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Can Small-Scale Agricultural Schemes in Ghana Survive under Climate Change?

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***Abstract* - Climate change has become a global phenomenon and a topic of discussion on many platforms. Among the challenges associated with climate change are the impact on water resources and agriculture. Agriculture in Ghana is mainly rain-fed and subsistence and the irrigation types are primarily furrow and the use of traditional watering can. Climate change is therefore likely to affect this type of agricultural system severely. This paper investigates whether small-scale agricultural scheme, which is the dominant agricultural activity in Ghana, could survive in the era of climate change. This paper begins with a review of climate change scenario in Ghana, agricultural and irrigation development and practices, and the impact climate change will have on small-scale agriculture. The paper has established that there is climate variability in Ghana and farmers have already observed hotter climates and declining rainfall over the last decades. Ghana's informal irrigation sector, which is supposed to provide all year round farming, has also been neglected for long and only about 0.2% of the agricultural land is under irrigation. These scenarios therefore suggest that small-scale agricultural schemes will be threatened in the era of climate change which will subsequently affect the livelihood of the farmers and food security situation in the country. The article has therefore suggested measures such as rainwater harvesting, integrated water resource management among others as some of the best ways for the informal agricultural sector to survive under climate change.**

Keyworks: small-scale agriculture, climate change, irrigation, farmers' livelihood, water resources

I. INTRODUCTION

Climate change has become a global phenomenon and a topic of discussion on many political and social platforms. The evidence of climate change, which is attributed to anthropogenic activities, has widely been accepted worldwide (IPCC, 2007; Zhang *et al*., 2007). Principal among the anthropogenic activities accountable for climate change are the extensive use of fossil fuel (oil, gas and coal), industrial emission, deforestation, drainage of wetlands, cement production and land use change (IPCC 2007; Enger & Smith, 2008; FAO, 2010). These activities emit Green House Gases (GHGs) into the atmosphere most especially carbon dioxide (CO_2) which is the main cause of climate change (IPCC, 2007; Nair *et al*., 2009). Climate change will affect the hydrological cycle and put pressure on water resources for crop production and processing (Boko *et al*., 2007; UNEP, 2012). It will cause drought especially in many African countries and affect food production which will result in poverty and hunger (Funk *et al*., 2008; Dasgupta *et al*., 2009; Richardson *et al*, 2011). Climate change is associated with rising temperature and declining rainfall especially in arid and semi arid regions and this will severely affect agricultural productivity in the affected areas.

Irrigation agriculture which plays a very significant role in food production will be very critical due to the perceived impact of climate change and population increase. According to FAO (2011) irrigation provides about 40% of the food supply in the world including horticultural crops from an estimated 20% of agricultural land. Irrigation is therefore one of the main ways for farmers to adapt to the impact of climate change and remain in business. However, will the over reliance on rain-fed and subsistence agriculture coupled with the current state of irrigation practices in Ghana survive the impact of climate change in the coming years? This review paper therefore brings to the attention of all decision and policy makers, and stakeholders especially the government to take a critical look at agriculture and food production in the country which is the engine of growth and the life-wire of many rural dwellers.

II. STATE OF CLIMATE CHANGE IN GHANA

Available information gathered through publications, literature, books, reports and personal research work point to the fact that Ghana is experiencing climate variability and change in recent years. Already, studies have shown that most farmers have observed warmer temperatures and reduction of rainfall figures over the past decades (Gbetibouo, 2009; Deressa *et al*., 2008). An ongoing research conducted in the northern part of Ghana using temperature and rainfall data from 1961-2010 also confirms a rising temperature and declining rainfall in the three northern regions. Also findings from 330 irrigation farmers sampled through questionnaires and interviews also indicated that over 80% of the farmers have observed rising temperatures and declining rainfall in the Upper West Region. This knowledge of farmers concerning rising temperatures and declining rainfall is not restricted only to the north but also in the central and southern part of Ghana. Kemausuor *et al.* (2011) research findings in Sekyedumase in the Ashanti region of Ghana indicated that more than 80% of farmers believe that temperature in the district had become warmer and over 90%

were of the opinion that rainfall timing had changed, resulting in increased frequency of drought. Yaro (2013) also found that farmers in the Gomoa East District in the Central Region have a clear knowledge of the increasing temperature and declining rainfall trends of the climate parameters in Ghana. Research conducted by the Friedrick Ebert Stiftung (FES) across the country with about 3000 respondents also confirms rising temperature and decline rainfall.

