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3 Sustainability and other determinants of smallholder farming systems in the Western Highlands of Cameroon

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Abstract

Smallholder farming systems in the Western Highlands of Cameroon (WHC) have undergone changes in land use, productivity and sustainability. Understanding the determinants that influence the system is essential when targeting appropriate intervention strategies for improvement. A field survey was carried out in three villages in this agro-ecological zone and analysed to understand the sustainability, general characteristics of the households and other forces that drive the farming systems in this area. The impacts of farming practices on farm sustainability were used as indicators to score sustainability in our research area. The results revealed that the household characteristics were very similar across the villages while the sustainability though generally low, differed depending on the intensity of off-farm inputs in the production systems and other socio-economic factors. Sustainability had significant negative relationships with the intensity of land use, off-farm inputs, and sole cropping practice and a positive relationship with the age of the head of the household. Study of the covariance relationships among the determinants using factor analysis showed that the determinants could be grouped to indicate a number of underlying common factors influencing sustainability. The common factors were intensity of land use over space, intensity of off-farm inputs, household adjustment factors and the mobility of the household, in descending order of importance, which explained 62.15% of the total variation of sustainability in the study area. Efforts are required to improve the sustainability of the farming systems in the WHC. The adoption of well designed intercropping systems and the use of natural organic resources for plant nutrients would be of benefit and provide satisfaction to both the producers and consumers in the system.

Key words

Farming systems, sustainability, determinants, Western Highland of Cameroon.

3.1 Introduction

Many arable areas in sub-Saharan Africa, most of which are in degraded or low potential areas, have been shown to be under severe pressure to increase productivity in order to feed a rapidly growing human population (Tchabi *et al*., 2008; Place *et al*., 2003). The sustainability of the farming systems are negatively linked toe poor soil fertility management and continuous cropping that exacerbates soil nutrient depletion (Waithaka *et al*., 2006), since the farming systems are usually located in heterogeneous environments too marginal for intensive agriculture and remote from markets and institutions (Tchabi *et al*., 2008; Wolf, 1986). Most households in sub-Saharan Africa make their living from growing crops and/or keeping livestock on small plots of land which makes it a precarious and insecure way of life. Since it is not possible to increase the area under production because of demographic pressure, effective technologies are required to increase farm productivity and enhance sustainability, thereby improving the well-being of these small holders. Based on modern research, the introduction of improved technology and methods of conservation for smallholder farming, without efforts first being made to understand the determinants of the system and farmers' perceptions, are usually not effective (Isaac *et al.*, 2009; Oreszczyn *et al.*, 2010). Understanding farmers' perceptions and determinants of agriculture remain a challenge for the adoption of environmentally sustainable practice.

Agriculture is a major earner of foreign exchange for Cameroon (30% of Gross Domestic Product) and provides employment for the bulk of the population. Most of the agricultural production is by small-scale farmers of the rural areas who make up about 90% of the farming population (FAO, 2002). Farming systems in the Western Highlands of Cameroon (WHC) have evolved over time yielding both positive and negative contributions to rural welfare and livelihood. The traditional on-farm input-dependent system characterized by shifting cultivation and intercropping is no longer sustainable because factors such as socio-economic and demographic pressure have shortened the fallow period. Asa result the rural population is forced to look for other income generating farming systems, especially after the drastic drop in the market value of the original cash crop, coffee.

The evaluation of agricultural production systems is an important step in the diagnosis of the systems which will yield strategies that can be used to improve the system. These include better decision-making (lowering risks and costs), an early warning system for emerging issues, sustainability balanced with development, understanding what impacts on the systems and allowing for corrective action, identifying limits and opportunities, continuous improvement and accountability and communication (Russillo & Pintér, 2009). Very few research attempts have so far been carried out to diagnose the factors governing agricultural production in the rural areas of Cameroon and especially in the Western Highlands of Cameroon (WHC) which is considered to be the food basket of the country. Land degradation has been attributed to demographic pressure as subscribed to by the neo-Malthusian theory (Malthus, 1989) though other proponents (Tappan & McGahuey, 2007) of the Boserup's (1965) theory have argued that technological innovations follow increasing population pressure. Traditional farming systems known for preserving soil health and quality have in fact shifted to 'mining' agriculture whose duration depends only on the depletion rates of assimilable nutrients (Van der Pol, 1992). Ruthenbeng (1980) pointed out that farmlands under the traditional system were originally part of natural systems close to the “steady state” but considered unproductive in terms of human objectives. “Slash and burn” or shifting cultivation is perhaps one of the best examples of an ecological strategy to manage agriculture in the tropics (Yanni, 1996). By maintaining a mosaic of plots under cropping and some in fallow, farmers capture the essence of natural processes of soil regeneration typical of any ecological succession. By understanding the rationale of the system, a contemporary discovery, the use of “green manures”, has provided an ecological pathway to the intensification of the shifting cultivation, in areas where long fallows are not possible anymore due to population growth or the conversion of forest to pasture (Flores, 1989). Hence, assessment of the factors prevailing in the systems can help to check the faults and provide a guide to alternative and more sustainable exploitative techniques.

