Positioning Agricultural Research for Effective Contribution to Climate Change in sub-Saharan Africa: enhancing *'knowledge to action'* and *'action to knowledge'*

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Abstract

Africa's development is and will continue to be greatly affected by the potential threats of climate change, leading to changes in the continent's development trajectory including disruption of the food systems. The expected changes are complicated by the pursuit of divergent interests by social groups, private sector and the governments operating at different levels. In this review paper we seek to provide a framework for promoting "actionable knowledge" on climate change at national, regional and global scales. Climate change negotiations and collective action form the international level domain. Divergent interests of social groups, private sector and governments constitute the national domain. In the climate change realm, it is obvious that interactions and feedbacks between 'internal' and 'external' domains are more inclined towards shaping dynamics within the African domain. The neutrality and carbon offsetting myth, carbon financing mechanisms, technology transfer, capacity building, and now reduced emissions from deforestation and ecosystem degradation (REDD) are differently perceived at the interface of the internal and external domains. The focus of this paper is not internal-external domains' interface, but how agricultural education can be enhanced so that knowledge generated can effectively be used by the different sub-units within the internal domain in translating climate change adaptation into a reality. How that translation should be done is a challenge that developing countries grapple with, especially when external subunits use trade and funding to pull the 'strings'. In such a scenario, Africa as an internal domain has its interests influenced by the sub-units of the external domains. If we consider countries as units in the internal domain, governments as well as being a facilitator and implementer, become principal agents in organizing and pushing for the mainstreaming of adaptation mechanisms for climate change. These roles of government are complicated by the urgency of meeting short-term requirements vis-à-vis a large-scale longer-term donor climate change adaptation. Could agricultural research play a bridging role in ensuring subunits within the internal domain have positive feedbacks that promote climate change adaptation? This paper focuses on how agricultural education can be refocused and re-structured so as to build on what we already know and build a strong foundation for future learning.

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1.0 Introduction

The potential impacts of climate change is seen at different scales in both developed and developing world, and such different perspectives shape their understanding of the common differentiated responsibilities. It is however generally envisaged that the effect of climate change on food and environment will worsen over space and time. Tremendous information and knowledge have been generated by the scientific community on potential impacts of climate change, yet little has been done to mainstream climate change adaptation into national agricultural planning and implementation. This failure is partly attributed to the nature and scope of agricultural education. Climate change is predicted to influence rainfall patterns and weaken farmers' adaptive capacity (Seth, 2007). Hotspots and typologies of ecosystem services have been predicted to change as a result of climate change and climatic variability (Yatich, 2008).

The current status of livelihoods, food security, ecosystems, poverty, natural resources, and levels of resilience are predicted to worsen. Cushioning such shifts will be dependent on vulnerability levels, adaptive capacities and how well we look from inside out for lessons and experiences. How geopolitical regimes pursue adaptation to climate change will determine how agricultural systems withstand future shocks. Achievements of the millennium development goals (MDGs) have been depicted to be dependent on climate change as well (Gomez-Echeverri, 2007). These threats have led to externally driven initiatives (e.g. the 'climate change adaptation in Africa' initiative by the IDRC, several carbon pilot projects in different locations by African Centre for Technology Studies and climate change theme projects by the CG centres) with minimal participation of African institutions, including universities. Stockholm Environment Institute (SEI) (2008) warns that low levels of economic activity render African countries disproportionately vulnerable to climate change impacts. African Development Bank (2008) estimated that greenhouse gas emissions from fossil fuel use in Africa at only about three per cent of total emissions. This is negligible compared to the amount of greenhouse gases (GHGs) released to the atmosphere by countries of the North, operating at ecological deficits, and emerging economies like China, India and South Africa. However, SEI (2008), argues that per unit gross domestic product (GDP) produced African economies are the most CO_2 intensive in the world at 1.65kg of CO_2 equivalent per US $ of GDP. SEI (2008) further attributes the low emissions to low levels of economic activity on the continent resulting in low aggregate emissions. This is the paradox that shapes Africa's position on the global debate. So what will African efforts contribute to reducing greenhouse gas emission if its emission contributes only three percent? Also has the climate change negotiations translated into technology transfer? And can agricultural education be positioned to shape climate change adaptation? Such questions are significant and will continue to shape the climate change agenda and Africa's position.

Social groups, the private sector and governments recognize climate change as a threat multiplier with varying impacts on their pursuits of economic wealth and political power (Reed, 2004). The groups' divergent interests, subsequent power relations and competitions in the face of declining resources are likely to weaken collective action for climate mitigation and adaptation at country levels. Multiple stakes, multiple perceptions on rights and interests and power relations at the local level, the fundamental focus of mainstreaming climate change adaptation, are often ignored. Collective action at the international level is complex, shaped by chauvinistic interests and is often puzzling. Given this scenario, would agricultural science research provide opportunities to bridge the complex science-policy interface?

Agricultural science research has had its goals shift over the years as country ideologies and interests metamorphosed. Efforts to meet food security goals may have weakened inherent adaptation of agricultural systems. Agroforestry and agroforestry research have neither survived negative impacts of competition from other land uses nor overcome partners' and farmers' perceptions of what it can or cannot offer for climate change adaptation. Climate and agricultural science research rarely synergize including the decision-makers within each sector (CGIAR, 2008). Interested and affected groups have rarely looked at mitigation and adaptation to climate change from inside out. Lessons and experiences of communities who have coped with climate variability have largely been ignored. National-level initiatives are driven by collective action at the international level. Subsequently, local

level mainstreaming initiatives are top-down and rarely evidence-based. At the national level, addressing climate change mitigation and adaptation is impeded by the challenges associated with links between knowledge systems and action domains. Understanding these links are fundamental in climate change adaptation. The way power relations translate into initiatives aimed at addressing climate change vis-à-vis dynamics of climate change at national levels shape institutional adaptation.

Given this background, we oppose the business-as-usual approach, and promote mainstreaming of climate change adaptation. This is achieved through understanding the political economy of climate change, institutional adaptation, disconnects between climate change modelling and action. Also of importance is understanding the implications for nesting climate change adaptation in different policy domains and drawing on subsidiarity principle to enhance functionality. We argue for a solid evidence base for taming climate change which can only be achieved if its future relevance and current gaps are re-examined by the users of agricultural research outputs and science-policy interface.

