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A Review on Impacts of Climate Change on Crop Production and its Adaptation in Sub-Saharan Africa

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ABSTRACT

Climate change, which is inevitable, has a large impact on economies and livelihoods of many people. Therefore, the need to mitigate its impacts is paramount. Consequently, this has motivated a substantial body of research on the matter. The central issues that have been addressed are the impacts of climate change as well as the adaptation strategies that can be employed. The aim of this paper is to review existing literature on the above issues with a focus on smallholder farmers in sub-Saharan Africa. Adaptation strategies identified include; adjustment in land use, change in technology, farm diversification and risk management. Some environmental, economic and institutional factors are revealed to hinder farmers from adopting these strategies. The study recommends emphasizes on polices enhancing adaptation by smallholder farmers. Additionally, future studies on climate change should widen the range of variables used so as to capture the current global food prices and adaptation transition costs.

Keywords: Climate change; adaptation; smallholder farmers; Ricardian model

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1.0 Introduction

There is a global scientific consensus and evidence that, climate change is inevitable and it will adversely affect economies and livelihoods across the world. However, developing world particularly sub-Saharan Africa (SSA) will be more affected compared to developed world. This is because SSA relies mainly on rain-fed agriculture. In addition, it experiences high temperature and low precipitation (Kurukulasuriya *et al.,* 2006; Herrero *et al.,* 2010). Further, farmers in this region use basic conventional technologies that limit their capacity to adapt.

Climate is defined as average weather and represents the state of the climate system over a given time period (Orindi & Eriksen, 2005). Climate changes over time may be as a result of natural variability or human induced increase of greenhouse gases in the atmosphere and is reflected in the variation of the mean state of weather variables including temperature, precipitation and wind (Robertshaw and Taylor, 2000). According to Intergovernmental Panel on Climate Change (2007), climate change is a change in the state of the climate that can be identified by changes in the mean and / or the variability of its properties, and that persist for an extended period, typically decades, or longer".

Climate change affects physical process in many parts of the world. These changes result in a rise in temperatures, a reduction in the amount of precipitation and erratic rain patterns. These changes have been well elaborated in the Intergovernmental Panel on Climate Change Report of (2007). The report indicate that, weather variability and sea-level rise are the most pressing predicted consequences of climate change with a 0.6 °C global temperature change, about 2% precipitation increase of the tropical latitudes and 3% precipitation decrease in subtropical areas within the 20th century (IPCC, 2007). In addition, these changes affect the direction and intensity of wind, affects the frequency of extreme events like drought, floods and cyclones (Anyoha *et al.,* 2013). The predicted climate change has the potential to increases the frequency of severe weather events which contribute to trapping poor households into chronic poverty as they lack safety nets (Barnet *et al*., 2008).

Understanding the impact of climate change on agriculture is vital to developing suitable adaptation strategies, as failure to do so may lead to overestimation of potential benefits or underestimation of potential losses. This paper is therefore aimed to provide a general overview of the impact of climate change and adaptation strategies employed by smallholder farmers. Additionally, the paper reviews existing analytical models for measuring the impacts of climate change.

2.0 Impact of Climate Change on Crop Production

SSA economies heavily rely on agriculture, fisheries, forestry, tourism and other sectors that are vulnerable to climate conditions (Collier *et al.,* 2009). Agriculture and other natural resources are major sources of livelihood for a large proportion of SSA economies. Agriculture employs between 60 percent and 90 percent of the total labor force in SSA economies (Thornton *et al*., 2006; Toulmin and Huq, 2006). Climate change will adversely affect agricultural productivity in SSA economies that will not only lead to food insecurity but also economic turmoil (Herrero *et al.,* 2010).

The adverse consequences of climate change are not limited to agricultural production. Climate change accelerates other natural disasters such as droughts, storms, earthquake and landslides that affect both the economy and agricultural sector indirectly. There is evidence that directly links these disasters to global climatic changes (Nigel, 2010).

