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LAND-USE CHANGES IN THE ENSET-BASED AGROFORESTRY SYSTEMS OF SIDAMA, SOUTHERN ETHIOPIA, AND ITS IMPLICATIONS FOR AGRICULTURAL SUSTAINABILITY

Tesfaye Abebe[1]

ABSTRACT: The enset-based agroforestry systems of Southern Ethiopia provide millions of households with a variety and continued production of food and other products. These systems exist in the tropical highland (Woyna dega) zones at altitudes of 1500-2300 m.a.s.l., where enset is grown in an intimate integration with coffee, vegetables, fruits, root and tuber crops, cereals and different types of trees. The study was conducted in the Enset-based agroforestry systems of Sidama administrative zone where 22% of enset in the country is produced. Here, enset covers about 26% of the total farm area and it serves as a staple food for millions of people. The systems combine production with environmental protection, and hence contribute to food security and long term wellbeing of the population. The stability of this system depends both on its diversity and on the specific characteristics of the two main native and perennial crops, enset and coffee. However, the composition and diversity of the enset-based agroforestry systems is changing in recent years as farmers respond to emerging challenges and opportunities. Increasing fragmentation of land and improvement in market access is leading to expansion of monoculture food crops, mainly maize and cash crop, *khat.* These crops are expanding at the expense of enset and coffee. Since enset is the most productive crop per unit area of land and time, the decrease in cultivation area of enset is likely to affect food security situation in the area. Moreover, the age structure of enset plantations show that the vast majority of farms have very small proportion of mature and harvestable enset plants. This aggravates the food shortage and forces farmers to shift to cultivation of annual crops such as maize to respond to the family's immediate food demand. This paper attempts to reveal that the future of these systems lies in the maintenance of enset as a key crop, because it plays significant roles towards the economic and ecological sustainability of the systems. It also demonstrates the strategies and approaches that could be followed to reverse the declining trends in enset cultivation.

Key words/phrases: Agricultural intensification, Enset-coffee systems, Land-use, Sidama, Tropical highlands.

[1] School of Plant and Horticultural Sciences, Hawassa University, P.O. Box 5, Hawassa, Ethiopia.
E-mail: tesfayea@hu.edu.et

INTRODUCTION

Enset (*Ensete ventricosum* (Welw.) Cheesman is a staple or co-staple food crop for an estimated population of 15 million people in the South and South-western parts of Ethiopia. It is cultivated within altitudes of 1500-3100 metres above sea level, in areas having a mean annual rainfall of 1000-1800 mm and a mean temperature of 10-20°C (BODEP, 1997). Temperature plays a significant role in the growth rate of enset. Accordingly, at the altitudinal range of 1500-2300 metres (Woyna Dega areas) where mean annual temperature is 15-20°C, enset grows fast and reaches full maturity in 6-8 years. On the other hand, in the high altitudes of 2300-3100 metres (Dega areas), where mean temperature drops to 10-15°C, it takes an average of 8-10 years and even more, to reach full maturity (BODEP, 1997). The major enset growing areas in Southern Ethiopia are Sidama, Gedeo, Gurage, Hadiya, Kembatta, Wolayita, Gamo, Gofa and Kefficho administrative zones. This study was carried out in Sidama administrative zone where 22% of enset in Ethiopia is produced (Fig. 1). In the tropical highland (Woyna dega) zones of Sidama at altitudes of 1500-2300 m.a.s.l., the diversity of crops is generally high and enset is grown in integration with coffee, fruits, vegetables, cereals, trees and livestock in multistorey agroforestry systems. Here, the climatic and soil conditions are suitable for the production of different types of crops, including high value crops such as coffee and *khat* (*Catha edulis*), and it is not clear how farmers allocate their land for the different types of crops in order to ensure attainment of household food security and income. The age structure of the enset crop, which gives an indication on sustainability of food supply, is not also known. This paper attempts to analyze the land-use dynamics of the enset-coffee agroforestry systems, the age structure of enset plantations and the overall effects of these changes on sustainability of the enset-coffee agroforestry systems of Sidama administrative zone in Southern Ethiopia.

STATUS OF THE ENSET-BASED AGROFORESTRY SYSTEMS

Composition and structure of the enset-coffee land-use systems

Most of the enset-coffee agroforestry systems of Sidama have evolved from forests. Farmers maintain the upper storey trees and clear the undergrowth to open up space for planting enset, coffee and other crops. More species and varieties of crops and trees are gradually introduced (Tesfaye Abebe and Bongers, 2012). In addition to species diversity, a high level of genetic diversity is found in two major crops, enset and coffee.