1.2 Contextualizing climate change

Christensen *et al.* (2007 summarizes the key attributes of the Intergovernmental Panel on Climate Change's IPCC's Fourth Assessment Report for Africa as: i) warming is very likely to be larger than the global annual mean warming throughout the continent and in all seasons, with drier subtropical regions warming more than the moister tropics; ii) annual rainfall is likely to decrease in much of Mediterranean Africa and the Northern Sahara, with a greater likelihood of decreasing rainfall as the Mediterranean coast is approached; iii) rainfall in the Southern Africa is likely to decrease in much of the winter rainfall region and western margins; iv) there is likely to be an increase in annual mean rainfall in East Africa and v) it is unclear how rainfall in the Sahel, the Guinean coast and the Southern Sahara will evolve.

The precarious food situation prevailing in most of southern Africa has been linked to a combination of factors including: unfavourable climatic conditions (Kandji et al., 2006), poor and depleted soils (Akinnifesi et al., 2008), environmental degradation, and macro-economic and political factors. There is a rapid rate of forest land disappearance and degradation, Pinstrup-Anderson et al (1997) estimated that 664,000 hectares of forest land were deforested in 1980s compared with just 92,000 hectares of reforestation.

Mendelsohn *et al.,* (2000) observed that agriculture losses in some areas of the Sahara were between 2 and 7 % of the gross domestic product (GDP); 2 to 4% in Western and Central Africa; and 0.4 to 1.3% in Western and Southern Africa. In Ethiopia, ENSO related conditions have been attributed to declining maize production in the South African region (Stige *et al.*, 2006). Maize production has been observed to decline in the southern African region. Drought is estimated to have caused 10 to 50 yield losses on 80% of area planted to maize area in southern Africa (Short and Edmeades 1991, cited by Kandji et al, 2006). In addition to less than optimal food production, dry season fodder shortage has also exacerbated food insecurity in the region (Kandji et al, 2006; Chakeredza et al, 2007).

Factors that are likely to complicate efforts to combat climate change include i) a 0.4 global overshoot of human's Ecological Footprint estimated at 7.1 acres per person (www.RedefiningProgress.org); ii) declining Africa's biocapacity; iii) increase in the number of countries with human development index (HDI) of less than 0.5 (UNDP, 2005); iv) population increase; v) stresses on health and well being; vi) heavy reliance on highly climate sensitive sectors; vii) high poverty levels, and viii) structural related factors like policy failures and corruption. Climate change as a threat multiplier will potentially worsen the existing scenario, although positive impacts will exist as a result of increased rainfall including increased productivity in the arid and semi-arid areas.

Africa's poor level of biocapacity is attributed to relatively low levels of economic activity, lack of technologies and imports of biocapacity. The continent receives imports of crop land and pastures land capacity through trade, and supplies other regions of the world with products from fishing ground and forests (Swiss Agency for Development and Cooperation and Global Footprint

Network, 2006). Such exchanges of biocapacity are likely to drive exhaustion of productive areas and enhance the impacts of climate change. South Africa's biocapacity is declining fast because it is pursuing development pathways which have been termed risky despite improvement of its people's living standards. Increased food and timber demands are driving conversion of tropical rainforests into agricultural land and therefore releasing aboveground carbon to the atmosphere.

Climate change is likely to disrupt African economies because they are natural resource dependent. Critical watershed and biodiversity areas have been converted to agricultural use to meet local and international demand for agricultural produce as well as energy requirements at different levels. Population increases lead to increased pressure on natural resources. Urbanizing environments and their associated demand for agricultural products drive land use change further afield as adjacent agricultural land is converted into commercial and industrial land use.

Perceptions of the approaches currently pursued including afforestation, offsetting, clean development mechanisms (CDM) and REDD programmes vis-à-vis short-term interests of African nations and by extension local communities are likely to falter gains already made. Mitigation and adaptation measures have been observed to weaken already existing coping mechanisms. High poverty levels drive new investments and initiatives that are likely to have perverse incentives (e.g. farmers cutting trees to plant new ones to access carbon financing) for climate change mitigation and adaptation. Mainstreaming climate change is resource intensive. Given high poverty levels, corruption, divergent interests, transaction costs, challenges associated with matching climate change 'dynamism' with institutional innovations, mainstreaming may not be treated as a priority for the African continent. Mechanisms to quantify uncertainties and potential impacts of such initiatives are just picking up.

Shifts in the policy arena, with or without exogenous influences, will shape emission rates. As countries adopt new long-term sectoral based economic planning blueprints (e.g. Kenya's Vision 2030) drifts towards ecological deficits and increased carbon footprints will be obvious. Parallel mechanisms to deal with adverse outcomes of paradigm shifts are not integrated into economic planning and development. Less resource endowed countries that are already funding mainstreamed programs, such as in Malawi, from their exchequer are confronting challenges associated with permanence, leakage, property rights (tenure of sequestered carbon), additionality and resource constraints (Michael Richards, 2008). Countries that previously allocated more than 10 per cent of their national budget for agricultural development as per the Maputo declaration are slowly sliding (FAO, 2008).

Impacts of climate variability are already constraining the capacity of local communities to meet their requirements. Kandji and Verchot (2007) provide an overview of impacts and responses to climate variability at local, regional and national levels. These impacts are likely to be worsened by climate change (FAO, 2007) if adaptation mechanisms are not mainstreamed. Questions abound as to whether African governments should pursue climate change mitigation or adaptation? What is clear in the literature is the none exclusivity of mitigation and adaptation, but there are controversies on carbon neutrality, carbon offsetting, afforestation/reforestation and REDD programmes that have differently influenced Africa's position on the climate change debate.