Temperatures are observed to have risen significantly since 1970 in Ghana and within the same period rainfall and runoff were also recorded to have declined by about 20% and 30% respectively (EPA, 2000). Research conducted using the General Circulation Models (GCM) in conjunction with Simple Climate Models (SCM) in the cocoa growing areas indicated that projected mean annual rainfall values in the semi deciduous forest zone of Ghana will decline by 2.8, 10.9 and 18.6% in 2020, 2050 and 2080 respectively while the evergreen rainforest zone, mean annual rainfall will also decline by 3.1, 12.1 and 20.2% respectively in the same periods. Mean annual temperature changes will rise by 0.8, 2.5 and 5.4 and 0.6, 2.0 and 3.9 ^{o}C in the semi deciduous and evergreen rainforest zones in 2020, 2050 and 2080 respectively (Anim-Kwapong and Frimpong, 2006). A temperature rise by 1.7 ^{o}C to 2.04 ^{o}C by 2030 in the Northern Savannah regions is also predicted (EPA, 2011). These and other several climate models projections show clearly signs of climate change and confirm Ghana's vulnerability even though the predictions primarily differ (ibid). These rising temperatures and declining rainfall as signs of climate variability will affect water resources for irrigation which will subsequently affect the lives of rural farmers. According to Dasgupta *et al*. (2009) there is generally evidence that agriculture and water resource sectors, human health and livelihoods of women will be affected by climate change. The establishment of the National Climate Change Policy Framework (NCCPF) to ensure climate resilient and compatibility through sustainable economic development with the objectives to lower carbon emissions and growth, develop effective adaptation to climate change and to ensure socio-economic development in Ghana is a clear indication and awareness of Ghana's vulnerability to climate change.

III. AGRICULTURAL DEVELOPMENT AND IRRIGATION CAPACITY

The Ghanaian economy is agricultural-driven (WB, 2008) with about 60-70% of the population involved in agriculture and also contributes about 35-40% to Gross Domestic Product (GDP) and about 40% of foreign exchange for the country (MoFA, 2012). However, agriculture in Ghana is mainly subsistence and rain-fed with very little irrigation practice which is primarily furrow and the use of traditional watering can. The overreliance on subsistence and rain-fed agriculture is already being challenged by drought in many African countries including Ghana. It is estimated that rain-fed agriculture covers about 80% of cultivated land and produces about 60% of agricultural output globally (Alexandratos and Bruinsma, 2012) and this situation is likely to be affected by climate change especially those in semi-arid and arid areas. Schmidhuber *et al*. (2009) argued that the subsistence nature of farming in Africa cannot bring about the rapid economic transformation to eliminate or reduce poverty in the life of the poor even without the effect of climate change. Rain-fed agriculture in semi-arid and arid regions generally produces low yields and is prone to water stress which may cause crop failure thus only crops such as sorghum, millet and wheat are mainly grown is such drought prone areas (FAO, 2010). It is estimated that 75 million hectares of land suitable for rain-fed agriculture presently will be lost by 2080 in Sub-Saharan Africa due to climate change (ibid) and this therefore call for the adoption of irrigation agriculture to sustain food production.

