Farmer choice of strategies alleviating food insecurity due to changing weather patterns

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1. Introduction

Food security remains a major uncertainty for households across the globe. Despite many efforts, sub-Saharan Africa still accounts for a large number of food insecure individuals (Conceição et al., 2016). Arouna et al. (2017) estimated that over 239 million people in sub-Saharan Africa are undernourished and consume less than 2100 food calories daily. Vulnerability to climate changes such as droughts or floods increases undernourishment risk and rises mortality in sub-Saharan Africa (Bain et al., 2013; de Onis and Branca, 2016). The persistent lack of adequate food, even if temporary, causes a number of sub-Saharan countries to be prone to social instability, which could lead to recurrence of the food crises observed in 2008 (Arouna et al., 2017). Household food security has been also affected by the unpredictable nature of weather pattern affecting crop yields.

Food security in sub-Saharan Africa faces many uncertainties ranging from inadequate production resources to weak value chains, which leads to poor linkage between farms and markets (Piesse and Thirtle, 2009; Trimmer et al., 2017). Farm productivity must double by 2050 to meet the growing needs of the sub-Saharan Africa population which is projected to increase from 1.0 billion in 2017 to 1.9 to 2.3 billion in 2050 (Godfray et al., 2010). Acute food insecurity in West Africa's rural areas is also reflected in expenditure pattern of nutrient dense foods consumed by urban households (Meng et al., 2018). Food crop availability, which determines good nutrition and living standards of the society, is exacerbated because of poor allocation of funds to agricultural research and irrigation schemes. In the beginning of 21st century, climate change and weather variability have been identified by researchers as contributing factors to food insecurity affecting society in the developing countries (Rosegrant and Cline, 2014). Other factors contributing to food insecurity in this region include food price increases, which sometimes lead to riots (Legwegoh et al., 2015) Strategies to improve household food security through crop intensification, value addition and market mechanism have been suggested (Godfray et al., 2010). Crop specific strategies to boost sub-Saharan Africa food security include intensification of rice production since rice is considered a staple on the continent (Molua, 2002; Nakano *et al.*, 2014; Conceição *et al*., 2016). Per capita cereal consumption has been about 175 kg in The Gambia, where rice accounts for 117 kg and other field crops for 58 kg (IFAD, 2007).

Knowledge of farming options to improve a farm household resilience and reduce the susceptibility to food insecurity that also counter adverse weather events, progressive changing climate (Mudombi-Rusinamhodzi et al., 2012), and poor resource endowment is a pre-requisite for the suitable strategy adoption fitting regional conditions. However, there has been inadequate number of studies examining the familiarity with alternative adaptation strategies among rural residents, especially in isolated vulnerable communities (Thomalla et al., 2006). This paper examines the awareness of strategies by subsistence farmers to cope with food insecurity and adaptation to progressive climate change in Lower River Region of The Gambia. The study applies survey data collected from the predominantly agricultural, poorly urbanized region of the Lower River Region in the summer of 2017, with special attention paid to adaptation strategies that have potential to improve crop production and household resilience to weather and climate adversities. Both climate change and weather effects are intertwined and although they differ (IPCC, 2007) the farmer adaptation plays key role because of agriculture’s role as the main employer in the country and an important sector of the economy. Specifically, the paper identifies adaptation mechanisms to improve rural household food security and scrutinizes factors that influence the knowledge of each strategy. Information about factors associated with such knowledge is essential in developing policies and programs needed to enhance food security in the studied region. Additionally, since the identified strategies are not unique to the region or The Gambia, the study offers insights useful in formulation of approaches applicable in effective handling of food insecurity in other parts of sub-Saharan Africa, which share similar socioeconomic and environmental conditions. The contribution of the current study is the quantification of the effects farm, farmer characteristics, and farming practices have on the probability of knowing about each of the adaptation strategies in a country and the region suffering from exceptional poverty. Decision-makers, who lack insights into the factors driving illiterate, ultra-poor farmer choices can now compare the influence of various factors on a particular strategy and elect strategies that fit best local environmental conditions and that lead to a sustained resiliency of rural household facing food insecurity.

2. Food security

Food security is defined as having access to sufficient volume of safe and nutritious food, which meets individual dietary needs and preferences for an active and healthy life (Rosegrant and Cline, 2014; Acevedo *et al.,* 2018; McCarthy *et al*., 2018). The Food and Agriculture Organization (FAO) conceptualizes food security as when people meets all the components of food security for sustenance of the life (Pinstrup-Andersen, 2009). Still, others categorize food security into three common pillars: food availability, access, and utilization (Faso *et al.,* 2006; Barrett, 2010). Food availability or access to the adequate volume meeting nutritional requirements is a common theme of various definitions. For many farm households the availability of food is linked to their ability to grow a variety of crops. The primary risk associated with crop production involves the uncontrollable weather events such as droughts or floods.

Weather patterns are the driving force of food availability and accessibility in the short run and the future weather patterns and climate change in Africa have been subject to a number of studies. Acevedo et al. (2018) evaluate food availability and, in particular, food production limitations as related to environmental conditions. Richardson et al. (2018) assess vulnerability of food insecurity under climate change and adaptation scenarios at a country level and find that sub-Saharan Africa would be severely affected by all considered scenarios. West et al. (2014) reported that closing the yield gap could enhance food availability that will meet the essential food needs of the growing population, while taking into account ecological sustainability. In a similar study of yield gap as a solution to food security in The Gambia, Sanyang et al. (2013) found that maize yield could be increased using an improved variety and through an efficient use of inputs. Overall, the studies of the effects at the aggregate level, national or regional, provide an overview of the effects, but need to be complemented by studies of households that take the brunt of the progressive climate changes and have to cope with the food insecurity in the aftermath of catastrophic weather events.

2.1. Catastrophic weather events in The Gambia and climate change

The Gambia is highly vulnerable to climate change impacts because of its small size and the economy heavily dependent on agriculture. About 17% of GDP was generated in agriculture in 2016 (theglobaleconomy.com, 2018). Table 1 shows the recent catastrophic weather events experienced by farmers in The Gambia. The sequence of floods and droughts negatively affected the country's production of staple grains and exposed farm households to food shortages. Floods are viewed as the particularly serious climate-related calamities experienced in Africa (Elum et al., 2017). Additionally, the frequency of weather-induced disasters has been increasing over time in The Gambia (Table 1) and other parts of sub-Saharan Africa for some time (Unganai, 1996). Even if the weather event was regional in scope, the unforeseen decrease in agricultural output can have a destabilizing effect by changing the available national supply of food grains. At the farm level, the empirical evidence suggests that farmer behavior is conditioned by short-term climate variations and extreme weather (Bryan et al., 2009).

The predominantly rural character of The Gambia and the scattered settlements pose a challenge in the delivery of the basic services such as primary education and health care, and create exceptional difficulties in supplying aid. The literacy rate was 55% in The Gambia in 2017 (indexmundi.com, 2018) and generally expected to be lower among rural residents, especially women. The Gambia placed 174 out of 189 countries in the Human Development Index measuring the overall quality of life as captured by the longevity and health, access to knowledge, and standard of living (UNDP, 2018).

The existing social, economic, and institutional constraints exacerbate the exposure of the country's rural population to adverse weather events and long-term changes in climate. In extremely poor societies, households lack resources to purchase staples at the marketplace, even if suppliers respond by increasing deliveries. Per capita Purchasing Power Parity (PPP) index places the Gambia towards the bottom of international ranking with the average annual per capita income of 9% as compared to the world's average (tradingeconomics.com, 2018). Per capita income in rural areas is less implying that the farm household dependence on own staple crops inventories is vital for food security. Extreme poverty combined with the scattered character of settlements and inadequate road system causes that the adaptation to climate change in the marginalized communities is largely unknown rendering the many proposed solutions potentially impractical. The challenge remote and poor communities present is that they are unattractive to international donors and their domestic political influence weak.

The coping with adverse weather patterns and adapting to gradual climate change are distinctly different (Dazé et al., 2009). The short-term orientation of coping although useful in reducing food insecurity, may not improve the resilience of households facing damaging effects of climate change. Studies examining the food insecurity identified links with the socio-demographic and economic characteristics. For example, large family size, and advanced age were negatively associated with food security, while more years of schooling or more income improved food security among urban poor repeatedly displaced by riverbank erosion (Shetu et al., 2016).

