Climate Change Management

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Climate Change Adaptation in Africa

Fostering Resilience and Capacity to Adapt

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Preface

It is widely known that Africa is one of the most vulnerable continents to climate change. As the Fifth Assessment Report (AR5) produced by the Intergovernmental Panel on Climate Change (IPCC) has shown, climate change is expected to have widespread impacts on African societies and Africans' interaction with the natural environment. There are also signs that the impacts of climate change are already being felt, not only in terms of increases in temperature, but also in respect of agriculture (with lower crop yields) and the availability of water resources, among others. The links between climate change and the incidence of diseases such as malaria are also becoming clearer.

The above state of affairs illustrates the need for a better understanding of how climate change affects African countries, and for the identification of processes, methods and tools which may help African nations to adapt. There is also a perceived need to showcase successful examples of how to cope with the social, economic and political problems posed by climate change in Africa.

It is against this background that the "Symposium on Climate Change Adaptation in Africa" was organised by Manchester Metropolitan University (UK), Addis Ababa University, the Research and Transfer Centre "Applications of Life Sciences" of the Hamburg University of Applied Sciences (Germany) and the International Climate Change Information Programme (ICCIP). The Symposium, held in Addis Ababa in February 2016, was a truly interdisciplinary event, mobilising African and non-African scholars undertaking research and/or executing climate change projects in the African continent.

This book, which contains a set of papers presented at the Symposium, focuses on "Fostering African Resilience and Capacity to Adapt", meaning that it will serve the purpose of showcasing experiences from research, field projects and best practice in climate change adaptation in African countries, which may be useful or implemented in other countries in the continent.

Consistent with the need for more cross-sectoral interactions among the various stakeholders working in the field of climate change adaptation in the African continent, this book aims to:

i. provide research institutions, universities, NGOs and enterprises from Africa and those working in Africa with an opportunity to display and present their works in the field of climate change adaptation;
ii. foster the exchange of information, ideas and experiences acquired in the execution of climate change adaptation projects, especially successful initiatives and good practice across the African continent;
iii. introduce methodological approaches and experiences deriving from case studies and projects, which aim to show how climate change adaptation may be implemented in practice; and
iv. to network African and non-African experts, and provide a platform so they can explore possibilities for cooperation.

Last but not least, a further aim of this book is to document and disseminate the wealth of experiences available today.

This book is divided into two parts:

- Part 1 contains papers that describe the adaptation methods and approaches.
- Part 2 entails institutional experiences on adaptation, as well as case studies, examples of projects and of good practice

We thank the authors for their willingness to share their knowledge, know-how and experiences, as well as the many peer reviewers, which have helped us to ensure the quality of the manuscripts. Thanks are also due to Magdalena Salewski for her valuable support for the manuscripts.

Enjoy your reading!

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Part I
Adaptation Methods and Approaches

Convenient Solution for Convenient Truth: Adoption of Soil and Water Conservation Measures for Climate Change and Variability in Kuyu District, Ethiopia

Abayineh Amare and Belay Simane

1 Introduction

The Ethiopian economy has largely remained dependent on agriculture, which provides about 44% of the GDP, over 80% of the export revenue and employment for about 80% of the population (CSA 2012). At present, Ethiopia is facing greater land degradation problem to the development of agriculture and food security (FAO 1986; Merrey and Gebreselassie 2011). The study by Yesuf et al. (2008) found out soil erosion in Ethiopia is estimated to cause a damage of about one billion tons of topsoil annually. According to Berry (2009) the loss of soil and essential nutrients due to unsustainable agricultural practices is costing $139 million or 3–4% of its agricultural GDP. The problem of soil erosion in Ethiopia is attributed to erratic and erosive rainfall, steep terrain, deforestation, inappropriate land use, land fragmentation, overgrazing and farmers' management practices (Osman and Sauerborn 2001). Soil erosion problem is further exacerbated by intense and continuous cultivation on sloping land, without supplementary use of soil amendments and conservation technologies (Bekele and Holden 1998). Additionally, it has been reported that climate change can increase potential erosion rates, which can lower agricultural productivity by 10–20%, and more in extreme cases (Jorge et al. 2011). The Intergovernmental Panel on Climate Change report revealed that rainfall intensities will increase in many parts of the world, increasing the potential for soil erosion (IPCC 2007).