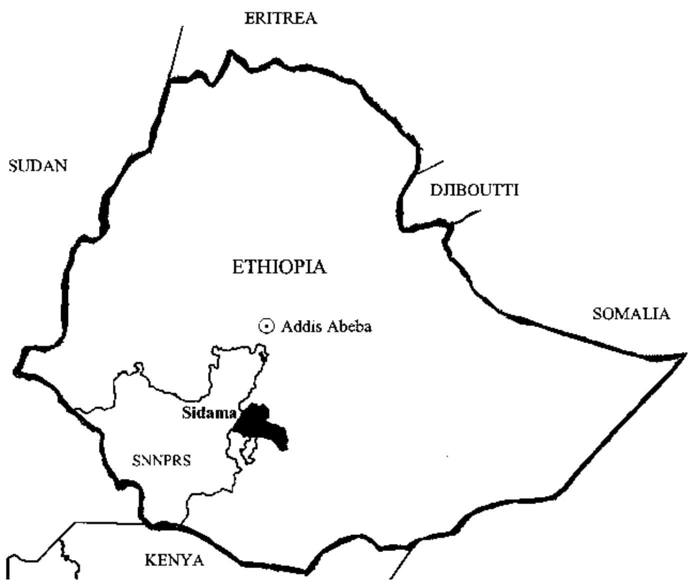

Fig. 1. Map of Sidama administrative zone in Southern Ethiopia.

The diversity and density of the crops vary spatially and temporally. The agroforestry systems show four distinct vertical layers of crops. Vegetables, spices, beans, root and tuber crops occupy the lowest strata up to 1.5 m. Coffee, enset, maize, *khat*, sugarcane and some fruit trees, such as banana and papaya, occupy the layer between 1.5 and 5 m. Larger fruit trees, such as avocado and white sapote, some shrubs and pollarded shade trees dominate the third layer between 5 and 12 m., and the fourth layer, above 12 m, which could sometimes extend up to 35 m high, is dominated by timber-producing shade trees (Tesfaye Abebe *et al*., 2006; 2010). The lower most stratum is the richest in species (64%); the second stratum is the densest because of the heavy dominance of enset and coffee (Tesfaye Abebe, 2005). The key components of these agroforestry systems are the perennial crops enset and coffee, with mean coverage of over 60% of the farm areas (Tesfaye Abebe *et al*., 2010).

The high diversity of species, which combines crops, trees and livestock with different uses and production cycles, is considered as essential component of sustainable agriculture because of the wide socioeconomic and ecological roles it plays in the systems. The roles include, among others, year-round production of food and wood products, decreased risks of production failure, increased productivity over time (Netting and Stone, 1996), maintenance of genetic diversity and landscape protection (Perfecto *et al*., 2009; Trenbath, 1999). Food species with high energy content are dominant crop species in the farms, and enset is the most important staple food crop.

The role of enset in the system

Enset is a multipurpose crop that produces food, fodder, fiber and other products. Food is extracted from the pseudostem and corm since the starch accumulated in the leaf sheaths and the corm are the main products. Three types of food products are namely, *kocho*, *bulla* and *amicho*. Yield of enset varies with the landraces used and with the climate. According to the nationwide survey made on enset production (CSA, 1997), the average yield of *kocho* and bulla per plant is 30.15 and 1.04 kilograms, respectively. Using an average density of 2000 enset plants per hectare and a harvesting age of six years, its productivity will be 10 tons $ha^{-1}yr^{-1}$, and this puts it among the highest productive crops in the country. Enset guarantees food security and stability in the household economy as the processed produce can be stored for a long time and live plants can be maintained on farm and harvested any time when the need arises (Almaz Negash, 2001; Admasu Tsegaye, 2002), which is why enset areas are not prone to famine (Desalegn Rahmato, 1995).