Ojogho (2010) investigated factors influencing food security among farming households and concluded that the educational attainment level improves household food security, while the increasing number of dependents or advanced age lowered food security. In addition, farmers producing larger output were less probable to experience food insecurity than farmers with less output and those with more income were more food secure. In another study, a large share of farmers indicated the weather, interpreted by the author as climate effects, being an important factor influencing the crop production and linked to food security (Sanusi and Salimonu, 2006).

3. Methods

3.1. Strategies to cope with food insecurity in the face of gradual climate change

Coping with food insecurity in the context of progressive climate change and the associated variable and extreme weather reflects adaptive capacity (IPCC, 2001) and is observed best at farm level. A series of events (Table 1) that directly affect harvests and expose households to food insecurity could have induced change in approach to farming in The Gambia. Knowledge of possible options is an indicator of adaptive capacity and a prerequisite of implementing changes to sustain adequate food supply in future determining the resilience of rural communities to food insecurity. The current study focuses on learning what a particular group of mostly illiterate farmers knows about available strategies because the local communities have already been affected by gradual climate change (Table 1) and adverse weather. Knowing what it is that the farmers already know narrows the focus of the adaptation strategies that fit local needs and which implementation can be accelerated through targeted assistance and advisory services to pre-empt or reduce negative effects of another catastrophic weather event and making households food secure.

Several adaptation strategies to alleviate food insecurity that can be known to rural households in The Gambia. The adaptation strategies are associated with the variable weather and the observed gradual climate changes, and to control their consequences, e.g., soil erosion, ultimately reducing the risk of food insecurity. Crop diversification has been practiced to reduce the effects of a single crop failure due to disease, insect infestation, or unfavorable weather. Changing crops has been acknowledged as a farm-level adaptation strategy (Rozenzweig and Perry, 1994) and new climate-ready crops with traits making them resilient to, for example drought, need to be developed by 2030 (Shakoor et al., 2013). To be readily adopted, crop diversification strategy must involve crops somewhat familiar to local farmers that have attributes contributing to nutrition, while meeting taste expectations.

Changing planting date is an adaptation strategy that is easily available to farmers (Rozenzweig and Perry, 1994; Lobell et al., 2008). It is inexpensive and as simple as observing the current weather and adjusting the planting until sustained precipitation occurs. Since illiterate farmers may depend on oral tradition and habits more so than literate farmers, knowledge of the possibility of shifting the planting date is important. In recent years in many parts of the world and Africa, the timing of monsoons or the rainy season has been less predictable. Yet, some farmers proceed with planting regardless of whether the rains arrived or not because they base their actions on tradition rather than actual developments. Planting when the rains are delayed results in poor establishment or even a complete failure of the crop requiring a second planting. Smallholders may lack seed to replant placing the household at risk of being food insecure.

Crop rotation is another adaptive strategy to address the food security as the climate undergoes progressive change (Shakoor et al., 2013). Crop rotation involves using familiar crops but in a different sequence and the incorporation of green manures whenever possible. Although experts suggest crop rotation, the actual use of that adoptive strategy by smallholders poses challenges. The current study verifies the knowledge of the strategy assuming this is a pre-requisite to its practice.

Early maturing crops offer an option of growing food in response to the current weather pattern such as delayed rains that prevented planting the intended, likely traditional, crop. Crops requiring shorter growing season are being developed by breeders, for example corn (Psvarayi and Vivek, 2007; Badu-Abraku et al., 2013), and address the risk of food insecurity. The importance of early maturing crops may increase over time as the climate changes become an established new pattern. For the smallholder farmers, the choice of early maturing crops involves not only staple grains, but also vegetable crops and legumes. Early maturing groundnut varieties require considerably less precipitation (Ntare et al., 2008) making them attractive in diversifying crops to reduce the risk of food insecurity, while dealing with weather uncertainties. The notion of early maturity varies with crops and for some legumes the medium maturity period may be more appropriate given their importance as a food crop (Singh et al., 2003). The latter are widely popular in The Gambia and West Africa as a whole.

Alley farming was developed with resource-poor farmers in mind (Carter, 1995). It has been developed in the late 1970s, mostly to improve productivity and as such associated with food security before the climate change has become an international concern. Alley farming involves including trees and shrubs (sometimes in the form of hedgerows) in a spatial arrangement with food crops (Kang, 1997). Planted in rows, trees or shrubs improve soil fertility, reduce soil erosion, conserve water (shading), and may be a source of firewood. Some of alley farming features have been constraining the adoption of this strategy including underground competition, but it has been adopted in areas suffering from firewood shortage (Adesina et al., 2000). A fast growing Cassia (*Cassia siamea*) is a typical tree used in alley farming in the Gambia. A lack of knowledge about studies of socio-economic factors influencing the adoption of alley farming was noted in the literature (Adesina et al., 2000), and the current study focuses on examining factors that influence knowing about this adoption strategy.

Another adaptation strategy is contour farming. Contour farming reduces soil erosion if the rains are moderately heavy (Giller et al., 2011). The focus area of the current study, located along the river, includes sloped fields and contour farming has been observed among some farmers.

Soil condition directly influences food security of farm households (Zanella et al., 2015). Fragile soils need to be farmed in ways to reduce the risk of erosion or effects of limited precipitation. Widely advocated conservation tillage protects the environment and zero-tillage is an adaptation strategy as the environmental friendly in the process of gradual climate change (Busari et al., 2015). Crops grown without tillage have been observed to have higher yields than the same crops with tillage and there are examples of crops grown without tillage being more resilient to drought and high temperatures (FAO, 2012) favoring this adaptation strategy from the food security and climate change standpoint. Farmer practices in The Gambia include tethering animals on zero-till fields after the harvest to fertilize the soil with their droppings before the new planting season.

Agroforestry has been practiced by smallholder farmers in sub-Saharan Africa (Mbow et al., 2014). It involves a deliberate choice and planting of woody perennials. Agroforestry improves soil fertility allowing smallholder farmers to incorporate tree organic matter into the soil when mineral fertilizers are unaffordable, counteracts soil erosion, can be a source of livestock fodder, and provides food increasing household food security. It is a cost-effective method improving food security (Garrity et al., 2010). is practiced also to counter climate variability (Nguyen et al., 2013) and Agroforestry systems vary throughout Africa (Mbow et al., 2014), but in the current study, agroforestry as an adaptation strategy implies that farmers planted trees in their fields also for the indirect improvement of household food security (e.g., supply of organic matter incorporated into the soil or nitrogen-fixing species (Shakoor et al., 2013)). In the study area farmers plant African locust bean (*Parkia biglobosa*), Apple-Ring Acacia (*Acacia albida*), and fast growing and drought resistant drumstick tree (*Moringa olefera*).

Integrated Pest Management (IPM) has been applied worldwide as a strategy that improves food security by controlling various pests. IPM also helps to suppress outbreaks of pests resulting from adverse weather such as excessive rains or periods of drought. Williams et al. (2008) identified damage caused by insects to staple crops as the primary driving force in pesticide applications in several West African countries. Weed suppression through the herbicide use is most commonly practiced because of direct labor saving effect and improved yields. As such IPM offers a strategy that improves food security of a household, but the use of IPM in the mix of crops and non-chemical practices smallholders in developing countries needs more research (Way and van Emden, 2000). With increasing weather variability creating conditions for outbreaks of variety of pests, IPM offers an adaptation strategy that may be of increasing relevance to household food security.

Inadequate household food inventories have been linked to two strategies that have an indirect effect on food production. They are temporary migration and long-term or permanent migration. Migration may be a feasible adaptation strategy to climate change under some circumstances (Adger et al., 2003). However, given the conditions of the surveyed region, the practiced form of migration is temporary migration. The migrants are typically young men who leave the household in the short term and work on farms in other regions. They are expected to bring food supplies, which are their in-kind payment back to the household. The short-term character of temporary migration, its reactive nature and occurrence only in years when the crop is short suggests that this strategy falls into the category of coping methods rather than adaptation from the standpoint of gradual climate change (Dazé et al., 2009), but is a workable approach when dealing with food insecurity.