Besides, population increase will also exacerbate food security which is defined as "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO, 1996)". Almost a billion people are said to be food in-secured with large population of hungry people in Africa, India and China (FAO, 2009). Research conducted by Lobell *et al.* (2008) suggests that places like central Africa will experience staple food decline due to population explosion. It is also estimated that by 2050 demand for food will increase by 2 ½ -3 times the current production capacity (Alcamo, 2003a) which means African countries must really change their agricultural production strategies to ensure food security if malnutrition, hunger and poverty are to be averted.

To ensure all year round food production, rain-fed and irrigation agriculture must go hand in hand especially in developing countries where drought and water stress seem precarious. Irrigation agriculture, unfortunately, has not been given the needed attention in Ghana as the country still rely mainly on the informal agricultural sector for food production. It is estimated that about 80% of Ghana's total agricultural output are small-holder and family-operated farms and out of this about 2.74 million households are into cultivation or rearing of animals with 90% having farms less than 2 hectares in size (Namara *et al.*, 2010; MoFA, 2011). Despite the contribution of the informal sector to food security situation and employment, the sector has not really been recognized (Namara *et al*, 2010). It is also estimated that about 70% of people living in developing countries are rural dwellers who depend on agriculture for their livelihood (Easterling *et al*. 2007) thus the use of irrigation is expected to alleviate poverty and improve the livelihood of the rural poor. According to Ruane *et al*. (2008) there is a high yield of crops of 2 to 3 times higher from irrigation agriculture than those who depend on rain-fed agriculture. In irrigation agriculture, average cropping intensity could always be higher than rain-fed agriculture because of proper management and water reliability. This therefore suggests that a combination of intensive rain-fed and irrigation agriculture is the way forward to guarantee food availability.

Unfortunately, the current capacity of agricultural land under irrigation is just 0.2% which can be translated into 30, 269 hectares even though the country has the capacity to put about 500, 000 hectares under irrigation. A research conducted by Namara *et al*. (2010) indicated that irrigation potential in Ghana ranges between 0.36 -2.9 Mha including

the use of valleys and flood plains. This is an indication that the country's real irrigation potential has not yet been tapped considering the current value of less than 31, 000 hectares under irrigation (table 1&2). This situation is similar in many African countries as revealed by FAO (2010) that irrigation development in many African countries has been low with less than 3.7% of sub-Saharan agricultural land as compare to Southern Asia with about 41% of irrigated agriculture. African countries including Ghana must therefore step up their effort to adopt expanded irrigation for food production.

Table 1. Distribution of land area for agric (2010)

Land Use	**Hectares**	**(%) area**
Total land area	23, 853, 900	100
Non Agric. area	10, 225, 721	42.9
Agricultural land use area	13, 628, 179	57.1
Area under cultivation	*7, 846, 551*	*57.6*
Area under irrigation	***30, 269***	***0.2***
Area not under cultivation	*5,751, 359*	*42.2*

Table 2. Total Area under Irrigation in Ghana

Area under irrigation		
Irrigation Schemes	2009 (ha)	2010 (ha)
Formal Irrigation Scheme / Project		
Existing Irrigation Schemes	10,067	10,127
Additional Area after Rehabilitation	500	500
Small Scale Irrigation Development Project	1,279	1,682
Small Farms Irrigation Project	322	324
Sub-total	***12,168***	***12,633***
Informal Irrigation Scheme/Project		
Small Scale Irrigation farms	17,636	17,636
Grand Total	**29,804**	**30,269**

Adapted from MOFA, 2011

Tables (2) above clearly outline the 0.2% land area which is under irrigation with the informal sector (small-scaled irrigation scheme) being larger than the formal sector and yet it is mostly ignored. Despite the meager 0.2% of land under irrigation, the few irrigation facilities are also underutilized and come with other challenges. An ongoing research in the northern part of Ghana revealed that most of the dams do not have well fitted structures to supply regular water to farmers. The general observation around the dams are broken canals, weeds in canals, siltation, drought among others due to lack of regular maintenance and supervision. Farmers also lack basic farm inputs, credit facilities, ready access to market and training among others. Additionally, the Ghana Agricultural Water Management Investment Framework (GAWMI) report outlined several challenges facing the irrigation sector and among these are the dependence on rain-fed agriculture, low irrigation application and underutilization of the irrigation schemes, slow expansion of the irrigation sector, weak institutional structures and lack of support for the scheme (MoFA, 2012). Unfortunately, many of these farmers do not form cooperatives to help them access credit facilities and negotiate for better prices for their products and soon get out of business (Hamida *et al*. 2012). These factors really hamper the effective growth of the small-scale agricultural schemes and thus affect the livelihood of small holders' irrigation schemes especially in the era of climate change.