In addition to food, enset has many other uses. The fiber extracted during processing is used locally for making strings, ropes and other products, or it is sold in markets for use by fiber factories. The leftover during harvesting, thinning and the leaves are important fodder sources for livestock. The leaves as well as the dry leaf sheaths are also used as packing, wrapping and binding materials. Moreover, some enset landraces are used as medicine for human beings and livestock. Enset also plays a very important environmental role. It protects the soil from erosion and runoff, it serves as shade and improves the microclimate for the undergrowth, and the litter from the leaves and other parts improve soil fertility. Unlike annual plants, small portion of the biomass is taken out of the system at harvesting, while the largest portion is returned directly as litter or indirectly through the manure. In general, enset has ideal attributes for low-input sustainable agricultural production systems: it is high yielding, it can be harvested any time once it is four years old, it doesn’t require external inputs, it protects and/or enhances the environment, and it has multiple functions. It is, therefore, no wonder that it has been supporting a dense population of over 500 persons per km^2 in areas where it is used as staple food.

Land-use changes in the enset-coffee systems

Sidama administrative zone is a major enset-growing area accounting for 22% of the total enset production area in the country (CSA, 1997). In the enset-coffee agroforestry systems of Sidama, enset covers an average of 26.4% of the total farm area (Tesfaye Abebe, 2005), with variation across sites and between farms. The proportion of land allotted to enset is more or less similar across the different wealth groups of farmers. Large farm holders can produce sufficient enset for consumption and allot an increasingly larger area to grow cash crops such as coffee and *khat*. Poor farmers have a slightly higher share of land under maize because, with a lower farm size, farmers cannot depend solely on enset, which takes at least four years to mature, but also need early maturing crops such as maize and sweet potato. This illustrates the fact that enset, as the main staple crop of the household, is a strategic crop and determines cropping plans, land-use, use of technology and consumption and marketing decisions (Desalegn Rahmato, 1995). If a household has sufficient enset plants for consumption, it grows high value crops for the market. If there is no market, cash crops will be curtailed in favour of food crops. If the number of mature, ready-to-harvest enset plants on the farm is insufficient to feed the family during the year, more land will be used to grow annual food crops such as maize and sweet potato. These additional annual crops are planted in the part of the farm usually allocated for transplanting enset. The nature of enset cultivation lends itself well to such flexible decisions. For the first two years enset is often grown in very high densities of about 10,000 or more plants per ha. If there is ample space, the thinnings are transplanted into the new plots; if there is not enough space, the thinnings are used as livestock feed or incorporated in the soil.

The crucial decisions that are made by the households to obtain a sustainable yearly harvest of enset are the total farm area to be planted with enset and the distribution of enset plants over age classes. In the enset-coffee agroforestry systems of Sidama, enset is normally harvested after five to eight years. If we take the harvesting age of six years, there will be six age classes of enset plantations each having proportional area coverage of 16.7%. This is not the case, however. In a study of age structure of enset in these land-use systems, Tesfaye Abebe and Bongers (2012) found that enset fields are dominated by immature enset plants; about 90% of the plants were less than four years old, while only 10% were five to eight years old. Poor farmers in particular have a smaller area under matured enset. The ratio of mature enset (age older than five years) increased with wealth: 4.7% (poor), 10% (medium) and 17.3% (rich) (Fig. 2). This confirms that farmers with a smaller area of farmland cannot afford to depend on enset only, as it takes at least four years to be harvested. Poor farmers are therefore forced to fill the consumption gap with annual food crops, such as maize and sweet potato – crops that are often grown as monocultures because of their high light requirement.

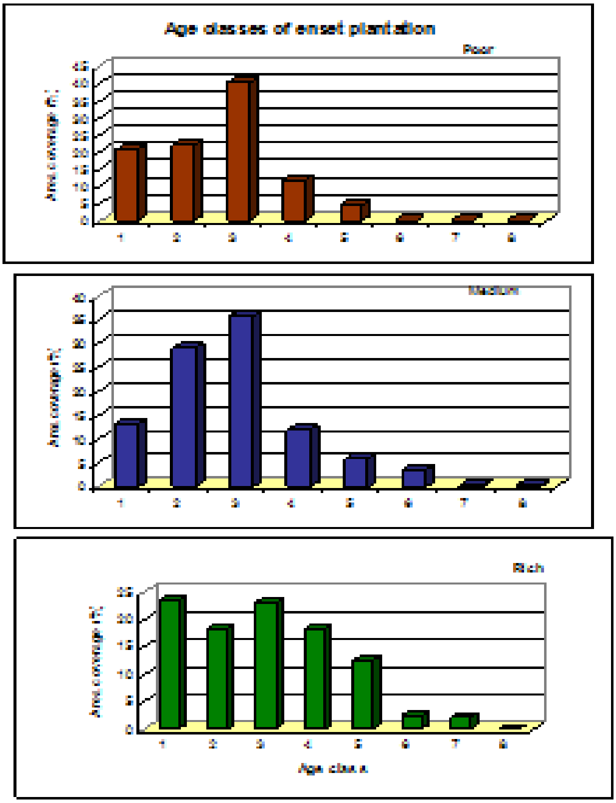

Fig. 2. Age structure of enset plantations among the different wealth category of farmers in the enset-based agroforestry systems of Sidama.