If the food insecurity is a recurring threat, it may evolve into a long-term migration. Long-term migration or permanent migration involves migrating in job search primarily to the country's urban areas or abroad. Such migrants are likely educated and once they find a job, expected, and, by tradition, obligated to send remittance in more or less regular intervals, which the household can use to purchase food at local markets. Remittance is a lasting adaptation strategy leaving the rural household members largely food secure as long as the migrant has a job. Whereas the temporary migration means that, the individuals will return to the household in time for planting, sending remittance means migrating longer distance in search of off-farm work and leaves less labor for farming. A lasting absence could lead to changes in the type of planted crops and the reduction of tilled farmland linking food security to remittance. Recently, some rural households in the Lower River Region have been observed selling assets to finance the cost of a household member migrating in search for a job abroad.

3.2. The study area and survey

Having data for a specific geographical location is vital because bringing understanding to the regional level even within a country is important (Vermulen et al., 2012). The current study uses survey data collected in 18 villages located in Lower River Region of The Gambia (Figure 1). The region is characterized by low population density. It is the poorest region in terms of farming and rural livelihood opportunities.

The natural conditions of the region are characterized by a unimodal rainfall between June and October. The average annual rainfall ranges from 600 to 900 mm. The seasonal temperatures vary between 32°C and 34°C and are generally higher in the eastern part of the country (Loum and Fogarassy, 2015; Bojang *et al.,* 2016). The main livelihood activity is subsistence rain-fed agriculture. The main field crops include maize (*Zea mays*), groundnut (*Arachis hypogea*), millet (*Pennisetum glaucum*), sorgum (*Sorghum bicolar*), rice (*Oryza sativa*), and guinea corn (*Sorghum vulgare*).

3.2.1. Sampling and data collection

National surveys are limited by financial constraints or political interest to prioritize food security of households from different areas. The questionnaire was prepared with reference to a similar study in North Bank Region of The Gambia (Kutir, 2015). The questionnaire was tested to assess the awareness of rural household to respond to food insecurity by choosing a strategy given weather extremes and gradual climate change. The enumerators were the socio-economic staff of the National Agricultural Research Institute (NARI) whose mandate is to survey and evaluate food security in The Gambia. Six enumerators were trained and the questionnaire was pre-tested. The questionnaire was translated into the country's major ethnic language Mandinka, spoken by at least one-half of the country's population. The questionnaire included questions pertaining to the socio-demographic characteristics of the farmer and his households, main and secondary economic activities, and farming practices.

The survey involved a face-to-face interview and was conducted in August 2017. Most interviews lasted 45 minutes on average and took place during the peak farming season, i.e., August. Farmers were interviewed during the day because of the fatigue later in the day. All respondents participated willingly in the survey after first being presented the explanation of the purpose of the study. A total of 10 farm household heads were selected randomly from each of 18 villages (180 households).

3.3. The selection of the estimation approach

The focus of the study on examining knowledge of adaptation strategies by farmers in Lower River Region poses a measurement challenge. The answer to a question pertaining to a specific strategy was limited to the choice between "Yes" and "No", the commonly applied coding of such response is 1 if the respondent choose "yes" and 0 in the case of "no". The decision to choose between two available options implies the binary nature of the coded response. The coding suggests the use of the suitable estimation technique to identify factors influencing the knowledge of a specific strategy and logit technique offers a solution. The logit model with dependent variable $y \in [0,1]$ takes the general form (Wooldridge 2002):

$$E[y|q\beta] = G(q\beta), \quad (1)$$

Where: $q\beta = \alpha + x\gamma + \varepsilon \quad (2)$

Contains an interceptα, a vector of explanatory variables x with coefficients vectorγ, random errorε, and G () =Λ (), the logistic CDF. The logit model directly estimates the choice of option describing knowledge of a strategy for each farmer while ensuring that the predicted responses for a given set of farmers fall in the unit interval. A chi-square test is used to verify the model's goodness of fit (Woolridge, 2002). However, the estimated coefficients cannot be interpreted until an additional step converts them into the probability of the dependent variable change in response to the unit change in the explanatory variable for the change from 0 to 1 in the case of a binary variable. The conversion quantifies the effects making it practical to gauge the adaptive capacity and relative importance of factors influencing the knowledge of a specific strategy to improve household food security.

4. Results

4.1. Survey summary results

The average age of the respondent was 34 years old (Table 2). The average age in The Gambia was estimated at 43.2 in 2013 (GBoS, 2013), yet, almost 58% of the population was 24 years old or younger in 2017 (indexmundi.com, 2018). Majority of the respondents were married (96%). The vast majority of the survey respondent did not receive any formal education (91%) (Table 2) reflecting the poverty of the region, even in comparison to other regions in The Gambia. Formal education can affect the knowledge of the adaptation strategies, and not knowing about possible options may exacerbate food insecurity in the study area.

4.2. Changes in probability of knowing the adaptation strategies

It is knowledge that is a necessary condition of choosing to implement any adaptive strategy and, therefore, only marginal effects and effects of the binary variables on the probability of knowing each strategy are discussed in the subsequent sections, while estimation results and calculated effects are presented in tables. Tables 3 through 5 show the logit equation estimation results.

4.1.1. Crop diversification

Among the socio-economic factors, women appear to have 11.5% higher probability of knowing about the strategy than men (Table 3). It is likely associated with women commonly cultivating a wider variety of crops, including vegetables, many of which mature within a period of time that is shorter than in the case of major grains.

Among farm characteristics, the farm size increased the probability of knowing about3crop diversification by 7.6% as the farm size increased by one hectare (Table 3). However, the probability of knowledge would also increase (by 5.7%) if the farms choose to reduce the amount of cultivated land. The latter could result from growing labor-intensive crops, such as vegetables given a variety of vegetables that are grown on farms in the region.

Linked to the reduced farmland is the positive effect of agroforestry practiced by the farm, which increases the probability of knowing crop diversification strategy by 4.5% (Table 3). Additionally, if the farm has been engaged in tree planting the probability of knowing about crop diversification strategy increased by 5.8%. Respondents from farms practicing agroforestry have a 6.8% higher probability of knowing about crop diversification than those where agroforestry has not been practiced.

Two opposite effects have been identified for knowledge of a respondent about the crop diversification where farming was the main activity and if the farm reported secondary activities. The former decreases the probability of knowing about crop diversification decreases by 18.2%, while in the latter increases it by 11.9%. Overall, factors increasing the probability of knowing about crop diversification as a strategy to reduce food insecurity seem to be characteristic of female respondents, importance of secondary activities, tree planting, and agroforestry.

4.1.2. Changing planting date

By changing planting date, farmers attempt to adjust to the shifting rain pattern and its critical importance for germination and establishing the crop. It appears that farmers who practice contour farming are 14.4% less likely to know about that strategy (Table 3), while those planting early maturing crops are 22.6% less likely to know about the strategy of changing planting date.

Farmers practicing agroforestry had a 23.5% higher probability of knowing about the strategy of changing planting date (Table 3). It is possible that practicing agroforestry broadens farmer knowledge by expanding alternative strategies to cope with food insecurity. In addition, farmers receiving government assistance have a 11.8% higher probability of knowing about the possibility of changing planting date. The knowledge involving the changing planting date may be driven by the series of weather events experienced in The Gambia in recent years and attributed to the changes in global climate.

4.1.3. Crop rotation

Respondents from households with higher incomes than the average in the sample had 8.5% higher probability of knowing about crop rotation as the strategy to improve their food security (Table 3). Also, as the farm size increased, a respondent was 10.5% more likely to know about crop rotation as a suitable approach. Clearly, the better off and larger farms apply crop rotation, which seems to assure household members of having sufficient food inventories as could be expected if crops, even in years of lower yields, harvested from a larger area produce adequate volume. Area expansion may not be a viable alternative for all rural households in the region. Only if some farms transfer their land to others, can the household farm area increase, pending adequate labor or access to machinery.

4.1.4. Early maturing crop

A number of early maturing crops have been and are being developed for African farmers including maize and groundnut. Knowing about the early maturing crops as an adaptation strategy to alleviate food insecurity risk and strengthen the farm household resilience against the progressive climate change decreases by 19% if a respondent received formal education (Table 4). The result seems counterintuitive but in a community of mostly illiterate farmers, having any level of education may imply that such farmers have already focused on strategies other than early maturity, including agroforestry, IPM, or no tillage. Farmers applying inorganic fertilizer had 17% high probability of knowing about this adoption strategy as compared to those who did not apply such fertilizer. The result suggests that should a farmer plant an early maturing crop, she may also add inorganic fertilizer to boost yields. Practicing planting at the recommended period lowers the probability of knowing about early maturing crops by 26%. There appears a knowledge gap among farmers adhering to traditional practices and informing them about an alternative adoption strategy involving early maturing crops is necessary in efforts to enhance food security.

