INDIGENOUS STRATEGIES AND EMPIRICAL MODELS FOR ADAPTABILITY OF THE MAIZE-BEAN INTERCROPPING SYSTEM TO CLIMATE CHANGE

[1,2]**S. Mapanda,** [1]**J.M. Chitja and** [2]**K. Duffy**
[1]University of KwaZulu-Natal, South Africa
[2]Durban University of Technology, South Africa
email@chitjaj@ukzn.ac.za

ABSTRACT

This review article discusses on different ways of indigenous strategies and empirical models as an adaptation to climate change by smallholder farmers in Africa. Indigenous adaptation strategies are methods that enable individuals or communities to adjust to the impacts of climate change in local areas. Some of the strategies practiced are: zero tillage, mulching, soil management techniques, organic agriculture and fallow system of cultivation, intercropping with legumes, early planting and use of tolerant varieties to drought, water conservation and crop diversification. Scientists developed many empirical models that are used to project the impact of climate change to agriculture. Some of the empirical models include: CERES-Maize Crop Model, Global Circulation Models (GCM) and historical data records. There is also use of empirical evidence such as indigenous land unit framework, indigenous early warning systems, use of rainmakers, movement of birds, ants and crying of dogs by the indigenous smallholder farmers in Africa. Intercropping system is the best practice used as a strategy to climate change adaptability, and one of the most suitable intercropping systems is that of maize and bean. However, the current research findings revealed that there is a lack of consideration of indigenous knowledge that could enhance livelihoods that depend on natural resources directly affected by climate change.

Keywords: Indigenous strategies, empirical models, climate change, smallholder farmer and food security.

INTRODUCTION

The Food and Agriculture Organization of the United Nations (FAO) (2011) stated that agriculture is the most important sector of many developing countries. Agricultural production systems are expected to produce food for a global population that will grow to 9.1 billion people by 2050. Therefore, to be secure and maintain food security, agricultural systems need to be transformed to increase the productive capacity and stability of smallholder agricultural production. Presently, there is a global drive to investigate ways to adapt agriculture to climate change due to the potential negative effects and implications on food security across and within regions. Climate change affects the food systems in several ways, ranging from: direct effects on crop production, changes in rainfall patterns leading to drought or flooding, warmer or cooler temperatures leading to changes in the length of growing seasons resulting in changes in markets, food prices and supply chain infrastructure. The World Bank (2013) reported that less than 4% of agricultural lands in Sub-Saharan Africa are irrigated and 97% of agricultural production is currently rain-fed and over 60% of the region's livelihoods are agriculture and natural resource dependant (Cooper *et al.,* 2008). As a result, food production is almost entirely dependent on rainfall and therefore is highly vulnerable to changes in precipitation and the occurrence of drought (World Bank, 2013). Due to the changes of the environment the food production yields will be altered whereby some crops will grow better in certain environments; maize crop will likely experience sharp declines. It is estimated that by 2050 yield of maize will be reduced by 15-20% (World Bank, 2013) and by 2080, the projections are even worse for agricultural productivity if substantial changes to policy and practices are not made now.

The Southern African Development Community (SADC) is one of the regions whose agriculture is expected to be impacted negatively by climate change (IPCC, 2007). Agriculture in the SADC region has been shown to be highly exposed to climate change and smallholder farming communities within the region have been found to be the most vulnerable (Ziervogel *et al.*, 2008). In addition, studies conducted by Pearce *et al*. (1996) revealed that Africa's agriculture is negatively affected by climate change. The World Bank (2008) reported that Sub-Saharan Africa is currently the most food-insecure region in the world. Climate change could aggravate the situation further unless adequate measures are put in place throughout Sub-Saharan Africa. Over the period, 1960-1963 there is increased intensity of drought/rainfall variability and floods observed throughout (Gommes *et al.* (1996). Easterling (2007) predicted that the effects of climate change will continue to have a negative impact on agriculture. The World Bank (2013) projected that per capita crop production and agricultural productivity will drop as predicted while food prices will rise. It is necessary to implement far reaching and innovative solutions in agricultural practices. The implemented policies should consider both increased productivity and be climate smart.