As the dry matter yield of enset per unit area and time is much higher than other crops (Admasu Tsegaye and Struik, 2001), and due to the large-scale environmental benefits of enset, research and extension efforts should focus on reversing the declining trend of enset plantations on small farms through a systematic allotment of enset plantations. To achieve this, the number of enset plants sufficient for annual consumption of a household should be estimated, and that number should be planted every year during the whole rotation period. For instance, if 60 mature enset plants are required for the household's annual consumption and the rotation cycle (harvesting age) is six years, then a total of 360 enset plants divided into six age categories (1-6) of 60 enset plants each should be grown. At the end of the sixth year the mature 60 plants can be harvested and replaced by new planting materials. This rotation would help to obtain a sufficient and regular yield from enset while maintaining the complex and integrated nature of the agroforestry systems.

In addition to farm size, access to markets also affects farmers' decision to allocate land for enset production. Farmers with good market access, either because of the physical proximity of markets or good access to major roads, devote a smaller proportion of their land to growing enset and a higher proportion to cash crops. This is because market access enables them to sell the cash crops and buy what they need for subsistence. The variation among farmers and the impacts of such drivers show that the land-use systems in the Sidama region are dynamic; farmers make individual choices and respond to emerging challenges and opportunities. When per capita land holding declines, mostly as a result of increased population pressure, farmers tend to produce more staple food crops than cash crops. Among the food crops, they give priority to annuals rather than perennials (such as enset), because of immediate subsistence needs. Farmers also assess their comparative economic advantage and respond to increasing market opportunities, as was manifested in the expansion of *khat* in the study areas (Tesfaye Abebe *et al*., 2010).

The enset-coffee agroforestry systems already carry a very dense population, which is still growing fast. The high population growth (2.5%) is likely to result in increased fragmentation of farmlands. This trends are likely to result in further expansion of annual crops and a reduction in the perennial components (crops and trees) and livestock, which are vital for the sustenance of the system. Likewise, the increasing commercialization of crops such as *khat*, which is associated with an increased share of annual food crops (maize and sweet potato), is leading to the reduction in the key native perennial crops, enset and coffee. The share of native and ecologically friendly multipurpose trees declines with better road access, while that of eucalyptus tends to increase. This will lead to further uniformity of the landscape.

DISCUSSION

Effects of the land-use changes on productivity and sustainability

A high species diversity which combines crops, trees and animals having different uses and production cycles have a potential to maintain the resource base, the land. Of course, this would depend on the quantity and quality of the inputs used in the system. Many studies propose the use of ‘sustainable intensification’ (Tilman *et al*., 2002; Pretty *et al*., 2003; Godfray *et al*., 2010), which seeks to combine increased production of food from the same area of land with a reduction in environmental impacts (Royal Society of London, 2009). While the enset-coffee agroforestry systems of Southern Ethiopia display the characteristics of sustainable agriculture, there is room for increasing productivity through intensification. If intensification involves a reduction in plant diversity and the perennial nature of the systems, leading to the development of monoculture fields, this could disrupt the ecosystem services provided by the integrated multistorey agroforestry systems. However, integrating high value crops into the systems without significantly affecting the composition and diversity of components could lead to sustainable intensification. Hence, maintaining the existing components of the enset-coffee agroforestry systems would contribute to its ecological and socioeconomic sustainability. Ecological sustainability indicates the extent to which natural resources are conserved so that farming can be continued, while economic sustainability shows its suitability and adaptability to local farming conditions and its economic viability (Pretty *et al*., 2003; Ojiem *et al*., 2006; Peyre *et al*., 2006; Holden and Linnerud, 2007). Below, we evaluate the ecological and socioeconomic sustainability aspects of the enset-coffee agroforestry systems and justify the need for their maintenance.

