The Role Of Agricultural Extension In Climate Change Adaptation And Mitigation In Agriculture

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Abstract: Global climate change poses great risks to poor people whose livelihoods depend directly on agriculture, forestry, and other natural resource uses. Waters sources will become more variable, droughts and floods will stress agriculture systems, some coastal food pro-reducing areas will be inundated by the seas and food production will fall in some places. Developing economics and the poorest of the poor likely will be hardest hit. Agriculture is, however, also part of the solution, offering promising opportunities for mitigating greenhouse gas emission through carbon sequestration, soil and land use management, and biomass production. A key element in supporting agriculture's role is information. Mitigation efforts will require information, education and technology transfer. Agricultural extension and advisory services, both public and private, thus have a major role to play in providing farmers with information, technologies, and education on how to cope with climate change and ways to contribute to greenhouse gas mitigation. This support is especially important for resource-scare smallholders, who contribute little to climate change and yet will be among the most affected. This paper thus opined that support from extension for farmers in dealing with climate change should focus on two important areas-adaptation and mitigation. To achieve the above the paper the discusses three ways in which extension can help with adaptation and mitigation. The three ways include technology and management information; capacity building/development; and facilitating, brokering and implementing policies.
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1 Introduction

Agriculture has received a lot of attention from climate modelers because of the high dependence of agriculture on the climate. Human dependence on agriculture, particularly in developing countries, also means that agriculture has an important role in debates about adaptation to the impacts of climate change in developing countries (Pesket, 2007).

Currently agriculture accounts for 24% of world output, employs 22% of world population and uses 40% of land area (FAO, 2003). Most studies of the impacts of climate change on agriculture indicate that there will be negative effects over the next century. Some estimate that 600 million additional people may be at risk of hunger if global temperature increases by 3 degrees Celsius (Warren et al, 2006), particularly in developing countries where people are already at risk. But climate change is only one of a range of factors that may affect global food production in the future, so it is important to try and understand the scale of these impacts in relation to other changes such as improvements in technology and farming systems.

Agriculture is undoubtedly the most important sector in the economies of most non-oil exporting Africana countries. It constitutes approximately. 30% of Africans GDP and contributes about 50% of the total export value, with 70% of the continents population depending on the sector for their livelihoods. Productions are subsistence in nature with a high dependence on the rain. The debate on climate change and its impacts on agriculture is therefore very crucial to very survival of the continent and its people. The continent is particularly susceptible In climate change because it includes some of the world's poorest nations. (CEEPA, 2002).

The climate in African is predominantly tropical in nature, which is broadly classified into three main climatic zone: humid Equatorial, dry, and humid temperate. Within these zones, altitude and other localized variables also produce distinctive regional climate. The climate also varies cyclically over periods of decades, centuries, and millennia as well as from year to year. Climate change, especially indicated by prolonged drought is one of the most serious climatic hazards affecting the agricultural sector of the continent. As most of the agriculture activities in African countries hinges on rain fed, any adverse changes in climate would likely have a devastating effect on the sector in the region, and the livelihood of the majority of the population (CEEEPA, 2002).

Though changes in the climate may affect the whole continent, its distribution may vary across the continent. Climate change in the already arid northern sub-region of the continent is expected to enhance desertification and bring a gradual decrease in forest cover. In the Sahara and sahel sub-regions, rainfall is predicted to drop resulting in soil degradation and an increasing number of dust storms. In north east Africa, more intensive dry periods and shorter net seasons are expected to affect even huge river systems south as the Blue Nile, leading to serious water shortage and adverse consequences for the agriculture and forestry sectors throughout the region. East and central African will also see its agricultural capacity decline. In West Africa more frequent and longer dry periods are expected, against threatening crop failure. Coastal areas may be affected by rising sea levels and intrusion of salt water into inland fresh water resources. Southern Africa also faces similar threats. The staple food for the region, maize, is particularly susceptible to drought. Wet lands of international importance and wildlife area are also under threat from drought in Southern Africa. Climate change, therefore, is expected to worse the food supply, hence, exacerbate the wide spread poverty in the region.

