of the farm machineries cooperatives.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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ICT and challenges of agricultural extension education

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After the novel coronavirus outbreak, many countries closed universities. This situation urges to implement online delivery as an alternative method. This study aimed assessing the access to and use of ICT by students, the ICT competencies possessed by the students, and assesses the current level of students' readiness for online education methods in the developing country like Ethiopia. Sample of 106 undergraduate students were selected. Semi-structured survey questionnaire was used for data collection. The findings revealed that most of the students have very limited access to and use of different types of ICTs. Mobile phones are the most popular ICT tool used by students. Poor ICT using competencies is another problem observed. ICT experts in the field of online education need to plan smartphone-based technologies, and it is recommended to offer zero-rated access to specific educational websites, and offer free or discounted mobile internet packages to all students who need it to switch to online classes.

Key words: Online education, coronavirus, students, university, mobile phones, ICT.

INTRODUCTION

Online education has become increasingly popular in the higher education of developed countries within the last two decades, and most higher education institutions in developed countries believe that this method of instruction will be critical for the future of higher education (Allen and Seaman, 2014). The accessibility of the Internet and flexibility of online courses have made online education an integral part of higher education (Li and Irby, 2008; Luyt, 2013; Lyons, 2004).

After the novel coronavirus (COVID-19) outbreak, many countries have decided to close schools, colleges, and universities. The Ethiopian government has also taken the coronavirus pandemic seriously. The initial responses included the closure of private and government schools and universities as of March 24, 2020. The Association of African Universities (AAU) has called upon universities in Africa to move "urgently" to implement alternative methods of delivering teaching and learning using technology and other distance learning techniques in the wake of the closures of higher education institutions to limit the spread of COVID-19 (Dell and Sawahel, 2020). The pandemic is expected to have enormous economic consequences and it is also having a devastating impact on global education. According to the latest figures released by UNESCO, some 1.3 billion learners around the world were not able to attend school or university as of March 23, 2020. UNESCO's figures refer to learners enrolled at pre-primary, primary, lower-secondary, and upper-secondary levels of education as well as at the tertiary level (McCarthy, 2020).

As a means of migration strategy to the loss of learning due to the pandemic, in higher education, many

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universities and colleges are replacing traditional education systems with online delivery methods. In this regard, the outbreak of the virus and lockdowns could be used as the best opportunity for technology interventions for distance learning and virtual online classrooms. However, the online classroom is a new area for both teachers and students in African universities. According to Dell and Sawahel (2020), this transition of teaching method requires expertise in online education, staff, and student training as well as more human power in the area of IT personnel to support both the instructors and the students.

There are a number of factors that make it difficult for people to obtain access to the Internet. These include things such as poverty: high device, data, and telecommunications charges; infrastructure barriers: digital literacy challenges and policy and operational barriers. These challenges represent significant barriers for millions of people in the developing world (West, 2015). According to Salehi and Salehi (2012), insufficient technical supports at schools and little access to Internet and ICT were considered as the major barriers preventing teachers to integrate ICT into the curriculum.

On the other hand, Only about 35% of the population in developing countries has access to the Internet (versus about 80% in advanced economies) (The World Bank, 2020). The internet sector in most Africa countries is relatively backward and the internet coverage rate in Africa lags behind than in all other regions (WIC, 2017). In developing countries like Ethiopia, where there is poor Internet connectivity and frequent power interruptions, implementing online classrooms is a serious challenge. In addition to infrastructure and connectivity, teachers' and students' familiarity with online delivery tools and processes are also key factors in providing distance learning or delivering online classrooms. Therefore, programs that can quickly target those in most need are crucial.

The objectives of this study are to assess the access to and use of ICT resources by students, the ICT competencies possessed by the students, and assess the current level of students' readiness for the introduction of online education methods.

METHODOLOGY

The study was conducted in the year 2019. The target population was undergraduate agricultural extension students in Hawassa University (HU), College of Agriculture (COA), Faculty of Environment, Gender and Development Studies (FEGDS), and the Agricultural Extension (AgEx) program in Ethiopia. For this study, all students enrolled to the agricultural extension program in the year 2018 (second year), 2017 (third year) and 2016 (fourth year) in a total of 106 students were taken as sample respondents. These students are those who are working in 16 zones of the southern regional state of Ethiopia as Agricultural Development agents (DA) in the Bureau of Agriculture and Government-sponsored agricultural extension mid-carrier professionals. Data were collected using a semi-structured self-administered survey questionnaire. The study fully followed the descriptive type of research.

RESULTS AND DISCUSSION

Background information of the sample students

Of the total students, 19 (17.9%) were female and 87 (82.1%) were male. All of the students were enrolled in the agricultural extension program in the faculty of FEGDS, but their field of specialization studied in the diploma program was different. Diploma was a prerequisite for admission to the University degree program. Accordingly, more than half (63.2%) of the students were from the plant science field of specialization (Table 1).

The mean age of students was 30.87, and the maximum and minimum ages of the students were 45 and 23 years, respectively. The average number of households (HHs) the students serving was 696.95 and the maximum number was 2735 HHs (Table 2). All of the sampled students were government-employed and paid monthly salary.

Students access to and use of ICT

Most of the students have no or very limited access to and use of different types of ICT resources such as desktop computers, laptop computers, and tablets. Most have access to mobile phones. They are almost having no access to Wi-Fi or cable Internet services, they are using Internet buying mobile data packages (Table 3).

All of the students had their own mobile phones, and 86 (81.1%) of the students had owned/used smartphones. Regarding money spent on mobile phone use, 91 (85.8%) of the students spent less than 25 ETB per day, and only 15 (14.2%) spent 26-50 Birr per day on mobile phone airtime for calling or data usage. However, 97.2% of the students did not get any financial support for airtime, even calling about government activities (Table 4). All of the students who owned smartphones that is 86 (81.1%) of the total students used the camera App and the internet on their phones (Table 4). This indicates that there is an opportunity for implementing online education using smartphones.

Students who have smartphones use the internet for different purposes. About 86% of the students' primary purpose of using the Internet is to browse social media and 64% use it to download different applications (Table 5).

Students encounter different problems when using mobile phones. This study revealed that out of the total students included in the study, 74.5% suffered from poor network connectivity, 64.2% complained about the high rate of pay for the services, 55.7% lacked electricity for charging their phone battery, and 51.9% had high cost of maintenance, 43.4% encountered application limitations

Table 1. Background information of students (N=106).

Variable	Response	Frequency	Percent
Gender of students	Female	19	17.9
	Male	87	82.1
Field of specialization in Diploma program	Plant science	67	63.2
	Animal Husbandry	7	6.6
	NRM	26	24.5
	Veterinary	6	5.7

NRM = Natural Resource Management.

Table 2. Demographic information of students (N=106).

Variable	Unit	Mean	Std.D	Min.	Max.
Age	Years	30.87	5.286	23	45
Number of households serving	Number	696.95	431.654	137	2735
Monthly salary	ETB	4565.77	1256.530	2470	7364

ETB =Ethiopian Birr (currently 33 Birr is equivalent to 1 USD).

Table 3. Access to and use of ICTs at the office (N=106).

Type of ICT resources	Response	Access to ICT		Use of ICT	
		Frequency	%	Frequency	%
Desktop computers	Yes	5	4.7	2	1.9
	No	101	95.3	104	98.1
Laptop computers	Yes	6	5.7	2	1.9
	No	100	94.3	104	98.1
Tablet	Yes	4	3.8	3	2.8
	No	102	96.2	103	97.2
Wi-Fi or Cable Internet	Yes	7	6.6	4	3.8
	No	99	93.4	102	96.2

and 29.2% encountered language limitations as major problems generally affecting their use of mobile phones (Table 6). This result also complements that of Kacharo et al. (2018) conducted a study on rural households' use of mobile phones in southern Ethiopia. Therefore, this shows that we have to work on the problem of infrastructure and improve connectivity.

Level of competencies possessed by students

ICT competencies among students were measured on a five-point Likert's type of scale: 5 points for high level of competence (extensive experience in the skill area or very skilled), 4 points for moderately high level of competence (good experience in the skill area or skilled); 3=points for average level of competence (some experience in the skill area or average); 2 points for low level of competence (little experience in the skill area or not very skilled) and 1 point for no level of competence (no experience in the skill area or not skilled at all). The study revealed that students either they have average skill or not very skilled or not skilled at all on most of the skill areas they were evaluated especially on using e-mail, preparing power point presentation, using e-library, computer internet browsing, and data information management (Table 7). From this, it can be concluded that most of the students are currently not ready for adoption of online education systems. However, the study also revealed that students who use smartphones

Table 4. Mobile phone ownership and usage (N=106).

Variable	Response	Frequency	%
Type of mobile phone owned	Cell phone	20	18.9
	Smartphone	86	81.1
Money spent on mobile phone per day	< 25 Birr	91	85.8
	26-50 Birr	15	14.2
Have you got any financial support for calling?	Yes	3	2.8
	No	103	97.2
Do you use Camera app of your mobile phone?	Yes	86	81.1
	No	20	18.9
Do you use Internet on your mobile phone?	Yes	86	81.1
	No	20	18.9

Table 5. Purpose and frequency of using the Internet on mobile phones (N=86).

Purpose of internet use	Most frequently		Least frequently	
	Frequency	%	Frequency	%
To brows social media	74	**86**	12	14
To receive and send emails	32	37.2	54	**62.8**
To download other Apps	55	**64**	31	36

Table 6. Major problems encountered when using mobile phones (N=106).

Problems encountered	Response	Frequency	%
Poor network and reception	Yes	79	74.5
High rate pay for the service	Yes	68	64.2
Lack of electricity to recharge phone	Yes	59	55.7
High cost of maintenance	Yes	55	51.9
Application limitation	Yes	46	43.4
Language limitation	Yes	31	29.2

are able to handle online education if they have an orientation or provide a detailed step-by-step guide.

Conclusions

In spite of all the sampled students being government employed with monthly salaries and offices that they are assigned to work in, they have no or very limited access to and use of different types of ICT resources such as desktop computers, laptop computers, and tablets, except mobile phones. This might be the major challenge for higher education institutions to introduce and implement online education to mitigate the COVID-19 pandemic impact on the higher education system. In addition to poor infrastructure and connectivity, poor ICT competencies among students is another challenge, where higher education institutions are expected to do more in addressing the treatment of COVID-19.

Recommendations

Most of the students have no or very limited access to and use of ICT resources like desktop computers, laptop computers, and tablets. However, except those who used cell phones, all smartphone users were able to get access to the internet using Ethio Gebeta mobile Internet packages from ethio-telecom. Therefore, ICT experts in the field of online education in higher education institutions in general, and particularly in universities,

Table 7. Level of competencies possessed by students (N=106).

No.	Competency areas (Skill areas)	Very skilled (5)		Skilled (4)		Average (3)		Not very skilled (2)		Not skilled at all (1)		Score	Rank
		n	%	n	%	n	%	n	%	n	%		
1	Word processing	3	2.8	9	8.5	36	34.0	35	33.0	23	21.7	252	5
2	Data search	4	3.8	18	17.0	32	30.2	27	25.5	25	23.6	267	4
3	Data analysis	2	1.9	8	7.5	34	32.1	31	29.2	31	29.2	237	6
4	Data/information management	1	0.9	8	7.5	25	23.6	35	33.0	37	34.9	219	7
5	PowerPoint presentation	0	0	6	5.7	17	16.0	31	29.2	52	49.1	189	10
6	Using e-mail	1	0.9	2	1.9	14	13.2	31	29.2	58	54.7	175	11
7	Using telegram	14	13.2	11	10.4	28	26.4	23	21.7	30	28.3	274	3
8	Mobile phone browsing	11	10.4	27	25.5	28	26.4	17	16.0	23	21.7	304	2
9	Computer Internet Browsing	2	1.9	8	7.5	17	16.0	26	24.5	53	50.0	198	8
10	Making e-payments (M-Birr, CBE Birr, Amole, mobile banking, Internet Banking)	8	7.5	17	16.0	20	18.9	23	21.7	38	35.8	252	5
11	Using e-library	2	1.9	10	9.4	14	13.2	22	20.8	58	54.7	194	9
12	Taking and sending pictures electronically	16	15.1	23	21.7	28	26.4	20	18.9	19	17.9	315	1

need to plan smartphone-based technologies that help online teaching.

Students are almost having no access to Wi-Fi or cable internet services, and those who have smartphones get access of internet buying mobile packages with a high rate of pay for the services. Therefore, if we plan to use smartphones as a tool for online teaching, it is recommended to offer zero-rated access to specific educational websites, and offer free or discounted mobile internet packages to all students who need it to switch to online classes. On the issue of student access to the internet, universities must collaborate with telecommunications companies (Ethio-telecom) to facilitate the provision of affordable or free access to the internet for as long as the students are accessing education-related websites and information.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the Hawassa University School of Graduate Studies.

The research involved human participants, who were informed about the purpose of the research and that their participation was voluntary.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Determinants of adoption of agricultural extension package technologies by smallholder households on sorghum production: Case of Gemechis and Mieso districts of West Hararghe Zone, Oromia Regional State, Ethiopia

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This study identified the socio-economic factors that significantly influence adoption of agricultural extension package technologies on sorghum crop production. Primary and secondary data were collected for the study. In the sampling procedure, multi stage sampling procedure was used. Data was analyzed using both descriptive statistics and econometric models. In econometric models Multivariate Probit (MVP) and Double Hurdle models were used. Multivariate Probit output indicates that, the probability of the household to use inorganic fertilizer (NPS and Urea), organic fertilizer, crop protection chemicals and row planting were 43.43, 63.07, 12.51, and 25.04%, respectively. Multivariate Probit output also shows that, the joint probability of success and failure of using all agricultural extension package technologies were 3.18 and 24.81%, respectively. Multivariate Probit and Double Hurdle models result confirm that district, extension visit, livestock holding, perception of the expectation of the coming rainfall, total farm land and participation on agricultural training significantly affect adoption decision and intensity use of different agricultural extension package technologies.