These strategies include the adoption of efficient environmental resources management practices such as planting of early maturing varieties, adoption of resistant varieties and selective keeping of livestock in areas where rainfall declined. The Sub-Saharan farmers are known to practice zero tillage in cultivation, mulching and other soil management techniques (Schafer, 1989; Osunade, 1994). It was discovered that natural mulch moderates soil temperatures and their extremes, suppress weeds, diseases and harmful pests and conserves soil moisture. Before the manufacturing of chemical fertilizers, local farmers were largely dependent on organic farming which is also capable of reducing Green House Gas (GHG) emission. Hence, according to Okoboi, *et al.* (2012) unless radical interventions occur, projected inorganic fertilizer consumption growth in Sub-Saharan Africa (SSA) until 2030 will remain at 1.9% per annum.

Furthermore, the forest played a major role in the global carbon cycle by sequestering and storing carbon (Karjalainen *et al*., 1994; Stainback and Alavalapati, 2002). Apart from this, local farmers also practiced the fallow system of cultivation, which encouraged the development of forests. Due to growth in population, lengths of fallow have been reduced to the extent that the practice no longer exists in many areas. Therefore, the study showed that the importance of forests was recognized by traditional institutions and the communal forest reserves were very common in traditional societies. Besides the fact that the well managed forests provided food and timber resources to the community, they also served as carbon sinks (Netting, 1993). A study of the Mende farming system in Sierra Leone demonstrated how farmers use sophisticated agronomic practices to mediate poor rainfall (Richard, 1986). More so in northern Nigeria, farmers used multiple cropping and varietal experimentation to mitigate against uncertain precipitation and high rates of evaporation (Watts, 1983). The Nganyi community of western Kenya used traditional methods of weather forecasting, the behaviour of ants, bird songs and timing of tree flowering to decide when to prepare land and sow seeds (Guthing and Newsham, 2011).

According to Ofori-Sarpong, 2001 smallholder farmers practice different inter-cropping strategies based on variation of soil moisture and the onset, character and duration of rainfall. The typical combinations include: cowpea-sorghum and millet-groundnut in years with poor rainfall. The maize-beans, maize-groundnut and maize-millet combinations are used during the years with moderate rainfall. Smallholder farmers in Ethiopia used multiple cropping, mainly intercropping of maize and bean to increase yield per unit area and reduce the risk from crop failure due to climate change and farmers were able to get additional income and alleviate food shortage (Hirpa, 2014).

INDIGENOUS STRATEGIES TO CLIMATE CHANGE ADAPTATION AMONG FARMERS IN AFRICA

Africa is considered to be among the most vulnerable regions to climate variability. Climate change is a major threat and a challenge to Africa mainly because many households, social groups and the region have limited capacity to adapt to climate change. In Southern Africa, the variability to climate change is shaped by the complex interaction of social, political, economic, cultural and environmental factors. In a recent study conducted by the International Panel on Climate Change (IPPC), it reported that Africa is expected to warm up during the century with the drier subtropical regions warming more than the most tropical. Annual rainfall is going to decrease throughout most of the region, with the exception of eastern Africa where annual rainfall is projected to increase. Due to this drying of the continent, it is estimated that 75 and 250 million people are likely to be exposed to additional water stress by the year 2020. To better reduce the impact of climate variability and change on food production and livelihood, this can be achieved by using available climate information to anticipate and manage annual climate related risks (Tarhule, 2005; Washington *et al*., 2006). Climate information is mainly obtained from meteorological seasonal climate forecast (SCFs). This information helps smallholder farmers and pastoralists to manage their crops and livestock to minimize risks during unfavourable seasons and maximize opportunities during favourable conditions.

Warren (1992) and Osunade (1994) described indigenous knowledge as institutional local knowledge that has been built upon and passed on from one generation to the other by word of mouth. It can also take the form of transferred skills. It is used as a basis of local level decision-making in many rural communities.

Woodley (1999) further explained that the knowledge set is influenced by the previous generation's observations and experiments which provide an inherent connection to one's surrounding and environment. Therefore, indigenous knowledge is transferable and provides relationships that connects people directly to the environments and changes that occur within it, which include the climate change. Indigenous knowledge has over the years played an important role in solving problems, including those caused by climate change. As a result farmers in Sub Saharan Africa developed several adaptation measures that have enabled them to reduce the vulnerability to climate variability and its extremes.