2. Climate Change Projections: A Summary

Evidence presented by the Intergovernmental Panel on Climate Change (IPCC) reveals that the world's climate is changing. The IPCC's climate change predictions are based on a wide range of scenarios of future emissions of greenhouse gases and aerosols, which all assume that business will continue as usual and concentrations of atmosphere Co_2 will rise from 90 to 250% above that of the year 1750. According to the 2007 report of the Intergovernmental Panel on Climate Change (IPCC), the best estimates from these models indicate that the global average surface temperature would rise from 1.7°C (3°F) to 3.9°C (7.°F) by the year 2099 depending on how much the concentrations of Co2 and other greenhouse gases increase. For all the scenarios studied, both temperature and sea levels are expected to rise over the 21 century (La Trobe, 2002; IPCC, 2001; Fraise *et al* 2005).

The estimate for Africa is that 25 to 42 percent of species habitat could be lost, affecting both food and non-food crops. Habitat change is already underway in some areas, leading to species range shifts, changes in plant diversity which includes indigenous foods and plant-based medicines (McClean, 2005). Land area may warm by as much as 1.6°C over the Sahara and semi-arid regions of southern African by 2050. Rainfall is expected to increase over Africa except in southern Africa and parts of the Horn of Africa, where rainfall is projected to decline by about 10% by 2050. Sea level rise is projected to rise around 25cm by 2050.

In developing countries, II percent of arable land could be affected by climate change, including a reduction of cereal production in up to 65 countries, about 16 percent of agricultural GDP (FAO, 2005). Changes in ocean circulation patterns, such as the Atlantic conveyer both may affect fish populations and the aquatic food web as species seek conditions suitable for their lifecycle. Highest ocean acidity (resulting from carbon dioxide absorption from the atmosphere could affect the marine environment through efficiency in calcium carbonate, affecting shelled organisms and coral reefs.

Climate change impacts can be roughly divided into two groups:

a) Biophysical impacts
- Physiological effects on crops, pasture, forests and livestock;
- Changes in land, soil and water resources,
- Increased weed and pest challenges,
- Shifts in spatial and temporal distribution of impacts.
- sea level rise, changes on ocean salinity,
- Sea temperature rise causing fish to inhabit different ranges,

b) Socio-economic impacts
- Decline in yield and production.
- Reduced marginal GDP from agriculture,
- Fluctuation in the world market prices,
- Changes in geographical distributions of trade regions,
- Increased number of people at risk of hunger and food insecurity,
- Migration and civil unrest. (FAO, 2007).

3. Potential Impacts Of Climate Change On Agriculture

Potential impacts of climate change on agriculture are broad and not completely understood. Despite the potential challenges such as increased disease pressure and more frequent occurrence of extreme climate events climate change may also bring opportunities for the introduction of new crops and increase yields.

Crop

There is a general belief that the beneficial effects of an increase of atmospheric carbon dioxide (Co_2) on plants, the Co_2 fertilization effect, may compensate for some of the negative effects of climate change. However, increased C assimilation may result in nutrients being more limiting to growth, thus necessitating increase fertilizer applications, which may increase lodging and disease (Lawlor and Mitchell 2000). Another important aspect is that photosynthetic rates of various species living diverse conditions such as and deserts, high mountains and tropical rainforest differ greatly (Salisbury and Ross, 1985). The biochemistry of photosynthesis differs among plant species and this greatly affects their relative response to Co_2. Most economically important crop and weed species can be classified as either a C_3 or C_4 type, the names referring to whether the early products of photosynthesis are compounds with three or four carbon atoms. The C_3 photosynthesis pathway is less efficient than the C4 pathway. Because, plants, (Kimball; 1983; Cure and Acock, 1986).

Over 90% of the world's plant species are the C_3 types, including wheat, rice potato, bean, most vegetable and fruit crops and many weed species However, C_4 species are distributed in warmer environments and generally have higher optimum temperatures for photosynthesis and growth and because their intrinsic water-use efficiency (the ratio of photosynthesis to transpiration) might better adapt to the greater evaporative demand that would result from warming (Bunce and Ziska, 2000). The C_4 group includes the important food crops, maize, millet, sugarcane and sorghum as well as many pasture and weed species.

