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# Determinants of crop diversity and composition in Enset-coffee agroforestry homegardens of Southern Ethiopia

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**Abstract**

Households in much of the tropics depend for their livelihoods on the variety and continued production of food and other products that are provided by their own farms. In such systems, maintenance of agrobiodiversity and ensuring food security are important for the well being of the population. The enset-coffee agroforestry homegardens of Southern Ethiopia that are dominated by two native perennial crops, Coffee (*Coffea arabica* L.) and Enset (*Enset ventricosum* Welw. Cheesman), are examples of such agricultural systems. This study was conducted in Sidama administrative zone of Southern Ethiopia to determine the factors that influence the diversity and composition of crops in the systems. Data were collected from 144 sample homegardens selected from four districts. Stepwise multiple regression analysis was used to relate indices of crop diversity and area share of major crops with the physical and socioeconomic factors. The study revealed that socioeconomic factors, mainly proximity to markets, affected negatively crop species richness. The production area of the main crops enset and coffee decreased with increasing proximity to market and road while that of maize and khat increased. At household level, farm size had a significant effect on area share of enset and coffee. As farm size increased the share of the cash crop, coffee increased but that of the staple, enset declined. Enset, which is the backbone of the system in terms of food security, is declining on small farms and the share of monoculture maize system is increasing. The trend towards declining agrobiodiversity, and reduction in the production area of the main perennial crops and their gradual replacement with monoculture fields could make the systems liable to instability and collapse. As these sites are high potential agricultural areas, intensification can be achieved by integrating high-value and more productive crops, such as fruits, spices and vegetables, while maintaining the integrated and complex nature of the systems.

*Keywords:* Agroforestry systems, coffee, crop diversity, Enset, homegardens, Sidama

## 1 Introduction

Crop diversification is a deliberate strategy of farmers to ensure subsistence and it has several advantages. These include, yield stabilization, risk reduction, staggered use of family labour, multiple production, making use of a variety of soils and agro-climatic conditions, and increased resource productivity over time (Soemarwoto & Conway, 1991; Almekinders *et al.*, 1995; Netting & Stone, 1996; Bayush Tsegaye, 1997). The species diversity of crops and trees in agricultural systems fosters recycling of nutrients, increases efficiency in the use of moisture, nutrients, and sunlight, and reduces incidence of weeds, pests, and diseases (Altieri, 1995; Trenbath, 1999; Tesfaye Abebe *et al.*, 2010). The number of species grown in a farm (species richness) is an important indicator of diversity. But from the utility point of view, it is not only the richness that matters but also the heterogeneity in functions. It is vital to

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have appropriate mixtures of different functional groups of crops to meet balanced nutrition and cash needs of households. Huang *et al.* (2002) identified three categories of functional groups in agroforestry systems, namely ecological, conservational and livelihood functional groups. The latter is defined as "a set of species with similar impacts on the life-security processes of the local people" and describes the functional groups presented in this study.

The dominance of perennial crops in a system is likely to have positive contributions towards soil fertility replenishment, soil and water conservation and microclimate improvement through its nutrient cycling and shading effects (Kumar & Nair, 2006). Most of the tropical homegarden agroforestry systems display the above three beneficial characteristics.

The traditional enset-coffee agroforestry homegardens of Southern Ethiopia are a good example. They are characterised by two dominant native perennial crops enset and coffee which together cover more than 60 % of the crop land. Enset (*Enset ventricosum* (Welw.) Cheesman) is a multipurpose crop and a staple food for about 15 million people in the region. It produces the highest dry matter yield in space and time as compared to other crops in the country (Admasu Tsegaye & Struik, 2001). Coffee (*Coffea arabica* L.) is the major cash crop that plays significant role in the household as well as regional and national economies. The two traditional crops can be considered as "key-stone" species due to their enormous socioeconomic and ecological contributions in the agricultural systems. The two crops are grown in an intimate association with several annual and perennial crops as well as trees in multistorey configurations. Different types of livestock, namely cattle, sheep, goats, equines and poultry, are also kept in the systems. Unlike most homegardens elsewhere that are defined as supplementary food production units (Ninez, 1987; Hoogerbrugge & Fresco, 1993), the homegardens in most of Southern Ethiopia are extended farm systems from where households derive all their subsistence and cash needs. The average size of these agroforestry homegardens is about 0.7 hectares, and they support a very dense population of 500–1000 people per km $^2$ (Tesfaye Abebe *et al.*, 2010).