McCarl *et al.* (2001) assessed global climate change and its impact on agriculture. The study reveals that temperature, precipitation, the incidence of extreme events (droughts, floods, storms) and sea level rise are driven by climate change. Moreover, the authors find that the aforementioned variables have a central influence on agricultural production. The authors argue that temperature, precipitation, atmospheric CO_2 content and extreme events are likely to alter plant growth and harvestable yield through a mixture of climatic and CO_2 fertilization effects as well as impacts on plant water demand. According to McCarl *et al.* (ibid) study, temperature affects respiration and evapotranspiration while

CO_2 concentration affects plants water use efficiency. Extreme events influence agricultural production especially where droughts and floods become more severe and frequent (McCarl *et al.,* 2001; Adams *et al*., 1998).

A similar study by Rowhani *et al.* (2011), shows that cereal yields increase with more seasonal precipitation and decrease with higher temperatures. The study also reveals that an increase in precipitation variability during the growing season reduced yields. The authors indicate that in Tanzania, by 2050, the seasonal temperature which is anticipated to increase by 2°C will reduce average maize, sorghum and rice yields by 13 percent, 8.8 percent and 7.6 percent respectively.

Lansigan *et al.* (2000) assessed the long term impacts of climate variability on sowing date, crop duration and crop yield. The authors found that the areas in which El Niño had occurred are often associated with drought leading to delayed sowing dates. They also found that weather and climate variability influence the initiation of the rice cropping season. This is because rice cropping season is often coincident with the onset of the rainy season. According to authors, cropping calendar should be adjusted to coincide with the period anticipated to receive adequate rainfall to support the growth of crops. However, this may not be an appropriate adaptive strategy to untrained smallholder farmers.

Tetteh *et al*. (2014 studied the impact of climate change on smallholder agriculture in Ghana. They revealed that climate change has had a negative impact on Ghana's gross domestic product (GDP) and crop productivity. According to the authors, the impact of climate change on the economy and smallholder farmers is substantial as it has become one of the major obstacles to reducing rural poverty. This assertion is based on the argument that crop failure, pest infestation, loss of ecosystems and valuable wood species has adverse effects on both individuals and the state's income.

In a study by Herrero *et al.,* (2010), it is stated that Kenya would be like any other place in the world due to the increase in temperature by about 1.5 times the global mean response. This temperature increase will have a significant impact on water availability thus exacerbating drought conditions. The areas that will experience an increase in rainfall will also be adversely affected and may have low agricultural productivity.

2.2 Adaptation Strategies to Climate Change in Agriculture

According to the report of the Intergovernmental Panel on Climate Change, IPCC (2001), adaptation refers to an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which reduces potential damage or exploits beneficial opportunities. Adaptation strategies are tools or mechanisms employed by farmers to cope with climate change. Below *et al.* (2010) classify adaptation strategies practiced by African small scale farmers into four categories that are not mutually exclusive. The strategies include: farm management; change in technology; farm diversification; and financial/ risk management.

Farm management involves adjustments in land use and is the most prominent adaptation strategy. Various researchers have carried out studies with an aim of finding out farm management practices that can be used by farmers to cope with climate change. Firstly, a study by Kombo and Muchapondwa (2012) revealed that smallholder farmers in Tanzania used short-season crops and drought-resistant crops in order to adapt to the negative impacts of climate change on their agricultural yields. Additionally, the farmers altered their planting dates in order to match with favorable rain season. Secondly, Tessema *et al.* (2013) indicates that in addition to tree planting, in Ethiopia, farmers were practicing terracing, early planting, and water harvesting as adaptive strategies. Thirdly, Kurukulasuriya and Mendelsohn (2006) showed how crop selection assisted in adaption to climate change in South Africa. Their study revealed that crop switching was an effective strategy for farmers. The authors' results indicated that the farmers who did not select the crop most suitable for a given climatic condition recorded higher magnitudes of climate change damages. Fourthly, trench and keyhole gardens have also been used by smallholders as an adaptive strategy. A study by Sekaleli and Sebusi (2013) indicated that a majority of smallholder farmers at Kolo and Ts'akholo in Lesotho have adopted this strategy. The gardens are easy to construct and maintain as they require locally available materials such as wood ash, aloe and manure (ATPS, 2013). Lastly, conservation agriculture, which is based on the principles of minimum mechanical soil disturbance, crop rotation and crop residue retention, helps to increase soil moisture content (Kassam*et al.,* 2009). As asserted by Thierfelder and Wall (2010), the high soil moisture content under conservation agriculture acts as a buffer against adverse weather conditions during the crop growing season. A study by Verhulst*et al*. (2011) found that, the increase in maize yield under conservation agriculture was 2.7 times higher compared to those under conventional agriculture.