2.0 Climate Change Action in Africa

2.1 Sub-Saharan Africa and Climate Change Adaptation

Adaptive capacity is driven by the totality of resources available (natural, human, financial and social) governance, technological advancement and planning practice, many of which still remain weak in the African continent (UNFCCC, 2008). However, through various funds from the UNFCCC about 24 countries in Sub-Saharan Africa have completed National Adaptation Programmes of Action (NAPA). So far little has been done in terms of implementation of adaptation priorities identified in the NAPA's for most countries. Most adaptation action is done by a few projects that operate on a

more sub-regional basis. Examples include, the Climate Change Adaptation in Africa Program (CCAA) run by IDRC and DFID and working in more than 10 countries; Tropical Forests and Climate Change Adaptation Project (TROFFCA in West Africa); GEF funded projects to assist African communities to assess risks and options to adapt to drought, coastal flooding and health risks, such as Coping with Drought and Climate Change (in Mozambique, Zimbabwe and Ethiopia) and Adaptation to Climate and Coastal Change in West Africa (ACCC) (in Senegal, Cape Verde, Guinea Bissau, Gambia and Mauritania). Adaptation to Climate Change in Eastern and Southern Africa (ACCESA)- Kenya, Mozambique and Rwanda. Little evidence exists about proactive country action on adaptation to climate change.

2.2 Sub-Saharan Africa and Climate Change Mitigation

Current rules within the Kyoto Protocol of the UNFCCC allows for developing country participation in climate change mitigation through the Clean Development Mechanism (CDM). The CDM makes provision for investment by industrialised countries and industry, in projects related to carbon reduction and carbon sequestration in the energy and forestry sectors in developing countries. These projects should contribute to sustainable development in developing countries (non-Annex 1 countries) while enabling developed countries (i.e. Annex 1 Countries with quantified emission reduction targets) to meet the Kyoto emission reduction and quantified emission target limitation targets (Art 12 of the Kyoto Protocol).

African countries are seriously lagging behind in the development of projects within the Clean Development Mechanism. As of May 2008, African Countries had only 5% of more than 3000 CDM projects at different stages in the pipeline (CDM Pipeline website). Reasons advanced for the poor performance of Africa have included, overly regulated CDM procedures, poor investment climate in Africa (financial, managerial, political), lack of capacity and poor governance for the inertia in the development of CDM project in Africa (Desanker, 2005, Minang 2007, Capoor and Ambrosi, 2006; 2008; and Walker et al., 2008). The fact that only afforestation and reforestation projects are eligible for CDM projects has been an important limiting factor for forestry projects as a whole.

However, about 50 Land Use, Land Use Change and Forestry (LULUCF) related projects have been identified in Africa (Jindal et al, 2008; Walker et al., 2008). Most of these projects are likely to serve the voluntary carbon markets where the regulations are less demanding.

Recent developments during the 13th Conference of parties to the UNFCCC in Bali, Indonesia offer new hope for better opportunities for Africa's participation through a potential Reducing Emissions from Deforestation and Degradation (REDD) framework in a Post 2012 Climate framework. Current REDD proposals allow the possibility for including avoided deforestation and forest management activities. This means more specific activities in these countries could be eligible compared to on afforestation a reforestation activities that are presently eligible within the CDM. The Bali Road Map sets out a on a two-year process to determine the modalities for a post 2012 climate agreement including for REDD (Decision-CP 13). The negotiations so far have seen very active participation of African countries, much more than have been registered to date. A case in point is the Congo Basin Group that have made submissions and actively participated in the debates as well as other African countries that have also participated in the negotiations through the RainForest Coalition. The best current proposals for REDD point to national level or sub-national level rather than project level accounting, hence comparatively high capacity and governance challenges beyond the project scale. It also raises challenges of equitable distribution of any benefits from REDD from to local level, and also land rights issues at multiple levels.

3.0 What role for agricultural systems in climate change mitigation in Africa?

Agriculture is Africa's most important economic activity as most of the inhabitants of the continent depend on it for a living, yet it is one sector that is likely to be hard hit by climate change. Temperature increases and rainfall changes are expected to reduce yields from Rain-fed agriculture by up to 50% by 2020 and net revenues from crop yields could drop by as much as 90% by 2100. Semi-arid and arid land areas in Africa are projected to increase by between 5-8% by 2080 and between 75 and 250 million people are projected to be exposed to increase water stress by 2025, hence profoundly affecting agriculture in these areas (IPCC Fourth Assessment Report). These threats and current effects of rainfall variability already felt by African farmers make a compelling case for putting Agriculture at the centre of climate change adaptation in Africa. In addition, the conversion of forest land for agricultural purposes accounts for a significant proportion of Africa's GHG emissions (though very low).

Agroforestry constitutes one agricultural system with tremendous potential for climate change adaptation and mitigation in Africa. The introduction of innovative tree-based production practices into farming systems could improve resilience to interannual variability in rainfall and temperature, simultaneously contributing to climate change mitigation through carbon sequestration. Diversifying production systems to include significant tree components can enhance productivity of higher value tree crops and products which may buffer against income risks associated with climatic variability. Tree-based systems enhance resilience and adaptation to climate change due to obvious advantages for maintaining production during wetter and drier years. Their deep root systems are able to explore a larger soil volume for water and nutrients, which help during droughts. Second, increased soil porosity, reduced runoff and increased soil cover lead to increased water infiltration and retention in the soil profile which can reduce moisture stress during low rainfall years (Verchot et al. 2007).

Agroecosystems and agroforests play an important role in global carbon cycles, holding about 12% of the world's terrestrial carbon (Dixon 1995). Verchot et al, (2007) estimate the carbon mitigation potential of agroforestry to be above 6000 $MtCO^2$ e over a 30 year period. Research within the Alternatives to Slash and Burn (ASB) Partnership for Tropical Forest Margins on agroforestry systems such as jungle rubber system in Sumatra, pine – banana – coffee system in eastern Java Indonesia, mixed cocoa and fruit tree plantations in Cameroon contain between contain 50 to 75 Mg C ha^{-1} compared to row crops that contain < 10 Mg C ha^{-1} (Palm et al. 2005). Thus converting row crops or pastures to agroforestry systems can greatly enhance the C stored in aboveground biomass.

Despite these potentials, several obstacles remain in the development of tree based systems that could serve poverty alleviation purposes, increase resilience to climate change and sequester carbon. One of these challenges is the lack of knowledge, skills and information.