In these systems, crop diversity is generally high and enset and coffee are still dominant in most of the sites. However, there exists variation among sites and between farms within a site. In some sites and farms, the share of the two major crops, enset and coffee, is declining while monoculture fields of new cash and food crops are expanding. This development is likely to affect the long-term sustainability of the systems because studies indicate that the diversity and complex structure of homegardens is believed to contribute to beneficial agroecosystem functions (Jensen, 1993; Wojtkowski, 1993). It is also argued that intensification could increase production but in many cases it reduces output stability and resource use efficiency; and enhances over-exploitation of the resource base (Almekinders *et al.*, 1995). The argument over this issue of diversification versus simplification could lead to the question of, 'why do farmers change the diversity and composition of crops in their farms?' Understanding the factors that lead to such land-use changes could contribute towards the design of productive and sustainable agricultural systems while maintaining its diversity and structure. This paper attempts to identify the socioeconomic and biophysical factors that determine crop diversity and area share of major crops in the enset-coffee agroforestry homegardens of Sidama, Southern Ethiopia.

The hypothesis put in the study was that a) access to market and road can affect the diversity and composition of species as farmers with access to market could focus on the production of commercial crops for market; b) altitude of a certain area could influence crop composition and diversity due to variation in ecological adaptability of the species; c) farm size which is related with wealth status of farmers, could also influence crop diversity and composition due to differences in production objectives: Small-holders may focus on satisfaction of household consumption needs, while large-holders can satisfy their consumption needs from a relatively small area and allocate a large portion of their farm to cash crops.

## 2 Materials and methods

This study was undertaken in 2001, on 12 sites (known as *Kebeles*[1]) selected from four districts in Sidama administrative zone, Southern Ethiopia. The four districts Aleta Wondo, Dale, Dara and Hawassa Zurya were selected randomly out of the 10 districts in Sidama where these agroforestry systems are widely practiced. The enset-coffee agroforestry systems of Sidama receive a mean annual rainfall of 1200–1500 mm, and a mean annual daily temperature of 15–20 °C. Soil type prevailing in the systems is predominantly Nitosols (SZPED, 2004).

Selection of the *Kebeles* was based on their distance to highways, and to market, and differences in altitude. Distance to market and highway were chosen because they influence the ease of transportation of agricultural produce for market, thereby affecting farmer's decision

[1] A *Kebele* is the lowest administrative unit in Ethiopia covering an area of about 800 hectares, usually inhabiting 400–800 households.

on choice of crops to grow. Altitude of sites may also influence crop choice due to agroecological adaptatability. Altitude was measured using altimeter. At household level, farm size and family labour, which are related with economic well-being of households, were used as selection criteria. Thus, within a site (*Kebele*), households were selected on the basis of their wealth status. Selection of the sites and households was therefore based on these major criteria, but there were also other socio-economical variables considered in the study (Table 1).

The records of *Kebele* offices were used to determine wealth status of farmers: At *Kebele* level, all resident farmers are categorised as poor, medium and rich, based on the criteria of land holding, number of livestock owned, the area of the farm occupied by coffee and enset, and the level of involvement in off-farm activities.1) Livestock are very important assets to the farming community, because they provide households with, a) protein supplement, b) manure to fertilize the farms, and c) generate income through sell of the animals themselves and/or their products. 2) The farm area occupied by enset is considered as criterion to determine wealth status because farmers having large stands of enset are food secure. Once established, it is not seriously affected by drought, and after four years of age, it can be harvested and processed anytime when the need arises. On the other hand, coffee is major cash crop in the area, and large coffee plantation means more income to the household, and hence higher wealth status. 3) Level of involvement in off-farm activities is related to wealth status of farmers because farmers who generate income through such activities as petty trading and off-farm employment, would have additional capital to buy farm inputs and livestock to maximize their production, and/or they can buy food if the need arises and become food secure. From each wealth category, four households were selected at random, making a total of 12 households per *Kebele* and 144 households for the whole study. Major characteristics of the different economic groups of sample farmers are shown in Table 2.