IV. IMPACT OF CLIMATE CHANGE ON AGRICULTURE

Climate change is known to have diverse impacts on hydrology, agriculture and human health among others. Climate change will also clearly impact on GDP, growth rates and development of many African countries including Ghana (Ludwig *et al*, 2009). Agriculture sustainability is the key to feed the rising population and improves the livelihood of farmers in rural areas in the mist of climate change. The lack of sufficient knowledge about climate change and its impact on agricultural production is a setback to long term sustainable agriculture in most developing countries including Ghana (Kotei *et al.*, 2007). Climate change is projected to have significant impacts on conditions affecting agriculture, including temperature, precipitation and glacial run-off (Funk *et al*., 2008; McCarthy *et al*., 2001). In developing countries, 11% of arable land could be affected by climate change, including a reduction of cereal production in 65 countries up to about 16% of agricultural GDP (FAO, 2005). Boko *et al*. (2007) emphasized that climate change and climate variability are likely to compromise agricultural production and food security with a reduction of crop yields by as much as 50% and crop revenues by 90% by 2012 and 2100 respectively in some Africa countries and small-scale farmers will be more vulnerable. Research has also shown that crop water demand will increase by +5% to +8% with larger signal of +15% without the effect of CO_2 globally due to transpiration, rising evaporative demand and longer planting season but likely to increase to about +20% by 2080 with the effect of CO_2 under climate change scenario (Fisher *et al*., 2006). According to Batima *et al*. (2005) water demands for livestock and crops production will rise exponentially as compared to current conditions which will expand overgrazing along water sources due to increased heat stress and future drought.

Global warming will precipitate high surface air temperature, greater evapotranspiration, lower soil moisture and results in increasing frequency of drought which will affect agriculture productivity. In Africa, by 2020, between 75 and 250 million people will be exposed to increased water stress and in some countries, yields from rain-fed agriculture could be reduced by 50 percent (IPCC, 2007). It was estimated in 2005 that 2.5 billion people in developing countries whose livelihood hanged on agriculture and 75% of the poor people globally, live in rural areas (FAO, 2010) and these people will be affected by the impact of climate change.

Unfortunately, rainfall pattern has also not been uniform across the African continent and while some areas experience heavy rainfall leading to floods, others suffer extremely from drought (Tadross *et al*., 2005). For the farmer, the total amount of rainfall and its distribution is much more important than the total annual rainfall. The beginning and end of the

rainy season is also as important as its quantity. Farmers sometimes observe early rains in a particular year and late in another year with differences in intensity and duration and this erratic nature of the rainy season affects farm planning and operations.

Despite the fact that climate change will affect agriculture and food production negatively, another school of taught also believe that climate change will improve agricultural productivity through CO_2 fertilization (Woodward, 1993; Lockwood, 1999). However, this requires optimization of other factors of production (FAO, 2011) and agronomic factors such as pest and weeds control, and moisture availability (Fuhrer, 2003) to warrant the benefit. Even though farmers in Africa are reported to have very good knowledge of the climate and have clear opinions on changes in rainfall, temperature, and wind speed (Maddison, 2007; Thomas *et al*. 2007; Mertz *et al*. 2009; Ifejika *et al*. 2009), this indigenous knowledge must be linked to improved agricultural practices and functional irrigation facilities to ensure that small-scale irrigation farmers adapt and survive the threat of climate change.