The most practiced adaptation measure to climate change at farm level is organic agriculture. Research showed that organic agriculture is the most holistic production management system that enhances agro-ecosystem health, utilizing both traditional and scientific knowledge (IFOAM, 2007). The advantages of organic agriculture are that it prevents nutrient and water loss through high organic matter content and soil covers, thus making soil more resilient to floods, drought and land degradation processes. Therefore, organic agriculture maintains soil fertility through farm internal inputs such as: organic manures, legume production and crop rotation (FAO, 2008a). Hence organic agriculture is being considered as a holistic approach in climate change adaptation. Basically, there are two major modifications in the production systems: (i) increased diversification and (ii) protecting sensitive growth stages by managing the crops to ensure that the critical stages do not coincide with harsh climatic conditions such as mid-season droughts (Hassan and Nhemachena, 2008).

Hassan and Nhemachena (2008) reported on several adaptation strategies that farmers perceive as appropriate. These included crop diversification, using different crop varieties, varying the planting and harvesting dates, increasing the use of irrigation, increasing the use of water and soil conservation techniques, shading and shelter, shortening the length of the growing season, and diversifying from farming to non-farming activities. Other strategies that serve as an important form of insurance against rainfall variability are: increasing diversification by planting crops that are drought tolerant and/or resistant to temperature stresses, taking full advantage of the available water and making efficient use of it, and growing a variety of crops on the same plot or on different plots.

By doing so farmers reduce the risk of complete crop failure because different crops are affected differently by climate changes (Benhin, 2006). It has been observed that the managing of farming systems resulted in smallholder farmers meeting their subsistence needs in the midst of environmental variability without depending much on modern agricultural technologies (Denevan, 1995).

According to United Nations Framework Convention on climate change (COP 18, 2012) in Africa many rural farmers have been practicing a range of agricultural techniques such as coping strategies and tactics to enable sustainable food production and dealing with extreme events. These include intercropping and crop diversification, use of home gardens, diversification of herds and income such as the introduction of sheep in place of goat in the Bara province in Western

Sudan, pruning and fertilizing to double tree densities and prevent soil erosion in semi-arid Senegal, Burkina Faso, Madagascar and Zimbabwe; manipulation of land use leading to land use conversion e.g. a shift from livestock farming to game farming in Southern Africa. The farmers used water conservation techniques to cope with arid conditions such the “Zai technique” in Burkina Faso: whereby farmers dig pits in the soil to collect organic material carried by the wind during the dry season, at the start of the rainy season farmers add organic matter from the animals which attracts termite activity resulting in termite tunnels that can collect rain deep enough that it does not evaporate thus increasing soil fertility, storing moisture and creating a favourable condition for the plant growth. This technique was also practiced in the Northern part of Ghana where prolonged droughts have deteriorated the soil (Ngigi, 2009). In Nigeria, adaptation strategies practiced by farmers include: crop diversification using different crop varieties, varying the planting dates, harvest dates, increasing the use of irrigation, increasing the use of water and soil conservation techniques, shading and shelter, shortening the length of the growing season and diversifying from farming to non-farming activities. It was revealed that rural women farmers were engaged in both farm and non-farm occupations in order to cope with challenges of climate change (Ajani, 2012).

Benneh (1970) concluded that the most common adaptation strategies that farmers in Ghana used were: the flowering of the Shea nut trees, migratory patterns of birds and the position of the constellation Pleiades and this helped farmers to determine when the rainy season is due. Apart from that when the rain season started, the farmers used the growth of certain grasses to determine soil moisture content and suitability for particular crops.