According to Below *et al.* (2010), change in technology as an adaptive strategy includes; irrigation systems, development of new crop varieties and improved climate information systems. The use of irrigation in areas that have water shortages is a pathway for increasing resilience among farmers during dry seasons. Additionally, irrigation increases productivity through supplementing rain water during the summer season (Orindi and Ericksen, 2005). However, decreasing rainfall is likely to reduce irrigation water supplies thus limiting opportunities for irrigation in many parts of SSA (Skees *et al*., 2008). Another technology involves development of improved crop varieties through crop breeding. A good example is the new drought tolerant maize seeds for Africa which yields 35 percent higher than local maize seed (Fischer and Edmeades, 2010; Setimela *et al*., 2012). Despite the improved seeds ability to mitigate the impacts of climate change, the efficiency of the seed delivery system in Africa is often overlooked (Cairns, 2013). According to Cairns, unlike in other developing countries, the development of seed delivery systems in SSA is slow, making improved seed varieties inaccessible to poor smallholder farmers.

Farm diversification such as crop diversification incorporates drought, pest and disease resistant crops. It serves as insurance against variable rainfall, as some crops are able to thrive well in areas with less rainfall (Nhemachena and Hassan, 2007). According to Orindi and Ericksen (2005) crop diversification reduces the risk of complete failure due to adverse climatic events because not all crops are affected by such events.

Farm financial and risk management adaptation strategies includes; managing production costs, leveraging on external financing and involvement in insurance programs to insure against farm losses. NGOs, insurance companies and banks have developed micro insurance and revolving funds (Below *et al,* 2010). Boko *et al*. (2007) considers the proactive development of capital services to be an important element in climate change adaptation for African farmers. Therefore, there is need for adequate financial management practices, financial education and financial solutions that are geared towards enabling SSA farmers to adapt to climate change.

It is critical to look for more appropriate strategies that incorporate all the elements discussed above that are tailored towards the specific needs of various categories of farmers including poor farmers. Skees *et al*. (2008) indicates that improved seed varieties can mitigate the adverse impacts of climate change. However, the study is quick to point out that improved seed varieties can only be accessed by the rich farmers. Poor farmers often replant seeds from their previous harvest because they cannot afford to purchase improved seed varieties. Similarly, irrigation schemes are also a good adaptive strategy but are capital intensive and not affordable to resource poor smallholder farmers (Tetteh *et al*. 2014). There is a need to understand factors that hinder farmers to adopt adaptive measures in order to address climate change.

2.3 Factors affecting adaptation to climate change

There exists vast literature on factors affecting adaptation to climate change. Some authors have cited household and farm characteristics, infrastructure and institutional factors as the most significant determinants of adaptation to climate change. For instance, a study by Uddin *et al*. (2014) indicated that age, education, family size, family income, farm size and involvement in cooperatives were significantly related to self-reported adaptation to climate change effects among farmers in Bangladesh. Age has been reported to have a significant but negative effect on adaptation to climate change implying that the probability of adaptation decreases as age increases. Older farmers could be more interested in following traditional methods familiar to them rather than adopting modern farming techniques (Uddin *et al*., 2014).

Education has a significant influence on adaptation to climate change. Several authors report a positive relationship between education and adaptation to climate change (Uddin *et al*., 2014; Fatuase and Ajibefun 2013; Quayum& Ali, 2012; Nhemachena and Hassan, 2007). Educated farmers are more knowledgeable and have information on the adverse effects of climate change and the appropriate adaptive strategies.