Key words: Household, agricultural extension package technology, Multivariate Probit model, Double Hurdle model.

INTRODUCTION

The most fundamental challenge facing the world today and Ethiopia as a country, is food insecurity. For instance, between 1998 and 2012 the average number of Ethiopians in need of food assistance fluctuated between 3 and 14 million (Integrated Regional Information Networks (IRIN), 2012). To divert the problem, the country, Ethiopia has undertaking different programs to enhance the productivity of agricultural crops at the farm level. Ethiopia has been implementing a participatory extension system (PES) since 2010 (Ministry of

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Agriculture (MoA), 2010) following the commencement of the first Growth and Transformation Plan. The major changes made in PES as compared to Participatory Demonstration Training and Extension System (PADETS) were organization of farmers in development groups and social networks (one in five farmers groups, development units), farmers training center (FTC) categorization into watershed management and full-package extension service provision to adopt better technologies (MoA and Agricultural Transformation Agency (ATA), 2014).

Despite such efforts to make the extension system effective and efficient, the system is not producing the desired results (MoA and ATA, 2014). Varies yield and quality improving technologies have been generated in the agricultural sector, but they are not reaching smallholder farmers. Equally, the agricultural sector is not reaching its full potential in terms of attaining food self-sufficiency and reducing poverty. The adoption of new technologies such as agricultural extension packages technologies (AEPTs) improves productivity of agricultural crops if they are implemented properly. Thus, effective and efficient use of AEPTs is encouraged by concerned stakeholders to boost agricultural crop productivity at farm level.

To fulfill the sharp rising demand for food either productivity must be improved, or more land must be cultivated. As it is well known facts which indicate that, cultivation of extra land is very much narrow in west Hararghe due to scarcity of agricultural land. One of the feasible remedy that contributes achieving food self-sufficiency is to enhance the productivity of land at farm level by implementing improved AEPTs. Ethiopian government is undertaking different efforts to improve the utilization of the AEPTs so that productivity of agricultural crops in the rural areas can be improved. Among the known efforts, thousands of development agents were trained and distributed in rural areas of the country. Numbers of FTCs were built and demonstration sites were established to adopt new technologies and implement the extension service in multidisciplinary system. Different projects have also been designed on implementing to enhance realization positive impact of these technologies. For instance Agricultural Transformation Agency (ATA) of Ethiopia is doing different encouraging activities such as developing evidence based application of inorganic fertilizer by developing a digital soil map for Ethiopian agricultural land (ATA, 2014) to improve implementation of new and improved technologies. Even though different efforts were undertaken by different sectors, the productivity of agricultural crops was not improved as it is expected with rapid growth of the food demand in Ethiopia.

Farmers have been adopting AEPTs in the selected districts of the study areas. However, some smallholder farmers did not adopt these AEPTs. Intensity use of AEPTs also deviates from household to another household which results in gaps in crop productivity on crops production in general and on sorghum crop production in particular. According to planning and program section report of West Hararghe Zone of Agricultural Office (WHZAO, 2017) and Muhammed (2020) only 9% of the total cultivated land is sown with full extension package technologies in 2016/2017 crop year. Based on the same report, when zonal cropland area of sorghum is considered, out of total cropland cultivated for different crops, 101,960 ha areas of land cultivated and sorghum crop was planted. Out of the total area planted with sorghum crop, only 841 ha (0.82%) was sown by improved seed with inorganic fertilizer; 12,605 ha (12.36%) was covered by improved seed without any fertilizer; 25,144 ha (24.66%) was covered by local seed without any fertilizer; and 63,370 ha (62.15%) was covered by local seed and organic fertilizer in 2016/2017 crop year (Muhammed, 2020; WHZAO, 2017). These figures show that, there are still problems of using important inputs such as inorganic fertilizer, improved seed and organic fertilizers on sorghum crop production. One of the possible reasons might be because of diverse socio-economic and institutional factors which are not, due attention is given by concerned stakeholders on sorghum crop production.

Plenty of research evidences were available on adoption of AEPTs on other major crops like wheat and maize. However, there are limited research findings that indicate factors that influence adoption decision and level use of AEPTs on sorghum crop production in holistic manner. There is still research gap that shows how the competing and supporting inputs are interrelated. The use of one input may positively or negatively affect the use of other inputs. This can be seen by taking all the package technologies used by the households by exploring important models. By taking only one input, the reality behind implementing and not implementing these technologies may not be identified. Therefore, it is very vital to identify socio-economic and institution factors that affect adoption of the AEPTs in inclusive way and intervene on these factors and enhance use of the AEPTs so that is contributes to the realization of food security plan. Thus, this study identified socio-economic and institution factors that affect adoption choice and use of intensity of AEPTs on sorghum crop production.

RESEARCH METHODS

Description of the study area

The study was conducted in Gemechis and Mieso districts of West Hararghe Zone, Oromia Region State, Ethiopia. According to basic data of West Hararghe Zone of Agriculture and Natural Resource Office (2017), Mieso district is located at about 300 km from Addis Ababa to east in West Hararghe Administrative Zone of Oromia Regional State and 25 km to West of Chiro town, capital of the zone; whereas Gemechis district is one of the districts in West Hararghe Zone which is located at 343 km east of Addis Ababa and

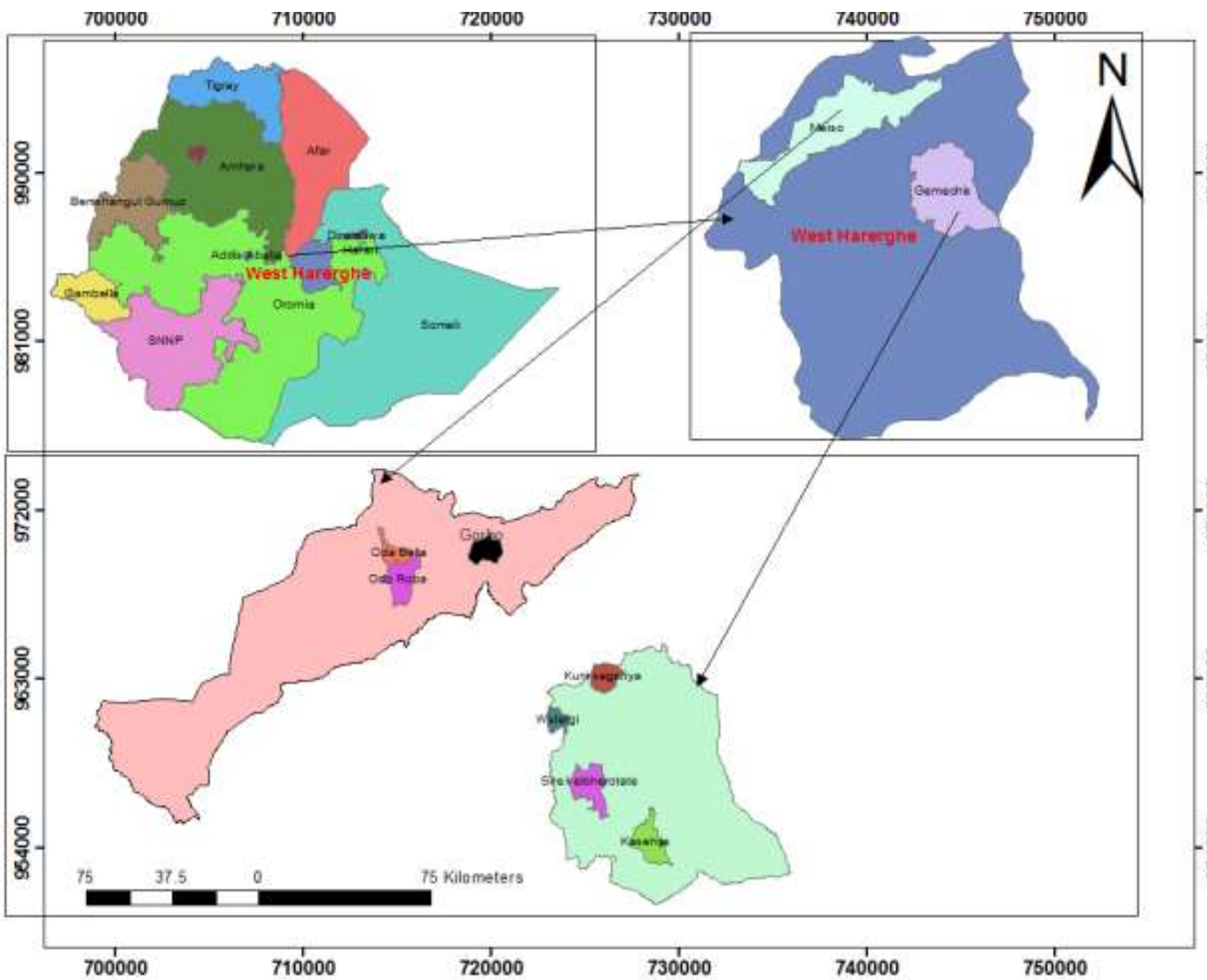

Figure 1. Location of the study areas.
Source: West Hararghe Zone Agriculture and Natural Resource Office.

about 17 km south of Chiro (Figure 1). Mieso district covers an area of 186,716 ha and it has 31 rural and one urban kebeles with total of 31,456 household members; whereas Gemechis district covers an area of 77,785 ha and it has 35 rural and one urban kebeles with total of 38,700 household members. According to the CSA (2017) population projection, Mieso district have 144,750 total populations of which 82,796 and 61,954 are male and female, respectively; whereas Gemechis district have 235,638 total populations of which 119,485 are males and 116,153 are females in 2019. The altitude of the Mieso district is within an altitude of 900 to 2500 m above sea level with an average annual rainfall of 790 mm; whereas Gemechis district is found within altitude of 1300 to 2400 m above sea level with an average annual rainfall of 850 mm. The two districts receive a bimodal rainfall where the short rain season is between March and April while the main rain is between July and September. The economic bases of the population of the two districts are mixed agriculture, which is crop and livestock production. The major crops grown in the district are sorghum, maize, and haricot bean. *Khat*, fruits and vegetables are important cash crops in Gemechis district. Kebele is the smallest administrative unit of the local government. Khat (*Catha edulis*) refers to plant containing a psychoactive substance, cathinone, which produces central nervous system stimulation analogous to amphetamine (Tekalign et al., 2011).

Data types and sources of data

The study was based on both primary and secondary data. Primary data were collected from the sample farm households to know information on different social, economic and institutional variables of sample households. Moreover, focus group discussion and key informant interviews were undertaken with concerned stakeholders so as to support the primary data. Secondary data were also collected from both published and unpublished documents.

Sampling technique, sample size and methods of data collection

Gemechis and Mieso districts were purposively selected for the study because of these two districts have potential of production of sorghum crop and can characterize the highland, midland and lowland parts of West Hararghe Zone.

To choose the sample kebeles and households, multi-stage sampling procedures were used. In the first stage, kebeles of the districts were stratified into three agro-ecologies. In the second stage, numbers of kebeles per the district and agro-ecology were decided and randomly selected based on probability proportional to size.

Table 1. Sample kebeles, agro-ecologies, total HHs and distribution of sample HHs.

District	Name of kebele	Agro-ecology	Total HH heads	Sample HH heads
Gemechis	Harotate	Midland	1494	34
	Kuni Sagariya	Highland	1319	30
	Kase Ija	Lowland	1320	30
	Walargi	Midland	1187	27
	Sub total		5320	121
Mieso	Gorbo	Lowland	1175	27
	Oda Bal'a	Lowland	1207	27
	Oda Roba	Lowland	1165	26
	Sub total		3547	80
Total			8867	201

"HH" refers to Household .
Source: Own survey (2019).

In the last stage, a total of 201 sample households from the selected kebeles of the two districts was taken and numbers of sample households per kebele was decided based on kebeles household population size (probability proportional to the size); finally, households were selected randomly and interviews were undertaken.

The sample size was determined based on formula provided by Cochran (1977). To decide the required sample size, 95% confidence level, 0.5 degree of variability and 7% level of precision were used. Therefore, by using Cochran (1977) formula, the sample size was:

$$n = \frac{pqZ^2}{E^2}$$

where n is the sample size, Z is confidence level (α=0.05), p is proportion of the households participating in adopting agricultural extension package technologies in sorghum production in the study areas and it is assumed that 50% (0.5), q=1-p = 0.5 and E the level of precision given as 0.07. The value of Z at α=0.05 confidence level is 1.96.

Therefore, the sample size was:

$$n = (0.5 \times 0.5)\ (1.96)^2 / (0.07)^2 = 196$$

The formula suggests that 196 sample households should be taken. However, 201 sample households were taken for the study (Table 1).

Based on interview scheduled, primary data was collected by employing a semi-structured questionnaire modified after conducting an informal survey. Pretesting was undertaken on 10 households to correct the questionnaires before formal survey was started. Trained enumerators were used to gather data on different social, economic and institutional variables from sample households. Focus group discussions and key informants' interviews were also made with farmers incorporated from important social groups such as influential persons, members from different social cooperatives, women, youths, development agents, concerned agricultural professionals and administration offices by the researchers.

Methods of data analysis

To address the objectives of the study, descriptive and inferential statistics and econometric models of data analysis methods were employed with statistical software package tool, Stata12. In the descriptive and inferential statistics part, simple measures of central tendencies and variations, frequency, mean, Chi-square test, t-test and percentages were used to assess characteristics of sample respondent households and agricultural extension package technologies used. In the econometric analyses, a Multivariate Probit model was used to identify factors influence adoption decision of agricultural extension packages technologies on production of sorghum and correlation among extension package technologies; finally, Double Hurdle model was employed to analyze the intensity use of AEPTs on production of sorghum crop in the study areas.