Maize is the staple food in Malawi and it accounts for 50-90% of calorific intake and is cultivated on over 70% of the land and there are big differences between actual yields and experimental farm yields. The maize-based cropping practice has promoted monocropping and ridge tillage for a long time and this form of agriculture has been practiced by smallholder farmers in defining their livelihoods and economic development of the country with varying levels of success. The potential maize hybrid yield in Malawi ranges from 5-8 tonnes per hectare but the average actual yield ranges from 1.5-2.5 tonnes per hectare. As a result of the routine, annual tillage of the soil with associated removal or burning of plant residues, this has contributed to the deterioration of the physical quality of the soil. This further poses a strong potential to increase the impact of climate change phenomena such as droughts, as the soil becomes less fertile and results in allowing infiltration of rain or irrigation water. Therefore, the adaptation solution was the approach of a technology called conservation agriculture which entails the application of wise soil and water management practices that improve and safeguard the quality of land and rainwater resources. Conservation Agriculture principles were introduced to 240 families farming on 0.1ha and 283 families farming on 0.2ha. As climate change continues to modify rainfall patterns, planting season, soil moisture consumption and soil nutrient retention and crop yields are being reduced, there’s been an introduction of Conservation Agricultural principles in Malawi. Conservation agriculture (CA) is a sustainable cropping system that may help in reversing soil degradation, stabilizing and possibly increasing yield, and reducing labour time and producing a high net return. CA is based on three main principles: (1) minimum soil disturbance (i.e. direct sowing of crop seeds); (2) permanent soil cover with living or dead plant material; and (3) crop rotation or association with leguminous or cash crops for family use or sale (FAO, 2012). Farmers in Malawi generally practice CA with the dibble stick, a pointed wooden stick, which aims at disturbing the soil as little as possible by only creating a planting hole where seeds are placed. Although planting basins and jab-planters are also promoted and have been tested, farmers in Malawi prefer the dibble-stick planting method because it is compatible with the traditional planting methods (i.e. planting the seed on the ridges is normally done with a pointed stick (Ngwira *et al.,* 2012). As a result, it has increased resilience to the negative impacts of climate change while boosting food production.

In Zimbabwe, Mutekwa (2009) identified other adaptation strategies including: (i) the growing of legumes such as beans, especially towards the end of the rainy season when cereal fails due to excessive rainfall. The reason being that legumes mature fast and provide nutritious relish. Apart from that they also fetch good prices on the market; (ii) Indigenous knowledge system is used as an adaptation strategy where farmers based on the lessons learnt from the previous climatic stresses, the farmers share knowledge during field days and trips; and (iii) It has been observed that conservation tillage is a useful option for improving the storage of rain water in the soil and it helps to mitigate agricultural drought. However, it requires adequate draught power, appropriate machines and good training of farmers to be effective.

Schafer (1989) and Osunade (1994) stated that most of the local farmers in Sub-Saharan Africa have been known to conserve carbon (C) in the soil through use of zero tilling practices in cultivation, mulching and other soil management techniques.

The indigenous farmers in Central Africa are known to make decisions on the cropping patterns based on the local predictions of climate and decision on the planting dates based on complex cultural models of weather. One of the strategies used to reduce the vulnerability of climate hazards was by developing an indigenous early warning systems for the prediction or forecast of the event by reading natural signs and predict the and event (Eyong, 2007). For example, a 70 year old man in north western Cameroon revealed that in his generation, when dogs cried too much, fowls crowed at mid-day, ants and flies moved in an unusual way it showed that a nearby river would overflow its banks and destroy crops (Eyong, 2007). The communities would offer important sacrifices or be prepared by strengthening their coping strategies. In addition, poor harvest, famine and other epidemics have been detected and reported before they occurred (Eyong, 2007).

The study on weather knowledge in many parts on the Sub-Saharan Africa revealed rich wealth of knowledge that farmers possessed. The local farmers developed intricate systems of gathering, prediction, interpretation and decision-making in relation to weather. For instance, the farmers in Murowa ward, Zimbabwe used adaptation strategies which include strengthening and improving indigenous land and water management, use of decision support tools such as seasonal weather forecast data, growing of drought resistant crops, improving indigenous animal breeds and development of irrigation infrastructure (Mutekwa, 2008). It was discovered that these systems of climate forecasts have been very helpful to the farmers in managing their vulnerability to a great extent. Farmers are able to make decisions on cropping patterns based on local predictions of climate and decision on the planting dates based on the complex cultural models of weather (Alidade and Shokemi, 2003).