**Table 1:** *The variables used in the analysis and their characteristics (n = 144)*

| *Factors* | *Range of values* | *Overall mean* | *Remarks* |
|---|---|---|---|
| Physical environment | | | |
| – Altitude of the farm | 1520–2040 (meters a.s.l.) | 1828 m | |
| – Slope of the farm | 0 –45 % | 10 % | |
| Socio-economic environment | | | |
| – Distance of farms to market | 0.04–6.0 km | 2.1 km | |
| – Distance to major roads (highways) | 0.02–26 km | 9.0 km | |
| – Farm size | 0.18–7.46 ha | 0.75 ha | |
| – Number of livestock | 0–21 TLU * | 3.1 TLU | |
| – Involvement in off-farm activities | Yes/no | | 30 % of the farmers involve in wage labour, carpentry, trading or other off-farm activities |
| – Family size | 3–22 persons | 8.3 | |
| – Farm labour force | 2–11 persons | 4.9 | |
| – Age of the household head | 25–92 years | 48 years | |
| – Educational status of the household head | Illiterate to secondary school complete | | 23 % illiterate, 22 % reading and writing 32 % elementary school, 20 % secondary school, 3 % completed secondary education |
| – Ethnic background | | | 93 % Sidama; 7 % others |
| – Gender of the household head | | | 95 % male headed, 5 % female headed |

(Source: Own survey)

* TLU: A Tropical Livestock Unit –TLU (Heady, 1975), is a standard used to quantify different livestock types and sizes using a cattle with a body weight of 250 kilograms.

**Table 2:** *Mean characteristics of sample households in respect to wealth status*

| *Indicators* | *Unit of measurement* | *Wealth status* | | |
|---|---|---|---|---|
| | | *Poor (n=48)* | *Medium (n=48)* | *Rich (n=48)* |
| Farm size | Hectare | 0.55 | 1.46 | 2.75 |
| Number of Livestock | TLU | 1.1 | 2.5 | 5.2 |
| Labour force | | | | |
| – Adult labour | Number | 2.3 | 2.6 | 3.0 |
| – Children aged 10–18 | Number | 1.4 | 2.4 | 3.4 |
| Area of land under cash crops | % farm | 33.8 | 45.5 | 52.1 |
| Total family size | Number | 6.4 | 8.5 | 10.2 |

### 2.1 Data collection

To determine farm-level diversity of crops, area of the homegarden was measured using meter tapes, and all crop plants in the farm were enumerated by species. To determine the area share of major crops, the different plots constituting the homegarden farm were identified and classified by the dominant crop, as coffee plot, enset plot, maize plot and khat (*Catha edulis* (Vahl) Forssk.ex Endl) plot.

Although the farms are agroforestry systems in which different crop species are grown, one can identify distinct plots in the systems where a certain crop is more dominant than the others. For instance, we can distinguish a coffee plot where coffee is the dominant crop, but there are minor intercropped species (see Figure 1a and b). Then, area of the plot was measured, and the space occupied by the intercrops deducted.

For instance, if the dominant crop in a plot is coffee, the plot is designated as coffee plot and the total area of the plot is measured. Then, the area occupied by the minor intercrops is calculated based on the spacing used, and deducted from the plot size, to estimate the area occupied only by coffee. This is done for all major crops of the farm. Afterwards the total area occupied by each major crop is summed up to determine its area share within the farm. Abundance of each crop species in the plots were determined by using sample quadrants having sizes of 1 m × 1 m for annual crops and 10 m × 10 m for perennial crops. The number of sample quadrants per plot accounted for about 10 % of the total size of the plot. In general, the total number of sample quadrants per farm varied from 6 to 72. The data obtained from these measurements were then used to calculate farm level diversity indices.

Each species was classified into a functional group in the form of a set of species with similar roles in the livelihoods of the local people. A total of ten functional groups were distinguished (Tesfaye Abebe *et al.*, 2010): root and tuber crops, vegetables, pulses, cereals, fruits, stimulants, spices and condiments, oil crops, medicinal and fragrance plants. Socio-economic data such has household size and labour force were collected using structured interview.

### 2.2 Data Analysis

Crop diversity and composition of farms were characterized by three indices. (i) Species richness ($S$) was calculated as the total number of crop species in a farm. (ii) The Shannon index ($H'$) was used to quantify the relative abundance of the different species and it is calculated as, $H' = -\sum p_i \ln p_i$ (Shannon & Weaver, 1949; Magurran, 1988), where $p_i$ is the proportion of crop area composed of species $i$. (iii) Evenness ($E$), which compares observed distribution with the maximum possible even distribution of the number of species in the sample (Pielou, 1969) was calculated using the formula, $E = H'/H'_{max} = H'/\ln S$ (Magurran, 1988).