Specification of the econometric models

In past researches, despite the recognition that adoption of technology components is multivariate, econometric methods were limited to use feasible approaches such as Multinomial Logit, in which adoption outcomes were redefined to create an order (Kamau et al., 2013).

Recognizing that, parameter estimates based on individual Probit models may be biased by cross-practice correlations. Based on the aforementioned justification, number of scholars such as Mabiratu and Perm (2020), Wondimagegn and Lemma (2016) and Kamua et al. (2013), used Multivariate Probit model for more than one outcome or dependent variables. Based on these justifications, Multivariate Probit (MVP) model regression was selected and used to estimate the probabilities that households use one, two, or three mutually exclusive agricultural extension package technologies. Dependence among decisions was tested and average partial effects were reported. Finally, Double Hurdle model was employed to estimate factors influence intensity use of agricultural extension package technologies.

Multivariate Probit model

Following Tabet (2007) the Multivariate Probit model assumes that each subject has T separate binary responses, and a matrix of covariates that can be any combination of discrete and continuous variables. Specifically, let $Y_i = (Y_{i1}, Y_{iT})$ denote the T dimensional vector of observed binary 0 and 1 responses on the i^{th} subject, i=1,…,n. Let X_i be a Txp design matrix and let $Z_i = (Z_{i1}, \ldots Z_{iT})'$ denote a T-variate normal vector of latent variable such that:

$$Z_i = X_i\beta + \epsilon_i, i = 1, \ldots, n \qquad (1)$$

The relationship between Z_{ij} and Y_{ij} in the Multivariate Probit model is given by:

$$Y_{ij} = \begin{cases} 1\ if Z_{ij} > 0\ ; \\ 0\ otherwise \end{cases} j = 1, \ldots, T \quad (2)$$

Double Hurdle model (Craggit model)

The Double Hurdle model allows for separate stochastic processes for participation and level of consumption decisions (Akinbode and Dipeolu, 2013; Eakins, 2013). The model was first proposed by Cragg in 1971 to allow for two independent processes within the analytical framework. Therefore, a positive observable use of agricultural extension package technologies inputs are dependent on both the choice of the household to adopt and the observed use of intensity. The first process is the decision to participate, and which has a dichotomous variable as the dependent variable. The second process measures the level of use. While the first process is similar to a Probit analysis is used to model the decision to participate, a truncated regression model determines the extent of use of the input. Since the first part of Double Hurdle model is similar with that the Multivariate Probit model result and it is discussed under Multivariate Probit model, only the second part of Double Hurdle model was discussed and analyzed to identify factors influence intensity use of agricultural extension package technologies. The Double Hurdle model is seen as an improvement to both the Tobit and the generalized Tobit (Heckit models) (Cragg, 1971; Eakins, 2013). The Cragg model explicitly allows the factors that determine the adoption and level of use to differ- an independent Double Hurdle model. Following Crag (1971) independent Double Hurdle model is specified as follows:

(A) The adoption decision Equation:

$$d_i^* = z_i{}'\alpha + \mu \quad (1)$$

where

$$d_i = \begin{cases} 1, if d^* > 0 \\ 0, \quad Otherwise \end{cases} \quad (2)$$

(B) The extent of use

$$y_i^* = x\beta + v_i \quad (3)$$

(C) The observed/positive use of agricultural extension package technology inputs

$$y - d_i \quad (4)$$

where d_i is the decision to adopt and y_i^* is the extent of use of the input adopted; y is the observed of agricultural extension package technology inputs use which is a function of both the decision to adopt and the extent of use. Also, μ, is the error term associated with the adoption decision and v_i is the error term associated with the extent of use equation. Thus, positive use of agricultural extension package technology inputs is observed if the household decides to adopt and also use the inputs chosen. Independence is achieved when the following is obtained with regards to the error terms of Equations 1 and 3, when:

$$\mu_i \sim N(0\,,1)$$
$$v_i \sim N(0\,,\sigma)$$

That is, there is no correlation between the two error terms. The independent Double Hurdle model is estimated by maximum likelihood as follows:

$$LogL = \left[1 - \varphi(z_i\alpha)\varphi\left(\frac{x_i{}'\beta}{\sigma}\right)\right] + \sum_{+} ln\left[\varphi(z_i{}'\alpha)\frac{1}{\alpha}\varphi(y_i - x_i\beta)\right] \quad (5)$$

If $z_i\alpha$ =1 then there is no zero adoption and in fact we have a Tobit model, which just estimates the extent of use of the adoption. Where, z_i is the vector of socio economic characteristics and other factors that determine the choice of adoption of any agricultural extension package technology input method among the respondents; $x_i$is the vector of socioeconomic characteristics and other factors that determine the extent use of the agricultural extension package technology input adopted; α and β are parameters to be estimated. This study carried out its empirical analysis on the assumption that the decision to participate and the extent use of agricultural extension package technologies are independent of each other.

Variables definition and working hypothesis

Dependent variables

The AEPTs on the production of sorghum crop in the study areas were included in the model as dependent variables are use of four classes AEPTs of inputs: Y^* was measured using dummy variables with a value of one when the input is used and zero otherwise (inorganic fertilizer = Y_1; organic fertilizer = Y_2; crop protection chemicals =Y_3 and row planting=Y_4). Use of improved sorghum seed was dropped from dependent variables as users of this technology were very few in number. The intensity use of inorganic fertilizer, use of organic fertilizer, use of crop protection chemicals, and row planting were analyzed using the second part of Double Hurdle model for those households used the AEPTs on the production of sorghum crop in the study areas.

Inorganic fertilizer (Y_1): The use of inorganic fertilizer refers to application of available and supplied commercial fertilizer by the local government. The commonly used inorganic fertilizers in the study areas were NPS Boron, NPS Zink, NPS Boron Zink, NPS blend, Potassium, and urea. It takes the value “1” if one or more of these fertilizers are used on sorghum plot; and “0” otherwise. Question is followed by how much amount kilogram of inorganic fertilizer used by the household in the study year on sorghum crop planted plot if the response is positive to know intensity use of AEPTs in the study year.

Organic fertilizer (Y_2): Organic inputs included were application of compost, farmyard manure and bio-fertilizer. It takes the value “1” if one or more of these organic fertilizers are used; and “0” otherwise. Question is followed by how much amount in quintal used by the household in the study year on sorghum plot if the response is positive to know intensity use of AEPTs in the study year.

Crop protection chemicals (Y_3): It is the application of chemicals for controlling diseases, pests, and weeds. It takes the value “1” if one of crop protection chemicals is used and “0” otherwise.

Question is followed by how much amount in kilogram or liter of chemicals used by the household in the study year on sorghum plot if the household response is positive.

Row planting (Y_4): It is refers to the use of row planting for sorghum crop production using recommended row and plant spacing. It takes the value “1” if the row planting is undertaken by the household and “0” otherwise. Question is followed by how much areas of land in hectare was planted by the household using row planting in the study year on sorghum plot if his response is positive.

Table 2. Summary of independent variables and their hypothesis.

No.	Variable	Measurement	Hypothesis of relationship
1	Age of the household head	Continuous	+
2	Administrative or social position of the HH head	Dummy	+
3	Sex of the HH head	Dummy	-
4	Household family size	Continuous	+
5	Education level of the HH head	Continuous	+
6	Frequency of extension visit	Continuous	+
7	The agro-ecological location	Dummy	-
8	District	Dummy	-
9	Slope of the plot	Dummy	-
10	Distance of the plot from the residence	Continuous	-
11	Livestock holding (TLU)	Continuous	+
12	Off/non-farm income	Continuous	+
13	HH Perception on rainfall distribution in the coming crop year	Dummy	+
14	Credit received and utilized	Continuous	+/-
15	Market access	Continuous	+
16	Number of plots	Continuous	-
17	Plot area	Continuous	+
18	Farmers' training	Dummy	+

The independent variables expected to have relationship with the adoption decision and use of intensity AEPTs in the production of agricultural crops are selected based on existing literature. Based on this, 18 variables were selected of which 11 and 7 are continuous and dummy variables, respectively (Table 2).

RESULTS AND DISCUSSION

Before presenting and discussing the results obtained from the econometric models, it is important to briefly describe the socio-economic, demographic, institutional variables and AEPTs adopted using descriptive statistics. This would help to draw a general picture about the study area, AEPTs used and characteristics of sampled household farmers.

Socio-economic and demographic characteristics inputs used by sample households

The average family size for the sample households was about 7.09 persons and ranging between 2 and 15 persons (Table 3).

The mean age of the sample household heads was 41.81 years with a maximum of 75 and a minimum of 22 years. The average education level of the household was 2.05 years. The average area of cultivated, homestead, grazing land and forest land by the sample households of the two districts was 0.74, 0.072, 0.048 and 0.034 ha, respectively. The average land size of the household is 0.924 ha (Table 3). The average number of plots of the sampled households during the survey time was greater than one in number, that is, 1.48 in average. The farm plots of the households take 18.44 walking minutes from the house of the households. The average farming experience of sample households ranges from 9 to 52, with a mean value of 23.27 years. As indicated in Table 3, the average livestock holding was 3.47 TLU. On average 0.232, 0.515 and 0.042 ha of land was allocated for maize, sorghum and *khat* production, respectively during main season of crop year of the 2017/2018 by sample households.

The amount fertilizer (organic and inorganic) used varied from farmer to farmer; as a result of socio-economic, environmental and other factors. Survey result revealed that, average amount of use of fertilizer NPS, Urea and farm yard manure used by the sample households was 19.88 kg, 17.39 kg and 8.38 Quintals respectively (Table 3). As we can see from t-statistic there is significance difference between using these technologies between these two districts. Gemechis district is better using the technologies than Mieso districts because of different factors such as agro-ecology and rainfall distribution.

Agricultural extension package technologies used by households

As shown on Table 4, the result of the survey indicated that, 43.28 and 23.38% of the sample HHs use inorganic fertilizers NPS kinds with urea and urea with other fertilizers, respectively. Regarding organic fertilizer, farmyard manure and compost are the major inputs used

Table 3. Age, family structure, crops grown and inputs used by HHs during the 2017/18 production year.

Variable description	Mean			Std.	t-statistic
	Gemechis	Mieso	Both		
Age	42.59	40.62	41.81	9.57	1.43
Family size	6.89	7.41	7.09	2.32	-1.55
Adult equivalent	5.20	5.59	5.36	1.60	-1.60
Man equivalent	2.87	2.59	2.77	1.07	1.88*
Education level	1.80	2.43	2.05	2.86	-1.54
Cultivated land (ha)	0.47	1.16	0.74	0.49	-13.38***
Homestead area (ha)	0.029	0.136	0.072	0.096	-9.24***
Grazing land (ha)	0.044	0.054	0.048	0.187	-0.36
Forest land (ha)	0.052	0.006	0.034	0.127	2.55**
Total farm land (ha)	0.58	1.46	0.93	0.72	-10.60***
Home to plot average distance (min.)	12.81	26.97	18.44	15.98	-6.81***
Number of plots	1.42	1.58	1.48	0.59	-1.95*
Farming experience	25.25	20.27	23.27	10.48	3.38***
Livestock holding	2.87	4.39	3.47	2.44	-4.53***
Total cultivated Land	0.519	1.397	0.865	0.76	-10.78***
Maize	0.125	0.395	0.232	0.27	-7.79***
Sorghum	0.25	0.917	0.515	0.45	-14.93***
Other crops	0.016	0.003	0.012	0.043	2.15**
Vegetables	0.033	0	0.020	0.06	3.98***
Khat	0.066	0.006	0.0422	0.097	4.48***
NPS	27.24	8.75	19.88	27.63	4.90***
Urea	10.51	4.53	8.13	17.39	2.41***
Farm yard manure	10.89	4.57	8.38	12.87	3.5***

***, ** and * represents significance at 1, 5 and 10% probability level, respectively.
Source: Own computation (2019).

by the farmer in the study areas. Majority (62.19%) of the sample households used farm yard manure and 13.43% of the sample households used compost. Out of the total respondent, only 5.47% of the respondent use improved sorghum varieties in the study areas. Thus, this shows more work is needed to improve utilization of improved sorghum varieties so that productivity of sorghum production can be improved.

Farmers use crop protection chemicals for controlling weeds, worms, pests, insects and diseases. Even though, some of the farmers used crop protection chemicals to control weeds most of the farmers prefer manual weeding. Out of the total respondent, only 12.44% used crop protection chemicals. Of the total household interviewed, only 25% of sample respondent household used row planting on production of sorghum crop.

Sample households used different types of inorganic fertilizers provided by the local government to the study areas. Among the supplied inorganic fertilizer, NPS and Urea are the common ones. From the total sample household respondents, 55.72% did not use any type of inorganic fertilizer. When we compare the two districts, 82.5% of sample households of Mieso district household did not use any kind of fertilizer as this district unsuitable agro-ecology for crop production and low annual rainfall amount and distribution.

Out of the total household respondents, 11.94, 8.96 and 1% used NPS only, NPS Boron, and Urea, respectively. Of the total respondents, 6.47% used NPS Boron and Urea in combination (Table 4). Of the total respondents, 15.9% used NPS and Urea in combination.

Summary of dependent and independent variables

The dependent variables include the inorganic fertilizer, organic fertilizer, row planting and crop protection chemical used as shown in Table 5). The independent or continuous variables are as shown in Table 6. Also, the independent or dummy variables are mentioned in Table 7.

Econometric result analysis

Multivariate Probit model was selected to know factors that affect adoption decision of agricultural extension package technologies by farmers to maintain or improve

Table 4. Farmers adopted ınorganic and organic fertilizer and other inputs in 2017/18 production year.