Give soil erosion problem posed by climate change, soil and water conservation technologies have been suggested as a key adaptation strategy for developing

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countries. The study on the adoption and continued use of stone terraces by farmers for soil and water conservation by Amsalu and de Graaff (2006) revealed that these soil and water conservation technologies reduced run-off and soil loss through improvement in soil structure, increasing infiltration and soil resistance to detachment due to increased soil cover.

The problem of land degradation due to soil erosion received great attention in Ethiopia following the 1973/74 famine (Lundgren 1993). Since then, several soil and water conservation and land reclamation projects were initiated with the support of donor agencies and efforts have been put in place in order to rehabilitate degraded areas. For these purpose various SWC measures were introduced (Dejene 2003; Amsalu 2006). A variety of conservation structures, applicable to different soil types, rainfall conditions and topography such as soil bunds, stone bunds, *Fanya juu* (to throw up') were developed (Hurni 1993). Furthermore, planting trees on hillsides and catchments areas, water harvesting in drier areas, stream development, construction of earth dams, pond, gully plugging, traces, diversion of drains, and check dam are SWC practices developed in different part of Ethiopia to which Kuyu district is not an exception (Asrat et al. 2004). However, earlier studies on adoption of soil and water conservation to combat land degradation problem in Ethiopia showed that farmers have not been changed markedly nor adopt most of the recommended conservation measures (Shiferaw and Holden 1998; Gebremedhin and Swinton 2003; Beshah 2003; Merrey and Gebreselassie 2011).

The causes for failures and low adoption of introduced soil conservation practices were attributed mainly to the approach in the development and transfer of the conservation practices (Shiferaw and Holden 1998). Among others, failure to recognize differences in agro-ecological and socio-economic settings in which farmers operate has been considered as contributing to low adoption of soil and water conservation measures (Bekele and Drake 2003; Pender et al. 2001). For instance Pender et al. (2001) showed that farmers' decision to adopt soil and water conservation measures depends up on specific characteristics of farm plots and the importance of the plot to the household economy. Furthermore, adoption of soil and water conservation measures are constrained by a combination of unfavourable physical environment, population pressure, institutional set up, and short term household benefit (Pender et al. 2001; Tizale 2007). Hence due to these complex set of factors influenced farmer's incentive to soil and water conservation, adoption of *these practices remains below expectations* in different parts of Ethiopia including kuyu district.

In different parts of Ethiopia, factors influencing adoption and management of SWC have been investigated (Graaff et al. 2008; Kassie et al. 2008; Kato et al. 2011; Teshome et al. 2012). However, due to heterogeneity in agro ecology, socio-economic characteristics and institutional arrangements in different part of the country, it is difficult to extrapolate results from other area. Therefore, this study is aimed to analyse determinants of adoption of soil and water conservation measures by smallholder farmers in Kuyu district.

1.1 Objectives of the Study

The study is set to ascertain the use of soil and water conservation measures as climate change adaptation techniques by the smallholder farmers in the study area. Specifically, the study aimed at: (1) to explore soil and water conservation measures that smallholder farmers in Kuyu district employed in response to climate change and variability; and (2) to examine factors that constrain and/or facilitate the adoption of soil and water conservation measures in the district.

2 Methods and Materials

2.1 Description of the Study Site

This research is undertaken in Kuyu district located in North Shoa zone of Oromiya regional state. The area lies approximately 160 km to the northwest of Addis Ababa, the capital city, on the way to Gojam. At present, this area is facing severe soil degradation. The total population of the district is 126,546 of which the rural population is 103,065 (CSA 2008). The average household's size is 6.5. It has three livelihood zones via: Ambo Selale Ginde-Beret Teff and Wheat Livelihood Zone; Muger-Abay-Jema Sorghum and Teff Belt Livelihood Zone and Selale-Ambo Highland Barley, Wheat and Horse bean Belt Livelihood Zone.

This site is located at about 9°36′34″–9°56′56″ N latitude and 38°05′00″–38°34′13″ E longitude. The total area of Kuyu district is 974 km^2. It receives its maximum rainfall during summer season-June, July and August (Mesfin 1984). The predominant economic activity and land use is mixed agriculture; having land use systems of agricultural land (mainly rain fed), grazing land, and forest/bush. The main crops grown includes: *teff (Eragrostis tef*), wheat, barley, and *nug* (*Guizotia abyssinica*) major rainy season in the area; and Sorghum in the next rainy season. Given the problem of soil erosion in the area, it is the most intervened area with various soil and water conservation measures.