Temperature is important for plant growth and development. There is an optimum temperature range for maximum yield for any crop. Temperature strongly affects the rate of plant development; higher temperatures speed annual crops through their development phases. Thus, warmer temperatures shorten the life cycle of determinate species, such as grain crops, which only set seed once and then stop producing. Warmer temperature also increases the water requirement of crops. If a crop variety is being grown in a climate near its temperature photosynthesis and shorten the growing period. Both of these effects will tend reduce yield (Wolfe, 1995).

Weeds, Insect And Diseases

Increases in the concentration of atmospheric Co_2 will likely stimulate the growth of weeds. Worldwide, weeds have been estimated to cause annual crop losses of about 12% (Oerke *et al*, 1995). Insect pests are responsible for major impacts on yield quantity. Insects are particularly sensitive to temperature because they are cold-blooded. In general, higher temperatures increase rate of development with less time between generations. Warmer winters will increase survival and possibly increased insect populations in the subsequent growing season (Gutierrez, 2000; Rosënzweig, et al, 2000).

Climate factors that impact growth, spread and survival of crop diseases include temperature, precipitation, humidity, dew, radiation, wind speed, circulation patterns and the occurrence of extreme events. Higher temperature and humidity and greater precipitation result in the spread of plant diseases, as wet vegetation promotes the germination of spores and the proliferation of fungi and bacteria and influences the lifecycle of soil nematodes (Rosenzweig *et al*., 2000).

Livestock

Effects of climate change on livestock are likely to liable based on be number of factors such as the magnitude of temperature increase and animal feed prices. Dairy cows are particularly sensitive to heat stress, with temperature optimum for milk production between 45°C (40°F) and 24°C (75°F). Decline in performance usually occurs as the main daily temperature approaches 24°C. In addition to ambient temperature, humidity and wind velocity also affect performance (Harris, 2003). At high relative humidity (80%) heat stress in dairy cows can begin at temperatures as low as 23°C (73°F) and stress becomes severe at 34°C (93°F). Heat stress can have a carryover effect to depress milk production and reproduction for up to 150 days (Wolfe, 2004).

Climate change will also affect other livestock industries such as beef, cattle and poultry, both through direct effects on production and indirectly through changes in grain prices, pasture productivity, or costs for cooling. Cooling costs are particularly worrisome in light of a steep upward trend in the price of fossil fuels. In general, analyses indicate that intensively managed livestock systems have more potential for adaptation than crop systems. Some of these adaptations may be enabled by the use of alternative energy sources on farm (Fraise et al, 2005).

Others Areas Of Impact Include

- Limit the availability of water: It is expected that the availability of water in most parts of Africa would decrease as a result of climate change.

Particularly, there will be a severe down trend in the rainfall in southern African
countries and in the dry areas of countries around Mediterranean Sea.

- Exacerbation of drought period: An increase in temperature and a change in the climate throughout the continent are predicated to cause recurrent drought in most of the region.
- Reduction in soil fertility: An increase in temperature likely to reduce soil moisture, moisture storage capacity and the quality of the soil, which are vital nutrient to agricultural crops.
- Availability of human resources: Climate change is likely to cause the manifestation of vector and vector borne diseases, where an increase in temperature and humidity will create ideal conditions for malaria, sleeping sickness and other infectious diseases that will directly affect the

availability of human resources for the agricultural sector.

4. Putting Agricultural Extension Back To The Development Agenda

Agricultural Extension (also known as agricultural or rural advisory services) plays a crucial role in promoting productivity, increasing food security, improving rural livelihoods and promoting agriculture as an engine of pre-poor economic growth Through it fell off the development agenda for a number of years, a recent confluence of factors-such as rising food prices renewed government and donor interest in agriculture and advisory services and a broad commitment to restructure global agricultural development institutions- has led to a resurgence of interest. (Davis, 2010).