Inputs used	Gemechis		Mieso		Both	
	Freq.	%	Freq.	%	Freq.	%
No use of any fertilizer	46	38.02	66	82.50	112	55.72
NPS (all kinds)	73	60.33	14	17.50	87	43.28
NPS only	24	19.83	0	0.00	24	11.94
NPS Boron	18	14.88	0	0.00	18	8.96
NPS Boron and Urea	13	10.74	0	0.00	13	6.47
NPS and Urea	19	15.70	13	16.25	32	15.9
Urea (with other fertilizers)	34	27.27	14	17.50	47	23.38
Urea only	1	0.83	1	1.25	2	1.00
Farm Yard Manure (FYM)	95	78.51	30	37.50	125	62.19
Compost	24	19.83	3	3.75	27	13.43
Improved sorghum seed	8	6.60	3	3.75	11	5.47
Crop protection chemicals	16	13.22	9	11.25	25	12.44
Row planting	49	40.50	1	1.25	50	25

"Freq." refers to frequency.
Source: Own survey (2019).

Table 5. Dependent variables.

No.	Types of variable	Unit	Mean	Sd.	Total number of users	%	Total number of non-users	%
1	Inorganic fertilizer use	kg	28. 002	40.36	89	44.82	112	55.72
2	Organic fertilizer use	Qn	8.30	12.99	75	37.31	126	62.69
3	Row planting Use	-	-	-	50	24.88	151	75.12
4	Crop protection chemical use	-	-	-	25	12.44	176	87.56

Source: Own computation (2019).

their plots productivity. The model was selected based on the justification discussed earlier in the methodology part. The adoption of improved sorghum variety by household farmer in the study areas was very small and it was dropped out from the Multivariate Probit model analysis. This study identified the most important determinants affect decision to use AEPTs using a Multivariate Probit model.

The result of the Multivariate Probit model shows that, the likelihood ratio test P (χ^2) (6)>20.324 = 0.0024 of the independence of the disturbance terms (independence of choice of multiple decision in using AEPTs) is rejected, implying that selection of several options of AEPTs in the study areas is interdependent and supporting use of Multivariate Probit model. The binary correlations between the error terms of the four agricultural extension package technologies are shown in Table 8. Results of the correlation between the error terms on Multivariate Probit model indicate that, some AEPTs are substitutes or compete (negative sign) and some are complements (positive sign). The correlation coefficients are statistically significant in two of the six pairs, confirming the suitability of Multivariate Probit specification choice and the choice of agricultural extension package technologies are interdependent.

The correlation coefficients of the error terms are significant for two relations indicating that they are correlated and insignificant for four pair equations indicating that they are not correlated. The simulated maximum likelihood estimation results suggested that, there was negative and significant interdependence between household decision to use organic fertilizer and row planting. This is due to these two technologies are labor intensive technologies and competes for the same labor forces. There was positive and significant interdependence between household decision to use inorganic fertilizer (NPS and urea) and row planting. This may be due to the fact that, once the famer decided to use inorganic fertilizer, row planting was used so that he can maximize the return he will get from the product. Multivariate Probit model regression output revealed that, the likelihood of household to use inorganic fertilizer NPS and urea, organic fertilizer, row planting and crop protection chemicals were 43.44, 63.07, 25.05 and

Table 6. Independent (Continuous) variables.

No.	Types of variable	Unit	Minimum	Maximum	Mean	Sd.
1	Age of the household	Year	22	82	42.08	9.94
2	Level of education of the household	Years of schooling	0	11	2.05	2.86
3	Family size of the household	Man equivalent	0.9	7.8	2.77	1.06
4	Frequency of extension contact	Frequency of visit	0	52	19.06	14.33
5	Distance of the farm plot	Minutes	2	90	18.44	15.98
6	Livestock holding of the household	TLU.	0	17.96	3.47	2.44
7	Off-farm income of the household	Birr	0	20000	775.12	2393.75
8	Credit received and utilized	Birr	0	10000	170.64	1045.55
9	Average market distance	Minutes	0	225	80.39	41.49
10	Number of farm plots	No.	1	3	1.48	0.59
11	Total farmland	Hectare	0.125	5.25	0.936	0.72

Source: Own computation (2019).

Table 7. Independent (Dummy) variables.

No.	Type of variables	Frequency	%	Frequency	%
1	Sex of the household head	Male 175	87.06	Female 26	12.94
2	District of the household	Gemechis 121	60.20	Mieso 80	39.80
3	Responsibility of the household heads	No responsibility 122	60.70	Have responsibility 79	39.30
4	Agro-ecology of the household lives	Highland/Midland 91	45.27	Lowland 110	54.73
5	Perception about the coming rainfall distribution	Better 93	46.27	Bad 108	53.73
6	Slope of the sorghum plot	Flat 132	65.67	Steep 69	34.33
7	Participation on training by the household	Participated 76	37.81	Did not participated 125	62.19

Source: Own computation (2019).

12.51%, respectively as shown in Table 9. As indicated in Table 9. Multivariate Probit model output also indicates that, the joint probability of using all agricultural extension package technologies options was only 3.19% and the joint probability of failure to use all of the agricultural extension package technologies was 24.82%. This implies the probability to use full extension package technologies is 3.19% which is very low at this time. Thus, more efforts and interventions are needed by concerned sectors and stakeholders to improve the probability of using all agricultural extension package technologies in holistic approach in sorghum crop production. In contrast to this, the probability of failure or not to use all agricultural extension package technologies is higher which should be minimized by encouraging adoption full extension package.

Determinants of adoption decision of agricultural extension package technologies

Multivariate Probit model is regressed for 18 explanatory

Table 8. Multivariate Probit simulation result for households agricultural extension package technologies decision to use.

Explanatory variable	Use of inorganic fertilizer (NPS and urea)	Use of organic fertilizer (FYM)	Use of Row planting	Use of crop protection chemicals
	Coefficient (Std. error)	**Coefficient (Std. error)**	**Coefficient (Std. error)**	**Coefficient (Std. error)**
Sex*	0.026 (0.365)	-0.015 (0.334)	-0.356 (0.387)	-0.231 (0.433)
Age	0.002 (0.144)	0.008 (0.014)	-0.003 (0.015)	0.004 (0.017)
District*	-1.308*** (0.503)	-1.406*** (0.498)	-3.147*** (0.890)	-0.179 (0.586)
Education level	-0.015 (0.054)	-0.091* (0.050)	0.028 (0.062)	0.044 (0.056)
Household size	0.441*** (0.138)	-0.078 (0.117)	0.255** (0.128)	0.201 (0.151)
Responsibility of the household	0.059 (0.252)	0.488** (0.246)	0.355 (0.263)	0.305 (0.290)
Agro-ecology* (lowland)	0.418 (0.279)	0.437 (0.291)	0.272 (0.283)	0.315 (0.345)
Extension visit	0.022** (0.010)	0.011 (0.009)	0.010 (0.012)	0.006 (0.012)
Slope of the plot* (Flat)	0.051 (0.156)	-0.014 (0.158)	-0.243 (0.164)	-0.192 (0.177)
Average distance of the plots from the residence	0.001 (0.008)	0.001 (0.008)	-0.012 (0.011)	-0.014 (0.011)
Livestock holding	0.103* (0.059)	0.101* (0.054)	0.160* (0.090)	-0.012 (0.079)
Credit utilized (ln)	-0.026 (0.071)	-0.003 (0.086)	-0.062 (0.077)	0.092 (0.065)
Perception of the HH about future rainfall distribution	-1.023*** (0.225)	-0.681*** (0.124)	-0.489** (0.206)	-0.480** (0.236)
Off/Non farm income of the HH	0.058 (0.041)	-0.006 (0.051)	0.010 (0.039)	-0.044 (0.048)
Market distance from the residence	0.006 (0.004)	-0.0001 (0.004)	0.004 (0.005)	0.003 (0.004)
Number of plots	-0.263 (0.245)	0.299 (0.217)	0.014 (0.257)	0.392 (0.258)
Total farmland owned by the HH	-0.215 (0.262)	-0.002** (0.240)	-0.092 (0.304)	-0.166 (0.317)
Participation of the HH on training	0.581* (0.314)	0.527 (0.265)	0.139 (0.358)	0.803* (0.447)
Constant	0.516 (1.091)	1.661 (1.065)	2.654** (1.312)	-2.208* (1.326)
Mean of Linear prediction of each equation	-0.270	0.506	-1.428	-1.502
Std .error of each prediction	0.504	0.477	0.656	0.599
Marginal success probability for each equation	0.4343	0.6307	0.2504	0.1251
Joint probability (success)	0.0318			
Joint probability (failure)	0.2481			
Correlation between independent variable	**Coefficient (Std. error)**			
Rho21	-0.302(0.191)			
Rho31	0.569***(0.133)			
Rho41	-0.195(0.196)			
Rho32	-0.477***(0.183)			
Rho42	-0.078(0.220)			
Rho43	-0.117(0.303)			

***, ** and * represent significance at 1, 5 and 10% probability level, respectively. Number of observations, 201; Number of simulations, 18; Log likelihood, -288.4647; Wald $\chi^2(72)$, 179.69; Log likelihood ratio test of $Rh_{ij}=0$, P> χ^2 (6) >20.3245, 0.0024.
Source: Multivariate Probit model output (2019).

Table 9. Intensity use of agricultural extension package technologies.

Explanatory variable	Second Hurdle model output (Use of Intensity)		
	Inorganic Fertilizer (NPS and urea)	Organic Fertilizer (FYM)	Row Planting
	Coefficient (SE)	Coefficient (SE)	Coefficient (SE)
Sex	4.928 (11.762)	-0.483 (13.761)	0.038 (0.035)
Age	-0.037 (0.544)	-0.158 (0.510)	0.001 (0.001)
District	-20.297 (19.486)	-36.447** (14.836)	0.103 (0.1070
Education level	0.704 (1.747)	0.805 (1.612)	0.004 (0.006)
Household size	14.874*** (3.548)	1.431 (4.156)	0.017 (0.012)
HH Responsibility	-10.737 (8.384)	-4.853 (8.375)	0.011 (0.026)
Agro-ecology	6.662 (16.470)	13.897 (9.760)	-0.010 (0.043)
Frequency of extension visit	0.6157* (0.358)	1.237** (0.515)	0.002** (0.001)
Average distance of the plots	-0.378 (0.3289)	-0.154 (0.288)	0.000 (0.001)
Livestock holding	4.304* (2.607)	-1.380 (2.189)	-0.028** (0.010)
Credit utilized (ln)	1.110 (2.319)	-3.710 (3.511)	-0.022*** (0.008)
Off/Non-farm income (ln)	-1.232 (1.212)	-5.233*** (2.004)	0.014*** (0.004)
Per. HH about coming RF	-21.103* (11.309)	-0.133 (6.452)	-0.044* (0.023)
Average market distance	-0.116 (0.133)	-0.325** (0.156)	0.001** (0.000)
Number of plots	10.695 (7.779)	20.198** (9.005)	-0.012 (0.054)
Total farmland owned	16.256* (8.984)	7.530 (10397)	0.127**0 (.054)
HH participation on training	-19.279* (10.226)	-18.689 (11.772)	-0.095** (0.042)
Constant	28.754 (33.392)	-14.468 (3.900)	0.045 (0.153)
Sigma	30.379*** (2.865)	21.01***4 (3.900)	0.078*** (0.008)
Number of Observations	89	126	50
Log likelihood	-493.105	-502.123	-16.510
Wald χ^2 (17)	69.19	60.98	31.65
Probability > χ^2	0.000	0.000	0.016
Akaike Information Criteria (AIC)	1060.211	1078.248	107.021

Source: Double Hurdle Model Output (2019).

variables to know factors that affect adoption decision of agricultural extension package technologies on sorghum crop production and the output of the model is presented on Table 9.

The variable district and perception of expectation of household on the coming rainfall from better to bad negatively and significantly influences probability to use inorganic fertilizer at 1% significance level of sorghum crop production. This means that, when we move from Gemechis to Mieso district the probability of using inorganic fertilizer decline. As household perceive negatively toward the coming rainfall distribution, the probability of using inorganic fertilizer become decline. Household family size and frequency of extension visit positively affects adoption decision of inorganic fertilizer at 1 and 5% significance level, respectively. Households with more family size have more probability of using inorganic fertilizer than those households with smaller family size on sorghum crop production. This may be due to those households who have more labor force may produce more output and earn more than those households who have smaller number labor force to purchase inorganic fertilizer. The positive relationship between household family size and adoption decision of inorganic fertilizer is also similar with that of Hassen et al. (2012) and Teame (2011). The positive relationship between frequency of extension visit and adoption decision of inorganic fertilizer is also similar with findings of Umeh and Ekwengene (2017) and Beshir et al. (2012). Livestock holding and participation of household farmer on agricultural training positively affect adoption decision of inorganic fertilizer plots at 10% significance level on sorghum crop production. The positive relationship between livestock holding and adoption decision of inorganic fertilizer may due to the fact that those households who own more livestock have probability of earning more income from the sale of their livestock and livestock products which help them to purchase inorganic fertilizer. However, study by Degefu and Mengistu (2017) shows that, the relationship between livestock holding adoption decision of inorganic fertilizer is negative.

The variable district and education level negatively and significantly affects adoption decision of organic fertilizer at 1 and 10% significance level on sorghum crop production, respectively. The negative relationship between education level and adoption decision of inorganic fertilizer is unexpected. This may be due to house who are educated are younger in age and they have smaller size of land which hinder them to use more inorganic fertilizer. The responsibility of the household and livestock holding positively affects adoption decision of organic fertilizer at 5 and 10% significance level on sorghum crop production, respectively. Livestock holding increases the probability of adoption decision of organic fertilizer at 10% significance level on sorghum crop production. The implication of this is because of those households who own more livestock obtain more livestock farmyard manure and eventually can use more organic fertilizer. Expectation of household on the coming rainfall from better to bad negatively affects adoption decision of organic fertilizer at 1% significance level. This means that, as household expectation is negative toward the coming rainfall distribution, the probability of using organic fertilizer declined. Participation of household farmer on agricultural training positively affects adoption decision of organic fertilizer at 5% significance level on sorghum crop production.