EMPIRICAL MODELS FOR BOOSTING ADAPTABILITY TO CLIMATE CHANGE

Climate change is a serious threat to agriculture, food security and the fight against poverty in Sub-Saharan Africa. Crop failure among the smallholder farmers is due to unexpected shock incidents of drought, flooding, excessive rainfall, pests and diseases. These increase the risk of longer periods of hunger and more severe livelihood hardship for the many rural poor who rely on small-scale farming for food and income (Tongruksawattana, 2013). In order to cope with increasing unprecedented incidents of shifts in precipitation patterns and rising temperatures, smallholder farmers are forced to undertake different adaptation strategies. The smallholder farmers in Zimbabwe used different adaptation strategies to cope with the climate change effects. They practiced crop diversification, since different crops are affected differently by the same climatic conditions and it improves household food security (Mutekwa, 2008). In addition, due to high frequency of mid-season dry spells and shortening of rain seasons, the farmers in Zvishavane district, Zimbabwe grew short season and drought-resistant crop varieties such as sorghum, rapoko and finger millet. As a result the smallholder farmers managed to build indigenous knowledge skills and experience acquired over years (Mutekwa, 2008). Ziervogel and Ericksen (2010) noted that the link between food security and climate change is complex. The reason being that food security consists of food and its production, trade, nutrition and how people and nations maintain access to food over time in the face of multiple stresses.

A study was conducted by Walker and Schulze (2006), for maize production in Bergville, KwaZulu-Natal, where smallholder farmers grow rainfed maize. Maize is regarded as a staple food in South Africa and the production is characterised by low yields which are often lower than the potential for the land (Walker and Schulze, 2006). The sustainability for smallholder farmers raises questions for equity, economic viability of their operation and household food security. Walker and Schulze (2006) investigated sustainability at the field scale using both field data and model simulation for an improved understanding of food security at the household level. Thornton and Wilkens (1998) concluded that at household level it is crucial for the farmer to minimise the fluctuations in the household income over time as well as to maintain or increase a particular wealth level and nutritional status so as a result the small scale farmer is more susceptible than commercial farmers to climate variability and its impact on yields.

Walker and Schulze (2006) assessed sustainability at the smallholder using the agro-ecosystem level and it measured the yield, soil organic carbon and nitrogen to a wide range of management practices and plausible climate scenarios. The management practices included: four tillage practices, two fertilizer practices and six climate scenarios. The yield of maize from the crop model simulation was compared against the famine figure (900kg/ha of maize) which is the amount of grain adequate to feed a family of four to survive to the next harvest season. A 49 year climate data set was used to measure sustainability and a goal-orientated framework was adapted from von Wire-Lehr (2001). The framework addressed the following questions:

1. How can an actual agro-ecosystem be identified as being sustainable or not?
2. What facets of a system make it sustainable?
3. Are there research and operational implications associated with climate?

MODELLING SMALLHOLDER AGRO-ECOSYSTEMS

A study of CERES-Maize crop model was conducted and there was extensive calibration for Southern Africa (du Toit *et al.*, 1994, 1997). The model was modified to CERES-Maize v3 for Southern African conditions using the historical field trial and commercial data in order to determine whether adaptations were site specific. The biophysical indicators assessed from the CERES-Maize crop model measured quantitative information on how agro-ecosystem responds to both management and environmental changes. The parameters measured were the maize grain yield, soil organic carbon and soil organic nitrogen levels. The management options included four types of tillage practice which were; no till, rip, disc and shallow tine in combination with applications of either inorganic fertilizer or manure. The application of organic fertilizer from farm animal and/or plant residues as shown to improve the soil nutrient besides its important role of improving soil conservation, when combined with conservation tillage practices that protect soil structure, reduce erosion and run-off and promote soil biological functions that is vital to soil productivity (Agwe *et al.,* 2007).

Adewojun (2006) and Abou-Hadid (2006) conducted a quantitative projection of future impacts from modelling studies at a variety of geographical scales, focusing on smallholder crops and ecosystems used by the smallholder farmers (Lasco and Boer, 2006). A study conducted by Jones and Thornton (2003) showed that aggregate yields of maize in smallholder farmers who depend on rain-fed systems in Africa and Latin America are likely to show a decrease of 10% by 2055.