Family size has been shown to have a mixed effect on adaptation to climate change. Some authors show a positive relationship between family size and adaptation to climate change. Their argument is that large family size provides cheap and available labor facilitating the adoption of adaptive measures against climate change effects (Mignouna *et al.,* 2011; Tiamiyu *et al.,* 2009; Deressa *et al.* 2009).

The choice of adaptive strategy by farmers who undertake adaptation methods is greatly influenced by environmental, economic and institutional factors. These factors are key determinants of the availability, accessibility and affordability of particular adaptation methods (Komba and Muchapondwa, 2012). While analyzing determinant of farmers' choice of adaptation method in Nile Basin, Deressa *et al*. (2009) concluded that access to extension and credits services, climate information and social capital are the most significant determinants of adaptation method.

Anyoha *et al*. (2013) reveals that farm size, farming experience, household size, social organization and sex of household size are significant determinants of climate change adaptation strategies in Nigeria. A similar study by Fatuase and Ajibefun (2013) concludes that farming experience, access to extension services, access to climate information and access to credit are the major factors that affect the choice of climate change adaptation strategies in Ekiti state, Nigeria.

2.4 Analytical Framework Used to analyze Climate Change Adaptation

There are various models that have been used to analyze adaptation to climate change. Most of the models have been ineffective and inconsistent. Examples of models used include; Crop simulation, agro economic zone (AEZ), and the Ricardian model.

Crop simulation models involve controlled experiments in which crops are grown in the field settings that simulate different climates and levels of carbon dioxide to allow estimation of sensitivity of a given crop variety to extreme weather events (Zhai *et al.,* 2009). However, the estimates of these models do not to include the effects of farmer adaptation to changing climate conditions and their results tend to overstate the damages of climate change on agricultural production (Mendelsohn and Dinar 1999). They also focus on crop production and do not incorporate livestock. Further, they fail to capture efficient long-term adaptation strategies to climate change (Van Passel et al, 2012).

The AEZ model combines crop simulation models with land management decision analysis in order to capture the changes in agro climatic resources (Zhai *et al*., 2009; Darwin *et al*. 1995, Fischer *et al.,* 2005). However, the model has many limitations that make it ineffective in analysing adaptation to climate change. Firstly, it tends to overestimate the effects of autonomous adaptation (Kurukulasuriya and Mendelsohn 2006; Zhai *et al*., 2009). Secondly, it is data intensive. Therefore, it is not possible to predict final outcomes without explicitly modelling all relevant components. Thirdly, it is difficult to build a general model that would predict actual yields across various locations (Derresa *et al.,* 2005; Derresa, 2010).

The traditional production function model has been applied by many scholars such as; Poudel and Kotani (2013); Lhomme *et al*. (2009); Isik and Devadoss (2006); Eitzinger *et al.* (2001). It assumes that agricultural production growth is basedon soil and climatic variables, which are treated as explanatory variables in the model (De Salvo *et al.,* 2013). The main advantage of the model is its ability to provide important information that considers the entire economy. However, the model has various weaknesses. According to De Salvo *et al*. (2013) the approach of the model is crop and site specific, and it endorses the *dumb farmer* hypothesis that ignores adaptation strategies employed by farmers. In their study on the impact of global warming on agriculture, Mendelsohn *et al*., (1994) compares the traditional production function approach to estimating the impact of climate change with the new Ricardian approach. They argue that the traditional production approach takes an underlying production function and estimates impacts by varying one or a few input variables such as temperature, precipitation, and carbon dioxide levels. They note that these estimates might rely on extremely carefully calibrated crop-yield models to determine the impact of climate change on yields. The results predict severe yield reduction as a result of global warming. The traditional production approach overestimates the damages from climate change due to its inability to take into account the infinite variety of substitutions and adaptations.