The variable district and household family size positively and significantly affects adoption decision of row planting at 1 and 5% significance level of probability on sorghum crop production, respectively. This means, households with more family size have more probability of using row planting than those households with smaller family size on sorghum crop production. The result might be due to household with more labor force have better probability of using row planting than household with smaller family size, since this activity is labor intensive. The result of MVP indicates that, being having more livestock holding increases the probability of adoption decision of row planting at 10% significance level on sorghum crop production. The implication for the positive relationship between livestock holding and adoption decision of row planting might be due to row planting activity utilizes more labor and requires hiring labor force. This is easy for those households who own more livestock since they solve problem of shortage of cash liquidity to hire labor force, so that they earn income from livestock and livestock products sales. Perception of expectation of household on the coming rainfall from better to bad negatively affects use of row planting and use of crop protection chemicals at 5% significance level. This means that, as household perception of expectation on the coming rainfall is negative, the probability of using crop protection chemicals declined. Rural household farmer forecast about the coming rainfall distribution based on the temporary weather condition of their areas.

Intensity use of agricultural extension package technologies

Double Hurdle model measures the decision and the extent to use with respect to a unit change of an independent variable on the expected value (mean proportion) of the dependent variable. Decision to use of agricultural extension package technologies were already analyzed and interpreted under Multivariate Probit model. In this case, only the Second Double Hurdle part is analyzed and interpreted. Three of the agricultural extension package technologies such as inorganic fertilizers (NPS and urea), organic fertilizer (farm yard manure), and row planting are selected and discussed because they were practiced by significant numbers of the farmer households. The determinants of intensity to use three agricultural extension package technologies such as inorganic fertilizers (NPS and urea), organic fertilizer (farmyard manure) and row planting which were undertaken by majority of the farmers are shown in Table 9.

The choice to use one new technology and the level of using may not be the same. In this case, selection of appropriate model is very crucial. Decision to adopt AEPTs was already discussed under Multivariate Probit model. Therefore, here, only intensity use of AEPTs in the second part of Double Hurdle model is discussed and analyzed.

Double Hurdle model result revealed that, when household family size increased by 1 man equivalent intensity use of inorganic fertilizer increases by 14.87 kg at 1% significance level keeping other factors constant. This may be due to households with more labor force engage in different economic activities; they may earn more income and get more chance to purchase more amount of inorganic fertilizer. The Double Hurdle model output reveals that, as frequency of extension visit increase by one contact, use of inorganic and organic fertilizer increase by 0.615 kg and 1.23 Quintals at 10 and 5% significance level on sorghum crop production, respectively keeping other factors constant. This indicates that, the level use of inorganic and organic fertilizer increases when contact of development agent advice increases as more advices motivate to use more inputs. Double Hurdle model result revealed that, when livestock holding and total farm land owned increases by 1TLU and 1 ha, intensity use of inorganic fertilizer increases by 4.30 and 16.256 kg, respectively at 10% significance level of probability by keeping other factors constant. The positive relationship between total farm land and intensity use of inorganic fertilizer may be due to farmers who own more land use more inorganic fertilizer because of economies of scale which make them reduce total cost per hectare. The Double Hurdle model output shows that, when off-farm income increases by 1% intensity use of organic fertilizer decreases by 5.23 Quintals at 1% significance level on sorghum crop production. The implication for this may be due to the fact that inorganic and organic fertilizers are two substitute goods and as a result those who earn more income may prefer to use inorganic fertilizer than using organic fertilizer as use of inorganic fertilizer less labor intensive input. The Double Hurdle model output indicates that, as average market distance increase by one minute, intensity use of organic fertilizer increases by 0.32 Quintal at 5% significance level on sorghum crop production. The implication of this may be due to the fact that when market distance increase frequency of household to go repeatedly to the market decline and eventually get more time to use organic fertilizer. The Double Hurdle model output shows that, as number farm plot increases by one use of organic fertilizer increases by 20.19 Quintals at 5% significance level on sorghum crop production. The implication of positive relationship between organic fertilizer use and number of farm plot might be due to the fact that farmer use organic fertilizer on some plots and inorganic fertilizer on other plots because using inorganic fertilizer on all plots may be difficult to afford the high price of inorganic fertilizer. The Double Hurdle model output shows that, as household perception change from better to bad, use of intensity of inorganic fertilizer and row planting decrease by 21.103 kg and 0.044 ha at 10% significance level, respectively by keeping other factors constant.

The Double Hurdle model output indicates that, as frequency of extension visit increases by one contact use row planting increases by 0.002 ha at 5% significance level on sorghum crop production. The Double Hurdle model output also shows that, as livestock holding increase by one TLU, use of row planting decreases by 0.028 hae at 5% significance level on sorghum crop production. This may be due to the fact that row planting and managing livestock are labor intensive activities compete for the same labor force. The Double Hurdle model output reveals that, as credit received and utilized increase by 1% use of row planting decreases by 0.022 ha at 5% significance level on sorghum crop production. The Double Hurdle model output also reveals that, when off-farm income and average market distance increases by 1% and 1 min use of row planting increases by 0.014 and 0.001 ha at 1 and 5% significance level, respectively by keeping other factors constant on sorghum crop production. The Double Hurdle model output depicts that, household who participate on agricultural training 0.095 ha and 19.279 kg uses less row planting and inorganic fertilizer at 5 and 10% significance level, respectively than who does not participate on training by keeping other factors constant. The relationship between participation on agricultural training and use of row planting and inorganic fertilizer is unexpected. The implication for the may be household who are screened for agricultural training based on the criteria than selecting model farmers for agricultural training or system of agricultural training have its own problems. Thus, concerned sector should revisit the procedure of screening farmers for agricultural training. Moreover, effectiveness and efficiency of agricultural training provided for farmers should be identified by undertaking further researches.

CONCLUSION AND RECOMMENDATIONS

The study identified the determinants of household's decision to use agricultural extension package technologies using Multivariate Probit model. The correlation between the error terms of different equations were significant indicating that, some AEPTs options such as inorganic fertilizer and row planting complement each other and others such as organic fertilizer and row planting substitutes each other. Multivariate Probit model regression output reveals that, the probability of the household to use organic fertilizer (NPS and Urea), organic fertilizer (farmyard manure), crop protection chemicals and row planting were 43.43, 63.07, 12.51, and 25.04%, respectively. The result also shows that the joint probability of using all agricultural extension package technologies is only 3.18% and the joint probability of failure to use all the agricultural extension package technologies options is 24.81%. Multivariate Probit model result also confirm that, district of the household, education level of the household, household family size, responsibility of the household, extension visit, livestock holding, perception of the expectation of the coming rainfall, total farm land owned and participation on agricultural training significantly influence adoption decision of different agricultural extension package technologies.

The result of the Double Hurdle model shows that, district of the household, frequency of extension visit, livestock holding, credit, off/non-farm income, perception of the expectation of the coming rainfall, average market distance, number of farm plot, total farm land and participation on agricultural training significantly affect intensity use of different agricultural extension package technologies. Various interventions are needed on significant factors such frequency extension visit, livestock holding, credit, off/non-farm income, perception of the expectation of the coming rainfall, average market distance, number of farm plot, total farm land and participation on agricultural training by concerned stakeholders. Multivariate Probit model shows that, there is interdependence of agricultural extension package technologies. Therefore, further research is needed to know how and why these technologies compete or substitute each other and identify optimum combinations of these technologies.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Seasonal climate dynamics, perceptions and multiple risk adaptations: Lessons from Smallholder mixed agro ecosystems in Semi-arid Kenya

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Climate variability is frequently associated with instances of dry spells and droughts, which principally result from highly variable rainfall and increasing temperatures. In mixing agro ecosystems, these phenomena primarily affected crop and livestock practices of smallholder farmers through generating social, economic and environmental losses. Resulting water scarcity, in quality and quantity, at household and landscape level is likely to negatively affect major water dependent livelihoods. In the event of associated and perceived climate variability impacts, households in Wote area of Eastern Kenya at individual level institute adaptations to manage these impacts. The present study used semi structured questionnaires and a focus group discussion to populate household's perceptions and adaptation mechanisms. This study results revealed that households perceived that climatic change and associated impacts are getting more severe. These include instances of higher temperatures and more variable season onset and a wide range of ecosystem deterioration indicators including effects on land health and vegetative cover. Anomalies and means computed from Gridded 10 year rainfall and temperature records from the Climate Research Unit-University of East Anglia (CRU) partially demonstrate similarity to some of these observations. Sampled households employ a wide range of adaptations strategies, principally crop based practices such as cultivation of fast maturing crops and crop diversification. These practices aim at building resilience, taking advantage of new opportunities and can primarily reduce the unforeseen damage and losses resulting from extreme climatic events. Hence, emphasis should be given to crop-based strategies, value addition, forecast based action and financing and localization of water harvesting.

Key words: Climate variability, smallholder, adaptation, Kenya, semi-arid.

INTRODUCTION

Climate change as per the Intergovernmental Panel on Climate Change (IPCC) is as a statistically significant deviation in either the mean of the climate or its variability, persisting for decades or a longer time scale (IPCC, 2001). The United Nations Framework Convention on Climate Change (UNFCCC) distinguishes climate change and climate variability with the former being associated with anthropogenic activities leading to alteration of the atmospheric composition: the latter is linked to natural processes (UNFCCC, 2014) including sea surface temperature changes (Lyon and DeWitt, 2012). Smit et al. (2000) in their analysis of adaptation explain there lies a strong relationship between climate change, climate variability and extremes such that adaptation to change necessarily includes adaptation to variability. From these definitions indirect and direct impacts on human wellbeing is quite explicit. In Africa, climate variability is primarily exhibited by intra seasonal, inter-annual and inter-decadal variations, which present a great challenge in understanding and prediction of trends (Hulme et al., 2001; Borona et al., 2015). In Africa, the rain fed agriculture is highly vulnerable to climate variability and change, which is highly dependent on seasonally unreliable rainfall (Challinor et al., 2007). Such rain fed agriculture covers 97% of the cropland and is mainly practiced by rural small-scale farmers (Calzadilla et al., 2009), using rudimentary techniques. Such numbers indicate Africa is indeed highly vulnerable to climate change and variability impacts, a situation that is exacerbated by non-climatic drivers such as high cost of inputs and high population growth rates (Tubiello and Fischer, 2007; Calzadilla et al., 2009).

Climate change and variability are frequently accompanied by instances of dry spells and droughts, which principally result from highly inconsistent rainfall and high temperatures. Dry spells are lengthy instances of absence of rainfall during onset of the growing period, which may gradually develop into droughts when this length is over 40 days (Mkandawire, 2014). As such, dry spells play a role in shortening of the growing season by occurring within the season, for example delaying the onset of the season. Subsequently, there is a high likelihood of crop failure as well as inter-annual yield variability, especially for moisture stress sensitive staple cereals such as maize (Kambire et al., 2010). Instances of dry spells in arid environments largely influence soil-moisture availability (Kisaka et al., 2015) and may contribute to crop-water deficit during key crop growth stages (Igbadun et al., 2005).

In the event of associated and perceived climate change and variability impacts as well as changes in socio economic conditions, farming communities at individual level employ adjustments or adaptations to manage associated impacts. These adaptation strategies are adjustments or responses by affected households in the face of experienced calamities, stressors or stimuli (Smit et al., 2000; O'Brien et al., 2004) and are an important component of assessing vulnerability to climate change and variability (Smit et al., 2000; Mirza, 2003).

Adaptation practices also aim at taking advantage of new opportunities. These adaptations can reduce the unforeseen damage resulting from extreme weather risks and are important in sub Saharan Africa where there is higher vulnerability exacerbated by lower adaptive capacity (Hassan and Nhemachena, 2008). These adaptations assist smallholder households to achieve their food, livelihood and income security in the face of climate risks and non-climatic drivers such as market fluctuations (Kandlikar and Risbey, 2000). The relationship between climate change and food availability is largely dependent on the timing and nature of adaptation mechanisms (Porter et al., 2014). This could be influenced by the effectiveness of employed adaptation mechanisms including the timing. Smit et al. (2000) and Kandlikar and Risbey (2000) add that adaptations could vary with prevailing climate stimuli and economic and institutional arrangements in place at a particular locality. This implies certain socio economic factors influence the nature and choice of adaptation mechanisms that a household employs (Deressa et al., 2009) with certain adaption mechanisms proving beneficial in addressing climate impacts while others fail (Porter et al., 2014).

According to Adger et al. (2009) in their detailed review, emphasize that a wide range of factors including knowledge on future climate, ethics and their manifestation as well as the value given to places and cultures equally influence climate notwithstanding physical and ecological barriers. Kandlikar and Risbey (2000), who indicate that infrastructure, information systems as well as research for development equally play a role in enhancing adaptation, further reiterated this aspect. Absence of these mechanisms in developing countries amplifies their vulnerability. As such, while adaptation mechanisms remain the key drivers of addressing climate-induced risks among many households in rural areas of SSA, there are combinations of forces that hinder these resilience efforts, subsequently increasing household's vulnerability. These forces range from those occurring at the household and community level to those manifested at the national and regional stage. The devastating impacts and complexity associated with the changing climate and associated evolution of farming community perceptions and innovative responses have inspired individual and collaborative research and/for development. In this regard a wide range of perception and climate trends studies have been carried out in sub Saharan Africa including those showing similarities and differences between meteorological records and farmer observations. Simelton et al. (2013) for example demonstrate some similarities between farmer perceptions and

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meteorological data for example inter-annual variability of rainfall at onset.