Agriculture or farming is a high-risk business, subject not only to pests and weather but also to changes in resource availability (scarcity or deterioration), market conditions and government policies. A complex combination of stimuli, opportunities and internal adjustment mechanisms has defined different mobility routes and destinations for the rural inhabitants of the WHC, all of which have significantly impacted on the sustainability of the farming system. As a result of demographic pressure and local land tenure policy, fallows have nearly disappeared in the WHC (Floret, 1998) and land degradation has been exacerbated by the exploitation of vulnerable lands. Household characteristics and the interaction of exogenous and biophysical factors, result in highly diverse, mixed smallholder agricultural systems (Shepherd & Soule, 1998; Wopereis *et al.*, 2006). Differences among households in labour availability, resource endowments and other conditions give rise to different approaches to managing resources, even within the same region. These management differences affect the type and growth of plants, the presence and productivity of livestock, the use of fertilizers and the functioning of soil micro- and macro-fauna, which in turn influence soil fertility and the sustainability of the production system. Smallholder farming is the only option for a large proportion of the rural populations in sub-Saharan Africa. The difficulties they face is the need to strike a balance between competing needs such as maximizing labour productivity, providing themselves with a livelihood and reducing land degradation. Many farmers practice low-input subsistence farming with the aim of satisfying food requirements and basic income demands. For such systems both productivity and sustainability are at risk unless there is some use of external resources. Additionally, smallholders have to find a balance between investing in inputs for crop and livestock production, growing food for the household and generating income to buy food that cannot be grown on the farm as well as providing for health, education, and other household and social needs. The adoption of economically sustainable land management practices and technologies is constrained by a shortage of land and capital resources (Shepherd & Soule, 1998). Raising agricultural productivity in smallholder agriculture systems requires an understanding of how the complex array of farm enterprises and household socioeconomic factors relate and interact with each other.

Many factors influence the farming systems of small-scale farmers. The preoccupstions of the farmer will depend on the size of the area to be farmed, since this is the factor that determines the amount of of inputs required and isthe source of outputs. The type of crops grown is influenced by the dependency of household members, risk aversion, and the discount rate of the enterprise (Walker *et al.*, 1986). In the WHC, market oriented crops are principally sole-cropped while crops produced to feed households are generally intercropped. The age of the head of the household and the household proper influence the type of production system. As the children age and expand the family labour force, and as the household head acquires experience, production constraints are relaxed, discount rates are lowered, and risk aversion is mitigated (Walker *et al.*, 1986). The types and sources of inputs are important considerations in determining the sustainability of the systems. Systems that emulate nature and rely to a lesser extent on external inputs, just as do mature ecosystems, may provide pointers for ecologically appropriate agricultural management (Dalsgaard *et al.*, 1995). Practices that depend on non-renewable inputs and negatively contribute to natural biological processes and biodiversity show little consideration for the future generations of farmers (Rigby *et al.*, 2001). These constitute salient indicators of agricultural production.