Statistical Package for Social Sciences - SPSS version 17 (SPSS Inc., 2008) was used for the analyses. Stepwise multiple regression was used to relate diversity indices (species richness, Shannon index and evenness index) to the physical and socioeconomic factors. Similarly, these regressions were used to relate the area occupied by major crops (coffee, enset, maize, khat, pineapple, and sweet potato) with the physical and socioeconomic factors. F-tests were as used to detect the level of significance of diversity indices and area share of major crops across the farmers' local and household environments. The data were checked for Normality, Linearity and Homoscedasticity to ensure that the assumptions of multiple regression are fulfilled.

**(a)**

**(b)**

**Fig. 1:** *Sample pictures of Enset-coffee agroforestry homegardens with different configurations*

**Table 3:** *Total and Mean ±SD farm-level crop diversity indices in the study districts*

| *District* | *No. of farms* | *Total no. of crop species* | *No. of crop species per farm* | *Shannon index (H')* | *Evenness index (E)* | *No. of functional groups of crops* |
|---|---|---|---|---|---|---|
| Dale | 36 | 57 | 17.86 $^{a}$ ±3.56 | 1.50 ±0.20 | 0.53 $^{ab}$ ±0.07 | 8.44 $^{a}$ ±0.91 |
| Dara | 36 | 56 | 17.47 $^{a}$ ±3.71 | 1.49 ±0.17 | 0.53 $^{ab}$ ±0.08 | 8.11 $^{ab}$ ±1.06 |
| Aleta Wondo | 48 | 64 | 15.46 $^{b}$ ±3.56 | 1.38 ±0.29 | 0.51 $^{b}$ ±0.11 | 8.13 $^{ab}$ ±0.91 |
| Hawassa Zurya | 24 | 33 | 12.33 $^{c}$ ±2.22 | 1.42 ±0.31 | 0.57 $^{a}$ ±0.13 | 7.67 $^{c}$ ±0.87 |
| Total | 144 | 78 | 16.04 ±3.94 | 1.45 ±0.25 | 0.53 ±0.10 | 8.13 ±0.97 |
| F-test ℗ | | | <0.001 | ns | <0.05 | <0.05 |

SD = Standard Deviation of the mean
Means followed by different letters are statistically different at P<0.05.according to DMRT

# 3 Results

## 3.1 Diversity and Composition of crop species

The total number of crop species recorded from the sample farms was 78, with an average of 16 crop species per farm. Crop species richness of farms varied significantly (P<0.001), while evenness index and number of functional groups of crops also showed variations (Table 3).

With regard to the composition of crop species in the systems, the two dominant crops coffee and enset accounted for a mean area share of 36.6 % and 26.4 % of the crop fields, respectively, followed by maize having a share of 16.4 % (Table 4). The other major crops (khat, sweet potato and pineapple) were not evenly distributed across all farms. Khat cultivation was more common on farms close to main roads while pineapple is widely grown in the lower altitudes.

**Table 4:** *Mean production area of major crops (% crop land; n =144)*

| *Crop species* | *Mean area* | *Standard deviation* | *Minimum area* | *Maximum area* |
|---|---|---|---|---|
| Coffee | 36.6 | 18.7 | 2.0 | 75.5 |
| Enset | 26.4 | 13.9 | 2.3 | 72.7 |
| Maize | 16.4 | 15.0 | 0.0 | 83.0 |
| Khat | 4.5 | 9.1 | 0.0 | 42.5 |
| Sweet potato | 2.6 | 3.8 | 0.0 | 18.4 |
| Pineapple | 1.6 | 4.8 | 0.0 | 34.0 |

## 3.2 Factors influencing crop diversity and composition at site level

### 3.2.1 Socioeconomic factors

Crop species richness of farms was influenced by distance to markets. In this case, crop species richness increased with distance to market (p<0.05), but evenness decreased (p<0.05) (Table 5). Diversity in functional groups of crops (richness and Shannon index) increased with increasing distance to major roads (p<0.05). On the other hand, Shannon and evenness indices of functional groups decreased with distance to markets, indicating that although there were fewer functional groups near the markets, they are relatively similar in abundance.