Farmers perceptions are an important aspect in detailing climatic variations because farmers are some of the hardest hit by climate extremes and their knowledge, perceptions and choice of adaptation can further inform on future action and solutions (Maddison, 2007; Gbetibouo, 2009; Morlai et al., 2011). In the face of climatic impacts, smallholder farmers have a wide range of perceptions that include observations on climatic trends. These range from increase to decrease or no observable change of certain climatic and related indicators of vulnerability to the changing climate as well as the surrounding ecosystems. This study demonstrates the importance of farmer perceptions and the wide range of response strategies employed to manage and benefit from climatic risks based on these perceived climatic risks.

Since rainfall changes and agriculture are intimately linked, heavy reliance on rain fed agriculture as the main source of livelihood by small-scale farmers, negates household economic status by increasing poverty when climate extremes strike. Specifically, smallholder farmers in Wote are becoming increasingly vulnerable as their adaptation efforts and key livelihoods such as drought resistant crops are eroded (Ifejika, Speranza et al., 2010; RoK, 2013) by ever severer climate impacts. The farmers were the entry point for this study since understanding climate based risks posed among them will inform appropriate and highly transferable adaptive capacities in mixed crop agro ecosystems. Appropriate crop-based adaptation mechanisms and related strategies may assist small-scale farmers to achieve food security in the face of devastating and recurrent extreme events. This constant duel between farmers and combinations of natural risks and hazards inspired the present study.

Therefore, the principal aim of this study is to characterize the nature of perceptions and adaptation strategies of small-scale farmers for the period of 2003-2013, identify changes in land and vegetative cover and utilization of gridded data to detect similarities and variations to farmer perceptions, especially where meteorological records are unavailable or unreliable.

RESEARCH DATA AND METHODOLOGY

The study was part of an ongoing project “Climate change, agriculture, and food security (CCAFS)” which cuts across the Consultative Group for International Agricultural Research (CGIAR) consortium (CGIAR-CCAFS, 2012). The project’s study areas in Kenya include a 10 × 10 Km^2 block in Wote, Makueni County (CGIAR-CCAFS, 2012). The coordinates of the specific sampling block (Figure 1) are 37°.378 E, 1°.657 S; 37°.298 E, 1°.702 S; 37°.244 E, 1°.624 S; 37°.326 E, 1°.581 S (Förch et al., 2011). A preceding study selected 200 households based on dominant production systems within the identified block via stratified sampling, with reference to the administrative divisions (sub-locations and villages) aided by village level leaders (Rufino et al., 2013a). This study purposively sampled 120 farmers who were cultivating the focus crops from 200 households. *Vigna unguculata* (Cowpeas), *Cajanus Cajan* (Pigeon peas) and *Sorghum bicolor* (Sorghum) (referred to as focus crops, hereafter) are examples of drought tolerant crops and their varieties widely cultivated by small-scale farmers in the Wote area in lower eastern Kenya (RoK, 2013). Data collection techniques included household surveys where semi structured questionnaires were used which were characterized by techniques such as multiple responses and likert scales. The likert scale was chosen since it has an array of merits and is one of the most common attitude or level of agreement to statement scales (Monette et al., 2013). In addition, a 15 member Focus Group Discussion (FGD) was held at the community level involving selected men and women with reliable historical knowledge on climatic dynamics and associated adaptation. The focus group discussion was held to populate general community level information on issues around climate variability and was mainly to supplement information gathered at household level. SPSS and Microsoft excel applications were used in cleaning and analysis of collected results from the household and community level. Descriptive statistics were applied in the analysis. At the time of this study, reliable data from synoptic meteorological stations was not available. This is so since the nearest stations are distant and located in different agro ecologies hence are likely to provide unrealistic trend and anomaly results. High-resolution gridded datasets were thus obtained for the study area from the Climate Research Unit, University of East Anglia (Harris et al., 2014). The latest and improved version (4.00) of this data was used by applying a Google Earth Interface to generate estimates of rainfall and temperature records for the study area. These datasets were used in computation of rainfall anomalies and temperature trends to identify the relationship with farmer’s perceptions in the study period.

The study area is largely semi-arid and experiences instances of climate variability. The areas climate is generally semi-arid with the southern part being mainly low-lying grassland, which is suitable for ranching. The mean temperature range is between 20.2 and 24.6°C and is characterized by extreme rainfall variability, which affects farming. Hilly areas receive about 800-1200 mm per annum while the rest of the areas receive about 500mm per annum (RoK, 2013). Further, the existing community mainly practices small-scale rain fed agriculture and livestock rearing. The dominant soils in the study area are luvisols and cambisols (Driessen et al., 2001). Luvisols have favorable physical properties including granular surface soils that are porous and well aerated. Cambisols are characterized by a loamy or clayey soil texture with good water holding capacity and internal drainage. The population density in the larger Makueni constituency, where Wote area lies, is 125 persons per Km^2 and is projected to rise (RoK, 2013).

RESULTS

Perceptions of farmers on climate variability dynamics and changes in selected environmental change indicators

Weather parameters such as rainfall and temperatures and their variation play a key role in influencing agricultural activities and subsequently livelihoods of Wote households.

Extremes of such events are indicators of climate variability and change (Blanco-Canqui and Lal, 2008). To understand the changes associated with weather patterns, households in the study area outlined variations

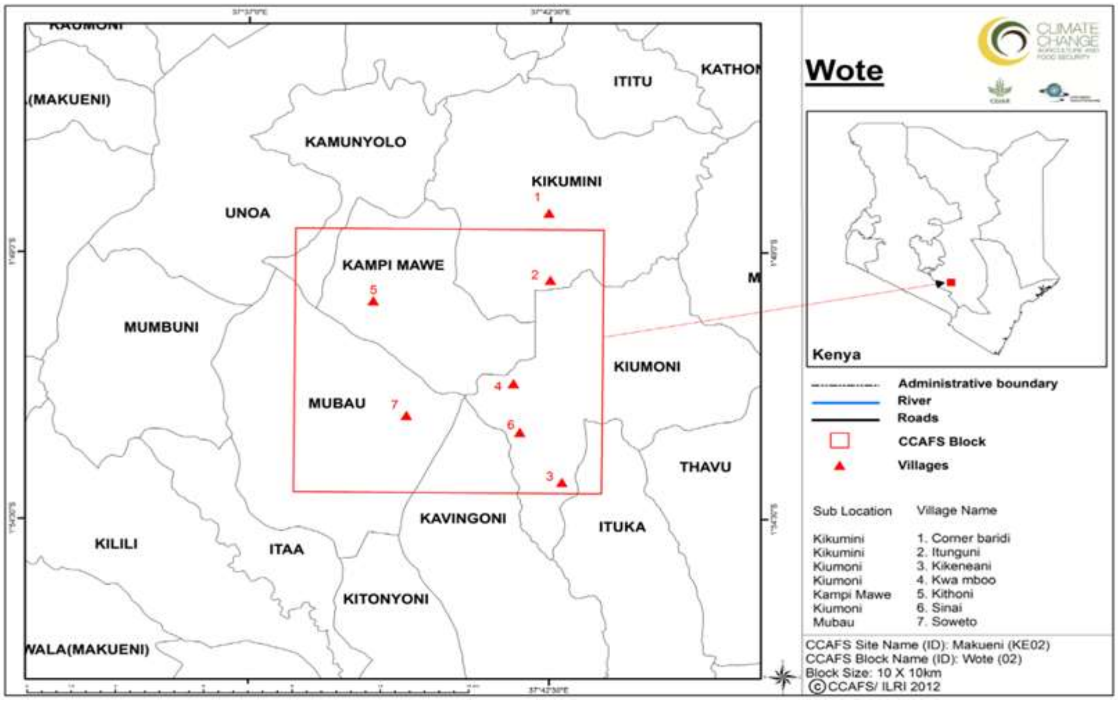

Figure 1. Map showing the study area, Wote, Eastern Kenya.
Source: Förch et al. (2011).

Table 1. Perception on selected weather parameters comparing with 10 years ago as indicated by Wote households.

Variable	Neutral		Slightly agree		Strongly agree		Strongly disagree	
	No	%	No	%	No	%	No	%*
Severer dry season	1	1	4	3	112	93	3	3
Rain prediction difficult			8	7	106	88	6	5
Temperature increased	10	9	10	9	90	85	8	8
Frequent floods	5	4	27	23	6	5	80	67
Higher yields with c. change	3	3	16	13	42	35	59	49
Climate change not big issue	4	3	25	21	74	62	16	13
Get adapted varieties			1	1	117	98	2	2
Dry season shorter			14	12	10	8	94	78
Temperatures decreased	9	8	23	19	9	8	76	63

n=120,*Percentages sum exceed 100% because these are multiple responses.
Source: Authors.

they had observed from the past ten years for specific weather parameters as a measure of perceptions for climate variability. Farmers put forward their perceptions of changes in weather against a four-point likert scale shown on the legend in Table 1 and further noted the direction of selected parameters (Table 2).

The results of the farmer's perceptions in Table 1 indicate that one of the key issues noted by Wote households is severer dry seasons among other risks. A large number of households, 93%, indicated that they strongly agree that there indeed has been a severer dry season over the past ten years. Further, most of the households, 85%, strongly agreed that over the last ten years temperatures have increased. Table 2 also indicates, 76% of the respondents stated that they had noted an increase in the number of hot days and an even a larger number, 88%, indicating increase in dry months. The responses in Table 1 reveal that most of the households interviewed, 88%, strongly agreed that they had difficulties in predicting the occurrence of rainfall over the last decade. The large percentage indicating the none importance of climate variability, 62%, is perhaps

Table 2. Households perception on changes in selected weather parameters over the last 10 years in Wote.

Parameter	Decrease		Increase		Not different	
	No	%	No	%	No	%*
Total amount of rainfall	115	96	5	4		
Short rain onset	98	82	22	18		
Long rain onset	91	76	15	13	1	1%
Long rain duration	112	93	2	2		
Temperature Intensity	20	17	91	76	7	6%
Number of hot days	25	21	91	76%	4	3%
Dry months in a year	14	12	105	88%		
Incidence of floods	99	83	5	4	14	12%
Ground water table	115	96	3	3		
Length of growing period	84	70	35	29		

n=120,*Percentages sum exceed 100% because these are multiple responses.

because of indicated large adaptation responses such as 98% getting adapted varieties. The survey result also revealed that the majority of respondents (96%) witnessed that the amount of rainfall had a decreasing trend in the last 10 years.

Further, in terms of precipitation volume, Table 2, there had been a decrease in the amount of rainfall as indicated by almost all of the households, 96%, with an almost equal number, 93%, experiencing a notable decrease in the long rain season duration. To further bring out the issue of rainfall failure, 67% of the households strongly disagreed that over the last decade there has been frequent floods and an even larger number, 83% stated there was a decrease in flood events over the last 10 years. Table 1, also outlines that while more than half of the households (62%) do not view climate variability as a great challenge almost all, (98%) strongly agreed they need to obtain varieties that could enable them adapt indicating that climate variability features as a concern in farming decisions. In a related aspect, almost half of the households, 49%, further strongly disagreed they had more yields in their farms with the climate variability phenomenon occurring.

Apart from weather related events, respondents further indicated changes in the natural environment and crop performance (Table 3) to identify the direction and timing of key ecosystem changes over the past decade. Almost all respondents, 91%, had experienced an increase in the incidences of crop failure in the last decade (Table 3). Other key perceptions is decrease in land fertility as noted by 91% of the households and decrease in the level of accessible ground water. In addition, increased incidences related to pests and diseases such as new crop pests and diseases have been experienced by most of the households; 94 and 92%, respectively (Table 3). Examples of diseases include blight, head smut, bacterial wilt and maize rust and pests included caterpillars, aphids, stalk borer and cutworms.

The direction of incidence of weeds was almost equal with 47% of the respondents reporting increase and 48% indicating decrease. These incidences indicate minimal change associated with weeds. Nevertheless, where weeds occur on farm there is great risk to crop yield quantity and quality and only add to harvest level drops, which magnify impacts from climatic factors. Only a small number of households, 6%, had perceived an increase in forested area and wild vegetation with almost all, 93%, indicating over the last ten years the vegetated area had decreased (Table 3).

Perceptions on significant climatic and non-climatic changes

In addition to identifying the direction of selected weather and aspects such as land fertility, pests and vegetation loss, households also indicated which of those changes had largely. This approach was also applied by a vulnerability study in the Lake Victoria basin (LVBC, 2011). This is to underline the importance of such climatic and non-climatic deviations to on farm activities. Such significance was noted by denoting a value of one (1) on the respective aspect(s) in this study by the respective household. This was to identify which parameter(s) has/have changed largely, such that the farming household's livelihoods are affected mostly. Changes in the total amount of rainfall were experienced in most, 72 %, of the households (Table 4). Another key change noted is incidences and/or outbreak of pests and diseases as reported by 47% of the respondents. Land fertility was identified as a key change affecting households with most of the households, 71% indicating there was a significant change.

Community perceptions on key calamities and ranking of Key calamities in Wote

At the community FGD, it was also evident the Wote area

Table 3. Responses on perceived changes in selected ecosystem change indicators over the last decades as observed by Wote households.

Indicator	Decrease		Increase		Not different/change	
	No.	%	No.	%	No.	%*
Forest and vegetation cover	112	93	7	6	1	1
Wild animal species	112	93	7	6		
Incidences of crop failure	10	8	109	91		
Incidence of weeds	58	48	56	47	4	3
Outbreak of pests and diseases	6	5	110	92	1	1
Resistance to pests	76	63	40	33	1	1
New crop pests	3	3	113	94	1	1
New crop disease	5	4	110	92	2	2
Ground water table	115	96	3	3		
Land fertility	109	91	8	7	1	1

n=120, *Percentages sum exceed 100% because these are multiple responses.

Table 4. Most significant weather and related changes by count by Wote households.