4.1.5. Alley farming

A respondent's knowledge of the alley farming increases by 10.5% as the household income increases (Table 4). A large effect on the probability of knowing about alley farming as the strategy of countering food insecurity is the practice of planting at the recommended time, which increases it by 31.1%. Respondents from farms using herbicide have a 30.3% lower probability of familiarity with alley farming.

4.1.6. Contour farming

Contour farming can be practiced in the region considered in the current study as the location of agricultural land shifts away from the bank of the river to higher ground. Male respondents had a 12.1% higher probability of knowing of contour farming than female respondents (Table 4). As the income increased, the probability of knowing about contour farming as the food security enhancing strategy increases by 7.7%. Two practices have the opposite effect on the probability of interest. Specifically, practicing soil conservation lowered the probability of knowing about contour farming by 20.6%. In contrast, practicing agroforestry increased such probability by 22%. Tree planning may be encouraged by sloping terrain and the results reflects that implicit link.

4.1.7. Zero-tillage

The increasing income lowered the probability of knowing about zero-tillage as the strategy to improve food security among the surveyed farmers by 7% (Table 5). Respondents practicing soil conservation had a 31.8% higher probability of knowing about zero-tillage. The result is plausible since the one of the zero-tillage benefits is the reduction in soil erosion. Also, those practicing agroforestry have a whopping 44.6% higher probability of knowing about zero-tillage. Agroforestry practice counters soil erosion.

4.1.8. Agroforestry

Agroforestry involves planting trees beside agricultural crops. The probability of knowing of agroforestry as the strategy enhancing food security increase by 18.6% it the household was engaged in the secondary activities (Table 5). However, respondents from households receiving government assistance had 25.7% lower probability of knowing about agroforestry. Relying on government assistance may have resulted from following the traditional practices, which seem to fail under changing climate conditions. Those from households facing low soil nutrients had a 14.4% higher probability of knowing about agroforestry since agroforestry benefit includes increasing soil organic matter by incorporating in the soil any of the leaves shed by planted trees. In addition, those having farm inputs had a 13.4% higher probability of knowing about agroforestry as a strategy improving food security.

4.1.9. Integrated Pest Management (IPM)

Female respondents are 24% more likely than males to know about this strategy (Table 5). Also, the knowledge of IPM increases considerably with change in respondent's age; the probability increases by 20% as the age increases by one year above the sample mean. Respondents from households with higher incomes can be expected to have 9.6% higher probability of knowing about IPM than those from lower income households.

The reported secondary activities increase the probability of knowing IPM by 18% (Table 12). Additionally, if a farm planted crops in recommended period, the probability of knowing IPM increases by 16% and possibly reflects the adherence to the received agronomic advice. Respondents from farms engaged in agroforestry have 31% higher probability of knowing about IPM. However, farms choosing to reduce the amount of farmed land have a 21% lower probability of knowing about IPM as a strategy of dealing with food insecurity and climate change.

4.1.10. Temporary migration

The calculated effects show that as the respondent advanced in age he had a nearly 22% lower probability of being familiar with the temporary migration as an approach to deal with food insecurity in a household (Table 6). An even stronger effect was associated with education. Respondents with formal education were almost 24% less likely to know about temporary migration as the strategy to address the food insecurity. The result is interesting because it suggests that the educated farmers were more likely to stay in the village rather than leaving it in contrast to numerous studies that provide evidence of the educated leaving rural areas and farming by taking advantage of job opportunities elsewhere. It is possible that the observed effect results from the relatively large number of the illiterates and from limiting the variable to a binary indicator of having any level of education vs. having none. Respondents who planted crops at the recommended periods had about 17% lower probability of knowing of temporary migration strategy than those who did not plant at the recommended dates (Table 6). However, the largest effect was associated with the use of herbicides; those applying herbicides had about 44% lower probability of knowing about the strategy involving temporary migration. Herbicide use reflects acquired knowledge of herbicide use and the variable acts as a proxy for the respondent boarder knowledge than that acquired through formal schooling.

4.1.11. Remittance

Migration in search of job opportunities to other regions of the country or abroad depletes the farm of its labor, but creates a chance to relief food insecurity by money transfers enabling food purchase by household members left behind. Increasing age of the respondent increases the probability of being familiar with that strategy by 3% in response to a one percent change in age (Table 6). The effect of gender is positive but of negligible amount (1%) suggesting women to be more aware of that strategy and likely the result of men migrating out of the household leaving women and children to farm. Having education also increases the probability of knowing about remittance as the strategy to alleviate food insecurity but by merely three percent.

Factors describing the farm and farming practices have a different effect than socio-demographic variables. Receiving free inputs lowers the probability of knowing about remittance as the strategy to address food insecurity by 20% (Table 6). Also, having farm inputs lowers the probability by 12%. The effects of the two variables suggest that having inputs encourages respondents to focus on farming and they are less likely to know about the possibility of migrating for jobs and sending remittance to their household. Experiencing soil problems lowers the probability of knowing about remittance as a potential strategy to improve food security by 36% as compared to households not suffering from soil problems. However, equally strong effect (36%), but of the opposite sign, is associated with the reduced farm size suggesting that farms that choose to operate less land are more likely to know about remittance as the strategy addressing food insecurity in the Lower River Region of The Gambia.

5. Discussion

From among eleven adaptation strategies considered in the current study, nine are directly related to the adoption of farming practices that have been found to improve productivity and, therefore, reduce the risk of food insecurity. Additionally, the nine strategies also make farming more resilient in the face of progressive climate change. Knowledge of the strategies among the predominantly illiterate, ultra-poor farmers is a pre-condition of implementation. The implementation will sustain the communities preserving the social and personal relationships while strengthening local economies.

The quantified effects apply to three categories of characteristics, namely the respondent traits, farm features, and practiced farming methods. Among respondent characteristics, being a female measurably increased the probability of knowing about the crop diversification, contour farming, and remittance as adaptation strategies. Women are more likely to plant a wider variety of crops including vegetables. They are also more likely than males to know about the IPM as a strategy, which is particularly important if they grow cash crops or crops that are both consumed on farm and sold (e.g., vegetables, groundnuts). IPM can be effective in increasing yields and improve food security. Female respondents are also more likely to be left on the farm as the male household members chose the long-term migration in search of jobs and being the recipients of remittances, they are familiar with that adaptation strategy. Recently, the long-term migration destined for Europe has intensified in the rural Gambia.

Although few respondents received any form of formal education, it proved to be influential in knowing about three adaptation strategies. The educated respondents were less likely to know about the early maturing crop strategy. It is possible that formal education enables farmers to be more successful in general and a specific strategy is of lesser importance. Education had the opposite effect on two strategies not directly related to farming. Remittance as an adaptation strategy was positively influenced by having education, possibly because the educated may have been the first to permanently migrate or to be able to secure existence remain in the village. The opposite effect of education was identified in the case of knowing about the temporary migration as an adaptation strategy.

Income positively influenced respondents' knowledge of four adaptation strategies that may be consistent with focused farming practices that are reflected in ability to raise crops consistently. Those adaptation strategies include crop rotation, alley farming, contour farming, and IPM. However, income negatively influenced the knowledge of the zero-tillage adaptation strategy. It appears that better off farmers are not aware of the latter strategy, which can actually prove helpful in the face of progressive climate change as the approach to assure the household food security.

Farm size was of particular importance for increasing the probability of knowing about crop diversification and crop rotation as an adaptation strategy. The result is not a surprise since more land allows both for crop rotation or a greater variety of crops. The strategies allow harvesting a crop even in years of unfavorable weather pattern and secure adequate supply of food to support the household. Since the surveyed farmers are smallholders, increasing the farm size does not involve a large expansion, but still requires additional area that may not be available.

Among farm, characteristics included an indicator of main household activities, which was farming for the majority of farms. Farming as the main activity lowered the probability of knowing about crop diversification as the strategy to improve food security under conditions of progressive climate change. However, the having a secondary activity increased that probability suggesting that respondents engaged in a wider variety of activities had a higher probability of knowing about crop diversification as a suitable strategy.

