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Agro-Diversity in the Forest-Savannah Transition Zone of Ghana: A Strategy for Food Security against Climatic and Socio-Economic Stressors

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Abstract

Food security is a major issue affecting about 239 million people in Sub-Saharan Africa. Therefore, local ecosystems-based adaptive strategies for reducing the impact of climate change and other stressors on food production systems are very relevant in the national food security agenda. This study assessed how farmers in communities of the environs of the Kogyae Strict Nature Reserves in the forest-savanna transition zone of Ghana exploit a range of options for food production that spread and reduce risks and ensure sustainability of the local environment. Through a cross-sectional survey involving focus group discussions, institutional data search and on-site observations, the study investigated different ways to which the natural diversity of the environment has been used by farmers to enhance farm productivity and farmer income. The study observed that climate variability, land expropriation for protected area establishment, inappropriate use of farm technology and low pricing for farm produce pose as major threats to sustainable agriculture in the area. These constraints have compelled farmers to adopt a range of agro-diversity practices for increased farm productivity and income. They include introduction of new crop varieties, adoption of innovative farm management practices, diversified farm fields and sequential cropping systems. The study noted that the diversified systems have boosted farmer productivity and incomes and contributed to their socio-cultural needs. The study recommends greater crop intensification through the use of appropriate technologies and improved access to markets to consolidate farmer gains and livelihoods as well as ensuring food and nutritional security.

Key words: agro-diversity, food security, climate change, Kogyae Strict Nature Reserve

1. Introduction

1.1 Changing Environmental Conditions and Threats of Food security

Most natural resource-dependent agrarian societies have limited asset portfolios needed to adequately cope with and adjust to climate change and its associated impacts. As such, they tend to be vulnerable to both natural and socio-economic stressors and face food security threats (Pascual et al., 2011). Local ecosystem-based strategies aimed at maintaining the adaptability of food production systems to reduce the impact of these stressors become very relevant in the national food security agenda. One such strategy is agro-diversity, which under changing environmental conditions, provides nutritional needs, reduce production risk, enhance the ability to cope with changes, and mitigate disasters (Liang, 2002). Agro-diversity, in this context, refers to "*the many ways in which farmers use the natural diversity of the environment for production, including not only their choice of crops but also their management of land, water, and biota as a whole*'' (Brookfield & Padoch, 1994, p 9). It encompasses diversity of resource management and cropping systems, including indigenous knowledge, the local genotypes of food crops, intercropping and agroforestry systems. It emphasizes farmers' resource management as a whole, and holds promise for conservation of biodiversity, protection of important land use systems, control of land degradation as well as enhancement of food security and rural livelihoods (Liang, 2002). Kremen, Iles and Bacon (2012) explained the concept in a narrower sense to mean "diversified farming systems" but maintained the key defining elements of agro-diversity, which include functional biodiversity at multiple spatial and/or temporal scales through practices developed by way of traditional and/or agroecological scientific knowledge.

Scherr and McNeely (2008) in explaining a similar concept coined the term 'ecoagriculture', which was explained to mean landscape in which biodiversity conservation is an explicit objective of agriculture.

In the era of climate variability and growing uncertainties about crop yield, food security becomes very critical for the health and physical wellbeing of the vulnerable. According to FAO, IFAD and WFP (2014), an estimated 805 million people remain generally undernourished globally by 2014. Out of this figure, about, 226.7 million people or 20.5% live in Africa. In Sub-Saharan Africa alone, about 214.1 million or 23.8% of the people are undernourished. The food security situation in the sub-region is compounded by an interplay of rapid population growth, underdevelopment of the agricultural sector, internal conflicts, poor governance, diseases, weak policies and natural disasters, among others, thus making the region the most economically vulnerable in the world (Boko et al., 2007; Ikejiaku, 2009; FAO, 2010).

In Ghana, the forest-savannah transition zone is considered as the food hub of the country (Titriku, 1999) and holds great potentials for increased food productivity. The area is, however, under threat from climate change (Owusu & Waylen, 2009), and other production pressures. The Kogyae Strict Nature Reserve and its fringe communities, which is the focus of this study, lie within this zone. A combination of climate variability and socio-economic stressors such as land expropriation for protected area establishment, decreasing trends in yields of traditional crops (Ayivor & Ntiamoa-Baidu, 2015) and low pricing for farm produce pose a major threat to sustainable agriculture in the area (Ofori et al., 2015). In order to circumvent any shortfall in productivity, farmers have diversified their farming practices through a range of agro-diversity practices including introduction of new crops into traditional cropping systems to ensure food security. This study explored the range of options available to farmers and investigated the diversity of farming practices within and across fields in the broader landscape. It also assessed the extent to which the diversity had impacted on the local productivity and food security.