Hillyer *et al*. (2006) reported that Ovambo farmers in North-Central Namibia developed a sophisticated way of identifying the productive potential of areas. They used a system called “indigenous land unit framework” which classifies land into categories according to their agricultural utility. The farmers used the land unit framework to decide what crops to plant and where according to the conditions of the growing season. Furthermore, Verlinden and Dayot (2005) classified indigenous land units based on the soil, vegetation and landform. For each category they identified a number of specific indicators such as texture or hardpan depth for the soil, species and structure for vegetation, and elevation or depression in landform. Therefore, this particular land unit classification helped farmers to know which crops to grow under particular conditions. For instance the land unit characterised by depressions in the landscape is desired for planting pearl millet in drier growing seasons whereas in wet growing seasons, farmers preferred to plant pearl millet in Omutunda which is a land unit characterised by elevation and more fertile conditions. In contrast, other land units such as sandy, dry and well drained Omufitu – the most suitable crops are legumes such as Bambara groundnut. The use of agro-ecological knowledge as an adaptive strategy to climate change have proved to be working for farmers in North Central Namibia. The understanding of agro-ecological dynamics allowed the farmers to adapt cropping and livestock strategies to the highly variable climatic conditions they encountered from one season to the next. According to Hillyer *et al*. (2006) farmers in Namibia managed to establish farms across a number of different land units as opposed to picking one specifically. This was because the use of different land units are recognized by farmers to perform well under different growing conditions i.e. a drier or wetter rainy season.

In Kenya, the smallholder farmers, rainmakers and meteorologists were brought together to produce a joint weather forecast. According to Onyango *et al*. (2010), by merging modern scientific and indigenous forecasting styles, it helped to better manage climate change risks and reduce poverty and provide communities with new tools for coping with extreme weather events. It was reported that there was a possibility to explore the use of both the local and meteorological knowledge, as a way to produce more intelligent, robust and locally seasonal forecasts. A report from the Kenya Meteorological Department on seasonal forecasting was broadcasted on the local Kenya radio station, and it assisted farmers to make appropriate cropping decisions. As a result, it removed a barrier in language used as well as the inhibition to the uptake of the forecast due to a relatively wide geographical area covered. The main reason was that forecasts were not locally specific; some farmers had come to question their usefulness and even doubt their credibility of local knowledge. The rainmakers are valued locally and their seasonal forecasts are much easier to understand than the meteorological ones. The reason is, that their predictions are given at the village level in contrast to meteorological forecasts which report across a wider geographical area and as a result their reports are much harder to extrapolate for any given village within that area. The rainmakers used the behaviour of plants and animal life. For example, the change in humidity and temperature, this was observed from flowering and leafing of shrubs and trees, the call of certain birds, the behaviour of ants and even the croaking of frogs and toads.

Scientists also developed models used to predict the weather for 30 years or more. These crop models are important because they are used to predict and stimulate crop responses to future conditions. According to Uehara and Tsuji (1998), the main challenge in assessing risk from climate change is the lack of longterm weather data and man's inability to predict the future weather. Therefore, the crop simulation models use longterm weather data to account for weather variability in assessing risk involved with adopting alternative crop management strategies at a site of interest (Uehara and Tsuji, 1998). A good example is the deterministic mathematical models that used simulated time series climatic variables which is known as stochastic weather generation and was found to solve the problem (Richardson and Wright, 1984). This type of model observed historical weather data as inputs and general synthetic weather data, which are statistically similar to the observed historical data records (Semenov and Jameson, 1999).

A study was conducted on the potential effect of climate change on the grain maize (*Zea mays)* in KwaZulu Natal province to assess the maize production in response to different scenarios of climate change. A daily time step stochastic model was developed to generate daily weather variables. Furthermore, according to Clemence (1997) an earlier version of ClimGen was used in several sites in South Africa, in order to collect data on wider variety of climates. These weather data were used to generate inputs for crop stimulation models and offered agricultural scientists the opportunity to evaluate long term effects of weather data that were impossible to be evaluated with limited observed records of historical data (Richardson, 1985). In the area of Cedara, a summer rainfall area located in the midlands of KwaZulu Natal and generated weather data (Clemence, 1997). They developed an input to the CERES – maize crop growth model. The results showed that there was a generally good agreement between simulated grain yields using observed and generated weather data sets.