Owing to insignificant diversification, the rural community of Cameroon in general and the WHC in particular depend nearly entirely on agricultural activities for food, feed and income. Rising demographic pressure has imposed intensive land system use over space and time and this in turn demands high amounts of off-farm inputs which seriously puts in question the sustainability of the system. According to Bergeret and Djoukeng (1993), the West region is considered to be one of the regions where agriculture is very dynamic. With 11% of the population occupying 3% of the national territory, with a density of about 200 inhabitants per square kilometre compared to the national average of 25 inhabitants per square kilometre, this region is believed to have a productive and intensive agricultural system. Most of the food and vegetable crops are exported to the big towns of the country and other neighbouring countries. However, the unregulated amounts of inputs used by farmers in this region necessitate some research on the health of the agricultural practices. This study attempts to quantify the sustainability of agricultural practices in the WHC adapted from sustainability indices developed by Rigby *et al.* (2001). The findings of this study are intended to make a contribution to the formulation of policies for sustainable agriculture development. They also provide a framework useful for the assessment of the sustainability of agricultural systems. Empirical research in the WHC addressing relationships between household structure and farm systems is limited. In addition to evaluating the sustainability of the different research sites using appropriate indicators, this study analyses the major factors influencing the farming systems in WHC by reducing a large number of inter-related variables to a few underlying factors that interact and determine the activities and performance of the agricultural system with an emphasis on sustainability. The specific objectives are:

1. to evaluate the relationship existing between agricultural production variables including sustainability score in the WHC
2. to illustrate possible interpretations of the influence of farming system determinants on sustainability
3. to identify the main constraints that influence agricultural production in the area

3.2 Materials and methods

3.2.1 Framework for assessing agricultural sustainability

The concept of sustainability lies at the heart of current debates over the use of the planet's natural resources. Agriculture is the most important user of environmental resources, including water, forests, pastures and nutrients, and its sustainability depends upon their availability (DFID, 2002). A growing interest in agricultural sustainability stems from concern about both threats to agriculture, the negative impact of agriculture on the environment, and the realization that decisions made now can have unforeseeable consequences in the future (Hansen *et al.*, 1997). Ikerd (1993) defines sustainability as the abilitytof maintain productivity and usefulness to the society in the long term, with environmentally sound, resource-conserving, economically viable, socially supportive, and commercially competitive characteristics. Sustainability is thus concerned with the need for agricultural practices to be economically viable, environmentally considerate and able to meet human food, feed and fibre needs in the long run (USDA, 1999; ATTRA, 2003) and thus integrates production and distribution (Lynam, 1994).

Sustainability takes into account economic, social and environmental concerns (Rasul & Thapa, 2003). This complex combination of interests makes it difficult to readily take a line of action to implement sustainability owing to the absence of simple diagnostic tools essential to evaluating the environmental effects of agricultural practices. The information needed for such evaluation is often difficult to obtain for financial or technical reasons (Girardin *et al.*, 1999).

To judge the sustainability of a system it is necessary to identify a set of attributes that constitute the components of a sustainable system, to develop measurement techniques for these indicators or performance criteria, and find some way of combining them to give a broad-based, multi-factor assessment of sustainability (Spenser & Swift, 1991). Due to variations in biophysical and socioeconomic conditions, indicators used in one country are not necessarily applicable to other countries. Therefore, indicators should be location specific and constructed within the context of contemporary socioeconomic situations (Dumanski & Pieri, 1996). The relevance of the indicators to assess sustainability and their usefulness both from societal and the farmers' perspective were considered in selecting them. The indicators make use of specific farming practices backed by pertinent literature criteria commonly adopted for agricultural sustainability (Rigby *et al.*, 2001).