The Ricardian model that was introduced by Mendelsohn *et al.* (1994) is significant since it is the first approach to demonstrate that cross-sectional evidence could provide quantitative estimates of the economic effects of climate change. Moreover, it is significant since it is one of the first empirical approaches to demonstrate that warming could be beneficial (Mendelsohn and Nordhaus, 2015). The Ricardian model explores the relationship between agricultural capacity and climate variables such as temperature and precipitation on the basis of statistical estimates from farm survey (Zhai *et al*., 2009). It is easy to compute and does not assume a *dumb farmer* hypothesis. The model also has the possibility of considering spatial correlations and is able to analyze panel data (De Salvo *et al.,* 2013). The Ricardian approach has been used by many researchers in developed countries [Dinar *et al*. (1998); Kumar & Parikh, (1998); Mendelsohn *et al*., (1996) and Cline (1996)], as well as researchers in developing countries [Derresa (2003); Gbetibouo and Hassan (2004); Deressa *et al*., (2005); Kurukulasuriya and Mendelsohn (2006); Derresa (2007); Seo and Mendelsohn (2008a) and Gebreegziabher *et al*. (2011)].

The Ricardian model has various limitations. For instance, it automatically incorporates climate change adaptations but it does not address factors affecting perception to climate change. It also fails to identify key adaptation strategies that reduce the implication of climate change on food production and fails to account for price changes (DI Falco *et al*., 2011; Derresa 2008; Zhai *et al*., 2009; Mendelsohn and Dinar 1999, Cline 1996). Darwin (1999) also criticizes the Mendelsohn Ricardian model. He argues that the estimated crop-revenue model in Mendelsohn Ricardian model is not hill-shaped with respect to temperature. This violates the principal Ricardian approach that the functional relationship between temperature and agricultural productivity is hill shaped. According to Darwin, the omission of irrigation from the analysis is the likely cause of this problem. In addition, the omission of irrigation makes the climate coefficients biased especially in the crop-revenue weighted regression. To solve theis problem, Darwin recommends including livestock production in the Ricardian regression. However, Darwin's recommendation is objected by Mendelsohn and Nordhaus (2006) who argue that including livestock in the model would be irrelevant as unlike crops, livestock are not influenced in any way by climate. According to them, the solution is to estimate an independent regression of livestock's net income on climate. Another limitation of the Ricardian model is the fact that it does not provide any insight on how farmers take into account the transition costs, that is, the cost of adaptation (Van Passel *et al.,* 2012). This limitation led to the development of a structural Ricardian model by Seo and Mendelsohn (2008b). However, the structural Ricardian model was developed under the assumption that global market prices of livestock are relatively stable over the century. The model also assumes that adaptation can take place when needed. This is not the case in reality especially if the change requires a significant capital investment. Another underlying assumption of the model is that climate is the only thing that will change when forecasting the impacts of climate change. However, this is not the case since population, technology and institutional conditions are bound to change over the century (Seo and Mendelsohn, 2008b).

To overcome the above weaknesses (of partial equilibrium models), discrete models have been developed. These models include the binary response model (binary probit and logit) multivariate model (multinomial probit and logit) and two stage process model (Heckman two stage probit). For instance, the ordered logit model is used by Mojo *et al*. (2010) to analyse determinants of perception of Ethiopian farmers and agricultural professionals on crop production quantity and quality of water. The results show that a majority of the simulated Ethiopian participants had realized a decline in water resources. The study postulates that climate changes and soil erosion could be the cause.

Kim *et al.* (2011) use both the probit and logit models to examine determinants of perception to climate change. They use the binary model because of a dummy dependent variable (perception). Their result indicates that rice farmers' perception of climate change is high. The perception level is influenced by their age, education and access to climate information which had a significant impact on climate change. The two models are similar except for the assumption of the distribution of the error term. Whereas the logit model is assumed to have a standard logistic distribution, the probit model is assumed to have a standard normal distribution (Kim *et al*., 2011). Therefore, the choice between the two models depends on the estimation and familiarity of the model rather than the theoretical or interpretive aspects.