Environmental change	No.	%*
Total rain amount	86	72
Land fertility	85	71
Outbreak pests and diseases	56	47
Incidence crop failure	31	26
Forest and vegetation cover	28	23
Resistance to pests	21	1
New crop diseases	7	6
New crop pests	6	5
Length of growing period	5	4
Weeds occurrence	5	4

n=120,*Percentages sum exceed 100% because these are multiple responses.

did not experience heavy rainfall related impacts over the past five decades. This gives more evidence of the area being semi-arid though there are some instances such as the el-Niño rains of 1997 reported in Table 5 during the focus group discussion. The results tended to align with the household survey results, Table 5, that most of the community has mainly experienced drought conditions over the last five decades in the years; 1964, 1965, 1974, 1975, 1980-1984, 2009 and 2010. To bring further calamities to perspective households were asked to rank the three key calamities they had experienced with the value of one representing the calamity that had affected them most. The ranking in Table 6 still indicates drought is the major climate related event affecting the households where ($\tilde{x}$ =1).

Observation in changes in rainfall and temperature from gridded rainfall and temperature data

Figures 2 and 3 demonstrate a characteristic inter-annual variation in rainfall with more years recording below the average values of the study period. Rainfall anomalies and seasonal average temperatures were computed using anomaly and temperature average equations as applied by Borona et al. (2016).There was an increasing trend in mean temperatures for both the short and long seasons. Absolute values indicate the highest seasonal rainfall records were in the year 2006. The MAM and OND were used as these are the long and short rain seasons in Wote. Furthermore, the period between 2003 and 2013 was applied to represent the 10 years prior to the study, the same period for the perceptions.

Responses to major climatic and non-climatic changes

Adaptation against drought and instances of unreliable or unpredictable rainfall within the growing season

Drought was ranked as a key calamity in the study area

Table 5. Major calamities in the last fifty years at the community level (Focus group discussion-Wote).

Period	Description of event
1961 and 1997	There was torrential rainfall known as el-Niño .The 1997 above normal el nino floods forced migration of people living along *Kaiti* river
1964 - 1965	There was a drought "*Atta*" implying the brown flour they received then as relief
1974-1975	Which they called "*Longosa*" signifying the minimal movement of Livestock as there was scarce pasture
1980-1984	The drought was known as "*Nikuvaa ngurete*" -"don't depend on me".
2009-2010.	Most recent drought

Table 6. Ranking of Key calamities in Wote.

Calamity	Household number*	Median($\tilde{x}$)
Drought ranking	110	1
Floods ranking	4	2
Erratic rain ranking	51	2
Frost ranking	2	1.5
Wind ranking	16	3
Crop disease rank	82	2
Crop pest rank	85	3
n=120	*Multiple responses	

Due to the ordinal nature of the data, the median ($\tilde{x}$) is the more useful measure of central tendency indicating the most occurring calamity (Huizingh, 2007, Harvey et al., 2014). Other events scoring highly in the ranking order include erratic rains ($\tilde{x}$ =2), floods ($\tilde{x}$ =2) and crop diseases ($\tilde{x}$ =2).

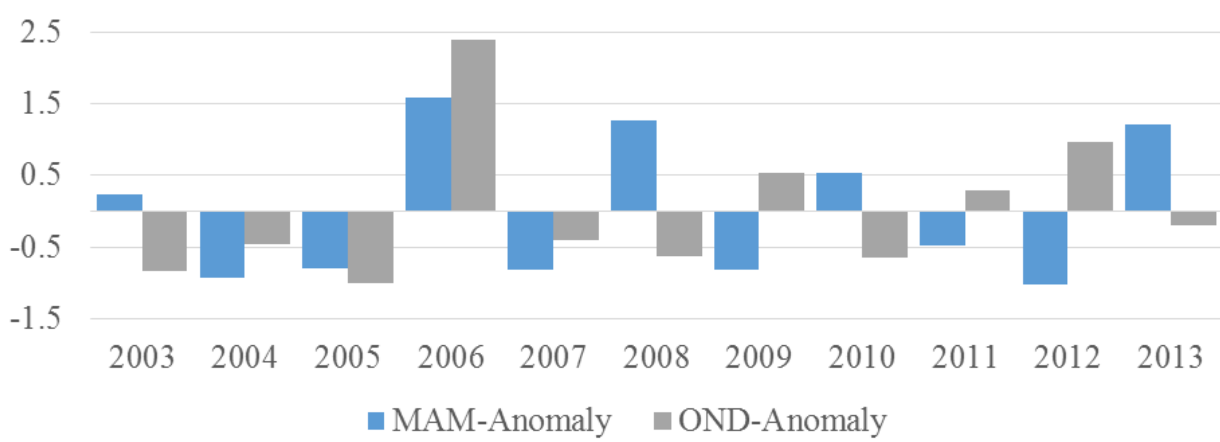

Figure 2. Rainfall anomalies, March, April, May (MAM) and October, November, December (OND), seasons for the period 2003 to 2013, Wote.

affecting most of the households over the years. As such, households engaged in an array of mechanisms to adjust to the frequent occurrences of drought events. Most response mechanisms revolve around farming, Table 7. Most of the households, 65%, have engaged in cultivation of drought resistant crops and varieties, 13% practicing crop diversification and 28% setting up terraces. Households in Wote have made efforts to adjust to erratic rains through several adaptation mechanisms, from Table 8 most of the households, 39%, established terraces with 18% cultivating cover crops to manage instances of erratic rains.

A few households employed related mechanisms such as contour ploughing, 4%, agro forestry, 8% and water catchment, 6%. Crop based mechanisms of adaptation also feature, though in smaller numbers, in adaptation to

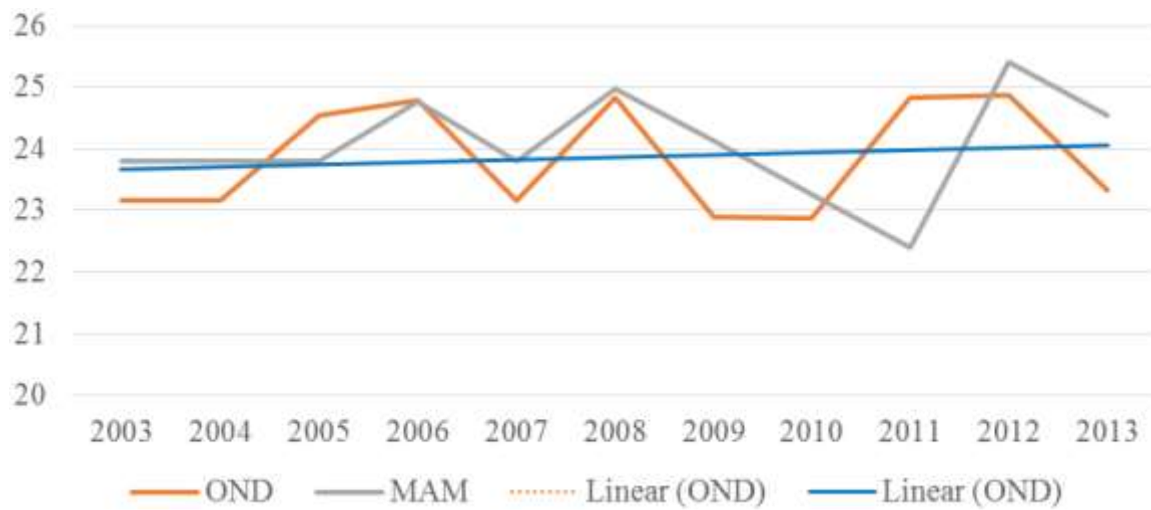

Figure 3. Mean temperature trends, March, April, May (MAM) and October, November, December (OND), seasons for the period 2003 to 2013, Wote.

erratic rains as shown in Table 8 just as they feature prominently in drought adaptation. In response to erratic or irregular rains, there is minimal cultivation of drought resistant crops perhaps there is a focus on moisture retention through terracing and cover crops.

Adaptations to crop pests and diseases in Wote

To adjust to the effects of crop pests and diseases households in the study area employed an array of mechanisms notably application of pesticides by most of the households, 88 and 65% respectively, Table 9. Potential mechanisms such as intercropping and cultural methods such as push-pull featured minimally as adaption means.

A small number of households responded to crop pests' instances by cultivating resistant crops, 7% and crop rotation 5%. Adaptation mechanisms aimed at adjusting to crop disease attacks, Table 9, are very similar to crop disease responses. Households, 13%, Table 9, indicated that they cultivated disease resistant crops in their farms as a means of curbing crop diseases a choice also featuring highly in crop pest responses.

Adaptations to changes in land fertility and vegetative cover changes in Wote

Households in Wote employ two main adaptation mechanisms to manage soil fertility including application of manure, 68% and inorganic fertilizer, 16%, Table 10. Vegetative cover provides a wide range of ecosystem goods and services such as soil erosion control vital for the sustenance of farming households in Wote. Loss of this cover implies loss of several vital ecosystem functions. To adapt to such changes in vegetative cover households engaged in an array of mechanisms including cultivation of cover crops, 11% and a few, 8% practicing agro forestry, Table 10.

Access to weather and calamities information as an adaptation mechanism in and selected adaptation mechanisms in Wote

Weather as well as pests and disease outbreak information access among vulnerable communities is important. Such information assists in informed adaptation decisions while engaging in farming especially when to purchase inputs and start land preparation. Households mentioned which specific weather information they had received over the last two years, which denoted the actual access to weather, and calamities information as a mechanism of adaptation. From Table 11, a larger number of the households, 81% had received weather information on extreme events forecast as well as forecast for the start of the rains. An equally larger number of the households, 73% had received information on occurrence of pests and diseases.

DISCUSSION

Perceptions to the changing climate and environment

Recent studies in the sub Saharan region have demonstrated the usefulness and importance of perceptions in climate variability and change studies among farming households including, Hassan and Nhemachena (2008), Deressa et al. (2009), Mertz et al.

Table 7. Drought adaptation mechanisms by households in Wote.

Adaptation means	No.	%*
Drought resistant crops	78	65
Terracing	34	28
Crop diversification	16	13
Early planting	9	8
Building wells	7	6
Early land preparation	6	5
Fast maturing crops	5	4
Off farm income	5	4
Agroforestry	3	3
Irrigation	3	3

n=120, *Percentages sum exceed 100% because these are multiple responses.

Table 8. Adaptation against erratic rains by households in Wote.

Adaptation mechanism	No.	%*
Terracing	47	39
Cover crops	22	18
Agroforestry	9	8
Water catchment	7	6
Contour ploughing	5	4
Drought resistant crops	5	4
Fast maturing crops	5	4
Manure	3	3

n=120, *Percentages sum exceed 100% because these are multiple responses.

Table 9. Adaptation to crop pests and diseases in Wote.

Adaptation mechanism against crop pests	No.	%*
Pesticides	105	88
Resistant crops	8	7
Crop rotation	6	5
Early planting	5	4
Weeding	2	2
Adaptation mechanism against crop diseases		
Pesticides	76	63
Resistant crops	16	13
Crop diversification	1	1
Fast maturing crops	1	1
Increasing acreage	1	1

n=120,*Percentages sum exceed 100% because these are multiple responses.

(2009), Apata et al. (2009), Simelton et al. (2011), Morlai et al. (2011) and Nizam (2013). In the present study, households mentioned that it was getting warmer over the study period. This increase in temperature is characterized with higher intensity and longer warm days and months. This scenario has implications on evaporation demand in the already semi-arid Wote area ecological profile. This could contribute to water stress

Table 10. Adaptations to land fertility and vegetative cover loss in Wote.

Adaptations to land fertility	No.	%*
Manure	79	68
Fertilizer	19	16
Terracing	8	7
Adaptable crops	5	4
Crop rotation	4	3
Adaptation to vegetative cover loss		
Cover crops	13	11
Agroforestry	10	8
Destocking	3	3
Buying fodder	2	2

n=120, *Percentages sum exceed 100% because these are multiple responses.

Table 11. Weather and calamities information received over the last two years by Wote Households.

Information received	No.	%*
Drought forecast	97	81
Start of rain forecast	97	81
Pests and disease forecast	88	73
Forecast for 24hrs or next 3 days	58	48
Weather for next 2 to 3 Months forecast	46	38

n=120, *Percentages sum exceed 100% because these are multiple responses.

even to the popular drought hard cereals. As the households mentioned, effects of temperature increase because of climate variability and change, have had an effect on crop growth and subsequent yields as well as livestock productivity with eventual contribution to food scarcity and assets loss. These trends have been discussed by related work exploring perceptions on climate change in ASALs in east Africa with reference to the same period, such as Mary and Majule (2009) in Tanzania and Macharia et al. (2012) in Kenya. Indeed temperatures are a key driver of crop growth and development and variations do negatively affect crop growth and production by altering soil water balance (Blanco-Canqui and Lal, 2008). Studies also show that temperature variation and intensity influence crop yields in several ways especially when such parameter is on an upward trajectory, increasing in intensity is experienced for lengthy times (World-Bank, 2013). For example, by altering organic matter content of soils (Letcher, 2009) which is critical for soil health. Temperature changes also affect crop growth and yield by influencing evapotranspiration (Datta et al., 2008) and more so by coinciding with sensitive crop growth stages (Lin et al., 2008). Datta et al. (2008) also argue that spatial-temporal changes in temperature among other weather parameters can also influence farmers on farm decisions on input use as well as crop management, which eventually affects the yield.

Rainfall distribution/regularity as reported by households has been exhibiting an unpredictable and erratic behavior. In particular, there is a worrying trend associated with late onsets and early cessations subsequently shortening the critical growing season length even during the more reliable longer rain season. Intra-seasonal distribution has an amplifying effect on this impact and this could be the reason households identified a decrease in rainfall volume perhaps due to fewer rainy days. This decreasing volume could even be more impacted by the higher temperatures leading to loss of and inadequacy of the scarce water resource above and below the soil.