A lot of research has been conducted to illustrate sustainable practices. The increased use of inorganic fertilizers, insecticides and pesticides in sole cropping systems has led to the contamination of water bodies and the spread of diseases, which have adversely affected aquatic life, livestock and people (Rahman & Thapa, 1999). Enormous losses are incurred in widely planted pure stands of high-yielding varieties (IRRI, 1976) when pests develop resistance to pesticides. Pesticide misuse can kill the numerous natural enemies of pests, causing pest resurgence and infestations by formerly innocuous secondary pest species. Pesticides are also a potential hazard to humans and the environment when the developing world is ill-equipped even to monitor the extent of the problem (Bull, 1982). Moreover, many farmers and governments cannot afford the large cost of agricultural inputs. Monocrops may be less productive under tropical conditions than well-conceived polycultures (Kass, 1978). Pingali *et al.* (1991) noted that intensive rice monoculture in the rice bowls of Asia resulted in: rice paddies flooded for most of the year without adequate drying periods, increased reliance on inorganic fertilizers, asymmetry of planting schedules and greater uniformity of cultivars. Over the long run, these changes imposed significant ecological costs due to negative bio-physical impacts such as the build-up of salinity and water logging, declining soil nutrient status, increased incidence of soil toxicities, pest build-up and reduced resilience of the ecosystem to pest attack. Yield advantages of multiple cropping systems are due to the reduction of pest incidence and more efficient use of nutrients, water and solar radiation (Altieri, 2002). Increased parasitoid and predator populations, availability of alternative prey for natural enemies, decreased colonization and reproduction in pests, chemical repellents, masking feeding inhibition by odours from non-host plants, prevention of pest emigration and optimum synchrony between pests and their natural enemies are presumably important factors in efficient pest regulation in intercrops (Altieri *et al.*, 1978; Gagné, 1982; Risch, 1981). The main strategy should be that a production system should exhibit tight nutrient cycling, complex structure and enhanced biodiversity. The expectation is the establishment of agricultural mimics, like natural models, that can be productive, pest-resistant and conservative of nutrients (Ewel, 1999). Badgley *et al.* (2007) found that organic methods could produce enough food on a global per capita basis to sustain the current human population, and potentially an even larger population, without putting more farmland into production. Based on 293 examples, theyconcluded that on average, in developed countries, organic systems produce 92% of the yield produced by conventional agriculture while in developing countries organic systems produce 80% more than conventional farms. They also posited that leguminous cover crops could fix enough nitrogen to replace the amount of synthetic fertiliser currently in use. Pretty *et al.*, (2006) examined 286 projects in 57 countries and found that farmers had increased agricultural productivity by an average of 79% by adopting sustainable agricultural practices such as integrated pest and nutrient management, conservation tillage, agro-forestry, water harvesting in dry land areas, and livestock and aquaculture integration in farming systems. Pretty & Hine (2001) found that farmers had, by adopting sustainable agricultural practices, achieved substantial increases in per hectare food production - the yield increases were 50-100% for rain-fed crops, and 5-10% for irrigated crops. Other specific examples of increased yields following the application of sustainable agricultural practices have been documented (Parott & Marsden, 2002; Pretty & Hine, 2001). These include:

- In the dry lands of Burkina Faso and Niger, soil and water conservation have transformed formerly degraded lands enabling the average family to produce an annual surplus of 153 kg of cereal per year.
- In Ethiopia, sustainable agriculture has resulted in a 60% increase in crop production
- In Honduras and Guatemala crop yields have increased from 400-600 kg/ha to 2000-2500 kg/ha using green manures, cover crops, contour grass strips, in-row tillage, rock bunds and animal manures
- In Peru, Bolivia and Ecuador farmers have increased potato yields by three fold, particularly by using green manures to enrich the soil.
- In Brazil, use of green manures and cover crops increased maize yields by between 20-250%.
- In Senegal, composting systems, green manures, water harvesting systems and rock phosphate increased yields of millet and peanuts by 75-195% and 75-165% respectively

Agricultural systems that will be able to confront future challenges are those that will exhibit high levels of diversity, productivity and efficiency (Funes-Monzote, 2009) as shown in Figure 3.1.