2.2 Research Design

The study followed a cross-sectional research design in which data from households were collected from June to August 2015. In view of the diverse impact of climate change and variability on smallholder farmers and the nature of the information needed on various aspects of this research, employing a single method of data collection method is impossible to satisfy data requirements. Therefore, this demands a multi-methods of data collection approach to generate adequate and reliable data that will be enhanced through triangulation. Many authors advocate this approach in such a way that it makes possible to develop an integrated system in which the first method sequentially informs the second method, contradictions and fresh perspectives appear, and different facets of the phenomena emerge in order to keep the data both comprehensive and authentic (Mathison 1988; Greene et al. 1989; Swanson 1992).

In similar vein, this research employed mixed methods of data collection both to collect data from primary and secondary sources. Primary data were collected using a pre-tested semi structured questionnaire, key informant interview and focussed group discussions. Moreover, secondary data were gathered through reviewing documents, reports and records maintained at district rural development and agricultural office. A total of 100 households were selected and surveyed using systematic random sampling technique. Lists of households were obtained from the sampled kebele offices.

To analyse the data, descriptive statistics such as frequencies, percentages, and means were used. In order to make a decision on whether or not a significant relationship existed between adoption of SWC technologies in Kuyu district and the variables investigated, a chi-square test and t-test were performed for dummy and continuous variables, respectively (Table 1).

Table 1 Descriptions, definition and values of variables used in the independent t-test and chi-square test

Variables	Definition	Values
Adoption	Adopted stone bunds	0 = not adopted (no stone bund structures on his/her farmland; 1 = adopted (presence of stone bund on his/her farmland)
Farm size	Landholding of the family	Total landholding in hectares (continuous)
Family size	Number of people in the family	Refers to the number of members who are currently living within the family
Age	Age of family head	It is a continuous variable measured in years
Livestock	Number of livestock owned in TLU	Continuous
Distance of the plot	Distance from their residence	It is a continuous variable measured in hours and refers to distance of the plot from the farmer's house
Education	Education level of the family head	It is a categorical variable representing illiterate, read and write, grade 1–4, grade 5–8, and above grade 8 of the household heads
Perception of soil erosion	Household head perception of soil erosion problem	0 = not perceive the problem; 1 = otherwise
Slope of the plot	Perceived slope of the plot	0 = plain; 1 = steep
Training	Household access to training on soil bunds	0 = not access to training; 1 = access to training

(continued)

Table 1 (continued)

Variables	Definition	Values
Access to credit	Access to credit	It is a dummy variable, which takes the value 1 if the farm household access to credit and 0 otherwise
Gender	Sex of the household head	Refers to sex of the head of the household having a binary value. If the household head is male, it takes a value of 1; 0 otherwise
Number of dependents in the household	Family member <15 and ≥65 years old	Total number of family members in this age range

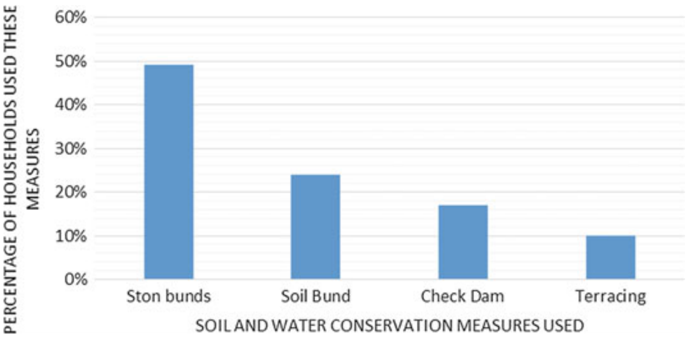

Fig. 1 Respondents use of soil conservation techniques as climate change adaptation strategies. *Source* Field Survey, 2015

3 Results and Discussions

3.1 *Soil and Water Conservation Measures in the Study Area: An Overview*

This study indicated that different types of soil and water conservation practices were undertaken in Kuyu district. Stone bund is the most widely and most intensively used soil conservation structures in the area. The study revealed that from 100 households interviewed, 49% were used stone bund on their farm plots as climate change adaptation strategy. The discussions with key informants revealed that it is due to high potential of stone in the area that farmers mostly used stone bund in their farm plots. Soil bund were used by 24% of farmers, next to stone bund. Moreover, Fig. 1 presents that check dam were used by smallholder farmers (17%) and followed by terracing (10%).