Now that extension is back on the agenda, it needs to be strengthened, improved and revitalized in order to help meet the new challenges facing agriculture, such as changes in the global food system, growth in non-farm rural employment and agribusiness, health challenges affecting rural livelihoods, the deterioration of the natural resources base and climate change.

There are four keywords to do this:

1. Provide a voice for extension within global policy dialogs. Until recently, there was no forum to speak for and support extension in contrast to the large and well-developed international structures in agricultural research. Stakeholders have recognized that a more formal, dynamic and proactive structure is needed. This will enhance understanding of the important role extension has to play in global food security, climate change, environmental protection and other critical global issues.
2. Support the development and synthesis of evidence-based approaches and policies for improving extension. Policymakers, planner and implementers need to know what types of extension approaches and methods are appropriate to use. But because it is difficult to show impact of extension, there is insufficient convincing knowledge and evidence about what constitute effective approaches and methods. Better evaluation tools are needed, along with appropriate advice for those who want to plan and implement programs.
3. Facilitate interaction and networking for institutional and individual capacity strengthening in extension. Extension practitioners and managers typically do not have much chance peer exchange. This kind of interaction allows for experience sharing that can strengthen capacity of extension staff and their organizations. Strengthening the human resources and institutions in extension will greatly enhance their effectiveness.
4. Promote the creation of an enabling environment for improved investment in extension. The focus on extension has fluctuated widely on the agendas of governments, program planners and donors in the past. Today, it is back on the agenda, but there is no clear information about where or how to invest in extension. Nor is it always clear what the role of extension is within the broader rural development agenda. There is need to provide information on why it is important to invest, how to invest and what the critical/role of extension is within the broader rural development framework.

Today's understanding of extension goes beyond technology transfer to facilitation, beyond training to learning, and includes helping farmers from groups, deal with marketing issues, and partner with a broad range of service providers and agencies. Agricultural Extension can the be defined as the entire set of organizations that support people engaged in agricultural production and facilitate their efforts to solve problems; link to markets and other players in the agricultural value chain; and obtain information, skills, and technologies to improve their livelihoods.

5. The Important Role of Agricultural Extension

There are several ways that extension systems can help farmers deal with climatic change. These include adaptation and contingency measures for what cannot be prevented. Extension can help farmers prepare for greater climate variability and uncertainty, create contingency measures to deal with exponentially increasing risk and alleviate the consequences of climate change by providing advice on how to deal with droughts, floods, and so forth.

Extension can also help with mitigation of climate change. This assistance may include providing links to new markets (especially carbon), information about new regulatory structures, and new government priorities and policies. Discussed below are three ways in which extension can help with adaptation and mitigation: technologies and management information; capacity development: and facilitating, brokering, and implementing policies and programs.

Technologies and management information

Extension traditionally has played a role in providing information and promoting new technologies or new ways of managing crops and farmers. Extension also links fanners to researchers and other actors in the innovation system. Farmers, extension agents and researchers must work together on farmers' fields to prioritize, test, and promote new crop varieties and management techniques. While extension must now go beyond such methods, there is still a need for simple technology transfer m order to incase resilience to climate change and mitigate GHG emissions (Davis, 2009). Today's farmers will need to be able to quickly respond to climate change and adeptly manage risk. This will be especially challenging for extension in terms of knowledge and information systems. Farmers need to have access to this kind of information be it climatic information, forecasts, adaptive technology innovations, or markets- through extension and information systems.

Extension agents can introduce locally appropriate technologies and management techniques that enables farmers to adapt to climate change by for example, developing and disseminating local cultivars of drought-resistant crop varieties with information about the crops advantages and disadvantages (Davis, 2009) Additionally, extension staff can share with farmers their knowledge of cropping and management systems that are resilient to changing climate conditions such as agro forestry, intercropping, sequential cropping, and non-till agriculture. Some of these practices have the added advantages of improved natural resources management. Tree planting can also help to improve soil, prevent soil erosion, and increase biodiversity. It is important to provide farmers with information about how the various options will potentially increase income and yields, protect household food security, improve soils, enhance sustainability, and generally help to alleviate the effects of climate change. At the same time, extension staff can play an important role in transferring indigenous technical knowledge to help farmers worldwide.