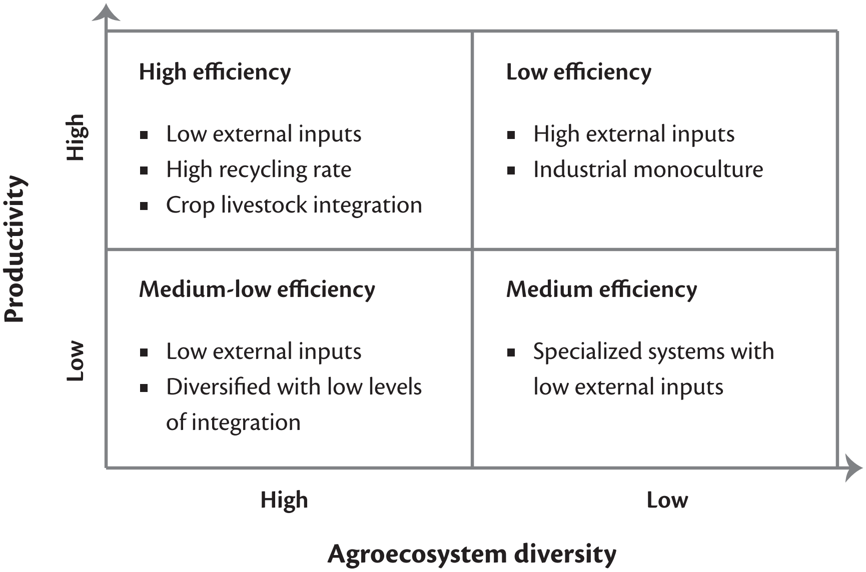

Figure 3.1
Features of green agro-ecosystems of the future: productivity, diversity, integration and efficiency (Funes-Monzote, 2009)

3.2.2 Sustainability score

Based on the principles of sustainability and the indicators outlined by Rigby *et al.* (2001), the impact of farming practices on farm sustainability was used as indicators to score the relative impact of farming practices on farm sustainability in our research area. Farm-management indicators are "raw" data that can be directly linked to activities. They can provide an early indication of likely changes which impact the environment, sometimes well before they can be measured by other indicators, such as those pertaining to soil and water quality. They can also serve as a proxy for "state" indicators where the latter are difficult or costly to monitor. Measuring farming practices is often more practical and cheaper than measuring actual changes in the environment (OECD, 2001).

Sustainability score (SUS) was estimated from the information gathered from 144 households in three villages (Bafou, Baleveng and Fongo-Tongo) found in the WHC. Information collected was based on seed source, maintenance of soil fertility, pest and disease control, crop management and weed control. The different options within each of the categories are outlined in Table 3.1.

Table 3.1

Farm practices used in the research area adapted from Rigby *et al.* (2001).

Seed source	Fertilizers	Pest/disease control	Crop management	Weed control
Impr = Improved planting material obtained off-farm	Synth = Synthetic fertilizers such as compound NPK, urea, superphosphate	Nat = Use of woodash, fallow	Rotat = rotation	Herb = chemical herbicides
Prev = Planting material obtained from previous harvest	Org = Organic fertilizers such as non-composted straw, FYM, animal dung, plant waste.	Synth = Synthetic pesticides (insecticides, fungicides, nematocides)	Inter = intercropping to encourage ecological diversity	C&C = Crop and Compost control (crop rotation, composting manure and crop waste to kill weed seeds)
	Comp = Composted such as organic fertilizers aerobically composted to kill pathogens			C Mgt. = Management of the crop (hand weeding or manual cultivation)

The scoring practice with respect to sustainability is given in Table 3.2 and it combines information from Table 3.1 on the different types of practices. Each farming practice was scored in absolute terms ranging from 0 to +3 points based on the criterion.

The scoring system could be interpreted positively or negatively as: 0 = no significant impact, 0.5 = marginal impact, 1 = significant impact, 2 = strong significant impact and 3 = very strong significant impact. The five categories of farm practice represent different proportions of the total number of points available. For example if a farmer depends totally on organic sources of fertilizer that accounts for +2.5 points whereas a farmer who depends totally on synthetic fertilizer would earn -8 points for that farm practice (soil fertility).

The score for each household was calculated by multiplying the total score attributed to each farm practice in Table 3.2. Hence the index values ranged between -14.5 and 23.5 depending on each household's pattern of input use in production. A linear transformation was applied to the values calculated so that the index scores ranged between 0 and 1.

Table 3.2

Scoring practices with respect to sustainability Rigby *et al.* (2001).

Farm practice	Dimension of sustainability				Total
	Minimises off-farm input	Minimises non-renewable inputs	Maximises natural biological processes	Promotes local biodiversity	
Seed sourcing					
Impr					+0
Prev	+1	+1			+2
Soil fertility					
Synth	-1	-1	-1		-3
Org	+1			+1	+2
Comp	+1	+1		+2	+4
Pest/Disease control					
Nat		+0.5	+1	+1	+2.5
Synth	-1	-1	-3	-3	-8
Crop management					
Rotat	+0.5	+0.5	+1		+2
Inter	+1	+1	+1	+1	+4
Weed control					
Herb	-1	-1	-1	-0.5	-3.5
C&C	+1	+1	+1	+1	+4
C. Mgt	+1	+0.5	+1	+0.5	+3