4.0 Agricultural education/Research

Climate change is causing and will continue to cause important changes in African agriculture. Farmers will need to react to these changes e.g. by adjusting their farming practices, crop varieties planted, cropping calendar, risk minimization strategies, etc. Over time, these changes will pose increasing challenges to agricultural extension as their competence to deliver appropriate services to the farming communities (under the changing scenarios) may become compromised due to limited knowledge. Agricultural educational institutions need to react pro-actively to this by ensuring that their agricultural graduates are well trained to appreciate and be able to deal appropriately with the effects of climate change in the fields. What are the key challenges for educational institutions, curriculum developers, to re-tooling old graduates who are already out there in the field? Some of the reactions to make agricultural education remain relevant to the realities of climate change in farmers fields may include revising/re-structuring/enlarging educational curriculum to include topics on "climate change and African agriculture", understanding and building on existing coping and adaptive strategies of local communities in the different geographical locations, etc.

Agriculturalists rarely interact with climatologists because of their nature of training. Climate change is neither the traditional mandate of meteorological services, nor agriculturalists. In whose realm does climate change lie? How is it handled by several sectors and how do the sectors interact with each other? The failure of African governments to adequately deal with these questions creates some confusion among institutions responsible for or training in agricultural education. Consequently, mitigation and adaptation interventions are developed at levels that are not operational. Agricultural decision makers fail to make the right decisions because of the inability of agricultural technocrats to offer strategic advice. In some instance there is overemphasis on the impacts and multiplier effects of climate variability because they are perceived as real. Despite increased collective action and awareness at the international level and looming threat of climate change, national-level institutional adaptation innovations do not match the *'dynamism'* of climate change. African governments are at different levels of putting in place appropriate institutional frameworks for dealing with climate change mitigation and adaptation at regional and national levels.

Stockholm Environment Institute (2008) undertook an inventory of institutions and programs active in African climate science and agricultural education and concluded that: i) there is lack of comprehensive baseline information; ii) impacts of climate change are isolated from the broader contexts in which development takes place; iii) institutions adopt adaptation mandates without clearly understanding vulnerability context; iv) failure to conceptualize adaptation in the context of the other climate information used in decision making, and v) there are disconnects between information producers and users. According to SEI (2008) most research are driven by international institutions, with some already investing in boosting the robustness of their supported projects to climate change impacts. These challenges were further expounded and re-emphasized during the CGIAR drivers of change workshop held from June 12-13, 2008 at the International Livestock Research Institute (ILRI) in Nairobi. During the workshop, links between international research and the focus on national interest by national agricultural research systems were explored. Availability of good historical data was seen as critical in understanding the dynamics of climate change, its impacts on agricultural systems and depicted dynamics are likely to shape the future. During the CGIAR workshop, some of the salient research elements that emerged as critical for climate change research include *inter alia:*

- **Answering the right questions:** Most of the simple problems have been solved except the complex problems which require more integrative approaches. However, the right questions must be raised with the right people. Perhaps agricultural and climate science research have been asking and solving the wrong questions, at least from the perspective of national agricultural research systems. This could be attributed to the failure of international institutions to influence policy processes because of poor link of research results to national interests or science-policy communication disconnect. Agricultural education graduates are also not prepared to deal with emerging challenges including climate change. Education institutions seldom review curriculum to train on climate change. The best that exists is climate change integrated into traditional courses in tertiary institutions. Science-policy linkages continued to evade scientists in the region. Many commentators including the Food Agriculture and Natural Resources Policy Analysis Network (FANRPAN) attribute this to the failure of scientists to package their science information in a manner that can attract the interests of agricultural policy makers.

- **Availability of data:** Despite increased awareness on climate change and flow of research funds, there are disconnects between modelling and what is most practically needed. In some places there is historical data but not used to predict huge climate uncertainty because of lack of collaboration between Meteorological and Hydrological services with the Ministry of Agriculture and agricultural policy makers. Meteorological services often produce data as an income generating activity. More cross-sectoral coordination is warranted to improve the current scenario.

- **Linking climate change research to the broader context:** Broader issues of agriculture often hide the importance of climate change at farmer or national level. Research undertaken

in Machakos by ICRISAT indicated that farmers attributed declining crop productivity to climate change, but when ICRISAT analyzed other factors from a broader context, declining crop productivity was linked to declining trends in the use of fertilizers (CGIAR, 2008). Rainfall trends were established to have remained constant over the years. This is because of government's policy rather than climate change. In Malawi, the heavy attention to fertilizer subsidy as a way of improving crop productivity may have obscured the need for attention on climate change. This supports SEI (2008) argument that adaptation initiatives require the understanding of the vulnerability context.

- **Doing science from inside out:** scientists often ignore lessons and experiences that local communities have gained over the years as they adapt to the impacts of climate variability. ICRISAT's research on adoption of new crop varieties in the Sahel shows that farmers eagerly adopt new crop varieties but over time they discard them and go back to their traditional crop varieties (CGIAR, 2008). Further research showed that the traditional varieties were more adopted than those developed and promoted by scientists. The same is true in Malawi for local open pollinated maize versus improved maize variety. Building on existing coping and adaptive strategies of local communities is therefore important. It is prudent to see climate change as an integrative science requiring integrating both local and scientific knowledge with local circumstances. However, this also calls for proper needs assessment in development for promotion of new technologies.

- **Dialogue:** The World Agroforestry Centre (ICRAF) has tried to address this challenge through the design and adoption of negotiation support systems in Southeast Asia for purposes of linking knowledge systems to action. Negotiation support systems are now being expanded to Africa through ICRAF's work on compensation and rewards for environmental services currently being tested in different agricultural landscapes across Africa.

- **Community of practice:** Platforms for sharing lessons and experiences are lacking. National and regional platforms will provide lesson learning and act as springboards for country-based or collective action for climate change. Through these platforms, there will be review of adaptation initiatives, methodologies, tools and approaches. Existing platforms should re-look at their focus and expand to include climate change mitigation and adaptation.

Agricultural and climate science research at the national level are compartmentalized, segmented and rarely promote synergies and collaboration. Use of research results and data at the national level are complicated by monocentric governance systems with distributed regime structures and excessive red tape. Disconnects between science-based evidence and policy implementation at different levels are lacking because policy implementation are left to the discretion of technocrats at different levels. Mainstreaming of adaptation in country policies, plans and programmes need to learn lessons and be informed by science-based evidence.