3.2 Determinants of Use of Soil and Water Conservation Measures

In this analysis, we used only stone bunds that the farmers used as climate change adaptation strategy in their farm plots. This is mainly because stone bund were used by many farmers and we are interested to examine the factors that influence adoption of soil bund. First, surveyed households were classified into adopters and non-adopters. Adopter households were those that had practiced conservation measures on their farm plots. The non-adopter households were those that had not practiced soil and water conservation measures on their farm plot (Bekele 2003).

The result indicated that among many explanatory variables, nine variables were found to significantly affect use of stone bund. The result of independent t-test showed that farm size, family size, age of the household head, number of livestock and distance of the plots from their residence were determining farmers use SWC practices (Table 2). Moreover, chi-square test result revealed that education of the household head, perception of soil erosion problem, slope of the plot, and training on soil and water conservation were significant determinant factors in adopting soil and water conservation measures in the study area. Interpretation of independent t-test and chi-square test results is discussed in detail as follow:

Farm Size. The effect of farm size is also found to be positive and significant, suggesting that farmers who hold large farms are more likely to invest in conservation. The positive influence might be explained by the propensity of retaining conservation structures increases with increasing availability of land resources. An increase in landholding size in the study area encouraged management of the land resource. This is true because farmers having larger farm size can allocate some part of the land to stone bund than those farmers who have small farms. Moreover, large farm operators will have more opportunity to use new practices on a trial basis and

Table 2 Differences of continuous explanatory variables between adopters and non-adopters

Variables	Adopters		Non-adopters		t-value
	Mean	St. deviation	Mean	St. dev	
Farm Size in hectare	1.82	0.232	1.12	0.33	2.8**
Family Size in number	6.048	1.678	3.234	2.123	0.224**
Age of HH in years	43.322	10.542	60.435	5.456	−7.14***
Number of dependents in the household	1.745	1.211	2.512	2.421	−0.135**
Number of Livestock in Tropical Livestock Unit	1.211	0.833	2.736	0.689	−9.074**
Distance of the plots in walking hours	22.571	10.567	30.492	11.688	−1.549***

Source Own survey, 2015
*** Significant at $p < 0.001$
** Significant at $p < 0.05$

more ability to deal with risk. This is consistent with the findings of earlier studies in different part of Ethiopia that report a positive and significant effect of farm size on the decision to use conservation measures (Amsalu and de Graaff 2007; Kassa et al. 2013). Contrary results were obtained from Toni sub-watershed, indicating that farmers with large farms have alternative land to plough, and can allow for a fallow period; hence, they may neglect the maintenance of SWC structures (Kebede and Mesele 2014).

Family Size. This is a major determinant in SWC, especially with respect to poor resource farmers who depend solely on family labour to maintain their farms. This might have a link with the high rate of adoption of SWC technologies in the district. Keil (2001) noted that household size influences the decision of farmers to undertake the conservation measures given household labour is the whole supplier of the required labour for undertaking the farming and soil conservation operation. This study proved that adoption of SWC is influenced significantly ($p < 0.05$) by household size. However, the result by Aklilu and de Graaff (2006) revealed that an increase in family size demands more food. Thus, family members may become involved in off-farm work to generate income for securing a consistent food supply that indeed reduce participating in the maintenance of SWC structures.

Age of the Household Head. The age of the household head was negatively and significantly ($p < 0.001$) related to the adoption of SWC in the study area. This may be explained by the fact that older farmers resisted the adoption of new technology. Another reason for the expected negative relationship between age and conservation effort is an assumed longer planning horizon for younger farmers relative to older ones. This finding is inconsistent with the result which showed the likelihood of adoption of conservation practices is more among older farmers than the younger ones, perhaps due to the experience of older farmers to perceive erosion problems and their limited participation in off-farm activities. With experience, farmers notice and recognize erosion problems, learn how to conserve soil and develop capacity and strategy to cope with erosion problems (Kebede and Mesele 2014; Kidane et al. 2012).