1.2 Agro-Diversity: A Conceptual Framework

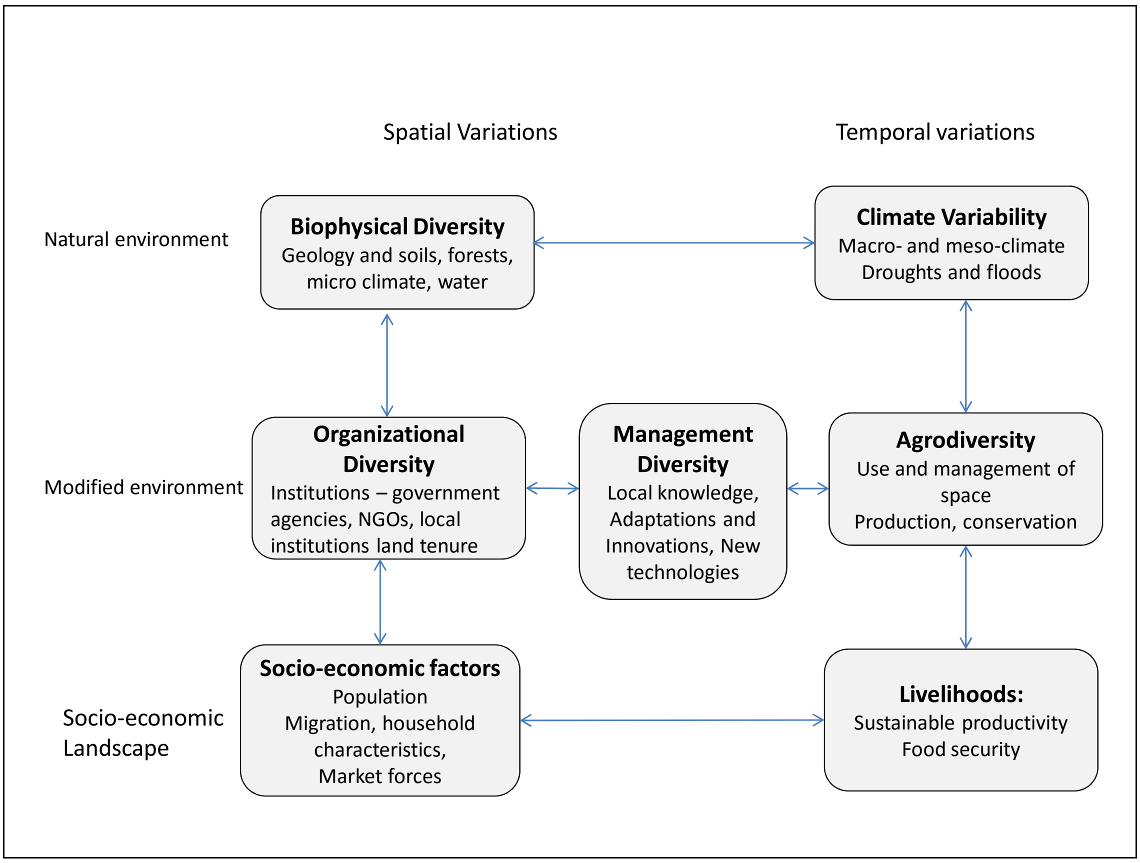

Figure 1. Agro-diversity Framework: Adapted from Brookfield and Stocking (1999)

Brookfield and Stocking (1999) developed a framework to explain four principal elements of agro-diversity that they identified; namely biophysical diversity, management diversity, agro-biodiversity and organizational diversity. These elements of the framework were distinguished under short- and long term scales. The short term could be months or a short sequence of years, and involve sequential diversity in farmers' decision-making on use of land, labour, capital and other farming resources. The long term scale, the other hand, extends from a few years to many decades. It involves change in cropping and management practices in response to both physical and socio-economic stressors. These changes may occur as soil and biota are modified by utilization and natural processes and obsolete technologies are discarded as new innovations are adopted (Brookfield, 2001).

Drawing from Brookfield and Stocking (1999), we developed a model (Figure 1) that comprises most of the principal elements of the Agro-diversity framework, but modified to suit the local context. The model guided the presentation of results and the discussions.

The model in Figure 1 shows the main components of biodiversity, their attributes and the inter-linkages. As shown in the figure, spatial variations occur as a resulted of inherent differences in the natural environment, modified environment and socio-economic landscape. These variations are depicted as biophysical diversity, organizational diversity and socio-economic factors.

The model illustrates how drivers of change operate at different time scales to bring about variability in climatic conditions, management systems and agricultural practices, which impact on food security and livelihoods.

The adaption of the Agro-diversity framework was informed by the complexity of the research problem under investigation and the fact that such a complex issue needed a robust framework that adequately discusses all the different dimensions of the problem and their inter-linkages. The Agro-diversity framework by Brookfield, and Stocking (1999) provided the basis for the study to adapt and come out with a simplified model that lends itself to juxtaposition of the findings in a very systematic way.

2 Setting and Methodology

2.1 Description of Study Area

The study area covers the landscape stretching from the headwaters of the Sene River (in the north) and the Afram River (in the south), to the Kogyae Strict Nature Reserve and its environs (Figure 2). The area lies within the forest-savannah ecotone in the middle belt physiological region of West Africa. The middle belt in Ghana runs across the country from east to west and is boarded to the north by the Guinea Savannah and to the south by the semi-deciduous forest zone. Average annual rainfall receipts in the area ranges between 1200mm and 1300mm with marked variability. The rainfall is under the influence of the movement of Inter Tropical Convergence Zone (ITCZ). The ITCZ is a low pressure zone where north-moving and south-moving air masses meet north of the equator in the Sub-Saharan African region. The annual average temperature of the area is about about 28^{o}C (Wildlife Department, 1994; Dickson & Benneh, 1995).