The area share of the dominant crops, enset and coffee, increased significantly with distance of farms to major roads with values of $F_{(4,139)} = 10.40$, p<0.01 for enset, and $F_{(4,139)} = 21.28$, p<0.001 for coffee. On the other hand the share of maize $F_{(3,140)} = 17.17$, p<0.001) and khat $F_{(2,141)} = 10.48$, p<0.001 decreased (Table 6). Proximity to markets was related to increased share of maize and khat, and a decrease in the area of coffee.

### 3.2.2 Physical factors

Altitude of farms influenced the composition of crops (Table 5). With increasing altitude of farms, the share of enset increased (p<0.05), but that of sweet potato and pineapple decreased (p<0.001). At the lower altitudes of these systems (1500–1750 meters a.s.l.) pineapple expanded as a cash crop and sweet potato as a food crop. Shannon and evenness indices decreased with increasing altitude.

## 3.3 Factors influencing crop diversity and composition at household level

Farm size is an indicator of wealth status of farmers (Table 2), and it has significant effect on area share of the dominant crops, enset and coffee (Table 6). There was a direct positive relationship between increase in farm size and the area share of coffee (p<0.01), but a decrease in the share of enset (p<0.05) (Table 6). With increasing farm size, farmers could satisfy their subsistence needs on a relatively small land and allocate increasingly larger proportion of their farm to cash crops. Farm size did not affect species richness and evenness of crop species, as well as functional groups. Other socioeconomic factors such as age, educational status and gender of the household head, as well as ethnic background did not affect crop diversity and area share of major crops.

# 4 Discussion

## 4.1 Socio-economic factors

Access to market, either through physical proximity of the market itself or through a link created by road infrastructure, affected significantly most of the diversity indices but the effects were not always similar (Table 5). Farmers close to markets grew relatively fewer crop species, because market access encouraged them to focus on easily marketable, often high-value products and to purchase other products necessary for household consumption. These findings confirm earlier reports which indicated that species diversity of agroforestry homegardens located nearby market areas was low because farmers concentrated on few commercial crops (Wiersum, 1982; Marten & Abdoellah, 1988; Jensen, 1993; Abdoellah *et al.*, 2006; Peyre *et al.*, 2006; Wiersum, 2006).

In road-access sites, farmers produced the major crops necessary for their subsistence, but they reduced significantly the share of enset and coffee in favour of

**Table 5:** *Regression results of Physical and Socioeconomic environments on crop diversity indices (n=144). The test statistics for the X-variables is Standardized Coefficient (Beta).*

| *Factors* | *Crop species* | | | *Functional groups of crops* | | |
|---|---|---|---|---|---|---|
| | *Richness (S)* | *Shannon index (H')* | *Evenness (E)* | *Richness (S)* | *Shannon index (H')* | *Evenness (E)* |
| Adjusted $R^2$ | 0.10*** | 0.22*** | 0.17*** | 0.03*** | 0.07*** | 0.13*** |
| Overall relationship between the dependant variable (Y) and independent variables (X) | $F_{(2,141)}$ = 8.21, p<0.01 | $F_{(4,141)}$ = 15.31, p<0.001 | $F_{(4,142)}$ = 18.08, p<0.001 | $F_{(1,142)}$ = 5.05, p<0.05 | $F_{(2,141)}$ = 5, 09, p<0.01 | $F_{(2,141)}$ = 10.62, p<0.001 |
| Physical environment | | | | | | |
| Altitude of the farm (m) | ns | -0.42*** | -0.37*** | ns | ns | ns |
| Slope of the farm (%) | ns | 0.21** | 0.17* | ns | ns | ns |
| Socio-economic environment | | | | | | |
| Distance to markets (km) | 0.20* | ns | –0.16* | ns | 0.18* | –0.29*** |
| Distance to major road (km) | ns | ns | –0.18* | 0.16* | 0.17* | ns |
| Farm size (ha) | ns | ns | ns | ns | ns | ns |
| Family size (n) | 0.28** | ns | ns | ns | ns | –0.25** |
| No. of livestock (TLU) | ns | ns | ns | ns | ns | ns |
| Farm labour force (n) | ns | ns | ns | ns | ns | ns |

Note: ns = not significant; *, **, *** = Significance at p<0.05, 0.01, 0.001, respectively.