Number of Livestock Owned. Livestock constitutes an important component of farming system in the study area. However, the result showed that the effect of livestock size on adoption of stone bund was found to be negatively significant. This may be explained by wealthy farmers have other resource options besides farmland and less concerned about adopting SWC technologies for improving productivity. This indicates that farmers with large livestock have more tendency to focus more on livestock than on crop production. Moreover, farmers who have large numbers of cattle may ignore structure maintenance, expecting frequent damage by cattle. This result is consistent with a study conducted by Amsalu and de Graaff (2007) in central highlands of Ethiopia which showed that livestock ownership has negative influence to adopt stone terrace. On the contrary, many empirical studies have shown positively and significantly effect of number of livestock on adoption of SWC measures (Damena 2012; Kassa et al. 2013).

Distance of the Plots. The effect of distance of the plots from farmers' residence on adoption of stone bund is found to be significantly negative. This analysis revealed that the tendency of retention of conservation structures decreases with increasing distance of plot from the residential area. Farmers whose plots are near to their residence use soil conservation measures than farmers whose plots are far from their residence because time and energy spent is relatively lesser than distance plots. This is perhaps due to plots far away from home take more time and energy to construct soil conservation structures as well as other farming practices. The cost of soil conservation includes not only cash costs, but also transaction costs of travel to plots distant from the homestead. Similarly, many empirical studies conducted in different period likewise found that distance of plots from homestead discouraged investment in soil conservation (Shiferaw and Holden 1998; Bekele and Drake 2003; Regasa 2005).

Education Status of the Household Head. As expected, level of education is positively and significantly related with adoption of conservation structures in Kuyu district. This is perhaps due to literate farmers are in a better position to get information and use it in such a way that it contributes in their farming practices. This could be attributed to the fact that household heads with relatively better formal education are more likely to use appropriate SWC practices and they also able anticipate the consequences of soil erosion than non-educated farmers. This result is in line with evidence from different parts of the country where adoption is high among farmers with higher education (Anley et al. 2007; Tizale 2007).

Perception of Soil Erosion Problem. Majority of farmers interviewed (58%) attested to the fact that there exists soil erosion problems in the study area. The chi-square test revealed that there exists a significant relationship between adoption of SWC technologies and perception of soil erosion problem(X^2 = 24.042, df = 1, p = 0.000), and that the tendency to adopt the technology was correspondingly high. However, this result contradicts with the finding by Awdenegest and Holden (2007) in Southern Ethiopia, where farmers' own initiatives were minimal, even under serious, advanced erosion.

Perceived Slope of the Plot. The slope condition of cultivated plots is an important determinant of farmer's investment in soil and water conservation measures. As expected, the influence of slope of the plot on farmer's decision to invest in soil bund is significantly positive ($p < 0.001$). In most SWC adoption studies, it has been shown that adoption of SWC measures are positively related to slope of the plot (Asrat et al. 2004; Rgasa 2005; Amsalu and de Graaff 2007). This might be because farmers cultivating sloping fields perceive the threat of soil loss better than farmers who cultivate gentle or level sloping fields that indeed motivate farmers more likely to adopt SWC technologies in their more steep farms than those cultivating less steep lands. Further, the slope of a plot influences the decision of SWC practices positively for the reason that erosion is more serious on steeper plot than flat plots. This suggests that targeting the stone bund on a steep plots might induces adoption of the measure.

Training on Soil and Water Conservation. Training on soil and water conservation significantly and positively influenced farmer's decision to adopt stone bund in the study area. This agrees with the argument that information obtained and the knowledge and skills gained through training accelerates farmer's decision on

Table 3 Differences of continuous explanatory variables between adopters and non-adopters

Variables	Chi-square values
Education status	13.48**
Perception of Soil Erosion Problem	24.042***
Access to credit	11.734
Slope of the plot	12.672***
Access to training	39.235***
Off-farm activities	0.044
Sex of the HH	2.13

Source Own survey, 2015
*** Significant at $p < 0.001$
** Significant at $p < 0.05$

conservation practices (Shiferaw and Holden 1998; Sidibe 2004). The possible explanation for this is that farmer who got training on SWC from development agent could be more encouraged to use SWC practices on their farm plots. This suggests that conservation efforts should encompass continuous training in order to encourage farmers to adopt. The chi-square result also showed that access to credit, off-farm activities, and sex of the household head no significant influence on adoption of stone bund (Table 3).