The landscape is underlain in places by the Voltaian sandstones, shales and granite and characterized by the presence of ironstones concretions (iron pans) at generally shallow depths below the surface of the soil resulting in poor groundwater infiltration in most places (Wills, 1962; Vargha, 1996; Yidana, Ophori & Benoeng-Yakubu, 2008). Soil types also vary from Savannah Ochrosols within the wooded savannah areas to Forest Ochrosol along the forest margins. The soil in the savannah areas are fragile, soft under the foot and liable to alternate flooding and drying as a result of the flat-bedded sandstone rocks near the surface. The soils of the forest are loamy and liable to dry out quickly because of free drainage caused by the presence of a 2.5cm to 5.0cm layer of humus (Wildlife Department, 1994).

The topography of the area is generally low-lying, albeit gentle and undulating with average heights of about 120 m above mean sea level. There are areas of occasional higher elevation, attaining heights of between 215 m and 230 m. A network of streams, dominated by tributaries of the Afram and Sene rivers, drain the area. The elevated areas serve as the watershed for most of these streams. The Sene River drains the northern part of the area while the Afram River and its tributaries drain the south into Lake Volta to the east. Most of the drainage channels have adjoining low lying areas that get flooded seasonally thus creating agroecological niches which are used by farmers for cropping. Apart from rivers Afram and Sene which are perennial, most of the streams dry up during the dry season (Hagan, 1998; Ofori et al., 2014). The landscape can be described as mosaic of diverse elements including forest types, human settlements, hydrological systems and numerous agroecological niches. The most dominant landmark in the area is the Kogyae Strict Nature Reserve. The vegetation of the reserve comprises elements of the forest-savanna transition zone, riparian woodland, typical savanna and boval forest.

There are also areas of bare rock outcrop mostly common in the southern and south-western end of the reserve (Wildlife Department, 1994).

In terms of local governance, the area is under the jurisdiction of Kumawu and Kwamang traditional areas in the Ashanti Region of Ghana. It has a fairly large human population made up of indigenous Asante and migrants from the northern parts of Ghana (Ayivor & Ntiamoa-Baidu, 2015).

The variations in biophysical conditions of the area give farmers in the area a range of options to engage in diversity of production and management techniques some of which were based on agroecological principles (Altieri, 1995). Agricultural production is the main livelihood activity in the area and it includes crop farming, livestock farming, hunting, lumbering and fishing (Oduro-Ofori, 2015).