3.2.3 Study area, data collection and analyses methods

Study area

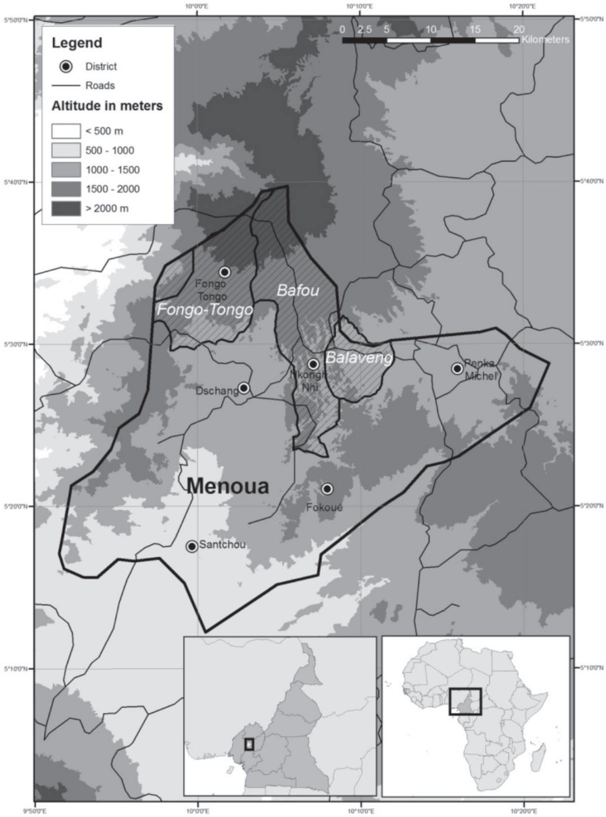

Figure 3.2
Geographical location of research site.

The study was conducted in three villages (Bafou, Baleveng and Fongo-Tongo) found in the WHC (Figure 3.2). The mean annual temperature of the region is estimated at 20°C. The average yearly rainfall is estimated at between 1000 and 2000 mm (Kay*et al.*, 1985), unimodally distributed and the average annual sunshine estimated at 2000 hours. The soils, described as the Djuttitsa soil series (Tchienkoua & Zech, 2003) are derived from trachy-basaltic materials and classified in the USDA soil taxonomy (Soil Survey Staff, 1990) as Andic Palehumult. The farming systems practices and their variations in the studied villages are assumed to be representative of the WHC. While Bafou and Fongo-Tongo villages extend to very high altitudes, Baleveng occupies mostly the low and medium altitude areas. The agricultural system in the WHC is labour intensive; hoes and machetes are the basic farm implements. Livestock comprise an integral part of the farming system, but the progressive conversion of pasture into cropland has caused a reduction in the livestock production of the average household, and so a parallel decline in the amount of manure available for improving soil fertility (Tchienkoua & Zech, 2003). Steep slopes and abundant rainfall are the norms, thus the tasks of field preparation and erosion control are uncommonly difficult for the region's many small holders. Because of high population pressure, land for food crop production is often cultivated on a more or less semi-permanent basis with about one year fallow alternating with about 2–3 years of cultivation. Land preparation often includes partial burning of weeds and residual crop biomass, and ploughing with ridges along the contour (Tchienkoua & Zech, 2003) and sometimes across the contour. It has been estimated that between 250 and 300 kg ha^{-1} $year^{-1}$ of NPK fertilizers (mostly 20:10:10) are applied by the local farmers (Fotsing, 1994).

Data collection

A survey based on interviews with 144 households was carried out in three villages: Bafou, Baleveng and Fongo-Tongo located in the WHC (Figure 3.2) in 2009, 2010 and 2011. The survey questionnaire included questions regarding many current characteristics of the farming system. The questionnaires contained variables on natural conditions, social-economic conditions, infrastructure, structure of agricultural production, inputs for agricultural production, farm output, profitability of agricultural production and farm diversity. The variables analysed in this study were: age of head of household (AHH), size of household (SHH), distance of farthest farm plot (DFF), number of irrigable farm plots (FIRR), number of sole crop species used by the farmer (SCR), number of animal species raised by the household (NAN), number of different farm tools owned by the household (NTO), number of companion crops in intercropping by the farmer (ICR), number of farm plots owned by the household (FOW), distance of the closest farm plot from the homestead (DCF), number of swampy farm plots owned by the household (FSW), average wage paid to hired workers by the farmer (AWA), fallow duration of cropland (FDU) and estimated sustainability score (SUS)

Statistical Analysis

The sustainability parameter was subjected to analysis of variance with the different villages used as the factor and mean separation at 5% probability was carried out using the Student-Newman-Keuls test. For other quantitative variables, means and standard errors were calculated. In the case of analysis of degree and sense of the relationship between qualitative variables, the corresponding contingency tables were constructed and the statistics calculated were used as the basis for the Chi-squared distribution.