Multivariate models are used in cases where there are more than two choices. The most used multivariate models are Multi-Nomial Probit and Multi-Nomial Logit. For instance, in their study, Nhemachena *et al*. (2007) used a multivariate discrete choice model to identify the determinants of farm-level adaptation strategies. Their results indicate that; access to credit, extension services and awareness of climate change are some of the factors that determine farm level adaptation. Another study conducted by Socio-economic team (2010) employs multivariate probit model to determine the perception of smallholder farmers towards climate change in dry areas of Tigray in northern Ethiopia. Their study shows that extension service, livestock ownership, gender of the household head, access to climate change information and perceived change in temperature has a positive and significant impact on adaptation to climate change.

Another model that is used in the literature is the Heckman sample selection model. The model is preferred because it can be estimated using the maximum likelihood approach without heavy computational burden. The model was employed by Maddison (2006) while determining factors that influence adoption of adaptation strategies towards climatic change in Africa. Maddison's study finds that education, gender, extension and experience significantly influence households in adapting to climatic change. Additionally, the author finds that; lack of appropriate seeds, credit accessibility, security of tenure and market accessibility are some of the barriers to household adaptation. The Heckman model was also employed by Deressa (2006) to assess the determinants of household adaptation to climate change in Ethiopia. From Deressa's study, the factors that determine adaptation are household size, gender, availability of credit, temperature and precipitation.

The Tobit model has been used when analyzing the intensity (or extent) of adaptation. Olarinde *et al*. (2014) employs the model to determine factors that influence the intensity and use of climate change adaptation strategies in Nigeria. A similar study by Idrisa *et al*. (2012) uses the Tobit model to determine farmers' awareness and adaptation to climate change. Their results indicate that extension services and education are significant factors that influence farmers' capacity to use adaptation strategies. Tobit models are preferred due to their ability to measure both adaptation and the extent of adaptation to climate change by farmers.

3.0 Conclusion

The analysis reveals that, climate change is and will continue to challenge smallholder farmers if appropriate adaptive measures are not taken. Adaptation to climate change impacts will help increase yields and revenues from agriculture. Adaptation, however, does not only require new interventions, but also requires the creation of awareness in local communities on the existence of climate change and the need to adapt. Further, there is a need to revise the approaches employed in measuring the impact of climate change so as to capture the current global food prices and adaptation transition costs. Finally, policy makers should take farming practices into account while making decision. There is a significant need to factor in the expected constraints of global warming and climate change on food security. Strengthening adaptation capacities of farmers in Africa will also help utilize the potential gains from working with the natural environment and the underpinning effective policies, strategies, and programs that can mitigate the impacts of climate change.

Reference

Adams R, Hurd B, Lenhart B,Leary N (1998). The Effects of Global Warming onAgriculture: "An Interpretative Review". Journal of Climate Research 11, 19-30.

Anyoha, N., Nnadi, F., Chikaire, J., Echetama, J., Utazi, C. & Ihenacho, R. (2013). Socio-economic factors influencing climate change adaptation among crop farmers in Umuahia South Area of Abia State, Nigeria; Net journal of Agricultural Science 1(2): pp. 42-47

Below T, Artner A, Siebert R, Sieber S (2010) Micro-level Practices to Adapt to Climate Change for African Small-scale Farmers. IFPRI Discussion Paper 00953.

Boko M, Niang I, Nyong A, Vogel C, Githeko A, Medany M, Osman-Elasha B, Tabo R, Yanda P (2007). Africa Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom, 1000 pp

Cline, W. (1996). The impact of global warming on agriculture a Ricardian analysis: comment. Am. Econ. Rev. 86, 1308–1311.

Collier B, Skees J, Barnett B (2009). Weather Index Insurance and Climate Change: Opportunities and Challenges in Lower Income Countries. The Geneva Papers. 34. Pg 401–424.

Darwin R, Tigras M, Lewandrowski J Raneses A (1995). World agriculture and climate change: economic adaptations, AER-703, US Department ofAgriculture, Economic Research Service, Washington DC (1995).