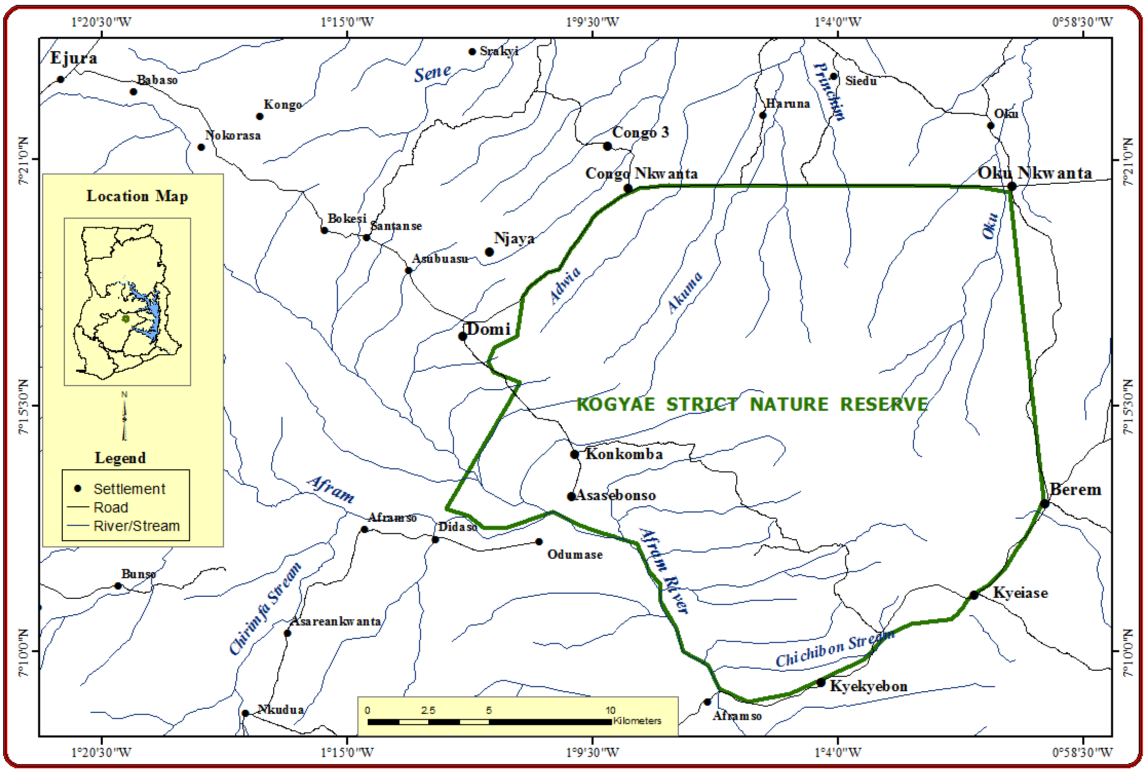

Figure 2. Map of the Study Area

2.2 Methods

The study was a cross-sectional assessment of agro-diversity practices in the study area involving systematic data collection from multiple units of enquiry. The methods included focus group discussions, key informant interviews, on-site observations and inquiries into institutional data. The study focused on nine (9) fringe communities of the Kogyae Strict Nature Reserve as central points, but extended a few kilometers away from the communities to cover farmlands and other land use types. The communities included Domi, Njaya, Congo Nkwanta, Oku Nkwanta, Berem, Kyease, Kyekyebon, Aframso and Asasebonso (Figure 2). One focus group discussion was conducted in each of the communities, totaling nine discussions. A total of 102 individual participants, made of 52% males and 48% females were engaged in the focus group discussions. Each group was made up of between nine (9) and 15 adult participants, aged 18 to 72 years. The selection of participants was facilitated by local assemblymen and agents of traditional chiefs. Questions posed to participants at the group discussions boarded on their perspectives on biophysical conditions of the area, general farming practices, changes in environmental conditions over time and socio-economic stressors such as marketing problems and how these influence their choice of farming system. Also, questions were asked about types of crops cultivated, cropping patterns and the adaptive farm management practices that have been introduced to cope with the changing environmental conditions. Secondary data were obtained from both published and unpublished sources including books, peer reviewed journals, technical reports and national and other relevant state documents.

Thematic technique was employed in analysing the qualitative data. This was done through a three-tier approach of identification of themes, descriptive accounts and interpretative analyses. Guided by the responses, the themes were identified and derived inductively from the Agro-diversity framework. Where necessary, direct quotes from some of the respondents were taken and presented in the discussions. Rainfall data was analyzed using Microsoft Excel to generate a line graph, with a linear trend line that had values for y (representing rainfall amount) and x (representing time in year). The value for R^2 representing the coefficient of determination was also generated and used in the interpretation of results.

3. Results and Discussions

The Bio-diversity Model adapted from Brookfield and Stocking (1999), served as a guide in the presentation and discussion of results of this study. Under the model, elements under the natural environment, modified environment and socio-economic landscape were discussed within the broader context of spatial and temporal variations.

3.1 Spatial Variations

3.1.1 Natural Environment

Floral diversity, variation in soils and differences in geological characteristics were distinct elements of the natural environment in the study area. These variations tended to impose physical constraints on crop production and in some cases, threatened food security. The most conspicuous of these was floral diversity as portrayed by the Kogyae Strict Nature Reserve and its adjoining areas. The entire reserve and its landscape are made up of diverse elements of forest vegetation, savannah woodland, modified forest/degraded fallow areas and farm plots. The 386 km^2 Strict Nature Reserve has two structural forms: the core area covering 220 km^2 and a special use zone (SUZ), a 166 km^2 modified area where limited human activities were permitted (Wildlife Division, 2002, Ayivor & Ntiamoa-Baidu, 2015). The core zone has the benefit of full protection and represented the most important ecological unit in terms of biodiversity richness and abundance. The zone contains floral species typical of forest-savannah transition zone of West Africa (Dickson & Benneh, 1995). Several mammalian species of conservation importance including the Burron's kob (*Kobus kob)*, Bushbuck (*Tragelaphus scriptus*), Waterbuck (*Kobus ellipsiprymnus*), Maxwell Duiker (*Cephalophus maxwelli),* and Grey Duiker (*Sylvicapra grimmia*) occur in this zone. The zone further supports a number of primate species including Spot-nosed Monkey (*Cercopithecus petaurista*), Black and White Colobus (*Colobus polykomos*), Olive Baboon (*Papio anubis*) and Patas Monkey (*Erythrocebus patas*). The Aardvark (*Orycteropus afer)* and Red River Hog (*Potamochoerus porcus*) are also known to occur (Wildlife Department, 1994, Ayivor & Ntiamoa-Baidu, 2015).

According to the respondents, though the Kogyae Strict Nature Reserve provides ecosystems services including the enhancement of micro climatic conditions in the area, one of their major concerns was crop raid by wild animals from the reserve. They reported that wild animals such as Patas Monkey (*Erythrocebus patas*) and Red River Hog (*Potamochoerus porcus*) raid their farms and cause a lot of destruction to crops, which only aggravates the already precarious situation. Additionally, they complained about shortage of arable land as a result of a recent re-zoning and expansion of the reserve to cover farm land areas.