3.3 Summary

Soil erosion is one of the most serious environmental problems in Ethiopia. Climate change aggravates this problem. A number of soil and water conservation methods were introduced to combat soil erosion but adoption of these practices remains below expectations. Thus, this paper explored major adaptation strategies smallholder farmers used to combat soil erosion problem caused by climate change and variability. A special emphasis was given to investigate determinants of farmers' adoption of stone bund for adapting to climate change and variability.

The common climate adaptation strategies used to mitigate the effect of flooding among farmers in the study area were stone bud, soil bund check dam, and hillside terracing which have direct effect on soil erosion. The result depicted that adoption of stone bund is conditioned by different factors at different levels of significance. Results of independent t-test and chi-square test showed that adoption of stone bund was positively and significantly determined by size of landholding, family size, education of the household head, perception of soil erosion problem, slope of the plot, and access to training on soil and water conservation. Furthermore, adoption of stone bund was negatively and significantly determined by age of the household head, number of dependents, number of livestock, and distance of the plot.

3.4 Conclusions and Recommendations

The study showed that stone bund, soil bund, check dam, and hillside terracing were major soil and water conservation measures in the study area. In Kuyu district, a rage of factors influenced farmers' decisions to invest in soil and water conservation measures. Result of independent t-test and chi-square test showed that adoption of soil bund was positively and significantly influenced by farm size, family size, education, perception of soil erosion, slope of the plot and access to training on stone bund, on one hand. On the other hand, adoption of soil bund is negatively and significantly determined by increase in age of the household head, increase in number of livestock, and increase in distance of the plot from their residence.

On the basis of the survey results, the following recommendations were made: conservation interventions that failed to account for inter household variation (age, education, family size) and inter-plot variation (slope of the plot) are unlikely to be effective. Hence, any development intervention intended to enhance agricultural productivity through promoting SWC practices in the study area need to consider those differences in program design and implementation. Moreover, it is also imperative to give a due attention to the importance of farmers' perception on soil erosion problem for adoption of soil and water conservation measures. The study suggested strengthening agricultural extension services to make farmers more informed and knowledgeable about climate change impact on soil erosion and the adaptation strategies to use.

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Between Climate Reliance and Climate Resilience: Empirical Analysis of Climate Variability and Impact on Nigerian Agricultural Production

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1 Introduction

Climate change is now a global phenomenon that portends significant developmental challenges. The agricultural sector is no exception to the impact of climate change (Choptiany et al. 2015). The potential and predicted impacts of climate change are resulting in increased frequency and intensity of rainfall, floods and droughts (IPCC 2015). Rain-fed agricultural production system is vulnerable to seasonal variability which affects the livelihood outcomes of farmers and landless laborers who depend on such system of agricultural production. (Choptiany et al. 2015; Vermeulen et al. 2012). Climate change affect agriculture through rainfall variability (IPCC 2015). This situation, therefore, makes climate change an important consideration for sustainable agricultural production (Easterling et al. 2007). In the events of erratic rainfall, irrigated land area is insurance to rain-fed agriculture and a predictor of resilience of agriculture to rainfall-induced vagaries (including, droughts and heat waves) and impact of climate change (Cassman and Grassini 2013). Hence, the need for the empirical analysis of the impacts of rainfall and irrigation on agricultural production in Nigeria.

The agricultural sector is increasingly showing high level of vulnerability and impact. Climate change across Africa is exacerbated by low level of adaptation and mitigation (IPCC 2015; Montpellier Panel Report 2015). Further, literature suggests that farmers are now adapting to climate change and building resilience to vagaries of climate change (Choptiany et al. 2015; Wood et al. 2014; Kristjanson et al. 2012).

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The agricultural production risk imposed by rainfall variability may be a motivation or hindrance to investment in improved agricultural technology and climate resilient agriculture. Besides, farmers who are unable to adapt to changing climate may find alternative livelihoods or remain impoverished. Others may become resilient by developing alternative systems of production that help them to cope with changing climate. There is, therefore, pseudo choice-making process that is constrained by initial endowment or capacity to innovate so as to overcome vulnerability by becoming climate-resilient through appropriate adaptation and mitigation strategies (Montpellier Panel Report 2015; Wood et al. 2014). It has been noted that any strategy to adapt agriculture and food systems to a changing climate must, therefore, exploit the diversified means of climate resilient strategies. (Vermeulen et al. 2012).