V. CONCLUSION AND RECOMMENDATIONS

It is quite clear that the climate in Ghana is changing through higher temperature and declining rainfall and this will affect food production significantly due to higher evapotranspiration which will cause low yields, crop failures and lower water levels in dams for continuous irrigation. This will therefore jeopardize food production, food security and worsen the plight of small-scale farmers in Ghana. The over reliance on subsistence and rain-fed agriculture coupled with the meager irrigation practices and population increase in the country cannot in any way be sustainable in the era of climate change. The question therefore is "will small-scale agricultural schemes survive under the influence of climate change? Your guest may be as good as mine. For small-scale agriculture to survive the effect of climate change, the following are thus recommended:

***Water harvesting and storage*:** Considering the rising temperature and declining rainfall in the mist of climate change, there should be a deliberate effort to harvest adequate rainwater for storage and use during the dry season. There should be the construction of more standard irrigation dams, reservoirs and recharge pools in addition to dredging of old dams to store sufficient water to help improve surface and ground water levels. Runoff and flood waters could be intercepted and channeled into dams, reservoirs and potential places to recharge underground aquifers. To address the perennial water challenges in the cities, water harvesting should be part of all building codes to provide adequate water for domestic and peri-urban agriculture.

***Integrated water resource management*:** There is the need to properly manage the available water resources through efficient, equitable and sustainable manner in the country. This is very important due to the imminent impact of climate change on water resources thus effective implementation of an integrated water resource management is essential in ensuring sustainable food production. This may require that farmers are educated on crop water requirement and training of water users associations to ensure sustainable irrigation water use; maintenance of irrigation canals to avoid water losses and if possible the use of closed tubes to transport water to farmers. It is also very important to plant trees around irrigation dams to reduce wind speed, direct evaporation and siltation of the dams.

Improved irrigation facilities: The need to revamp the irrigation sector to improve agriculture productivity has become more important now than ever. It is already clear that the country cannot rely on rain-fed and small-scaled agriculture but rather considers irrigation as one of the best options to survive climate change. Water harvesting and management will be an important factor to ensure all year round farming considering the current trend of rainfall and temperature variability. To ensure sustainability of irrigation agriculture, there should be the urgent need for repairs and maintenance of the irrigation structures, regular dredging of the dams and purposeful harvesting of water into the dams. Irrigation farmers should also be supported with farm inputs, credit facilities and ready markets for their products. The Irrigation Development Authority (IDA) should also be well resourced to provide support for the small scale irrigation farmers.

Modification of agricultural practices: To ensure agricultural sustainability in the era of climate change, there should be a total paradigm shift from the traditional method of farming to a more adaptive mechanism to withstand the impact of climate change. The sort of crops and certain farm practices must completely be changed and farmers must be prepared to accommodate new methods of farming. For this reason farmers must be supported with new varieties of crops that are climate resistance, high yielding crops, short duration crops, drought resistance, low water consuming and early maturity crops coupled with agro-forestry practices, mulching among others. Zero tillage and proper land preparation are all important steps to guarantee food security and keep small scale farmers in business.

VI. REFERENCES

[1] J. Alcamo, P. Döll, T. Henrichs, F. Kaspar, T. Lehner, T. Rösch and S. Siebert, "Development and testing of the Water GAP 2 global model of water use and availability". Hydrol. Sci. J., 48, 2003a, 317-338.

[2] N. Alexandratos and J. Bruinsma, "World agriculture Towards" 2030/2050: the 2012 Revision. ESA Working paper No. 12-03. 2012, Rome, FAO

[3] E. Amankwah and T.O Ocloo, Contribution of Small Scale Irrigated Agriculture to Food Security. Journal of Development in Sustainable Agriculture Vol. 7(2) pp 115-121, 2012.

[4] G.J. Anim-Kwapong and E.B Frimpong, Vulnerablity of agriculture to climate- impact of change change on cocoa production: Vulnerability and Adaptation Assessment under the Netherlands Climate Change Studies Assistance Programme Phase 2 (NCCSAP2). CRIG, New Tafo, 2006.