The SUZ permits specific human activities such as human habitation in existing settlements within the zone and cultivation of annual crops such as maize, cassava, legumes and vegetables. Activities such as tree felling, charcoal production, bush burning and poaching are prohibited. Thus, the system of farm management was different in the SUZ compared to other areas. In particular, crop cultivation in the zone was based on agroecological principles, which according to Altieri and Nicholls (2012) tend to synchronize crop production with the environment in such a way as to ensure environmental sustainability and crop productivity. Native trees were minimally disturbed and cultivation of perennial cash crops such as cocoa, oil palm and cashew was strictly prohibited. The landuse type could best be described as modified environment based on the Agro-diversity framework (Figure 1).

In order to maintain overall crop productivity, most farmers had in the past 10 years, shifted from the traditional ways of cropping to more adaptive systems in response to newly emerging physical constraints. The most notable shift was from yam as the dominant crop, to maize as a mono-crop on one hand, and a mix of cassava with other crops on the other. Rice cultivation was also noted to be growing in importance, as swamps previously uncultivated were increasingly being taken over by rice farms (Ofori et al., 2015).

Another element of the natural environment which brought diversity to the landscape and imposed physical limitations to the soil was rock outcrops. In most parts of the landscape, the Voltaian sandstone and granite outcrops, which dominate the geology of the area, rise close to the surface thus, offering little opportunities for agricultural activities. These phenomena were observed mostly in Kyekyebong, Kyease and other communities along the southern fringes of the reserve. According to the respondents, the soils in most parts of the study area are very shallow as a result of the underlying rock and lacked enough groundwater to sustain crops in times of prolonged drought. Moreover, during periods of heavy rains, the soils easily get flooded causing massive destruction to the traditional crops. This is consistent with earlier studies which indicated that shallow soil in areas of rock outcrops dries out quickly during dry seasons when there are no rains and cannot support perennial crops (J. M. Baskin & C. C. Baskin, 1988; Ware, 2002). Most of the traditional tuber crops namely cassava and yams were absent in these areas and instead fast growing pauses such as cowpeas and beans together with vegetables were dominant. Nevertheless, in low lying areas where the soils are deeper, a reasonable amount of moisture remains over a longer time. Such areas supported dry season vegetable farming and wet season rice.

3.1.2 Modified Environment: Organizational Diversity

Most of the modified natural environments outside Kogyae Strict Nature Reserve came with diversity of agricultural landuse types. Notable examples of the modified areas included:

- degraded farmlands at various stages of fallow;
- forest thickets which stood out as tiny patches within the landscape;
- assortment of farm units of different shapes and sizes;
- diversity of cropping systems; and
- variety of farm management types.

The diversity in management practices was mostly occasioned by the system of land tenure. Local heads of the Kwamang and Kumawau traditional areas hold the land in trust for the people. The communal land holding system is prevalent in the area. The system engenders individual occupancy of parcels of land ranging from less than a hectare to about five hectares, depending on the ability of individuals to negotiate with the local heads. The system also allowed leasehold agreements between the landowners and the large migrant population in the study area. The migrants indicated that they try to optimize the use of their land holding units through agricultural intensification in order to break even since they owe some financial obligations to the land owners.

Land expropriation for protected area establishment was another major land related issue that residents cited as introducing variations into their farming practices. The residents along the southern fringes of the reserve, for instance, claimed that their most productive lands which supported commercial tree crops notably cocoa and oil palm were expropriated for the establishment of the Kogyae Strict Nature Reserve. Their main concern was that these were perennial cash crops that guaranteed their financial security against food crop failure and old age. In order to address some of these local concerns, Ogra and Badola (2008) proposed a system of compensation that reflects ground level realities; one that reduces the burden of costs people have to incur and sacrifices they have to make to conserve biodiversity.

An intriguing land tenure issue encountered in the north-eastern fringes of the Kogyae Strict Nature Reserve was the emergence of certain interest groups and operators, who had acquired large tracks of lands for various reasons, not necessarily for crop farming. It was observed that some of these operators converted the lands traditionally known for annual crop production into the production of perennial cash crops such as cashew and teak for the export market. This emerging phenomenon had resulted in the displacement of a large number of small holder-migrant farmers who had no legal agreements with the land owners. This obviously has serious implications for food security.

3.1.3 Institutional Support

The Crop Research Institute (CRI) of the Council for Scientific and Industrial Research (CSIR) has proposed an innovative method of planting yam to reverse its dwindling fortunes and improve yield per unit area. Unlike the traditional system where yam is planted in haphazardly-spaced mounds, a new method has been developed in which elongated ridges, one meter apart, are raised across the slope for yam cultivation. The yam crop, which is inter-planted with groundnuts for its nitrogen fixation properties, is uniformly spaced at an interval of 1x1 meter. The low-lying space in between the parallel ridges maintains rain water for plant use for a longer time. The new method supports 4,000 yams per acre as against an average of 2,000 yams per acre for the traditional method. Furthermore, unlike the traditional method where several stakes are erected to support the yam vines, the new method uses only a few stakes that are erected at regular intervals to support nylon ropes, which support the vines. The new system also sustains permanent cropping for up to five years because fertilizers are applied to maintain high yields. At the time of the field study, CRI through the Agricultural Directorate of the Ministry of Food and Agriculture at Ejura was actively disseminating this new innovation for adoption by farmers.