Smallholders also practice the reduction of the farm size since in the study area farmers heavily depend on manual labor to perform all field tasks. Operating on the reduced area increased the probability of knowing about crop diversification as a strategy because the reduced area encouraged planting not only staple grains, but also vegetables to feed the household members. It also increased the probability of knowing about long term or permanent migration and receiving remittance suggesting that as the household labor resources decline, the remittance secures adequate provisions, while limiting farming. Reduced farm size also lowered the probability of knowing about IPM as the adaptation strategy against food insecurity.

Practicing agroforestry increased the probability of knowing about four adaptation strategies among the respondents, i.e., crop diversification, changing the planting date, contour farming, and zero-tillage. All four strategies require some skills and training and the suggested positive effect of agroforestry is important and suggests that there may be a synergistic effect of farming practices on the knowledge of other adaptation strategies.

7. Concluding remarks

Aggregate models and large-scale modeling efforts provide inadequate insights to tackle the food security and the effects of climate variability at local level. The current study attempts to broaden the understanding of what subsistence, vulnerable, and devoid of political influence rural residents know about the available adaptation strategies that have the potential of making farm households exceedingly resilient.

The literally peripheral location of very poor rural areas, their relative inaccessibility and their absence from the aggregate national and international projects perpetuates their chronic exposure to food insecurity. Yet, it is the low developmental level that often offers relatively high returns on targeted assistance. Familiarity with poor communities is a prerequisite of effective education and support programs aiming at alleviating the food insecurity risk. This study attempted to identify factors associated with knowing specific adaptation strategies that have been found to contribute to food production. Results provide opportunity to be geographically selective in emphasizing the adoption of various strategies. Their adoption is urged also by the effects of progressive climate change and the evidence of repeated adverse weather events causing crop failure or substantial decline in yields.

The identified respondent and farm features and farm practices have measurable effects on the knowledge of the on-farm and off-farm adaptation strategies. The estimated relationships provide insights about plausible factors rather than strictly causal effects. The poverty of the surveyed communities limit to some extent the possibility to collect a rich, diverse data set reflecting the challenge of studying such communities. However, in the case of very small and poor countries like The Gambia this is the only feasible approach. Moreover, since there is other small and poor countries and peripheral poor regions in larger countries, results from this study help to fill the gap in the literature.

Formal education is a major factor that was found to contribute to the knowledge of adaptation strategies. Additionally, assuring schooling opportunities for both genders suggests spreading the knowledge improving household food secure situation. The relevance of secondary to farming household activities has been confirmed. Primary staple crop production needs to be supplemented by other activities, but because the households are resource-poor, programs providing initial boost for such activities are needed because knowing about them was linked to other adaptation strategies.

Knowing about several adaptation strategies that have the potential for improving food security was related to the soil erosion phenomenon in the Lower River Region of The Gambia. Alley farming, contour farming, agroforestry, and zero-tillage adaptation strategies were known to the surveyed residents and the factors associated with that knowledge point to the focus of any outside programs intended for immediate alteration of the possibility of being food insecure. When combined with formal education, such strategies will become known to younger and older generations strengthening the knowledge and contributing to the sustained resilience.

Outmigration remains an adaptation strategy that is likely to decrease farming in the affected households. If the migrants successfully secure a job elsewhere and send remittance to their families, migration is an effective adaptation strategy. However, the risks involved are high and the immediate payoff uncertain since the travel and settling in a new environment can involve a lengthy period of time. Short-term migration is feasible and also known to the surveyed residents, but appears less desirable as an adaptation strategy in its effectiveness to sustainably reduce food insecurity.

The major limitation characteristic of studies of small poor countries of The Gambia is the very inadequate research staff to conduct a large project. Consequently, projects must be limited in scope or involve additional resources, likely from external sources. Still, studying a single ultra-poor region offers a path to learn about the existing communities and enable the residents to undertake meaningful approach to improve household resilience to adverse events posing a threat to food security. Learning about what the community members already know recognizes their critical role in the ultimate selection and implementation of adaptation strategies consistent with the existing preferences leading to sustained enhancement of household resilience.

References

Acevedo, M. F., Harvey, D. R., & Palis, F. G. (2018). Food security and the environment: Interdisciplinary research to increase productivity while exercising environmental conservation. *Global Food Security*, *16*(January), 127–132. http://doi.org/10.1016/j.gfs.2018.01.001

Arouna, A., Lokossou, J. C., Wopereis, M. C. S., Bruce-Oliver, S., & Roy-Macauley, H. (2017). Contribution of improved rice varieties to poverty reduction and food security in sub-Saharan Africa. *Global Food Security*, *14*(August 2016), 54–60. http://doi.org/10.1016/j.gfs.2017.03.001

Bain, L. E., Awah, P. K., Geraldine, N., Kindong, N. P., Sigal, Y., Bernard, N., & Tanjeko, A. T. (2013). Malnutrition in Sub - Saharan Africa: Burden, causes and prospects. *Pan African Medical Journal*, *15*, 1–9. http://doi.org/10.11604/pamj.2013.15.120.2535

Barrett, C. B. (2010). Measuring food insecurity. *Science (New York, N.Y.)*, *327*(5967), 825–828. http://doi.org/10.1126/science.1182768

Bojang, P. O., Yu, P., Yang, T., & Kuo, C. (2016). Optimal Cropping Patterns for Profit Maximization Using a Linear Programming Model : A Case Study in Njawara Village , The Gambia ., 10–13.

Conceição, P., Levine, S., Lipton, M., & Warren-Rodríguez, A. (2016). Toward a food secure future: Ensuring food security for sustainable human development in Sub-Saharan Africa. *Food Policy*, *60*, 1–9. http://doi.org/10.1016/j.foodpol.2016.02.003

Connolly-Boutin, L., & Smit, B. (2016). Climate change, food security, and livelihoods in sub-Saharan Africa. *Regional Environmental Change*, *16*(2), 385–399. http://doi.org/10.1007/s10113-015-0761-x

de Onis, M., & Branca, F. (2016). Childhood stunting: A global perspective. *Maternal and Child Nutrition*, *12*, 12–26. http://doi.org/10.1111/mcn.12231

GAMBIA NAPA, 2007. (2007). Banjul November 2007, (November), 105.

GBoS. (2013). The Gambia 2013 Population and Housing Census Preliminary Results. *The Gambia Bureau of Statistics*, 23. Retrieved from www.gbos.gov.gm

Godfray, H. C. J., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., … Toulmin, C. (2010). Food Security : The Challenge of, *327*(February), 812–818. http://doi.org/DOI: 10.1126/science.1185383

IFAD. (2007). Enabling poor rural people to overcome poverty in Nigeria. *Building a Poverty-Building a Free World*, 8.

Kutir, C. (2015). Farmers Awareness and Response to Climate Change : A Case Study of the North Bank Region , The Gambia, *6*(24), 32–41.

Loum, A., & Fogarassy, C. (2015). The effects of climate change on cereals yield of production and food security in Gambia. *APSTRACT: Applied Studies in Agribusiness and Commerce*, *9*(4), 83–92. http://doi.org/10.19041/APSTRACT/2015/4/11

M'koumfida, B., Yaffa S, & Bah A. (2018). The Impacts of Saline-Water Intrusion on the Lives and Livelihoods of Gambian Rice-Growing Farmers. *Res. Rev. J Ecol. Environ. Sci.|*, *6*(1), 1–7. Retrieved from http://www.rroij.com/open-access/the-impacts-of-salinewater-intrusion-on-the-lives-and-livelihoods-of-gambian-ricegrowingfarmers.pdf

Mccarthy, U., Uysal, I., Melis, R. B., Mercier, S., Donnell, C. O., & Ktenioudaki, A. (2018). SC. *Trends in Food Science & Technology*. http://doi.org/10.1016/j.tifs.2018.05.002

MENG, T., FLORKOWSKI, W. J., SARPONG, D. B., CHINNAN, M. S., & RESURRECCION, A. V. A. (2018). Alimental Food Consumption Among Urban Households: an Empirical Study of Ghana. *Journal of Agricultural and Applied Economics*, *2*(May), 1–24. http://doi.org/10.1017/aae.2017.30

Nakano, Y., Tanaka, Y., & Otsuka, K. (2014). To What Extent Do Improved Practices