4.1 Agroforestry Research and Education

Over the years, the World Agroforestry Centre (ICRAF) and its partners have developed approaches, tools and methodologies on how to quantify carbon, its potential impacts and landscape-level measurement and monitoring of carbon stocks (Kandji et al., and Verchot, 2007; ICRAF, 2006; Lusiana et al., 2007). Apart from training university students, ICRAF facilitates and supports curricula development and reviews to shape universities' contributions to the pool of knowledge of emerging large-scale environmental and development challenges like climate change. Despite these efforts evidence-based decision making is scanty just as research and research results are scattered and uncoordinated. International agricultural and climate science research institutions, government research institutes, Universities, private sector, and advocacy institutions are compartmentalized, segmented and operate as independent entities. Meteorological services have reduced its role to producing and selling data. Agricultural research is focused on how to improve production in the different agricultural sectors.

Research institutes expect the same advocacy institutions to use generated knowledge to shape policy, their interests withstanding. Scientists have attributed weak linkages between science and policy to their failure to appropriately package research results and create demand for their outputs. It is not so much about the lack of knowledge on climate change, but how best generated knowledge can be used to catalyze change, in this case climate change adaptation. It is much more about understanding and framing use of knowledge by action institutions. In order to promote 'knowledge to action' and 'action to knowledge' in different domains, three questions become relevant: what type of relevant agroforestry education exists in Africa? What are the gaps? What can be done to promote synergy, 'knowledge to action' and 'action to knowledge?'

4.2 Relevant Agroforestry Education

In Africa agroforestry research-development-education continuum has been evolving. Agroforestry research is broad and multi-disciplinary. It brings together different disciplines and expertise including foresters, environmentalists, economists, educationists, climatologists, agriculturalists, hydrologists, GIS analysts and policy experts. International institutions adopt two tracks in addressing multi-disciplinarity in agroforestry research: i) deliberately employ scientists with different expertise to ensure that these experts are in-house or source for expertise through exchange programs or collaborate with other institutions to fill any gaps. In the region the focus has mainly been on climate science in the hope that this informs agricultural research and development. Climate science research is externally driven and those involved report based on donor requirements and rarely promote policy changes. When funding for a specific projects ends, the project ceases and the research outputs are forgotten. A review by SEI (2008) shows that regional research institutions lack resources, undertake macro-level analysis with limited understanding of local level phenomena; not focused on specific issues that agricultural policy makers are interested on; and much of the work is focused on gaining atmospheric dynamics which are important strategically but not of interest to farmers.

Relevant agroforestry research and training in African universities have or is influenced by historical, structural, perceptive and the objectives of education. Curricula of many African Universities established during the colonial period have not been reviewed over the years and where review has been done; it has been mainly piecemeal (Ngugi et al., 2002). The general trend is that newly established universities offer nothing different from what is offered by universities established during the colonial period. Forestry education, agricultural and climate related science offered in African Universities are patterned and shaped after models that were already in place in Europe and North America (Temu and Kiwia, 2008). Temu and Kiwia (2008) further argues that agricultural science and related degree programmes focus more on biophysical aspects as a means to an end, which is mainly improving productivity of agriculture. No room was made for broader-agricultural training that would prepare the governed for self-sustenance (Temu et al., 2003). Temu et al. (2003 recognized the need to promote multi-disciplinarity and curricular reviews: integrating natural resource management and entrepreneurship in tertiary agricultural education.

An in-depth analysis of courses offered by newly established universities does not reveal a shift, including integration of emerging large-scale environmental problems. Since climate change is an emerging issue, it is not adequately integrated in universities' existing curricula. It is limited by the segmented and entity based nature of university curricula. 'Traditional' and emerging degree programs are broad and deal with bits and pieces of climate change and agroforestry. Subjects that are relevant for climate change science are rarely offered in Universities and many experts in the region have learnt through on-the-job training in international funded research institutes. Structural factors that limit training on emerging issues include: i) inadequate funding, ii) lack of laboratories and equipment, and iii) lack of expertise and poor lesson learning and experience sharing between universities and international institutes that are undertaking cutting-age research.

There has been general decline in the number of students being admitted into mainstream agricultural degree programs. This has been attributed to lack of job opportunities. Students take

particular courses that would be easy to secure well paying jobs. Such decline in the level of expertise in agricultural science is a major constraint to innovations in the agricultural sector and will affect food security in the long run. There are ongoing initiatives to promote revitalization of agricultural and agroforestry education/research. These initiatives will potentially be affected lack of frameworks and approaches to translate '*knowledge into action'* and '*action into knowledge'*.

4.3 '*Knowledge to Action'* versus *'Action to Knowledge'*

Meine (2008) has framed 'knowledge to action' or 'action to knowledge', using the concept of boundary organization. Meine's framework however needs to be understood in the context of multi-layered regime structures and how they are either influenced or influence regional and international level policy domains. In linking action to knowledge and vice versa, Meine situates large international assessment efforts, such as the Inter-government Panel on Climate Change (IPCC) and the Millennium Ecosystem Assessment (MEA) (figure 5).

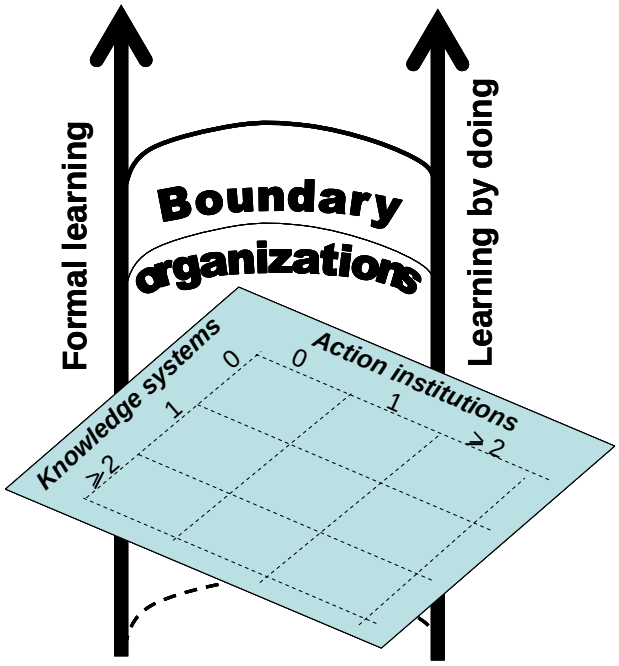

Figure 1: Typology of boundary organizations on the interface of knowledge and action, with examples of six classes of boundary work