Variability and extreme rainfall events have the potential to transform agricultural production system (rain-fed or irrigated) and diversifications of agricultural production (Liverman and Kapadia 2010; Nelson et al. 2009). The ability to circumvent the negative impact of climate and weather variability in agricultural production is an important consideration for climate adaptation and resilient agriculture for maximizing its benefits agricultural livelihoods and economic development.

The paper builds on emerging literature on the impact of climate variability on agricultural production (Ajetomobi et al. 2015; Craparo et al. 2015; Gourdji et al. 2015). It reveals the reliance and/or resilience of agricultural production to climate change and variability (Schlenker and Lobell 2010; Schlenker and Roberts 2009; Guiteras 2009; Kurukulasuriya et al. 2006). The study also underscores the contexts of vulnerability, impact and adaptation to climate change (Metternicht et al. 2014), including productivity, food security and livelihoods (Carandang et al. 2015; Arumugam et al. 2015).

2 Materials and Methods

2.1 Type, Measurement and Sources of Data

Time series data were extracted from harmonized databases of the Central Bank of Nigeria (CBN), National Bureau of Statistics (NBS), Nigerian Meteorological Agency (NIMET) and the Food and Agriculture Organization (FAO) of the United Nations in the Statistical Bulletin of the NBS (NBS 2013). Supplementary data on occurrence of flooding of the magnitude of national emergency situation were obtained from various publications. The specific data extracted included: agricultural production index, incidences or occurrence of flooding in a specific year, mean annual rainfall in millilitres, and value of agricultural (food) imports in million US dollars. The index of agricultural production is the relative level of the aggregate/composite volume of agricultural production (base year = 1990) (http://faostat.fao.org/site/362/DesktopDefault.aspx?PageID=362).

Since the impact of climate change is considered over a long period time (usually more than 30 years), this paper analysed times series dataset that spanned a period of 43 years (1970–2012) to estimate the impact of rainfall and irrigation on aggregate agricultural production in Nigeria. This criterion of sufficient time period also satisfies the econometric properties of large sample size (or observations) of the generalised methods of moment (GMM) estimation (Craparo et al. 2015; Gourdji et al. 2015; Hansen 2012), and consequently the estimation of the impact of rainfall and irrigation on agricultural production.

2.2 Analytical Methods

Descriptive analyses (means and standard deviations) were used to analyse the dataset to elaborate the variables. The GMM econometric technique was employed in estimating the impact of rainfall and irrigation on agricultural production. The choice of GMM was informed because the ordinary least squares estimation technique (regression) might result in biased estimation which is particularly linked to spurious regression and endogeneity problems (Fan et al. 2008). The issue that may cause spurious regressions is the possible existence of unit roots or non-stationarity of variables in the time series data analysis. This problem was handled by differencing while the problem of endogeneity of correlated independent variable (Fan et al. 2008) was resolved with the use of instrumental variables in the GMM estimation procedures.

Following Fan et al. (2008), and Arellano and Bond (1991), a GMM estimator as an estimation method was stated as:

$$\Delta y_{it} = \sum_{e=1}^{m} a_e \Delta y_{it-e} + \sum_{e=1}^{n} \beta_e \Delta x_{it-e} + \Delta \eta_{it} + \Delta u_{it} \tag{1}$$

where y is the dependent variable; x is a set of independent variables, i = 1, …, N; m and n are the lag (Δ) lengths sufficient to ensure that u_{it} is a stochastic error and η_i are instrumental variables. Blundell and Bond (1998) suggest that if the simple autoregressive AR(1) model is mean-stationary, the first differences Δy_{it} will be uncorrelated with individual effects.

The procedure for examining the nature of dataset for stationarity is to establish whether or not there exists a long-run relationship between the dependent variables and the independent variables. According to Engel and Granger (1987), homogenous non-stationary time series, which can be transformed to a stationary time series by differencing d times, is said to be integrated of order d. Thus, Y, (a time series variable) is integrated of order d [$Y \sim I(d)$] if differencing d times induces stationarity in Y_t. If $Y_t \sim I(0)$, then no differencing is required as Y is stationary (Jefferis and Okeahalam 2000). The test proposed by Dickey-Fuller to determine the stationarity properties of a time series is called the Unit Root test denoted by DF. The regression equation for the DF class of unit root test is:

$$\Delta Y_t = \varphi Y_{t-1} + \varepsilon_t;\ \varepsilon_t \sim N(0, \sigma^2), Y_0 = 0 \quad (2)$$