Increase Productivity of Small-Scale Rice Cultivation in A Rain-fed Area? : Evidence from Tanzania. *National Graduate Institute for Policy Studies*, *14*(November), 1–28. Retrieved from http://www.grips.ac.jp/r-center/en/discussion_papers/14-21/
Piesse, J., & Thirtle, C. (2009). Three bubbles and a panic: An explanatory review of recent food commodity price events. *Food Policy*, *34*(2), 119–129. http://doi.org/10.1016/j.foodpol.2009.01.001
Pinstrup-andersen, P. (2009). Food security : definition and measurement, 5–7. http://doi.org/10.1007/s12571-008-0002-y
Richardson, K. J., Lewis, K. H., Krishnamurthy, P. K., Kent, C., Wiltshire, A. J., & Hanlon, H. M. (2018). Food security outcomes under a changing climate: impacts of mitigation and adaptation on vulnerability to food insecurity. *Climatic Change*, *147*(1–2), 327–341. http://doi.org/10.1007/s10584-018-2137-y
Rosegrant, M. W., & Cline, S. a. (2014). Global Food Security : Challenges and Policies, *1917*(2003), 10–13. http://doi.org/10.1126/science.1092958
Sanyang, S. E., Jarju, A. K., & Manneh, M. (2013). A Study on Maize Value Chain : Enhancing food Security and Commercialization in North Bank Region of the Gambia, *4*(12), 3238–3245.
Trimmer, J. T., Bauza, V., Byrne, D. M., Lardizabal, A., & Guest, J. S. (2017). Harmonizing Goals for Agricultural Intensification and Human Health Protection in Sub-Saharan Africa. *Tropical Conservation Science*, *10*, 194008291772066. http://doi.org/10.1177/1940082917720666
van der Geest, K., & Warner, K. (2014). *Vulnerability, Coping and Loss and Damage from Climate Events*. *Hazards, Risks and, Disasters in Society*. Elsevier Inc. http://doi.org/10.1016/B978-0-12-396451-9.00008-1
West, P. C., Gerber, J. S., Engstrom, P. M., Mueller, N. D., Brauman, K. a, Carlson, K. M., … Siebert, S. (2014). Food Security and the Environment. *Science*, *345*(6194), 325–328.

Table 1. Chronology of climate-related events in The Gambia

Date	Event
2016	Drought in The Gambia
2012	Floods and Windstorms in The Gambia
2011-12	Drought in The Gambia
2010	Floods Greater Banjul area
2002-2003	Effect of salinization in swamp ecologies in WCR, LRR and NBR, The Gambia
2002-2003	Drought in The Gambia
1990-91	Drought in The Gambia

Notes: WCR = West Coast Region; LRR = Lower River Region; NBR = North Bank Region.
Source: GAMBIA NAPA 2007; van der Geest & Warner, 2014; M'koumfida *et al.* 2018.

Table 2

. Descriptive statistics of variables included in the empirical model (N=180)

Variable name	Variable description/ units of measurement	Mean	Std. Dev.	Min	Max
Dependent variable					
Diversification of crops	1= Yes	0.76	0.43	0	1
IPM	1= Yes	0.31	0.46	0	1
Remittance	1= Yes	0.32	0.47	0	1
Independent Variables					
	Socio-economic characteristics				
Age	Years	49.39	13.94	19	90
Gender	1= Male, 2= Female	1.5	0.501	1	2
Household size	People	5.03	15.83	1	211
Education level	1= no formal education, 2= primary, 3= junior high school, 4= junior high school 5= tertiary	1.21	0.77	1	5
Contour farming	1= Yes	0.26	0.44	0	1
Income	The Gambian Dalasis	9392.27	22848.02	370	291770
	Farm characteristics				
Soil conservation	1= Yes	0.69	0.46	0	1
Low soil nutrients	1= Yes	0.65	0.48	0	1
Inorganic fertilizer	1= Yes	0.77	0.42	0	1
Farm inputs	1= Yes	0.58	0.443818	0	1
Farm size	Hectares	1.00419	0.916053	0.05	6
Early maturing crop	1= Yes	0.039	0.19	0	1
Household secondary activities	1= Farming, 2=Animal husbandry, 3= Fishing, 4=Business, 5=Laborer, 6=Employee, 7=Others	2.35	2.10	1	7
Household main activities	1= Farming, 2=Animal husbandry, 3= Fishing, 4=Business, 5=Laborer, 6=Employee, 7=Others	1.26	1.06	1	7

Herbicide	1= Yes	0.84	0.36	0	1
Purchase seed	1= Yes	0.83	0.38	0	1
Irrigation facilities	1= Yes	0.94	0.24	0	1
Reduce farm size	1= Yes	0.69	0.46	0	1
Planting during recommended period	1= Yes	0.67	0.47	0	1
	Other non-farm characteristics				
Soil affected problems	1= Yes	0.78	0.41	0	1
Free farm inputs	1= Yes	0.89	0.32	0	1
Government assistance	1= Yes	0.66	0.48	0	1

Table 3. Logit estimation results of crop diversification crops, changing planting date, and crop rotation as the adaptation strategy and marginal effects and effects.

Variable name	Crop diversification				Changing planting date				Crop rotation			
	Coefficient Std. error	Z P>z	Effect Std. error	Z P>z	Coefficient Std. error	Z P>Z	Effect Std. error	Z P>Z	Coeff Std. err	Z P>z	Effect Std. err	Z P>Z
lage	-0.2288	-0.29	-0.0139	-0.14	0.5541	0.61	0.0498	0.60	0.4310	0.66	0.0706	0.57
	(0.7875)	(0.77)	(0.1002)	(0.89)	(0.9082)	(0.54)	(0.0823)	(0.55)	(0.6503)	(0.51)	(0.1236)	(0.57)
Gender	1.1506*	2.13	0.1150*	1.82	0.5046	0.81	0.0367	0.66	-0.3554	-0.91	-0.0630	-0.85
	(0.5402)	(0.03)	(0.0632)	(0.07)	(0.6214)	(0.42)	(0.0555)	(0.51)	(0.3903)	(0.36)	(0.0739)	(0.39)
lHhsize	-0.3445	-1.00	-0.0326	-0.76	0.4327	1.10	0.0384	1.07	-0.1301	-0.54	-0.0198	-0.43
	(0.3456)	(0.32)	(0.0429)	(0.45)	(0.3943)	(0.27)	(0.0357)	(0.28)	(0.2432)	(0.59)	(0.0459)	(0.67)
lincome	0.2301	1.00	0.0230	0.79	0.2211	0.78	0.02363	0.4	0.4347*	2.09	0.0851*	2.21
	(0.2305)	(0.32)	(0.0293)	(0.43)	(0.2838)	(0.44)	(0.0595)	(0.69)	(0.2076)	(0.04)	(0.0385)	(0.03)
Purchase seed	-1.0480	-1.55	-0.07192	-0.56		-	-	-				
	(0.6775)	(0.12)	(0.1293)	(0.58)	-							
Planting trees	1.4825*	2.94	0.1709*	2.93		-	-	-				
	(0.5046)	(0.00)	(0.0583)	(0.00)	-							
Farm size	0.6484*	2.12	0.0761*	2.05		-	-	-				
	(0.3065)	(0.03)	(0.0371)	(0.04)	-							

Secondary activities	1.0586*	1.90	0.1187*	1.76	-	-	-	-				
	(0.5584)	(0.06)	(0.0677)	(0.08)								
Main activities	-1.4550*	-1.94	-0.1827*	-2.00	-	-	-	-				
	(0.7500)	(0.05)	(0.0913)	(0.05)								
Agroforestry	1.7581*	3.93	0.2215*	4.67	2.5417*	4.43	0.2352*	5.21				
	(0.4470)	(0.00)	(0.0474)	(0.00)	(0.5734)	(0.00)	(0.0451)	(0.00)				
Reduced farm size	1.1375*	2.39	0.1250*	2.22	-	-	-	-				
	(0.4769)	(0.02)	(0.0564)	(0.03)								
Constant	-2.8268	-0.76	-	-	-4.4957	-0.99	-	-	-3.0482	-0.96	-	-
	(3.7437)	(0.45)	(-)	(-)	(4.5481)	(0.323)			(3.1610)	(0.34)		
Education				-	-0.7969	-0.96	-0.0766	-1.00	-0.5547	-0.82	-0.1259	-0.98
	-	-	-		(0.8332)	(0.34)	(0.0764)	(0.32)	(0.6757)	(0.41)	(0.1286)	(0.33)
1farm_size				-	0.1567	0.50	0.0198	0.70	0.5084*	2.21	0.1046*	2.47
	-	-	-		(0.3140)	(0.62)	(0.0282)	(0.48)	(0.2305)	(0.03)	(0.0423)	(0.01)
Contour farming				-	-1.5167*	-2.57	-0.1440*	-2.79				
	-	-	-		(0.5907)	(0.01)	(0.0516)	(0.01)				
Early maturing crop				-	-2.5508*	-2.46	-0.2264*	-2.54				
	-	-	-		(1.0370)	(0.01)	(0.0892)	(0.01)				
HH sec activities				-	0.1270	0.22	0.0131	0.25	-0.3536	-0.94	-0.0581	-0.82
	-	-	-		(0.5674)	(0.82)	(0.0523)	(0.80)	(0.3750)	(0.35)	(0.0713)	(0.42)
HH main activities	-	-	-	-	-	-	-	-	-0.0498	-0.07	0.0004	0.00