The District Agricultural Directorates collaborates with Crop Research Institute, Soil Research Institute and the Ghana Meteorological Agency to support farmers in the following areas:

- choice of planting materials, particularly those that are early-maturing and drought resistant;
- efficient methods of land preparation such as the ‘zero tillage’ system which encourages the use of weedicides to clear the land before planting;
- facilitation of farmer networking; and
- produce marketing.

Other civil society organizations such as Society of African Missionaries and St. Luke Society are intervening to get farmers and buyers agree on standard measurements. Other agencies like the World Vision International, the World Food Programme, ADRA and JICA have collaborated at various times with MOFA to provide extension services to farmers.

3.2.1 Socio-Economic Stressors

A broad spectrum of socio-economic stressors including human population pressure, land shortage, bad land management practices, market forces and household characteristics were identified as affecting agricultural production systems. These factors dictated the type of adaptive strategies farmers adopted to enhance food security.

Respondents reported of general land shortage due to a combination of factors including rapid population growth in the face of limited arable land. Analysis of data from the Ghana Statistical Service showed that population of major settlements in the study area has increased by over 600% from 1950 to 2010 (GSS, 2014, 1984). Consequently, population pressure on land has compelled most famers to work in marginal areas such as rocky areas with only shallow soil cover and wetland areas. Several others have been forced to change their traditional cropping systems to suit the new set of conditions that have been compounded by decreasing fallow periods. Essentially, the traditional bush fallow system has given way to continuous cultivation on the same piece of land, which necessitated the adoption of improved maize and cassava varieties, application of chemical fertilizers and the use of agrochemicals.

Available data from Ejura-Sekyedumase District within the vicinity of the study area indicated that from 2005 to 2014, cropped area for the major crops in the area had increased considerably (Table 1). The data suggest that whereas yam and cassava, which are tuber-crops increased only by 13% and 17% respectively, cereal crops experienced higher percentage increases. The high increase in cropped area for rice by 95%, for instance, corroborates our observation that farmer-adaptation to changing climate conditions was tilting more towards swamp farming.

Table 1. Cropped area for major crops in Ejura-Sekyedumase District from 2005 to 2014 (Ha)

Major Crop	Cropped area in 2005	Cropped area in 2014	Percentage increase
Maize	14,952	21,228	30%
Yam	8,788	10,552	17%
Cassava	2,984	3,422	13%
Rice	168	3,068	95%

Source: SRID, 2014.

3.2.2 Influence of Market Forces

Market forces played an important role in the diversity of farming systems in the area. During field investigations, it became obvious that crop cultivation was driven by economic considerations, social change, institutional arrangements and cultural values. It was observed that market forces were intricately linked with production capital, access roads and perishability of products. The farmers claimed that when they had to contract loans to finance their farming enterprises they were compelled to sell their produce soon after harvest to honour their loan obligations. They preferred fast yielding varieties such as cowpea and early maturing maize

(42 days maturation). For most farmers, the maize crop ensures food security whereas cowpea provides income. The rational farmers therefore cultivated these fast growing crops twice a year to help meet their food requirements and financial obligations. In some instances, middlepersons pre-financed certain activities such as rice cultivation, which is relatively more capital intensive and quite laborious. Gashayie and Singh (2015) referred to such micro-finance schemes as 'trade credits' which farmers may receive from input suppliers, intermediary traders and shops, or agro-processors, pledging to repay from future harvest income. Such agreements are informal and based on trust.

The nature of access roads also determines demand and supply situation and for that matter the choice of crop to be grown by farmers. During the wet seasons, most of the communities in the study area could hardly be accessed by haulage trucks except tractors. Large quantities of food stuff get locked up during such periods, thus compelling farmers to sell to any available buyer at reduced prices. As a result farmers sometimes find it difficult to recoup their investment, which invariably affects the next seasons farming investment. To avert this situation, crops such as maize and rice are preferred to vegetables which are perishable.

For other individual farmers, farming decisions were driven by other considerations. A 75 year old respondent from Oku Junction, for instance, changed his system of farming from traditional upland farming involving maize/yam/groundnuts to marshland rice farming, in order to make use of uncultivated marshlands close to the community. Other factors which influenced his decision were the walking distance and the relatively higher income from rice cultivation compared to maize.

Yam cultivation in particular, has been affected adversely by temporal dynamics. The land requires up to seven years of fallow to ensure high crop yield. Under present conditions, such long fallow periods are no longer feasible due to population growth and other production pressures. A 61 year old woman from Oko Junction reported: *In the 1970s and the '80s my husband used to transport four tractor-loads of yam to the market at Ejura on annual basis. Presently, what he produces is barely enough for home consumption.* The dwindling fortunes of yam farming in the area is a great disincentive to the farmers as yam farming, according to MEDA (2011), appears very profitable.