[5] P. Batima, B. Bat, L. Tserendash, Bayarbaatar et al. Adaptation to Climate Change, Vol. 90, ADMON Publishing,

[6] Boko, M., I. Niang, A. Nyong, C. Vogel, A. Githeko, M. Medany, B. Osman-Elasha, R. Tabo and P. Yanda, 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, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge UK, 2007, 433-467.

[7] S. Dasgupta, D. Laplante, S. Murray and D.Wheeler. Sea-Level Rise and Storm Surges: A Comparative Analysis of Impacts in Developing Countries, Policy Research Working Paper 4901, DRG, Environment and Energy Team, the World Bank, 2009.

[8] T.T Deressa, R.M Hassan, C. Ringler, T. Alemu and M. Yesuf. Analysis of the Determinants of Farmers' choice of Adaptation Methods and Perceptions of Climate Change in the Nile Basin of Ethiopia. International Food Policy Research Institute. Washington, DC, 2008.

[9] W.E Easterling, P.K Aggarwal, P. Batima, Brander etal. Food, fibre and forest products. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 2007, 273-313.

[10] D.E Enger and F.B Smith. Environmental Science: A Study of Interrelationships, 11th Edn., McGraw Hill, USA, 2008.

[11] EPA. Ghana's Initial National Communication under the United National Framework Convention on Climate Change. Accra, Ghana, 2000.

[12] EPA. Ghana's Second National Communication under the United National Framework Convention on Climate Change. Accra, Ghana, 2011.

[13] FAO. World Food Summit Plan of Action, Rome, 1996.

[14] FAO. Impact of Climate Change, Pests and Diseases on Food Security and Poverty Reduction: Special event background document for the 31st Session of the Committee on World Food Security. FAO Publication, Rome, 2005. pp. 1-10.

[15] FAO. The state of Food Insecurity in the World Economic Crises: Impact and Lessons Learned. Rome, 2009.

[16] FAO. Enduring Farms: Climate Change, Smallholders and Traditional Farming Communities. FAO, Rome, Italy, 2010.

[17] FAO. Climate Change: Water and food Security. FAO Water Report 36. Rome, 2011.

[18] G. Fischer, F.N Tubiello, H. vanVelthuizen and D. Wiberg. Climate change impacts on irrigation water requirements: effects of mitigation, 1990-2989. Technol. Forecast. Soc., 2006, doi: 10.1016/j.techfore.2006.05.021.

[19] J. Fuhrer, "Agro-ecosystem responses to combinations of elevated carbon dioxide, ozone and global climate change Agriculture", Ecosytems and Environment 97: 2003,1–20

[20] C. Funk, M.D Dettinger, J.C Michaelsen, Verdin et al., "Warming of the Indian Ocean threatens Eastern and Southern African food security but could be mitigated by agricultural development". Proceedings of the National Academy of Sciences, 105(32): 2008, 11081-11086.

[21] G.A Gbetibouo, "Understanding farmers' perceptions and adaptations to climate change and variability": The case of the Limpopo Basin, South Africa, Washington, D.C: International Food Policy Research Institute (IFPRI), 2009.

[22] S.C. Ifejika, B. Kiteme, P. Ambenje, U. Wiesmann and S. Makali, "Indigenous knowledge related to climate variability and change: insights from droughts in semi-arid areas of former Makueni District, Kenya", 2009.

[23] IPCC, Summary for Policymakers, Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, S. Solomon, D. Qin, M.Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller, (Eds.),Cambridge University Press, Cambridge, 2007, 1-18.