									(0.7557)	(0.95)	(0.1462)	(1.00)
Government support				-	1.3113*	2.48	(0.1177*	2.57				
	-	-	-		(0.5289)	(0.01)	(0.0458)	(0.01)				
Soil conservation				-		-	-	-	-2.0517*	-4.72	-	-6.31
									(0.4347)	(0.00)	0.3949*	(0.00)
	-	-	-		-						(0.0626)	
Irrigation facilities				-		-	-	-	19.2925	0.01	0.1989	1.35
	-	-	-		-				(1999.535)	(0.99)	(0.1470)	(0.18)

*Significant at 10 %

Table 4. Logit estimation results of planting early maturing crops, alley farming, and contour farming as the adaptation strategy and marginal effects and effects.

Variable name	Early maturing crops				Alley farming				Contour farming			
	Coefficient Std. error	Z P>z	Effect Std. error	Z P>z	Coefficient Std. error	Z P>Z	Effect Std. error	Z P>Z	Coeff Std. err	Z P>z	Effect Std. err	Z P>Z
lage	-0.4780	-0.68	-0.08	-0.68	-0.8724	-1.36	-0.1792	-1.43	0.7289	1.04	0.1274	1.05
	(0.7067)	(0.50)	(0.12)	(0.50)	(0.6413)	(0.17)	(0.1216)	(0.15)	(0.6982)	(0.30)	(0.1209)	(0.29)
Gender	-0.1735	-0.40	-0.03	-0.40	0.1042	0.27	0.0373	0.48	0.6941*	1.67	0.1213*	1.71
	(0.4323)	(0.69)	(0.07)	(0.69)	(0.3895)	(0.79)	(0.0785)	(0.63)	(0.4159)	(0.10)	(0.0709)	(0.09)
lHhsize	0.4100	1.43	0.07	1.46	0.1534	0.62	0.0221	0.45	0.0676	0.25	0.0118	0.25
	(0.2859)	(0.15)	(0.05)	(0.14)	(0.2490)	(0.54)	(0.0492)	(0.65)	(0.2670)	(0.80)	(0.0466)	(0.80)
lincome	0.3386	1.52	0.06	1.56	0.5324*	2.56	0.1048*	2.75	0.4408*	2.08	0.0771*	2.17
	(0.2221)	(0.13)	(0.04)	(0.12)	(0.2077)	(0.01)	(0.0382)	(0.01)	(0.2115)	(0.04)	(0.0354)	(0.03)
Agroforestry	-	-	-	-	-	-	-	-	1.2589*	2.70	0.2201*	2.88
									(0.4664)	(0.01)	(0.0763)	(0.00)
Constant	0.2582	0.07	-	-	-1.7316	-0.53	-	-	-	-2.31	-	-
	(3.5580)	(0.94)			(3.2472)	(0.59)			8.3773*	(0.02)		
									(3.6225)			
Education	-1.1509*	-1.67	-0.19	-1.72	-0.3948	-0.58	-0.0788	-0.59	-1.0611	-1.24	-0.1855	-1.26
	(0.6885)	(0.10*)	(0.12)	(0.09*)	(0.6840)	(0.56)	(0.1346)	(0.56)	(0.8550)	(0.22)	(0.1476)	(0.21)
1farm_size	0.0469	0.20	0.01	0.20	0.1111	0.52	0.0212	0.49	-0.0929	-0.40	-0.0162	-0.40

	(0.2324)	(0.84)	(0.04)	(0.84)	(0.2151)	(0.60)	(0.0428)	(0.62)	(0.2323)	(0.69)	(0.0406)	(0.69)
Contour farming	-	-	-	-	-	-	-	-	-	-	-	-
Early maturing crop	-	-	-	-	-	-	-	-	-	-	-	-
HH sec activities	-0.5722	-1.37	-0.10	-1.40	-0.1890	-0.51	-0.0329	-0.44	0.5904	1.50	0.1032	1.53
	(0.4166)	(0.17)	(0.07)	(0.16)	(0.3728)	(0.61)	(0.0741)	(0.66)	(0.3935)	(0.13)	(0.0673)	(0.13)
HH main activities	0.5760	0.61	0.10	0.61	0.6892	0.90	0.1424	0.95	1.0457	1.30	0.1828	1.32
	(0.9422)	(0.54)	(0.16)	(0.54)	(0.7667)	(0.37)	(0.1496)	(0.34)	(0.8034)	(0.19)	(0.1383)	(0.19)
Soil conservation	-	-	-	-	-	-	-	-	-	-3.05	-	-3.38
									1.1754*	(0.00)	0.2055*	(0.00)
									(0.3849)		(0.0608)	
Inorganic fertilizer	1.0267*	2.37	0.17	2.52	-	-	-	-	-	-	-	-
	(0.4330)	(0.02*)	0.07	(0.01*)								
Planting in recommended period	-1.5452*	-3.14	-0.26	-3.39	1.5904*	3.16	0.3112*	3.43	-	-	-	-
	(0.4924)	(0.00*)	(0.08)	(0.001*)	(0.5029)	(0.00)	(0.0909)	(0.00)				
Herbicide	-1.6229*	-2.66	-0.3026*	-2.61		-	-	-	-	-	-	-
	(0.6101)	(0.01)	(0.1158)	(0.01)	-							
Purchase seed	-1.49704	-1.5	-0.1113	-1.24		-	-	-	-	-	-	-
	(0.9988)	(0.134)	(0.0896)	(0.21)	-							

*Significant at 10 %

Table 5. Logit estimation results of zero-tillage, agroforestry, and IPM as the adaptation strategy and marginal effects and effects.

Variable name	Zero tillage				Agroforestry				IPM			
	Coefficient	Z	Effect	Z	Coefficient	Z	Effect	Z	Coeff	Z	Effect	Z
	Std. error	P>z	Std. error	P>z	Std. error	P>Z	Std. error	P>Z	Std. err	P>z	Std. err	P>Z
lage	0.08919	0.12	0.0146	0.12	0.1822	0.29	0.0368	0.29	1.3955*	1.71	0.2046*	1.76
	(0.71649)	(0.90)	(0.1171)	(0.90)	(0.6336)	(0.77)	(0.1279)	(0.77)	(0.8142)	(0.09)	(0.1164)	(0.08)
Gender	0.0690	0.16	0.0113	0.16	0.2931	0.75	0.0592	0.75	1.6597*	3.39	0.2434*	3.82
	(0.4202)	(0.87)	(0.0687)	(0.87)	(0.3908)	(0.45)	(0.0785)	(0.45)	(0.4898)	(0.00)	(0.0637)	(0.00)
lHhsize	-0.1488	-0.58	-0.0243	-0.58	0.1339	0.57	0.0271	0.57	0.0167	0.06	0.0024	0.06
	(0.2572)	(0.56)	(0.0419)	(0.56)	(0.2352)	(0.57)	(0.0474)	(0.57)	(0.2948)	(0.96)	(0.0432)	(0.96)
lincome	-0.4495*	-1.97	-0.07*	-2.05	0.0357	0.18	0.0072	0.18	0.6509*	2.63	0.0955*	2.81
	(0.2283)	(0.05)	(0.0359)	(0.04)	(0.1950)	(0.86)	(0.0394)	(0.86)	(0.2470)	(0.01)	(0.0340)	(0.01)
Farm size	-	-	-	-	-	-	-	-	-0.0896	-0.35	-0.0131	-0.35
									(0.2591)	(0.73)	(0.0380)	(0.73)
Agroforestry	2.7244*	4.71	0.4455*	6.11	-	-	-	-	2.1248*	3.73	0.3116*	4.29
	(0.5782)	(0.00)	(0.0729)	(0.00)					(0.5703)	(0.00)	(0.0727)	(0.00)
Reduced farm size	-	-	-	-	-	-	-	-	-	-3.03	-	-3.37
									1.3795*	(0.00)	0.2023*	(0.00)
									(0.4555)		(0.0601)	