----------Action----------

---Knowledge---

	0. None	1. Decision	⩾2 Collective action
0. Conjecture & ignorance	*Daily life of U&Me ☺*	A (ignorant decisions)	0 $A_1 \Leftrightarrow A_2$ (ignorant politics)
1. One truth	K (science, Knowledge for own sake)	II K ⇔A (Technology Transfer; Scientific policy advice such as IPCC; Decision Support Systems - DSS)	III A_1 K ⇔ ⇳ A_2 (Joint fact-finding)
⩾2 Multiple ways of knowing	$K_1 \Leftrightarrow K_2$ I (Interdisciplinarity, tacit + scientific knowledge)	K_1 IV ⇳ ⇔A K_2 (Integrated Assessments such as MEA)	K_1 A_1 V ⇳ ⇔ ⇳ K_2 A_2 (Negotiation Support Systems - NSS, RUPES)

Table 1: Typology of boundary organizations on the interface of knowledge and action, with examples of six classes of boundary work
Source: Meine van Noordwijk, 2008

Based on figure 6, Meine (2008) and University of Arizona (2000) developed typologies of boundary organizations based on a 0, 1 and ≥2 classification of actors and ways of knowing. Meine (2008) identifies 6 classes of boundary spanning activities as:

0. A ⇔ A, no K, meaning not informed by any since;
I. K ⇔ K, no A, knowledge not influencing any action;
II. K ⇔ A -- the archetypal boundary work of technology transfer, science-policy advice, public funding for science and ***decision support systems***; the IPCC effort falls within this class with its 'policy relevant' but not 'prescriptive' synthesis of science
III. K ⇔ (A ⇔ A) -- boundary work such as 'joint fact finding' that cam emerge at a certain stage in (mediated) political negotiations
IV. (K ⇔ K) ⇔ A – integrated assessments, such as the Millennium Ecosystem Assessment (MEA)
V. (K ⇔ K) ⇔ (A ⇔ A) – ***negotiation support systems*** and the emerging reward mechanisms for environmental systems, where both the articulation of knowledge and the actions are negotiated

In order to effectively promote 'knowledge to action' or 'action to knowledge', the six classes of boundary spanning activities, must be understood in the contexts of feedbacks, strong or weak, across the different multilevel regime structures. Within each level, there are sector-based policy domains (in this paper we have used agriculture, forestry, energy, water and wildlife) which relate with climate change adaptation in different ways, a relationship that is limited by vertical planning and governance systems pursued by different African institutions.

The national level sub-unit is charged with policy formulation and implementation facilitation. Lower level sub-units are mainly responsible for translating policy provisions into actions with lessons and experiences feeding into the national level policy formulation sub-unit. In the case of climate change, national levels lessons and experiences feed into regional and international level negotiations and decisions. Policy, plans, projects and programmes implementation at different regime structure levels are often not informed by research undertaken by different organizations at different levels. Implementation of policies, plans, projects and programmes is also affected by complexities associated with multilevel governance systems (figure 5). Regional-level initiatives influence and are shaped by what is happening at the national-level domain. Discussions at the international level on several policy areas and collective learning and action initiatives influence what is happening at the national and country-level domains. International level negotiations and collective action are also influenced by what is happening at the regional and national levels. Climate change adaptation or any other large-scale environmental problems are then nested in the different levels of governance providing opportunities of learning lessons across different levels.

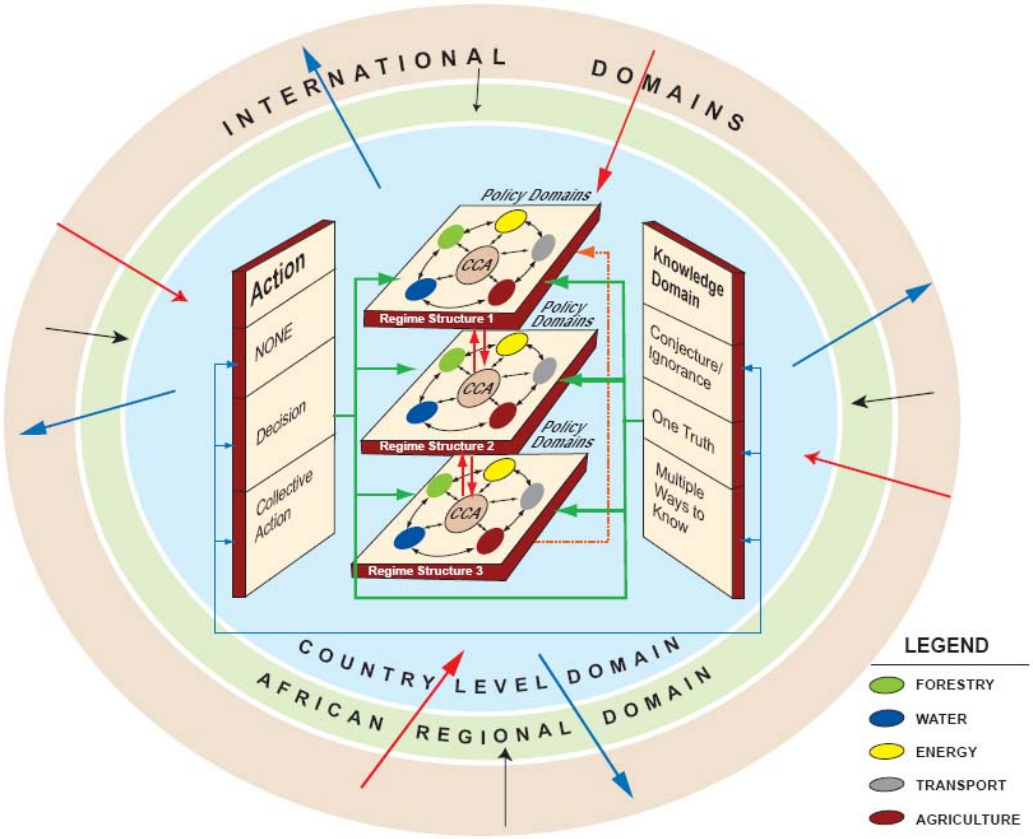

Figure 2: Relationships between different domains and how nested climate change adaptation (CCA) could be addressed through interactions between action institutions and knowledge systems