Darwin, R. (1999) "The Impact of Global Warming on Agriculture: A Ricardian Analysis: Comment." American Economic Review, 89(4), 1049–52.

Deressa, T., Hassan, R., Ringler, C., Alemu, T., &Yesuf, M. (2009) Determinants of farmers' choice of adaptation methods to climate change effects in the Nile Basin of Ethiopia. Glob. Environ. Chang.19, 248–255.

Di Falco, S., Veronesi, M., Yesuf, M., (2011) Does Adaptation to Climate Change provide Food Security? A Micro-Perspective from Ethiopia: American Journal of Agricultural Economics

Dinar, A., Mendelsohn, R., Evenson, R., Parikh, J., Sanghi, A., Kumar, K., McKinsey, J., Lonergan, S. (1998). Measuring the Impact of Climate Change on Indian Agriculture, World Bank Technical Paper No. 402, Washington, DC.

Gbetibouo, G. A., (2009). Understanding farmers' perception and adaptation to climate change and variability: A Case of the Limpopo Basin, South Africa, IFPRI Discussion paper.

Intergovernmental Panel on Climate Change (IPCC). Climate Change (2007): Impacts, Adaptation and Vulnerability: An Assessment Report of the Intergovernmental Panel on Climate Change; Cambridge University Press: Cambridge, UK, 2007.

IPCC, 2007: Climate Change 2007: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom, 1000 pp.

Jaim, W., Mizanur, R. (1999). Agricultural mechanization through private sector: A case of power tiller for multiple uses. In Proceedings of the 1999 Farm Economy Conference, Dhaka, Bangladesh, 15–16 July 1999

Komba, C & Muchapondwa, E. (2012). Adaptation to Climate Change by Smallholder Farmers in Tanzania; ERSA working paper 299

Kumar, K. & Parikh, S. (1998). Climate change impacts on Indian Agriculture: the Ricardian approach. In: Dinar, A., Mendelsohn, R., Evenson, R., Parikh, J., Sanghi, A., Kumar, K., McKinsey, J., Lonergan, S. (Eds.), Measuring the Impact of Climate Change on Indian Agriculture, World Bank Technical Paper No. 402. World Bank, Washington, DC.

Kurukulasuriya and Mendelsohn, (2006a). A regional analysis of the impact of climate change on African agriculture. Mimeo: School of Forestry and Environmental Studies, Yale University

Kurukulasuriya P & Mendelsohn R (2006b). A Ricardian analysis of the impact of climate change on African cropland: CEEPA Discussion Paper No. 8, Centre for Environmental Economics and Policy in Africa, University of Pretoria

Kurukulasuriya, P., & Mendelsohn, R.(2006c). Crop Selection: Adapting to Climate Change in Africa. CEEPA Discussion Paper, no. 26. Pretoria, South Africa: University of Pretoria, Centre for Environmental Economics and Policy in Africa.

LansiganF, SantosW, Coladilla J (2000) Agronomic impacts of climate variability on rice production in the Philippines. Agriculture, Ecosystems & Environment 82(3):129-137

Maddison, D., (2006). The perception of and adaptation to climate change in Africa. CEEPA Discussion Paper No. 10. Centre for Environmental Economics and Policy in Africa, University of Pretoria.

McCarl B, Adams R, Hurd B (2001). Global Climate Change and its Impact on Agriculture. Review of Agricultural Economics, 22(1), 134-159.

Mendelsohn, R and Dinar, A., (1999). “Climate Change, Agriculture, and Developing Countries: Does Adaptation Matter?” World Bank Research Observer 14(2):277–93.

Mendelsohn, R., & Nordhaus, W. (2015). The Impact of Global Warming on Agriculture: A Ricardian Analysis: Reply. Available from: Robert Mendelsohn Retrieved on: 27 August 2015

Mendelsohn, R., Nordhaus, D. & Shaw, D. (1994) “The Impact of Global Warmingon Agriculture: A Ricardian Analysis.”American Economic Review, 84(4), pp. 753–71.