3.3 Temporal Variations:

3.3.1 Climate Variability

One significant element under the natural environment that was reported as having changed over time was climate. Local sources reported that there has been a one to two-month's shift in the farming calendar in the area over the past three decades. Prior to the 1980s, there were early rains in mid-March, which heralded the commencement of the planting season but this is no longer the case. The farmers reported that the normal rainfall pattern in the area has changed giving way to erratic patterns which has made it difficult for them to predict the farming calendar. Under rainfed agricultural system, the rainfall variability delays the planting season and has far reaching implications for crop yield and food security. According to the respondents, the crops most affected by the climate variability are maize, yam and groundnuts. In 2013, for instance, maize recorded very low yields during both the major and minor seasons due to erratic rainfall. Most of the respondents claimed that their harvest for that year reduced on the average from 6 bags/ha to about 4 bags/ha (1 bag = 50 kg).

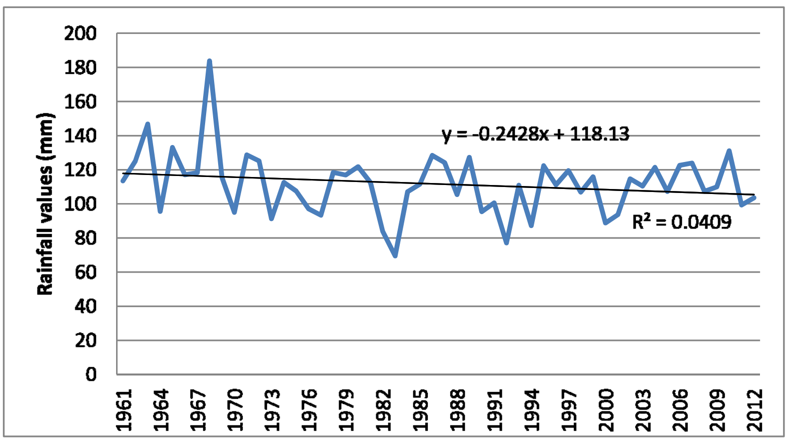

Figure 3. Rainfall Data for Ejura from 1961 to 2012

Rainfall data for the period 1961 to 2012 corroborates the local claims (Figure 3). As illustrated in Figure 3, rainfall amounts for Ejura, the nearest meteorological centre to the area have been on a downward trend from 1961 to present.

The trend equation as indicated in the figure is $y = -0.2428x + 118.1$, where y represents the rainfall amount (mm) and x represents time in years. This means that over the period (1961-2012), rainfall decreased by 0.243mm annually. However, temporal variation can explain only four percent (4.0%) of the total variation observed in trend of rainfall amounts. Thus, the greater proportion of change in rainfall in the area is caused by other factors (possibly climate change) rather than time.

3.4 Management Diversity

Management diversity entails all the methods of managing the land, water and biota for crops and the maintenance of inherent soil quality. The fieldwork revealed that within the farming landscape, there was a mosaic of agro-diverse units differentiated from each other by farm sizes, type of tillage systems, soil management techniques and type of crops cultivated. These may be classified either under the traditional small holder system or the modern mechanized system where farm units were relatively larger.

The traditional management practices encompassed 'slash and burn' using rudimentary tools such as the hoe and cutlass with the engagement of mainly family labour. The system depends on natural rainfall and therefore vulnerable to erratic weather conditions. Most of the farmers who were engaged in traditional systems adopted zero tillage in which either weedicides or 'slush and burn' were used to clear the land instead of mechanical tillage involving the use of tractors. Under the system, a variety of crops such as maize, cassava, yam, cowpeas and vegetables, notably pepper, garden eggs, okra and tomatoes were planted as mixed crops. Nutrient cycling through systems of fallow was the main soil management technique. Yields per crop may not be particularly high but different maturation periods for the different crops spread the risk of crop failure and makes the farm units more resilient to environmental stressors. Harvesting particularly, in mixed cropped areas, could be spread over a longer time period which ensures household food security. The combination of different crops together with an assortment of plants in the fallow plots ensures a rich array of flora diversity within each farm space.

The mechanized system was adopted mostly by farmers who cultivated relatively larger plots (usually more than one hectare). Maize mono-cropping was the preferred practice because of the ease of planting in rows; length of growing period which has implications for the timing of loan repayment; ease of harvesting; storage considerations; and the availability of market for maize. The farmers, however, admitted that in spite of its advantages, mechanized farming has resulted in increased incidence of grass cover and water logging. This has adverse implications for the growth of maize and cassava which require well-drained soil conditions. In place of these crops, rice cultivation was gradually taking over, which explains the high percentage increase in cropped area for rice among farmers over the last decade (Table 1). Kremen, Iles and Bacon (2012) posited that diversified farming systems have the tendency of reducing negative environmental externalities, enhancing agricultural sustainability and resilience, and contributing significantly to global food security

3.5 Agro-Diversity and Livelihoods

Farmers' rational response to biophysical constraints and socio-economic stressors has been to engage in agro-diversity practices in order to make the best use of the set of environmental conditions available to them. The study observed that though the diversity of farming practices, as well as variations in cropping systems within and across fields among the small holder farmers were guided by individual choices and preferences, household characteristics such as sex, level of education and resource endowment dictated the type of adaptation and innovative strategies adopted. For instance, women were observed to practice more vegetable farming and mixed cropping than men because they were directly engaged in household food provision. Also, wealthier farmers were observed to be engaged in commercial mono-cropping and plantation agriculture, and employed the services of tractors compared to poorer farmers.