Source: Yatich et al (unpublished)

4.4 Challenges, opportunities, gaps and way forward

Positioning agricultural and agroforestry education to address climate change will require an integrated approach including strategic policy development, cross-sectoral policy formulation and implementation and coordination, and institutional adaptation. Lack of strategic policy formulation to deal with emerging threats of climate change is likely to heighten its impacts at various levels. Mainstreaming climate change adaptation is a challenge in the face of differing mandates of the different sectors and power relations that shape feedback mechanisms. It will take time for the advantages of cross-sectoral policy frameworks to be achieved because reviews of legal regimes in Africa are long, tedious, bureaucratic and jingoistic. There is need to explore opportunities to deal

with challenges related to sectoral policy planning and its implications for climate change adaptation and mitigation in Africa.

Decentralization and devolution provide opportunities for climate change mitigation and adaptation and also find expression in numerous legal instruments. In most countries, the tendency is to move away from more or less exclusive state competencies to stronger management responsibilities and property rights in local governments and communities.

Ongoing initiatives could provide lessons and experiences for refocusing and restructuring agricultural education and agroforestry. Economic and institutional reforms in African economies have however created constraints and opportunities for climate change adaptation. Reed (2004) enumerates these opportunities as the dismantling of state-controlled marketing systems, the removal of bureaucratic obstacles to initiating small-scale enterprises, the opening of market outlets for new crops and products, and the opening of some political structures to public participation. Institutional reforms have also created constraints for the poor: entrenchment of political and economic elites, new resource management regimes that preclude access for the poor, decentralization reforms that shift power to regional power brokers but not to the poor, and increased vulnerability to economic shocks that threaten the meager asset base of the rural poor (Reed, 2004). These constraints do not prepare the poor to adapt to climate change or promote interventions at the strategic level to boost the resilience of agricultural systems against impacts of climate change.

There is need therefore to promote integrative science and match research outputs to national-level interests. Universities core activities are teaching and knowledge generation, research and community service. In order to promote sharing of tools, approaches and methodologies universities need to building synergies in implementing their mandates. It is only through this that collective action and learning among tertiary institutions can be enhanced. Government-based institutions, universities and regional/international research institutes need to work together to find strategies for influencing policy at different levels because: i) they generate knowledge that is relevant for policy change and are ii) interested in achieving change. Leveraging resources to achieve desired use of research results to influence policy will require networking and understanding the outcomes of the interactions between action and knowledge domains.

Conclusion

Disconnects between action research and policy practices are attributable to the failure to correctly identify boundary spanning activities. Complexity of governance systems and feedback mechanisms between multilevel regime structures affect the implementation of large-scale environmental problems, climate change inclusive. Interventions aimed at addressing large-scale environmental problems like climate change adaptation are further complicated by the quality of Tertiary Agricultural Education (TAE), which tend to operate as independent entities. This is further reflected in the public sector where different policy domains are sector-based and operate independently. Action research is externally driven and often does not inform policy formulation and implementation, but contribute to a knowledge system that can be tapped into by action institutions to influence policy. Such potential is limited by divergent interests of institutions expected to have demand for solid evidence for policy influence. Providing a framework for identifying boundary spanning activities and how these can shape or be shaped by interactions among different multilevel regime structures would be the first step in addressing climate change mitigation and adaptation. Such a framework will also heighten the need for curricula review in tertiary institutions so as to promote synergy and coordination of training in the different agriculture related disciplines. The proposed framework will also promote evidence-based decision making and dealing with the challenges for climate change adaptation.

References

Akinnifesi F.K., P. Chirwa, O.C. Ajayi, S. Gudeta, P. Matakala, F.R. Kwesiga, H. Harawa and W. Makumba (2008). Contributions of agroforestry research and development to livelihood of smallholder farmers in Southern Africa: 1. Taking stock of the adaptation, adoption and impact of fertilizer tree options. *Agricultural Journal 3:58-75*

August Temu, Inonda Mwanje, Kebadire Mogotsi. 2003. Improving Agriculture and Natural Resources Education in Africa: A Stitch in Time. Nairobi, Kenya: World Agroforestry Centre (ICRAF)

Cammack D. 2007. Understanding the political economy of climate change is vital to tackling it: Prepared for UN Climate Change Conference in Bali, December 2007. Overseas Development Institute (ODI), United Kingdom (http://www.odi.org.uk/climatechange)

Capoor, K., and P. Ambrosi. 2006b. State and trends of the carbon market 2006. A focus on Africa. World Bank, Washington DC.

Chakedreza, S., L. Hove, F.K. Akinnifesi, S. Franzel, O.C. Ajayi and G. Sileshi (2007). Managing fodder trees as a solution to human-livestock food conflicts and their contribution to income generation for smallholder farmers in sub-Saharan Africa. *Natural Resources Forum Vol.* 31(4): 286-296

Christensen, J., Hewitson, B.C., Busuioc A., Chen, A., Gao., X., Jones, R., Kwon, W.-T., Laprise, R., Magana, V., Mearns, L. Menenedez, C., Raisaenen, J., Rinke, A., Kolli, R. K. and Sarr, A.2007. Regional Climate Projections, in IPCC Fourth Assessment Report "Climate Change 2007: The Scientific Basis", Cambridge University Press. In: Stockholm Environment Institute. 2008. Climate change and adaptation in African agriculture. A research report prepared for Rockefeller Foundation. Stockholm Environment Institute.

CGIAR. 2008. Proceedings on the "Drivers of change workshop" held in ILRI from June 12 to 13, 2008. The CGIAR Regional Plan for Collective Action in East and Southern Africa.

David N., Aida I., Temu A., and Kitalyi A. 2002. Agricultural Education in Kenya and Tanzania (1968-1998). Technical Report No. 25. Regional Land Management Unit (RELMA): Nairobi: World Agroforestry Centre (ICRAF).

Desanker, P.V. 2005. The Kyoto Protocol and the CDM in Africa: a good idea but... Unasylva 222:24-25

Dixon, R.K., 1995. Agroforestry systems: sources or sinks of greenhouse gases? Agroforestry Syst. 31, 99–116.