Mendelsohn, R., Nordhaus,W., Shaw, D. (1996). Climate impacts on aggregate farm values: accounting for adaptation. Agric. For. Meteorol. 80 (1), 55– 67.

Mendelssohn,R, and Dinar A (1999). “Climate Change, Agriculture, and DevelopingCountries: Does Adaptation Matter?” World Bank Research Observer 14(2):277–93.

Mignouna, D., Manyong, V.M., Rusike, J., Mutabazi, K., &Senkondo, E. (2011). Determinants of adopting imazapyr-resistant maize technologies and its impact on household income in Western Kenya. Agric.Biol. Forum ,14, 158–163.

Mignouna, D., Manyong, V.M., Rusike, J., Mutabazi, K., Senkondo, E. (2011). Determinants of adopting imazapyr-resistant maize technologies and its impact on household income in Western Kenya; AgBioForum , 14, 158–163.

Mojo, D., Todo, Y and Matous, P., (2010) Perception of farmers and agricultural professionals on changes in productivity and water resources in Ethiopia. World Academy of Science, Engineering and Technology 66

Nhemachena C, Hassan R (2007) Micro-Level Analysis of Farmers’ Adaptation to Climate Change in Southern Africa: IFPRI Discussion Paper 00714

Nigel TA (2010). Climate change in Kenya: focus on children. Applied Knowledge, with additional input from UNICEF Kenya and Jazmin Burgess, UNICEF UK

Quayum, M. Ali, A. (2012). Adoption and diffusion of power tiller in Bangladesh. Bangladesh J.Agric. Res. 37, 307–325

Rowhani B, Linderman M, Ramankutty N (2011). Climate variability and crop production in Tanzania: Agricultural and Forest Meteorology 151(4): 449-460

Seo, S. & Mendelsohn, R: (2008a) “A Ricardian Analysis of the Impact of Climate Change on South American Farms,” Chilean Journal of Agricultural Research, 68, 69–79.

Seo, S. & Mendelsohn, R: (2008b) Measuring impacts and adaptations to climate change: a structural Ricardian model of African livestock management. AgriculturalEconomics38. Pp 151–165

Skees JR, Barnett BJ, Murphy AG (2008). Creating insurance markets for natural disaster risk in lower income countries: The potential role for securitization. Agricultural Finance Review 68:151–157.

Tetteh, E., Opareh, N., Ampadu, R., &Antwid, K. (2014). Impact of Climate Change: Views and Perceptions of Policy Makers on Smallholder Agriculture in Ghana. International Journal of Sciences: Basic and Applied Research (IJSBAR) 13(1): Pp 79-89

Tetteh, E., Opareh, N., Ampadu, R., Antwid, K. (2014). Impact of Climate Change: Views and Perceptions of Policy Makers on Smallholder Agriculture in Ghana. International Journal of Sciences: Basic and Applied Research (IJSBAR) 13(1): Pp 79-89

Tiamiyu, S. Akintola, J. &Rahji, M. (2009). Technology adoption and productivity difference among growers of new rice for Africa in Savanna Zone of Nigeria; Tropicultura 27, 193–197

Toulmin C, Huq S (2006). Africa and climate change. In Sustainable Development Opinion, ed. International Institute for Environment and Development. London: IIED.

Uddin, M., Bokelmann, W., & Entsmi, J. (2014). Factors Affecting Farmers’ Adaptation Strategies to Environmental Degradation and Climate Change Effects: A Farm Level Study in Bangladesh: Climate, 2:223-241. Accessed from www.mdpi.com/journal/climate

Van Passel, S., Massetti, M., & Mendelsohn, R. (2012). A Ricardian Analysis of the Impact of Climate Change on European Agriculture: Climate Change and Sustainable Development Series

Zhai F, Lin T, Byambadorj E (2009). A General Equilibrium Analysisof the Impact of Climate Change onAgriculture in the People’s Republic of China.Asian Development Review, vol. 26, no. 1, pp. 206−225