A core challenge for extension in the future is to shift from providing "packages" of technological and management advice to, instead, supporting farmers with the skills they need to choose the best option to deal with the climate uncertainty and variability and to make informed decisions about if and how to engage in new markets for carbon emissions. Some farmers will also need access to new technologies and management options in those areas where climate change renders their current farming system invaluable.

Capacity Development

One of extension's major activities over time has been adult and non formal education. The role continues today and is even more important in light of climatic change. In addition, extension is also responsible for providing information using techniques ranging from flyers and radio messages to field demonstrations. Recent innovative extension activities include the adult education and experimental learning approaches utilized in Farmer Field Schools, (FFS), and extension and education approach already working with farmers on issues of climate change. Climate Field School (CFSs) have been established in West Java, Indonesia to deal with climate change in agriculture. Another example is a multimedia campaign planned by True Nature Kenya and the World Agro Forestry Centre that will show films and offer educational follow-up by extension agents to publicize grassroots solutions to the problems of climatic change (Davis, 2009).

Climate change will initiate extreme events like sudden onset disasters and new vectors of human and livestock disease. Evidence is emerging that the biggest impacts will be in the form of small droughts, floods and other events that cause severe hardship but do not attract the attention of the international community. The capacity of farmers to cope with such different forms of risks will become ever more crucial, and extension efforts must pay special attention to educating farmers about their options farmers about their options to enhance resilience and response capacity. There is a need for capacities to engage new sets of actors, including humanitarian agencies. Education must thus more beyond technical training to enhance farmer's abilities for planning, problem solving, critical thinking, prioritizing, negotiating, building consensus and leadership skills, working multiple stakeholders and finally, being proactive.

Capacity development is important within extension as well. Extension agents have traditionally been trained only in technical expertise and often lack "soft" skill such as communication, development of farmer groups, system thinking knowledge management and networking. To improve outcomes in rural development, farmers and extension agent need new skills that will require agricultural education and extension curriculums to include valuing and understanding the knowledge and experiences of rural people and co-learning (that is, farmers and extension agent learning together rather than extension agents training farmers in one-way information transfer).

There are many different ways to inform and educate farmers about adaptation options. Climate change adaptation funding should focus on extension. Systems and programs that incorporate a good understanding of what practices and skills are needed best promote activities that help in the climate change effort and on in creasing the capacity of extension agents and farmers, needed.

Facilitating, Brokering, and Implementing Policies and Programs

Another role of extension, which will be critical for climatic change issues, is that of acting as an honest broker, bringing together different actors within the rural sector. Traditionally this has meant linking farmers to transport agents, markets, and inputs suppliers, among others.

With climatic change, it will be increasingly important for extension system to link farmers and other people in rural communities directly with voluntary and regulated carbon markets, private and public institutions that disseminate mitigation technologies, and funding programs for adaptation investment. Increased access to meteorological information will be imperative.

Extension also has san enormous challenge in bringing together farmers' concerns and those of other actors as they address both climatic and market uncertainties together. Extension has the chance to make a significant contribution to overcoming this gap through enhanced farmer decision making (Davis, 2009).

Extension agents may also play a role not only in brokering but also in assisting farmers in implementing policies and programs that deal with climate change mitigation. For instance, regarding carbon credits, extension agents could be employed to educate farmers in their area: assist in forming community groups: link farmers to governmental, non governmental, and private organizations at the national and international levels: and perhaps assist with proposed preparation or negotiations with other players.