The unit root test above is valid only if the series is an autoregressive, AR(1) process. The Augmented Dickey-Fuller (ADF) tests use a difference method to control for higher-order serial correction in the time series. Another alternative test for stationarity is the Phillips-Perron (PP) test. The PP test allows for individual unit root process so that the autoregressive coefficient can vary across units (Olayide and Ikpi 2013; Ajetomobi 2008). The stationarity tests make a parametric correction for higher-order correlation by assuming that the Y series follows an AR(p) process and adjusting the test methodology. The ADF is identical to the standard DF regression, but augmented by k lags of the first difference of the series as follows:

$$\Delta Y_t = \alpha Y_{t-1} + \sum_{i=1}^{k} \omega i \Delta Y_{t-1} + \varepsilon_t \quad (3)$$

where the lag k is set so as to ensure that any autocorrelation in Y_t is absorbed and that a reasonable degree of freedom is preserved, while the error term is white noise or stationary.

The GMM is widely preferred and used in applied econometric research for empirical impact analysis. Zhang and Fan (2004) applied a GMM method to empirically test the causal relationship between productivity growth and infrastructure development using India district-level data, while Fan et al. (2008) assessed the impact of public expenditure in developing countries.

2.3 Variables Used for the Estimation of the GMM

In estimating the GMM model, aggregate agricultural production index was specified as the dependent variables while annual mean rainfall (in millilitres) and proportion of arable land under irrigation were the independent variables. The instrumental variables were incidence of flooding and annual total value of agricultural (food) imports (in million US dollars) (Quian and Schmidt 1999). These variables are predicted to have impact on aggregate agricultural production in Nigeria. The estimations were carried with E-Views 7 econometric computer software package.

3 Results and Discussion

3.1 Description of Variables

Results in Table 1 show the description of variable used in the analysis. The results reveal that the index of aggregate agricultural production was above the average for the base year (1990 = 100). This result indicates that agricultural production

Table 1 Description of variables used in estimating the generalized method of moment model

Variable and measurement	Mean	Std. deviation
Index of aggregate agricultural production	119.48	67.87
Mean rainfall in mm	355.39	64.24
Proportion of arable land under irrigation	0.80	0.10
Flood occurrence (dummy)	0.42	0.50
Total agricultural (food) imports in million US dollars	2236.47	1971.98

increased above the base year period. The mean rainfall for the study period was 355.39 (± 64.24) mm. The average proportion of arable land under irrigation was less than one percent (0.80 ± 0.10). Flooding incidence of national catastrophe magnitude was recorded for average of 42% of the study period. The total agricultural (food) imports in million US dollars were worth 2236.47 (±1971.98). The implications of the results in the context of the Nigeria agricultural policy call for concern. In that, the national agricultural policy agenda seek to promote food self-sufficiency by gradual reduction in the share of food imports that have comparative and competitive advantages. However, the country still spends a lot of foreign exchange on food imports (Olayide et al. 2011), and therefore, not self-sufficient in food production. For the country to move progressively towards self-sufficient in food production and food security (availability, access and stability), it should ensure increased food production under climatic changes which would have implications for rainfall and irrigation under the current agricultural production system.

3.2 Results of the Stationarity Tests

As a necessarily steps for estimating times series econometric models, we examined the variables used for the GMM model for stationarity or unit roots using comparable standard test statistic recommended in literature (Breitung 2002). The natural logarithms of the variables (except incidence of flooding which is a dummy variable) were tested for stationarity/unit root using comparable test methodologies of Augmented Dickey-Fuller and the Philips-Perron. Both tests yielded similar results (see Table 2). Only average annual rainfall and value of total agricultural (food) imports were stationary (white-noised) at level. All the variables (including, average annual rainfall and value of total agricultural (food) imports) were, however, stationary at first difference which suggests that they were auto-regressive of order I (ARI) variables (Breitung 2002), and they are co-integrated with their past values. This result also informed the estimation of the GMM by suggesting the incorporation of appropriate lag length (first difference) in the model estimation (Fan et al. 2008).

Further, the stationarity tests of the variables suggest that the interdependence with one-year lag or past values. For instance, this result has implications for