Constant	-0.4400	-0.12	-	-	-1.8377	-0.58	-	-	-	-3.37	-	-
	(3.5529)	(0.90)			(3.1850)	(0.56)			14.7696	(0.00*)		
									(4.3777)			
Education	-0.3706	-0.50	-0.0606	-0.50	-0.9645	-1.36	-0.1948	-1.39	-0.9639	-1.10	-0.1414	-1.11
	(0.7398)	(0.62)	(0.1207)	(0.62)	(0.7071)	(0.71)	(0.1403)	(0.17)	(0.8797)	(0.27)	(0.1274)	(0.27)
1farm_size	0.2575	1.04	0.0421	1.05	0.1723	0.81	0.0348	0.81				
	(0.2469)	(0.30)	(0.0399)	(0.29)	(0.2132)	(0.42)	(0.0428)	(0.42)				
HH sec activities	0.4512	1.11	0.0738	1.13	0.9197*	2.47	0.1858*	2.63	1.1228*	2.60	0.1647*	2.79
	(0.4047)	(0.27)	(0.0653)	(0.26)	(0.3724)	(0.01)	(0.0706)	(0.01)	(0.4321)	(0.01)	(0.0591)	(0.01)
HH main activities	-0.1939	-0.23	-0.0317	-0.23	1.0147	1.36	0.2050	1.38	0.8335	0.87	0.1222	0.88
	(0.8310)	(0.82)	(0.1358)	(0.82)	(0.7477)	(0.18)	(0.1483)	(0.17)	(0.9533)	(0.38)	(0.1388)	(0.38)
Government support	-	-	-	-	-1.2744*	-3.49	-0.2574*	-4.02				
					(0.3652)	(0.00)	(0.0640)	(0.00)				
Soil conservation	1.9420*	4.22	0.3175*	5.39								
	(0.4597)	(0.00)	(0.0589)	(0.00)								
Planting in recommended period	-	-	-	-	-	-	-	-	1.2325*	2.68	0.1807*	2.90
									(0.4594)	(0.01)	(0.0624)	(0.00)
Low soil nutrients	-	-	-	-	0.7143*	1.84	0.1443*	1.90				
					(0.3880)	(0.07)	(0.0758)	(0.06)				
Farm inputs	-	-	-	-	0.6621*	1.89	0.1337*	1.95				
					(0.3512)	(0.06)	(0.0685)	(0.05)				

*Significant at 10 %

Table 6. Logit estimation results of temporal migration and remittance from household members migrating for work as the adaptation strategy and marginal effects and effects.

Variable name	Temporal migration				Remittance from household members migrating for work			
	Coefficient Std. error	Z P>z	Effect Std. error	Z P>z	Coefficient Std. error	Z P>Z	Effect Std. error	Z P>Z
lage	-1.1227*	-1.78	-0.2165*	-1.84	2.2522*	2.13	0.35*	2.29
	(0.6318)	(0.08)	(0.1180)	(0.07)	(1.0582)	(0.03)	(0.1511)	(0.02)
Gender	-0.3898	-0.99	-0.0752	-1.00	1.7734*	2.55	0.27*	2.84
	(0.3938)	(0.32)	(0.0752)	(0.32)	(0.6963)	(0.01)	(0.0960)	(0.00)
lHhsize	0.3638	1.47	0.0702	1.51	-0.2022	-0.58	-0.03	-0.59
	(0.2467)	(0.14)	(0.0466)	(0.13)	(0.3468)	(0.56)	(0.0530)	(0.56)
lincome	0.0993	0.53	0.0192	0.53	0.1345	0.4	0.02	0.40
	(0.1875)	(0.60)	(0.0361)	(0.60)	(0.3393)	(0.69)	(0.0521)	(0.692)
Reduced farm size	-	-	-	-	2.3313*	3.71	0.36*	4.91
					(0.6290)	(0.00)	(0.0730	(0.00)
Constant	6.7115*	2.05		-	-9.6094*	-1.78	-	-
	(3.2776)	(0.04)	-		(5.3884)	(0.08)		
Education	-1.2271*	-1.72	-0.2367*	-1.77	1.7940*	1.8	0.28*	1.90
	(0.7125)	(0.09)	(0.1339)	(0.08)	(0.9972)	(0.07)	(0.1454)	(0.06)

HH sec activities	-0.5141	-1.37	-0.0992	-1.40	0.1852	0.31	0.03	0.32
	(0.3751)	(0.17)	(0.0710)	(0.16)	(0.5879)	(0.75)	(0.0903)	(0.75)
HH main activities				-	-2.3794	-1.54	-0.37	-1.60
	-	-	-		(1.5473)	(0.12)	(0.2290)	(0.11)
Irrigation facilities	-1.0999	-1.44	-0.2121	-1.47				
	(0.7636)	(0.15)	(0.1441)	(0.14)				
Herbicide	-2.2687*	-3.32	-0.4376*	-3.71				
	(0.6833)	(0.00)	(0.1180)	(0.00)				
Farm inputs	0.4446	1.18	0.0857	1.19	-1.0937*	-1.89	-0.12*	-2.01
	(0.3779)	(0.24)	(0.0720)	(0.23)	(0.5776)	(0.06)	(0.0838)	(0.05)
Recommended planting	-0.8909*	-2.19	-0.1718*	-2.31				
	(0.4065)	(0.03)	(0.0745)	(0.02)				
Free farm inputs				-	-1.2968	-1.59	-0.20*	-1.66
	-	-	-		(0.8178)	(0.11)	(0.1205)	(0.10)
Soil affected problems				-	-2.3125*	-3.01	-0.36*	-3.58
	-	-	-		(0.7689)	(0.00)	(0.0994	(0.00)

*Significant at 10 %

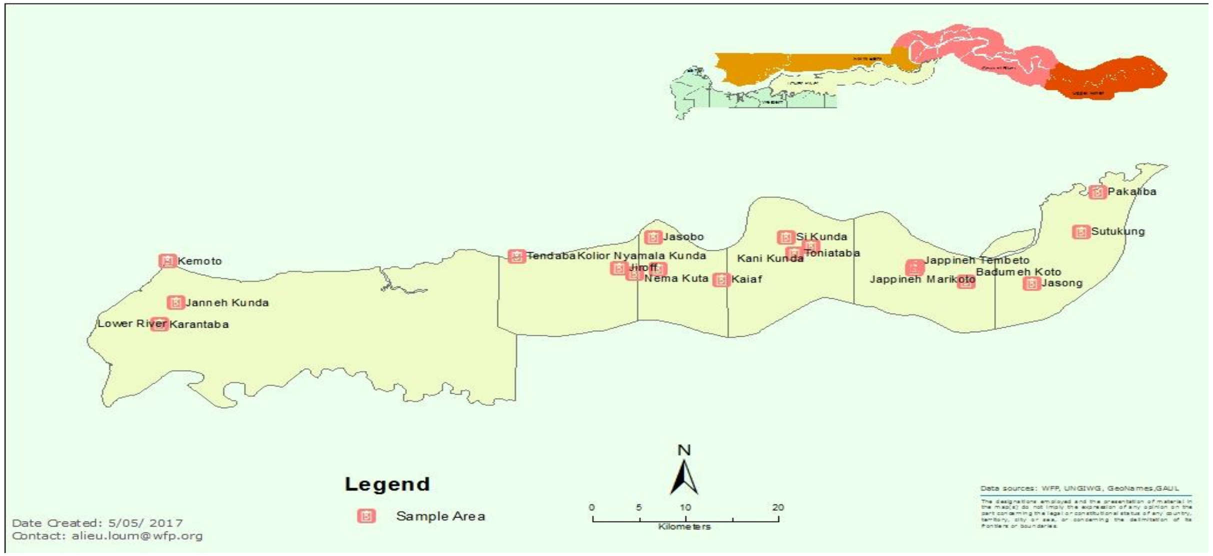

Fig. 1 Location of the surveyed villages in Lower River Region of The Gambia