Rainfall failure and poor distribution leads to dry spells, which are a precursor of drought conditions, which severely affects farming activities by causing crop failure (Zeleza, 1997) or bringing about low yield quality. Macharia et al. (2012), in a perception to climate change and variability study among farmers in arid and semi-arid areas of eastern Kenya, also found out that changes in rainfall patterns and increased drought instances or more frequent drought spells. Related perception studies in arid and semi-arid areas of East Africa have similarly shown a similar trend in reduction of rainfall amount and distribution (Mary and Majule, 2009; Mongi et al., 2010) including instances of erratic rainfall in several African countries (Simelton et al., 2011). Erratic or unpredictable rains are associated with delayed and inconsistent onset, shorter duration and even consecutive rainy days characterized by intense downpour within the onset and cessation window (Simelton et al., 2011). Such erratic rains are a concern in arid and semi-arid environments such as Wote, as the households emphasized. This is because erratic rains negatively affect farming activities particularly making prediction of the start of rains difficult for farmers subsequently contributing to ill-timed and inadequate land preparation.

Significant changes in weather and other key elements in Wote

Since variation in rainfall occurs in Wote as a key change, households are at risk of effects resulting from such key determinant of crop development and more so livelihoods largely dependent on farming. In particular, households mentioned the total rainfall amount has decreased and this trend could be contributing to incidences of crop failure as a direct or indirect impact. Perhaps households experienced lower rainfall volume because of shorter rainfall duration and inconsistency in the number of rainy days or rainfall intensity. In addition, household’s livelihoods are largely dependent on crop and livestock keeping hence the likely paying of attention to and observation of rainfall changes.

Rainfall indeed is a key source of water, a precious commodity in farming households used in crop cultivation, household chores as well as watering of livestock. Inadequacy and variation of such rainfall and by extension climate variability (Wallace, 2000), has been linked to crop failure, livestock death or disposal and food insecurity around SSA (Haile, 2005). Severe crop failure could have far-reaching implications on the households in the study area because of the heavy reliance on farming as a primary livelihood strategy. Kurukulasuriya et al. (2006) in their marginal climate impacts study, note eventual effects of crop failure on household revenues on affected households, more so in the drier areas of Africa. Studies have also pointed out that yields can be sustained or even increased in severe climate events, when appropriate adaptation measures are employed (Dinar and Mendelsohn, 2011). This could explain why some households identify climate variability not being a key concern. Nevertheless, this study reveals that climate variability is a risk to reckon with as households are compelled to institute a wide range of adaptation mechanisms.

Other than rainfall variation, the experienced decrease in land fertility could be partly attributed to repeated cultivation of land over the years due to land scarcity; the focus group discussion participants mentioned this. In addition, the increase in population, leads to reduced land sizes and reduced fallow intervals where land is not taken out of production for nutrient replenishment. This contribution resulting from rise in population numbers is also mentioned in other studies such as Bekunda et al. (1997) and Gruhn et al. (2000). Loss of fertility could further contribute to loss in other on-farm resources such as less fodder, less firewood and less crop residues and an array of other ecosystem goods (Sanchez et al., 1997; Sanchez, 2000). In addition, since most of the households are small holders there is a high likelihood, they have minimal investments to purchase inorganic fertilizers. Other potential drivers could include; variable and inadequate rainfall and rapid evaporation that induces soil erosion and insecure land ownership rights that curb soil fertility investments (Gruhn et al., 2000).

Relating farmer perceptions to rainfall and temperature records

Analysis of CRU rainfall records for the study period (2003-2013) demonstrated a trend of drier years more than wet years. The resulting anomalies such as highest rainfall records in the year 2006, 334 mm (MAM) and 734 mm (OND)depict observations made by NASA in 2006 and 2007 (NASA,2007). Rainfall anomalies indicate that the long (March-April-May) and short (October-November-December) seasons include 6 and 7 years respectively with below average records in the MAM and OND seasons (Figure 2). These records demonstrate similarities with some key farmer observations relating to rainfall distribution. This scenario could perhaps be resulting from, as farmers put it, rainfall amount has decreased, and the season onset and cessation have become late and early respectively. Subsequently the rain or growing season has shortened. It is also likely farmers experienced less number of rainy days hence the observations such as increase in the number of dry days and months and fewer records of floods. The semi-arid environment of the study area can also be a causal factor of these observations.

Figure 3 demonstrates inter annual variation in seasonal mean temperatures for the short and long seasons. We used a linear trend line to detect any monotonic trend (Increase or decrease). The linear trend line indicates an overall rise in seasonal temperature means during the study period. This observation exhibits some similarity with the farmers observations in particular the perception that the number of hot days and months and subsequent temperature intensity has increased over the years. Observed similarity between farmer perceptions with rainfall and temperature records, demonstrates a method of understanding intra seasonal trends in climatic parameters in particular where instances of limited data are prevailing. In addition, observed similarity outlines the value and importance of including both resident farmer perceptions and climate records in climate variability studies to generate valid inferences and insights. This combination is also useful where both data sources and options exhibit limitations.

Other studies such as Jiri et al. (2015) and Shisanya and Mafongoya (2017) show that farmers had experienced increased temperature and reduced rainfall volumes which were positively reflected by meteorological records. Mamba et al. (2015) on the other hand demonstrate how correct perceptions on weather variability as compared to rainfall records informed adaptations that aided in investment decision making which facilitates better yields and food security. These studies indeed show farmers largely make correct and reliable observations that can be equated to or compared with meteorological data. These observations are important as they inform appropriate policy, which leads to fitting adaptation steps. In addition, the importance and usefulness of meteorological data and farmer perceptions is complementary as each has its own strengths and weaknesses.

Response strategies against climatic and other environmental changes

A large number of households in the semi-arid Wote area cultivate crops and varieties that target the prevalent drought in the area. These crops and varieties include certain varieties of cowpeas, pigeon peas and sorghum. These crops and their varieties have demonstrated physiological characteristics that make it conducive to thrive in the soils in this area and more so withstand the prevalent moisture stress. Cultivation of these legumes guarantees the households a source of food, fodder and income even in instances of extreme drier conditions. Combining these strategies with related adaptation approaches such as early planting, cultivation of fast maturing crops and early land preparation even further assures of robust resilience even when multiple extreme conditions strike. Crop based drought and erratic rains response mechanisms are widespread as described in adaptation studies involving smallholder households. These include growing of drought tolerant crops and varieties (Mahu et al., 2011; Mwang`ombe et al., 2011; Rufino et al., 2013b) and crop diversification (Woodfine, 2009).

Another popular crop based response intervention is crop diversification targeting to address drought conditions. Smallholder farmers in Wote cultivate different focus crops within the same plot in the same growing season. In other instances, the level of diversification goes a notch higher to include different varieties. It is likely that few of the households in Wote that involved in crop diversification aim at reducing the risk of extreme events where all crops fail. Agroforestry is widely applied in farming communities and involves cultivation of certain multipurpose legumes to minimize loss of available soil moisture and ensure water availability for crop growth. Agroforestry, which involves on farm cultivation of certain multipurpose trees and shrubs such as mangoes, is also a key strategy that offers farmers in Wote the wide range of products and services. In particular, this highly beneficial mechanism facilitates control of soil erosion in the face of erratic rains and is a concurrent source of food, income, fodder and firewood. Related studies similarly demonstrate that an approach such as crop diversification is a popular means adopted against climate extremes among farmers in other areas of sub Saharan Africa (Deressa et al., 2009; Mertz et al., 2009; Bizuneh, 2013) including semi-arid parts of Kenya (Recha, 2011).

A more labour intensive avenue in response to erratic rains is establishment of terraces. This demonstrates commendable efforts by households to institute radical interventions to capture and control runoff in the prevailing dry agro ecology. Terracing aims to conserve elusive soil moisture in arid and semi-arid areas (Mwang`ombe et al., 2011). Terraces are classified as structural interventions or modifications of original land topography in sloppy landscapes aiming at soil erosion control and enhancement of soil moisture retention (Blanco-Canqui and Lal, 2008). This soil water management benefit could be the same driver informing some of the farmers to respond to erratic rainfall by adopting contour ploughing. In a further effort to capture, the scarce water resource households set up water catchments. These establishments have a high adaptation potential and include certain water harvesting systems aiming at capturing precipitation in semi-arid environments as Woodfine (2009) mentions.

The large number of households utilizing pesticides indicates access to such chemicals and more so knowledge on modern farming techniques in response to crop pests and diseases occurrence. The farmers however did mention, during the focus group discussion, that they would welcome support in form of information on the appropriate chemicals and application procedures or dosage to use in pest control through farm demonstrations and exchanges with support from private or public extension services. This indicates that while smallholder farmers are able to access pesticides sold at local agro veterinary centers they may not have the necessary knowledge on dosage and appropriate application times and products. In other cases, they may violate the restricted entry interval or appropriate time to visit crops once agro chemicals are applied (WSDA, 2009). This could increase their vulnerability since uninformed utilization of such pesticides may influence their health and safety. Further, unintended abuse of agro chemicals can result in resistance by pests as well as destruction of ecologically useful parasites and predators (Lenné, 2000). Nevertheless, pesticides play a big role in alleviating hunger resulting from crop yield losses when used appropriately.

As instituted by a few of smallholder farmers in Wote, early or timely planting as a means of avoiding pests is primarily to ensure crops are past sensitive growth stages before pests strike. Crop rotation on the other hand controls pests by ensuring crops are not cultivated in a specific plot of land over long periods of time, a state that encourages pest concentration and constant attack and possible massive crop failure. These results further show there is an opportunity in investing in and focus on strategies against crop pests and diseases that are crop based.

Application of manure to manage soil health is commonly practiced because of the availability of the product within households and is mostly obtained from reared livestock albeit in smaller quantities. This manure is a substitute to the more costly inorganic fertilizer and primarily promotes soil fertility and subsequent improved crop performance. The importance of manure cannot be underestimated as this input plays a part in ensuring food sufficiency by improving crop yields. In most instances, manure is applied just before planting is done or continuously as crops grow with the aim of maximizing plant yields. Manure does indeed contribute to the improvement of soil fertility by addition of key nutrients (Nitrogen, Potassium and Phosphates) to soils when applied appropriately (Woodfine, 2009). Most smallholder farming communities are unable to access the inorganic fertilizers because of their high costs, though there are proposed solutions with potential benefits such as integrated soil fertility management (ISFM) (Vanlauwe, 2002). Further as Muyanga and Jayne (2006) mention farmer behavior could also inform soil health management" less endowed farmers are risk-averse and are less likely to spend on new technologies rather they exhibit the 'wait and see' mentality".

Among households in the study area, natural vegetation plays a big role in the provision of a wide range of environmental services and goods including; soil erosion control, food, fodder and fuel wood. Destruction and/or modification of vegetative cover will hence bring about loss of such products and services, which are vital for the livelihoods of the households. Cultivation of cover crops as pertains to adaptation to vegetative cover loss aims at reducing open soil surface, which encourages soil erosion and eventual crop loss. These cover crops also contribute in reducing the exposure of seedlings to high temperatures at sensitive crop growth stages. The mechanism is mentioned in other studies related to adaptation such as land degradation studies in Ghana by Mahu et al. (2011). Agro forestry on the other hand in response to vegetative cover improvement aims at ensuring farming communities restore vegetative cover through planting of multipurpose trees and shrubs on farm. This ensures households benefit from an array of environmental goods and services including raising the value of land. As such, institution of agroforestry practices is a noble adaptation strategy that ensures constant supply of key environmental benefits including in periods when extreme events prevail. Establishment of agro forestry systems is also an important shelter from effects of wind and water erosion at landscape level; plants roots anchor the soil and subsequently reduce runoff (Blanco-Canquis and Lal, 2008).

Weather as well as pests and disease outbreak information access among vulnerable farming communities is important. Such information assists in informed adaptation decisions while engaging in farming such as when to start farming with regard to the start of rains. Ranking of extreme weather information such as drought indicates the exposure and sensitivity of the households to drought, which has been noted as the key calamity, by households in Wote. Information on the start of rains is equally key since rainfall greatly influences land preparation dates as well as start of planting and subsequent performance of crops in arid and semi-arid areas. Rainfall also influences several other household aspects such as pasture availability and subsequent livestock productivity. Households equally showed importance to weather information for the next 24 h to three days. Such ranking indicates that households prefer weather information into the near future. Weather information for one to three days plays a key role in averting sudden climate extremes notably flash floods and dry spells which could severely affect household's wellbeing. Access to forecasts of varied composition and timing including drought forecasts in appropriate lead times, provides an avenue for informed and participatory forecast based action to avert impacts (Ingram et al., 2002; Roncoli et al., 2009).

Conclusions

This study demonstrates that smallholder households in the Wote area of eastern Kenya perceive that there has been changes in the local climatic conditions over the last decade. These observations tally with some climatic estimates generated from CRU gridded rainfall and temperature records. There is a wide range of changes in climatic parameters as experienced by the farming households. These changes include instances of increased temperatures as well as more dry days and months. Furthermore, there are perceived instances of change in the amount of rainfall as well as late onset and early cessation of the growing season. Farmers experience other environmental change indicators partly resulting from, their own land use activities and climatic factors. These environmental change indicators include loss of vegetative cover and deterioration of soil fertility. These wide ranges of climatic and non-climatic changes have prompted a plethora of responses with the motivation of cushioning and accruing benefits from occurring impacts. Crop based strategies are primary responses among the households and include strategies also identified by related studies in Africa.

The study forms a platform for informing action aiming at supporting smallholder farmers in mixed crop agro ecosystems. To this end, the study identifies principal entry points that can effectively support such households including more emphasis on the crop based strategies including but not limited to drought resistant varieties. Furthermore, novel-farming techniques can be encouraged or supported, with more emphasis on farm value addition and improved farming systems appropriately blending the use of organic and inorganic fertilizers. In addition, in the face of unpredictable climate variation forecast based action and financing methods come in handy. This effort can be accompanied by localization of climate adaptation policies with incentives that inculcate the culture of water harvesting.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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