[24] F. Kemausuor, E. Dwamena, A. Bart-Plange and N. Kyei-Baffour, "Farmers' Perception of Climate Change in the Ejura-Sekyedumase District of Ghana". ARPNJournal of Agricultural and Biological Science, Vol (6) 10 pp 26-37,

[25] R. Kotei, J.M Seidu, J.W Tevor and A.A Mahama "Farmers' Perception about the Effects of the Physical Environment on Crop Production in the Sekyere-West District", Proceedings of the Ghana Society of Agricultural Engineering, 2007, pp. 16- 25. [26] D.B Lobell, M.B Burke, Tebaldi et al. "Prioritizing climate change adaptation needs for food security in 2030. Science, 319, 2008, 607-10

[27] J.G Lockwood, "Is Potential "Evapotranspiration and its relationship with Actual Evapotranspiration sensitive to elevated atmospheric CO2 levels", Climate Change 41, 1999, pp 193-212 [28] F. Ludwig, P. Kabat, S. Hagemann and M. Dorlandt "Impact of climate variabillity and change on development and water security in Sub-Saharan Africa", IOP Conference Series: Earth and Environmental Science, 6, 2009, 2009, 292002

[29] D. Maddison, "The perception of and adaptation to climate change in Africa". Policy Research Working Paper 4308, Sustainable Rural and Urban Development Team, The World Bank Development Research Group, Washington, 2007.

[30] J.J McCarthy, O.F Canziani, N.A Leary, D.J Dokken and K.S White (eds) Climate change 2001: impacts, adaptation & vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, Cambridge, p. 1000, 2001.

[31] O. Mertz, C. Mbow, A. Reenberg, A. Diouf "Farmers' perceptions of climate change and agricultural adaptation strategies in Rural Sahel". Environ Manage 43: 2009, 804–816

[32] MoFA. Agriculture in Ghana: Facts and Figures, 2010. Statistics, Research and Information Directorate (SRID), Accra. 2011.

[33] MoFA. Ghana Agricultural Water Management Investment Framework: Part 1: The Pre-Investment Reform Action Framework. 2012.

[34] J. Nair, Technologies and management for sustainable biosystems, New York: Nova Science Publishers. 2009.

[35] E.R Namara, L. Horowitz, S. Kolavalli, Kranjac-Berisavljevic et al. Typology of Irrigation Systems in Ghana. IWMI working Paper 142.2010

[36] K. Richardson, W. Steffen and D. Liverman, Climate Change: Global Risks, Challenges and Decisions. Cambridge Uni. Press, UK, 2011.

[37] J. Ruane, A. Sonnino, P. Steduto and C. Deane Coping with water scarcity: what role for biotechnologies? Land and Water Discussion Paper No. 7. FAO. Rome.2008.
[38] J. Schmidhuber, J. Bruinsma and G. Boedeker, Capital Requirements for Agriculture in Developing Countries to 2050: Expert meeting on how to feed the World in 2050. FAO. Economic and Social Development Department. Rome.2009.
[39] M. Tadross, C. Jack and B. Hewitson, On RCM-based projections of change in southern Africa summer climate". Geophys. Res. Lett., 32, 2005b, L23713,
[40] UNEP, The UN-Water Report: Status Report on the Application of Integrated Approaches to Water Resources Management. Nairobi, Kenya. 2012
[41] A. Woodward, S. Hales and P. Weinstein Climate Change and Health H in Asia Pacific region, Who will be most vulnerable? Climate Research 11 (1): 1998, 31-38
[42] World Bank, World Development Report 2008: Agriculture for development. Washington, DC, 2008.
[43] J.A Yaro, "The perception of and adaptation to climate variability/change in Ghana by small-scale and commercial farmers". Reg Environ Change (2013) 13: 2013, 1259-1272
[44] X. Zhang, F.W Zwiers, G.C Hegerl et al., Detection of human influence on twentieth-century precipitation trends. Nature 448: 2007, 461-65
[45] S. D Hamidatu, R. Adams and E. Amankwah (2012) "Building on Community Supported Agriculture for Commercial Food Production in the UWR". ARPN Journal of Agricultural and Biological Science Vol. 7 (11). 2012, pp 953 - 957