Rosenzweig and Hillel (1998) revealed that agricultural crop production is significantly affected by climate variables due to photosynthetically active radiation, air temperature and water being the driving forces for crop growth. The best crop model that measures changes in crop production in response to changing climatic variables is the crop simulation experiment. CropSyst is a multi-year multi-crop simulation model that was developed to study the effect of cropping system management on productivity and environment (Stockle and Nelson, 2000; Stockle *et al*., 2003). This model can be used to model the growth and development of several crops such as maize, wheat, barley, soyabean and sorghum and it produces good results. However, most studies used climate scenarios generated from global circulation models (GCM) and crop models.

In addition, adaptation is the main key that will shape the future severity of climate change impacts on food production. Although farmers have been practicing inexpensive changes such as shifting the planting dates or switching to already released crop variety, and these have helped to moderate negative impacts of climate change. The best results are mostly achieved by the development of new crop varieties and expansion of irrigation. These adaptations require a substantial investment by farmers, government, scientists and development organizations (Lobell *et al.,* 2008).

THE IMPORTANCE OF INTERCROPPING SYSTEM TO CLIMATE CHANGE

According to Beets, (1990) in Carlson (2008), mixed cropping is the practice of growing more than one crop in a field at a given time. Therefore, the intercropping system is the practice of growing more than one crop simultaneously in alternating rows of the same field. Vandermeer (1992) Ofori and Stern (1987) revealed that intercropping is divided into the following four groups:

- Row-intercropping: Growing two or more crops simultaneously where one or more crops are planted in regular rows, and crop or other crops may be grown simultaneously in a row or randomly with the first crop.
- Mixed-intercropping: Growing two or more crops simultaneously with no distinct row arrangement. This type of planting can be suitable for grass-legume intercropping in pastures.
- Strip-intercropping: Growing two or more crops simultaneously in different strips wide enough to permit independent cultivation but narrow enough for the crops to interact ergonomically.
- Relay-intercropping: Growing two or more crops simultaneously during part of the life cycle of each. A second crop is planted after the first crop has reached its reproductive stage but before it is ready for harvest.

Intercropping with maize in sub-arid regions is a way to grow a staple crop while obtaining several benefits from the additional crop. The main benefit of intercropping is an increase in yield per unit area of land.

When maize is intercropped with a legume there is a possibility that it reduces the amount of nutrients taken from the soil as compared to a pure stand maize crop when nitrogen fertilizer is added to the field Intercropped legumes use the inorganic nitrogen instead of fixing nitrogen from the air and thus compete with maize for nitrogen. However, when nitrogen fertilizer is not applied, intercropped legumes fix most of their nitrogen from the atmosphere and thus do not compete with maize for nitrogen resources (Adu-Gyamfi *et al.,* 2007).

In addition, intercropping systems increase the diversity of the physical structure of plants and produces many benefits such as increased canopy cover which helps to reduce the weed populations once the crops are well established (Beets, 1990). There is also a variety of rooting systems in the soil and this reduces water losses, but increases water uptake and increases the transpiration rate. The increased leaf cover helps to cool the soil and reduces evaporation thus conserving soil moisture (Innis, 1997). Another benefit of plant diversity in intercropping system may reduce the impact of pest and disease outbreaks by providing more habitat for predatory insects and increasing the distance between plants of the same crop. Intercropping modifies the plant environment such that the insect pests of the different component crops are affected in their reproduction behaviour resulting in reduced insect pest pressure. Other ecological benefits of intercropping system is less land needed for crop production, diversification of food products, reduction of pesticides and herbicides use and a reduction in soil erosion. This system has several benefits to smallholder farmers because it reduces the need for external farm inputs, diversification of diet, and addition of cash crops, increased labour utilization efficiency and reduced risk of crop failure.

One example of intercropping system is maize and beans. According to Tsubo *et al.* (2005) a simulation model was produced to determine the best planting methods for maize and bean intercrops in sub-arid South Africa. They found that intercropping of maize and beans increased the total yield. Therefore, intercropping system is a good technology for smallholder farmers who depend on maize as their staple crop. For intercropping system maize and bean in South Africa, the best time to plant is at the beginning of rainy season, November or December (Carlson, 2008).