Ecological sustainability aspects

Several features of the enset-coffee agroforestry systems are important for the ecological sustainability, including (1) maintenance of species diversity, which is important for risk spreading and minimization, genetic conservation of native species, efficient resource use and biological pest control; (2) reduced use or elimination of soluble or synthetic fertilizers, increased or improved use of manure and other organic materials as soil ameliorants, and soil conservation; (3) reduced use or elimination of chemical pesticides, replacing these with integrated pest management practices and system diversity; and (4) self-sufficiency, by using on-farm or locally available ‘internal’ resources and a minimum or conditional use of purchased 'external' resources, which contributes to the long-term conservation of the resource base and environmental resilience of the systems (Tesfaye Abebe *et al*., 2006; Tesfaye Abebe and Bongers, 2012).

Socioeconomic sustainability aspects

The maintenance of high species diversity in the enset-coffee agroforestry systems also contributes to socioeconomic stability. As in other agroforestry systems, the diversity of crop, tree and livestock species with different uses and production cycles enables the year-round production of different products, reduces the risk of production failure, allows flexible use of labour and enables efficient cycling of locally available resources, which means that production does not depend on external inputs (Kumar and Nair, 2006; Tesfaye Abebe, 2005). Moreover, the enset-coffee agroforestry systems also possess several specific features that promote socioeconomic sustainability. They not only have a high species diversity, but also a high diversity in functional crop types, notably staple food crops and cash crops, in addition to the usual supplementary home garden crops (Tesfaye Abebe *et al*., 2006). The carbohydrate-rich basic food crops, enset and maize are supplemented by pulses, vegetables, fruits and animal products that provide proteins, fats and vitamins, and by trees that provide resources for construction and household energy. This is of crucial importance for households, especially poor families. The cash crops - coffee, *khat* and pineapple that are incorporated into the systems, also give a more balanced household income. Both the diversity of crops and the inclusion of the perennial enset spread the risk to households of individual crop failures. The possibility of flexibly harvesting enset as a staple food is one of the main reasons why the Southern highlands of Ethiopia are relatively free from hunger (Desalegn Rahmato, 1995; Brandt *et al*., 1997).

Like the ecological sustainability of these agroforestry systems, its socioeconomic sustainability cannot be explained by its species diversity alone, but also by the specific features of the two key species, enset and coffee. Enset is both a food crop and a provider of different products, such as fiber and fodder. It is therefore ideally suited to low-external input agricultural production systems (Almaz Negash, 2001; Bizuayehu Tesfaye, 2002), while its high productivity and multiple functions provide sustenance for a very dense population, which is often two to three times higher than in the cereal-based systems found in other parts of Ethiopia (Tesfaye Abebe, 2005). Coffee serves as a main cash crop supplementing the mainly subsistence-oriented enset production. Consequently, not only from an ecological point of view, but also from a socioeconomic point of view, coffee and enset can be considered as key species.

CONCLUSION AND RECOMMENDATIONS

The traditional enset-coffee agroforestry systems are characterized as a sustainable land-use system, but this does not mean that they are not subject to change. Decreasing farm size and increased commercialization is affecting the systems. The shift from the traditional enset-coffee systems towards inclusion of other food and cash crops has increased household income. However, the expansion of open-field food crops (maize, sweet potato) and of monocultural cash crops (*khat*, pineapple), causes not only a gradual loss of species diversity and tree biomass, but also a decrease in the perennial crops and native tree species, to the detriment of the dominance of the two key species, enset and coffee. As these are considered to play a significant role in the stability and resilience of the agroforestry system, it is expected that the land-use change will have negative impacts on the landscape. It results in a gradual reduction of the ecological benefits derived from these integrated and complex systems, which threatens their long-term sustainability. We should therefore opt for the maintenance of the perennial component in systems and the integration of new crops into the existing multistorey system, without affecting the biodiverse nature of enset-coffee agroforestry systems and without losing their essential key species, enset and coffee. This can be achieved through directed extension services by government institutions and local organizations. Additional research should focus on the integration of expanding cash crops (such as *khat* and pineapple) into the existing systems without changing the multistorey structure of the home gardens. As enset plant produces the highest volume of food per unit area and time, and because of its different end uses and diverse ecological roles, the future of these home gardens depends on the maintenance of enset-based staple food production. Thus, strategies should be developed to reverse the increasing dependence on maize and enhance the systematic production of enset.

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