**Table 6:** *Regression results of Physical and Socioeconomic environments on area share of major crop (n=144). The test statistics for the X-variables is Standardized Coefficient (Beta.)*

| *Factors* | *Area share of major crops (% of farm area)* | | | | | |
|---|---|---|---|---|---|---|
| | *Enset* | *Coffee* | *Maize* | *Khat* | *Sweet potato* | *Pineapple* |
| Adjusted $R^2$ | 0.14*** | 0.38*** | 0.27*** | 0.13*** | 0.31*** | 0.31*** |
| Overall relationship between the dependant variable (Y) and independent variables (X) | $F_{(4,139)}$ = 10.40, p<0.01 | $F_{(4,139)}$ = 21.28, p<0.001 | $F_{(3,140)}$ = 17.17, p<0.001 | $F_{(2,141)}$ = 10.48, p<0.001 | $F_{(1,142)}$ = 62.56, p<0.001 | $F_{(3,140)}$ = 21.94, p<0.001 |
| Physical environment | | | | | | |
| Altitude of the farm (m) | 0.19* | ns | 0.24* | ns | –0.55*** | –0.55*** |
| Slope of the farm (ns | 0.16* | ns | ns | ns | 0.18* | |
| Socio-economic environment | | | | | | |
| Distance to markets (km) | 0.25** | 0.19** | –0.18* | –0.21** | ns | ns |
| Distance to major road (km) | –0.28** | 0.50*** | –0.61*** | –032*** | ns | ns |
| Farm size (ha) | 0.20* | 0.23** | ns | ns | ns | 0.17* |
| Family size (n) | ns | ns | ns | ns | ns | ns |
| No. of livestock (TLU) | ns | ns | ns | ns | ns | ns |
| Farm labour force (n) | ns | ns | ns | ns | ns | ns |

Note: ns = not significant; *, **, *** = Significance at p<0.05, 0.01, 0.001, respectively.

other cash crops such as khat and pineapple whose marketing was realised due to road access. In order to compensate for the smaller area share of the staple food enset, farmers increased the share of annual food crops mainly maize and sweet potato (Table 6). A situation, where such replacement of traditional staple crops took place, has also been reported for the Chagga homegerdens in Tanzania, where maize is gradually replacing the staple food banana (Fernandes *et al.*, 1984).

Access to both market and major roads resulted in a higher evenness (uniformity in abundance) of crops. This could have been due to the decrease in the share of the dominant crops (enset and coffee), and expansion of other cash and food crops. On road access sites, many farmers were gradually shifting from the traditional cash crop (coffee) to crops such as khat and pineapple to exploit marketing opportunities (Tesfaye Abebe *et al.*, 2010). Both khat and pineapple have high demands but they are perishable and they should be delivered to consumers while fresh. The road access has provided the farmers with such means.

The change in land use is sometimes associated with introduction of external inputs. This was particularly true for maize. In these systems, maize was normally grown in any available open space within the integrated agroforestry systems sharing an average of 10–15 % of the cropland. Over the recent years, its cultivation is expanding, also due to agricultural extension endeavours that are promoting its intensification through the use of improved seeds and fertilizers (Tesfaye Abebe *et al.*, 2006). The share of maize has therefore increased largely on small farms and on farms that have access to roads, and reached as high as 40 % at some sites. According to official reports (SZPED, 2004), the use of chemical fertilizers in the administrative zone has increased by 50 % in the preceding 10 years. Farmers managing the homegardens are now applying half to full dose of Urea and DAP (Diammonium Phosphate) fertilizers on their maize plots (Personal communication). The increasing share of maize, which is associated with the use of more external inputs has introduced elements of dependency on the hitherto self-sustaining systems. On the other hand, high input technology in such subsistence systems have several shortcomings such as high cost of inputs, poor adaptation of seeds, soil mining, and other problems related to availability and timely distribution of inputs including new seeds (Bayush Tsegaye, 1997). Hence, technological advancements in such subsistence systems cannot often be realised with external input levels, but through complete and more efficient utilisation of available resources (Almekinders *et al.*, 1995).

### *4.2 Biophysical factors*

Altitude and slope of the farms affected heterogeneity of crop species. In the lower altitude sites where temperatures are high, the share of such crops as sweet potato and pineapple was increased because of their good adaptability to the climatic conditions. However, this was also associated with road access, because most of the low-altitude sites also had better access to the roads that facilitate marketing. Soemarwoto & Conway (1991) have reported a decrease in plant species diversity of homegardens with increasing altitude. In the present study, altitude did not affect species richness, but Shannon and evenness indices decreased with increasing altitude, indicating the relatively homogenous composition of the crops in the lower altitude sites.