Furthermore, a study was conducted by Sangakkara *et al*. (2003) and they found that intercropping maize with either a food legume bean – Phaseolus vulgaris or green manure Sunhemp – Crotolaria juncea under rain fed conditions was positively beneficial. The intercropping of legumes increased the germination of maize and most importantly the incorporation of the legume residues increased the maize shoot biomass over time. In addition, the legume reduced its nitrogen use efficiency, and thus illustrated a lower mining effect in contrast to maize monocropping system, which had a higher nitrogen uptake. In addition, the intercropping of maize with beans resulted in increased harvestable yield over a period of time and it also enhanced soil fertility especially of nitrogen (Hoffman *et al*., 2001).

CONCLUSIONS

There is a lack of consideration of indigenous knowledge that could enhance livelihoods that depend on natural resources directly affected by climate change.

According to Nyantakyi-Frimpong (2013), many policy makers remain sceptical of the credibility of indigenous knowledge, considering it an inadequate basis for sustainable agriculture. On the other hand researchers emphasize that because indigenous knowledge is locally specific and embedded in traditional norms, its scalability and shared learning are difficult as practices and beliefs are endemic to the group in which they are held. As a result, more attention is given to high technology, high cost and genetically modified agriculture.

Parry *et al*. (2007) noted that international fora including governments throughout Africa continue to undervalue the role of indigenous knowledge in national climate change adaptation policies. Instead, policy makers are turning to International Financial Institutions (IFIs) and donors to transform farming by introducing large-scale industrial agricultural practices as the key to adaptation to climate change (World Bank, 2008). On the contrary this method of production depends on hybrid seeds, synthetic fertilizers and machinery run with large carbon inputs, further jeopardizing the climatic stability on which all types of agriculture rely (Robertson *et al.*, 2000).

Ngenwi *et al*. (2010) identified how indigenous knowledge of women can be strengthened to better adapt to climate change variability and change. It was discovered that indigenous knowledge practiced by women in agriculture had synthesized lessons on adaptation strategies. As a result poor social conditions are exposed to and exacerbated by climate change (70% of the 1.3 billion people in the developing world) are living below the threshold of poverty. However, the common phenomenon in many developing countries is that women in communities generally do not own land and have hardly any rights regarding the management of natural resources, despite often working in the fields. Despite these odds, women have been able to cope with and adapt to the negative effects of exclusion from the control of resources and to climate change through indigenous knowledge practices.

In general, the traditional or local knowledge is strongly tied to local culture. Therefore, over a period of time smallholder farmers have acquired knowledge about the inner workings of their immediate surrounding or environment.

However, there are obstacles to integrate indigenous knowledge into formal climate change mitigation and adaptation strategies. As researchers we need to actually integrate indigenous knowledge into formal western science. According to Adugna (1996) indigenous knowledge adds value to climate change studies by creating a moral economy whereby a person is identified within a cultural context and it promotes decision-making processes or a rule of thumb to be followed based on observed indicators or relation within events. This makes the communities to act within these rules to maintain security and assurance or risk isolation from their community. Farmers are living in an uncertain and risk based environment, but such rules provide farmers with a sense of community belonging and stability.

Davies and Ebbe (1993) stated that indigenous knowledge is increasingly exhibiting a resemblance with scientific methods but many ideas in indigenous knowledge were earlier regarded as primitive and misguided. The advantage of indigenous knowledge system provide mechanisms for participatory approaches and share the same guiding principles with sustainable development framework with 3E concerns – Economy, Equity and Environment.

Mutekwa (2009) concluded that there are new and old intervention strategies which need to be intensified through participatory approaches such as farmers' field days and trips. Also Agricultural Extension Officers need to explain and train farmers on the importance of seasonal climate forecast information and how they use it to make efficient use of their limited resources through informed investment decisions.

United Nations Framework Convention on Climate Change reported that adaptation plans and strategies are the next important step for the developing countries. Farmers have been practicing the strategies for a long time so there is a need to bridge the gap between adaptation assessment and planning, and adaptation implementation, and to build on the indigenous knowledge. Adaptation options need to be matched to priority needs both in the context of community-based action and in national and sectorial planning as well as disaster risk reduction. Adaptation plans must be integrated into top down and bottom up approaches for planning to enable sustainable development and the efficient use of resources for adaptation.

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