Through indigenous knowledge of the biophysical environment, farmers were able to understand and identify crop suitability as a way of adaptation. They adopted strategies such as sequential rotation of crops that addressed climate variability; utilization of agro-ecological niches within fields (notably swamps), which brought variations in cropping patterns; adoption of mono-cropping under mechanized system to increase productivity; introduction of rice farming within swamps and along river courses which brought crop diversity across fields; and mixed cropping system which combined crops of different maturation periods. Table 2 presents a summary of the agro-diversity practices, their characteristics, the diversity of crops cultivated under each system and livelihood and food security implications.

Under the auspices of the Wildlife Division, some farmers were also able to adopt agroecological practices within a managed wildlife protected area (SUZ) to enhance crop production whilst at the same time conserving wild species. Though the success of this arrangement had remained debatable (Ayivor & Ntiamoa-Baidu, 2015), it has nonetheless added to the diversity of farming systems in the area.

Table 2. Agro-diversity Practices in the Forest-Savanna Transition Zone

Land use type / Type of farming	Characteristics	Diversity	Livelihood /food security
Core zone of the Kogyae Strict Nature Reserve	Under permanent conservation to protect habitats and conserve biodiversity	Rich diversity of flora and fauna	Ecological services
Special Use Zone	'Slash and burn', farming based on agroecological principles (Altieri, 2012); prohibitions on indiscriminate felling of trees	Diversity of flora / fauna / annual crops – maize, cowpeas, yams, groundnuts, cassava, vegetables	Ecological services, food , income
Areas with shallow soils / rock outcrops	Cultivation of crops mostly in the wet season; land clearing is by 'zero tillage' (i.e. use of weedicides to clear the land) or 'slash and burn'	Annual crops – cowpeas, vegetables, maize	Food, income
Fallow lands	Cultivated areas left to fallow in order to replenish soil fertility	Diversity of flora	Ecological services
Swamps / wetlands farming	Low lying areas that become water log during the wet season; land clearing is by 'zero tillage'	Annual crops – rice, dry season vegetables	Food, income
Modern mono-cultural crop farming	Machanized farming covering relatively large areas; mostly mono-crpped for two cropping seasons per year; tillage is by tractor plough	Maize	Income
Traditional mono-cultural crop farming	Subsistence/commercial farming based on family labour; land clearing is by 'zero tillage or' 'slash and burn'	Rice, maize	Food, income
Tree crop farms/plantations	Perennial tree crops on plantation basis; mixed cropping for first two years; tractor plough	Cashew, cocoa, oil palm. teak	Income
Rotational farming	Subsistence/commercial farming based on family labour; land clearing is by tractor plough or 'slash and burn'	Annual crops – maize, cowpeas, yams, groundnuts, cassava, beans, vegetables	Food, income
Mixed cropping	Subsistence/commercial mixed crop farming based on family labour; this may also involve the use of agroecological niches within farm (Ofori et al., 2015); land clearing is by tractor plough or 'slash and burn'	Annual crops – maize, cowpeas, yams, groundnuts, cassava, beans, vegetables & rice	Food, income
Rotational Fallow	Subsistence/commercial farming based on family labour; land clearing is by tractor plough or 'slash and burn', cultivated land allowed to lie fallow for a few years for soil nutrient replenishment	Annual crops – maize, cowpeas, yams, groundnuts, cassava, beans, vegetables	Food, income

3.6 Conclusion

Spatio-temporal variations in the biophysical and socio-economic landscape of the forest-savannah transition zone of Ghana have necessitated locally-based adaptive strategies to sustain agricultural production systems and to ensure food security. Using the 'Agro-diversity framework, this study discussed these diverse elements and how local farmers have adapted to the biophysical environment and socio-economic conditions. A holistic view of farmer adaptation to the complex mix of biophysical and socio-economic diversities informed our conclusion that through agro-diversity, farmers are making efforts to ensure environmental resilience, sustain their food production systems and spread risks of crop failure and enhance food security.

This notwithstanding, increasing human population and other production pressures in the face of climate change pose potential threat to future sustainability if more pragmatic soil and water management measures are not put in place. The study therefore recommends a more effective system of knowledge dissemination on improved method of yam cultivation introduced by the CRI of CSIR to increase yam output since yam was considered one of the major cash crops in the area. To improve soil management techniques, the zero tillage system of land clearing is recommended for farmers in the area. Already most rice farmers have adopted the system and achieving good results. Agricultural Extension Agents of the Ministry of Food and Agriculture should be capacitated to extend their services to the areas where their presence is less The study finally recommends greater crop intensification through the use of appropriate technologies and improved access to markets to consolidate farmer gains and livelihoods as well as ensuring food and nutritional security.

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