Slope of the farm affected positively the Shannon and evenness indices of crops. This could be attributed to the presence of different micro-environments that are suitable to different types of crops. In hilly farms, the home was often located on the top and the crop fields stretched down the slope, often ending up in swampy areas or creeks. Steep slopes were often covered with perennial crops. The bottom of the slope where water stagnates for several times of the year was often used to grow plants such as sugarcane, eucalypts and bamboo or it was set-aside for grazing. The presence of such different microclimatic sites suitable only for specific types of crops could have contributed to a better evenness in the share of the major crops.

### *4.3 Household environments*

Among the household characteristics, farm size affected the area share of major crops but not crop diversity of farms. Small farmers produced most of the food crops for their own consumption, while large holders produced the same type of food crops sufficient for household consumption and allocated the extra land to cash crops, especially coffee. That is probably why the diversity of crop species did not increase on large farms. This confirms earlier reports (Jacob and Alles, 1987; Okafor and Fernandes, 1987; Wiersum, 2006) which indicated relationships between farm size and cropping intensity, but not diversity.

Farm size is a very important factor that could affect integrity of the enset-coffee agroforestry homegardens. Poor farmers with small land-holding allocated about 27 % of their crop land to enset, but the dry matter yield was often insufficient to cover household consumption requirements (Tesfaye Abebe & Bongers, 2012). This was because the proportion of matured and harvestable enset plants is often small, and this situation would force farmers to harvest immature enset plants whose dry matter yield is low. Furthermore, livestock holding, which is crucial for enset cultivation due to manure production, was low which in turn negatively affected the yield of enset. In the study areas, livestock are kept within farm compounds grazing in front yards, and fed with enset leaves and other crop residues. The manure is collected by women and applied around enset plants. Thus, the production of enset and livestock are interdependent. When the yield from enset is not sufficient to feed the family and when farmers do not expect enset harvest in the immediate future, they bring more of the enset field into cultivation of annual food crops, especially maize and sweet potato (Tesfaye Abebe *et al.*, 2010). Shortage of land was, therefore, the main cause for the increasing share of annual crops.

Since, the perennial nature of the components is considered to play a significant role in the stability and resilience of homegarden systems (Trenbath, 1999; Montagnini, 2006), we expect that their decline will have negative impacts on the landscape. It will result in a gradual reduction of the ecological benefits derived from these integrated and complex systems, and threatens their long-term sustainability. To ensure food and livelihood security, we argue for the maintenance of the perennial components in the homegardens and the integration of new crops into the existing multi-storey systems, without affecting their biodiverse nature. As enset produces the highest volume of food per unit area and time (Admasu Tsegaye & Struik, 2001), and because of its different end uses and diverse ecological roles, the future of these homegardens depends on the maintenance of enset-based staple food production (Tesfaye Abebe & Bongers, 2012). Thus, strategies should be developed to reverse the increasing dependence on maize and enhance systematic production of enset again.

The expansion of annual crops can be reversed by well-planned staggered planting of enset in which the crop is grown to full maturity. Accumulated starch from enset is highest when it attains physiological maturity (Taye Bezuneh & Asrat Feleke, 1966; Admasu Tsegaye & Struik, 2001), and this takes about five years, after transplanting. Growing enset until it attains full maturity enables farmers to benefit from its high yield potential. To this effect, the principles of successive rotation cycles used in forestry can be applied to manage and sustainably harvest enset plantations. To achieve this, the enset field could be divided into five equal-sized plots of different age classes (1–5 years) of enset plantations. The plot size, or the number of plants in each plot should be sufficient for the household's annual consumption. Every year, plot of the matured enset (aged five years) will be harvested, and replanting made on the same plot to ensure regular supply through rotational harvesting. The shortage of manure to maintain soil fertility can be backed by the use of compost. In this regard, the bulk of coffee husk which is wasted in these sites every year (personal observation) could be used for composting. Such interventions would contribute towards food security and improvement of the systems, particularly of small farms.

As these sites are high potential agricultural areas, sustainable intensification can be achieved by integrating high-value and more productive crops, such as fruits, spices and vegetables, while maintaining the integrated and complex nature of this system. This might contribute to achieving stability in the use of land in the long term, while at the same time meeting the needs of the local population.

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