ICRAF. 2006. Tackling Global Challenges through Agroforestry.ICRAF 2006 Annual Report. World Agroforestry Centre, Nairobi.

IPCC(Intergovernmental Panel on Climate Change). 2007. Summary for Policymakers. In: 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, 7-22.

Jindal R., B. Swallow, J., Kerr (2008). Forestry-based carbon sequestration projects in Africa: Potential benefits and challenges. Natural Resources Forum 32: 116-130.

Kandji, S.T.;Verchot, L.V. 2007 Impacts of and adaptation to climate variability and climate change in the East African community - a focus on the agricultural sector Nairobi, Kenya : World Agroforestry Centre ICRAF 27p.

Kandji, S.T, Verchot L and Mackensen J (2006). Climate change and variability in southern Africa: impacts and adaptation in the agricultural sector. World Agroforestry Centre and UNEP: Nairobi, 35 pp.

Luis Gomez-Echeverri. 2007. Incorporating climate risk management in Africa. A presentation to the Africa-Europe Forum. United Nations Environment programme (UNDP).

Mendelsohn, R., A. Dinar and A. Dalfelt (2000) Climate change impacts on African agriculture. Preliminary analysis prepared for the World Bank, Washington, District of Columbia, 25 pp. In: Stockholm Environment Institute. 2008. Climate change and adaptation in African agriculture. A research report prepared for Rockefeller Foundation. Stockholm Environment Institute.

Meine van Noordwijk. 2008. 'Action to Knowledge' and 'Knowledge to Action' framework. A presentation made during the Global Research Project 6 workshop held on March 9-10, 2008 at Kentmere, Nairobi Kenya.

Michael Richards. 2008. Paying the Real Value of Malawi's Trees: Potential and Challenges of Payments for Ecosystem Services. The EDF Programme for Malawi. Report of Consultant in 'Developing Financial Incentives for Sustainable Forest Management'

Minang, P. A (2007). Implementing Global Environmental Policy at Local Level. Community Carbon Forestry Perspectives in Cameroon. PhD Thesis, University of Twente, Enschede, The Netherlands.

Palm, C.A., Van Noordwijk, V., Woomer, P.L., Alegre, J.C., Arevalo, L., Castilla, C.A., Cordeiro, D.G., Hariah, K., Kotto-Same, J., Moukam, A., Parton, W.J., Ricse, A., Rodriques, V. and Sitompul, S.M. 2005. Carbon losses and sequestration after land use change in the humid tropics. In C.A. Palm, S.A. Vosti, P.A. Sanchez and P.J. Ericksen (eds), *Slash-and-Burn Agriculture: the Search for Alternatives*. Columbia University Press, New York, pp. 41-63.

Participatory Research and Development Initiative –PRDI. 2008. Political Economy of Bali Climate Conference: A Roadmap of Climate Commercialization. *A Policy Discussion Paper on the Key Elements of UNFCCC Climate Change Negotiation held in Bali, Indonesia, December 2007. PRDI.* (www.prdibd.org/ www.equitybd.org).

Reed D. 2004. Analyzing the Political Economy of Poverty and Ecological Disruption. World Wide Fund for Nature (WWF), Washington D.C.

Redefining Progress Organization. 2007. Ecological Footprint Accounts: Moving Sustainability from Concept to Measurable Goal (www.RedefiningProgress.org)

Seth D. Vordzorgbe. 2007. Climate change and risk management in Africa: Major issues. Expert Background Paper for the Session on Risk Management and Climate Change. World Economic Forum on Africa, Cape Town, 13 – 15 June 2007.

Stige, L.C., J. Stave, K.S. Chan, L. Ciannelli, N. Pretorelli, M. Glantz, H.R. Herren and N.C. Stenseth (2006) The effect of climate variation on agro-pastoral production in Africa. P. Natl. Acad. Sci. USA, 103, 3049-3053. In: Stockholm Environment Institute. 2008. Climate change and adaptation in African agriculture. A research report prepared for Rockefeller Foundation. Stockholm Environment Institute.

Stockholm Environment Institute. 2008. Climate change and adaptation in African agriculture. A research report prepared for Rockefeller Foundation. Stockholm Environment Institute.

Swiss Agency for Development and Cooperation and Global Footprint Network. 2006. Africa's Ecological Footprint: Human Well-Being and Biological Capital. 2006 Factbook. (www.sdc.admin.ch/www.footprintnetwork.org/http://www.footprintnetwork.org/Africa)

Temu, A.B.; Kiwia, A. World Agroforestry Centre (ICRAF), Nairobi (Kenya). African Network for Agroforestry Education (ANAFE) 2008. Future forestry education: responding to expanding societal needs.-- Nairobi, Kenya: World Agroforestry Centre (ICRAF) 17p.

United Nations Development Programme. Human Development Report 2004. New York. 2005.

Verchot, L.V.;Noordwijk, M. van;Kandji, S.;Tomich, T.;Ong, C.;Albrecht, A.;Mackensen, J.;Bantilan, C.;Anupama, K.V.;Palm, C. 2007 'Climate change: linking adaptation and mitigation through agroforestry' *Mitigation and Adaptation Strategies for Global Change* 12 5 p. 901-918

Walker s. T. Pearson, P. Munishi, S, Petrova (2008) Carbon Markets for the Forestry Sector in Africa. An FAO – Winrock International Study Report

Yatich, T.; Kalinganire, A.; Alinon, K.; Weber, J.C.; Dakouo, J.M.; Samake, O.; Sangaré, S. World Agroforestry Centre (ICRAF), Nairobi (Kenya) 2008. Moving beyond forestry laws in Sahelian countries. -- Nairobi, Kenya: World Agroforestry Centre (ICRAF) 6p. ICRAFP

Yatich T., 2008. Climatic variability and its influences on land use, human health and ecosystem services in Nyando and Yala River Basins (unpublished).

Yatich Thomas, Alex Awiti, Elvin Nyukuri, Joseph Mutua, Agnes Kyalo, Joseph Tanui and Delia Catacutan. 2007. Policy and institutional Context for NRM in Kenya: Challenges and Opportunities for Landcare. ICRAF working paper no. 43. Nairobi: World Agroforestry Centre.