Adaptation to climate change might require farmers to use management practices and technologies that are beyond those existing today. Research must play proactive role to generate necessary responses and technologies that farmers will need to handle such future challenges. Nevertheless, the education process involved in establishing an extension program aimed at mitigating production risks associated with climate variability seems to be an efficient and effective way to introduce a climate change program. The following adaptation strategies could be part of combined climate variability/change extension program:

- ❖ Changing planting or harvest dates are effective, low cost options. The major risk in implementing these strategies could be shifting to a different market window with lower prices.
- ❖ Changing varieties is another low cost option, although some varieties can be more expensive or requires investments in new planting equipment. In reality, this is a continuous process. Examples are the development of new peanut varieties resistant to Tomato Spot Wilt Virus (TSWV) disease, a major threat to peanut production in the southeast- United State and the increased adoption of genetically modified cotton varieties resistant to certain types of herbicides and pests.
- ❖ Increased use of irrigation, fertilizer, herbicide and pesticide may be necessary to achieve maximum benefits from increased atmospheric Co2. Climate change is also likely to increase weed and pest pressure in most cases as discussed earlier.
- ❖ Changing crop species or livestock produced could bring new profits, but is a risky and more expensive option because the necessary infrastructure or marketing mechanisms may not exist locally.
- ❖ Investments in new irrigation or drainage systems or other capital items are likely to be essential if climate change increases climate variability.
- ❖ Adaptation strategies could also include changes in tillage practices, selection of varieties with greater drought and heat tolerance and development and implementation of improved Integrated Pest Management (1PM) programs for better management of crop pests and diseases. The extent of adaptation depends on the affordability of such measures, access to know how and technology, the rate of climate change and biophysical constraints such as water availability, soil characteristics and crop genetics.

6. Mitigation

Dissemination and promotion of emission reduction strategies in the agricultural sector to help mitigate climate change would be a new activity for climate extension program. Management of forestry and agricultural activities is regarded as an important option for greenhouse gases (GHG) mitigation. Activities in these sectors can reduce and avoid the release into the atmosphere of the three most important GHG's: Carbon dioxide (CO_2),. Methane (CH4) and Nitrous oxide (N_20). A number of opportunities to mitigate climate change, while reducing costs and increasing profitability, may be available for farmers.

Soil carbon sequestration has additional appeal because practices that enhance soil carbon also improve soil quality and soil fertility: thus, enhancing several ecosystem services. Soils store carbon for long periods of time as stable organic matter, which reaches an equilibrium level in natural systems that is determined by tillage and other management practices, climate, soil texture and vegetation. When native soils are distributed by agricultural tillage, fallow or residue burning, large amounts of Co_2 are released (Allmaras *et al,* 2000). However, a significant portion of the carbon captured by plants through photosynthesis can be sequestered by soils managed with direct seeding and other techniques that minimize soil disturbance. Irrigation can enhance carbon sequestration over native soil levels by overcoming the moisture limitation to increased plant biomass production. Examples of management practices with the potential to increase soil organic carbon include:

- Adoption of conservation and no-tillage practices,
- Optimize crop rotations by using legumes, rotations crop pasture, green manures;
- Improved fertilization to stimulate biomass prosecution and root growth, also enhances photosynthesis.
- Optimize manure management.
- Promotion of land sue shifts that enhance soil organic matter (e.g. forest, wetlands), mixed cropping systems that combine annual and perennial crops (e.g. Agro-forestry).

A climate change extension program should also include mitigation strategies that are technically sound and affordable. Examples include conservation tillage, energy conservation, bio-fuels, conservation practices and improve nitrogen management. Many of these are already being promoted due to increased competition and high energy costs. A program to help to educate farmers about potential opportunities in carbon trading markets and establishment of base line carbon levels for different ecosystems and agricultural activities should also be undertaken to promote farmers engagement.

7. Conclusion

Climate change threatens agricultural production through higher and more variable temperatures, changes in precipitation patterns, and increased occurrences of extreme events such as droughts and floods. These impede the economic opportunities of poor farming communities and small holders in many developing countries. Extension has a major role to play in helping farmers adapt to and mitigate climate change. To capture this potential role, adaptation and mitigation funds could be used to support extension efforts that deliver new technologies, information, and education about increasing carbon sequestration and reducing greenhouse gases emissions. These role can be exploited in a cost effective way to help resource-poor small holders deal with the issues of climate change that will so radically affect their livelihoods.

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