Simple correlation analyses were performed for the variables collected from the study area. Groups of correlated variables (excluding sustainability score) were defined for the study site by using factor analysis. Factors were extracted with the factor procedure of the SPSS version 13 package using the principal factor analysis and the Varimax rotation method. New variables were created by standardizing and averaging selected variables from each factor for which the eigenvalues of the correlation matrix were one or greater. The basis for selecting measured variables from each factor is in partial correlation coefficients that are often referred to as factor loadings (Johnson & Wichern, 1992). The new variables are called latent variables. To study the relationships between the latent variables and sustainability score, a multiple regression model was determined for the study area. Sustainability score was the dependent variable and the latent variables were the independent variables. The model was of the form $Y = b_0 + b_1L_1 + b_2L_2 + \ldots b_nL_n + \varepsilon$, where Y represents estimated sustainability score, b_0 to b_n are coefficients, L_1, to L_n are the latent variables and ε represents residual error.

3.3 Results

3.3.1 Relationship between agricultural production variables and different villages of the WHC

The relationship between the production variables and the different villages are presented in Tables 3.3.

The production variables evaluated were types of farming, labour source, level of education of the heads of households, gender of the heads of households, major means of transportation of the heads of households, major sources of income of the heads of households and the sustainability score of the villages.

The Pearson's chi-square test indicated that the villages were not independent with regard to the labour source and means of transportation. There was a strong relationship (at 5% level of significance) between the different villages and the labour source used for production and between the villages and the means of transportation to their farms. The households of Baleveng and Fongo-Tongo depended more on family members as labour source while the Bafou households used more hired labourers. In the same light, more Bafou households used motorcycles for transportation compared to the Baleveng and Bafou villages. All the other production variables were independent of the villages (Table 3.3). The farming types, level of education, gender of heads of households and major sources of income were similar across the study sites (Table 3.3). With regard to sustainability, the sustainability score was signif-

Table 3.3

Relationship between the villages and production variables.

Variable		Village			χ^{2a}
		Bafou	Baleveng	Fongo-Tongo	
Type of farming (%)	N	47	52	45	3.04ns
Mainly crop production		51.1	34.6	37.8	
Crop and livestock production		48.9	65.4	62.2	
Labour source (%)	N	43	49	43	10.73*
Family		23.3	55.1	46.5	
Hired		23.3	12.2	20.9	
Both family and hired		53.5	32.7	32.6	
Level of education of head of household (%)	N	44	51	44	5.32ns
No formal education		4.5	7.8	4.5	
Primary		36.4	49.0	55.3	
Secondary		56.8	43.1	43.2	
Tertiary		2.3	0.0	0.0	
Gender of head of household (%)	N	47	52	45	0.88ns
Male		80.9	75	82.2	
Female		19.1	25	17.8	
Major means of transportation of head of household (%)	N	45	36	47	10.9*
Pedestrian transportation		26.7	58.7	48.6	
Motorcycle		62.2	39.1	43.2	
Motor vehicle		11.1	2.2	8.1	
Major sources of income by household (%)	N	47	52	42	0.12ns
Farming		27.7	30.8	28.6	
Farming and off-farm activities		72.3	69.2	71.4	
Sustainability score+		0.26a	0.44b	0.31a	

+Means followed by the same letter are not significantly different ($p<0.05$)

[a]*indicates significant difference at 5% probability level while ns indicates non-significant difference at 5% probability level for the different Chi square contingency table analysis.

icantly higher ($p < 0.05$) in Baleveng village than in Bafou and Fongo-Tongo villages (Table 3.3).

3.3.2 Determinants used for the factor analysis.

The mean values and the variability of the determinants selected for factor analysis are presented in Table 3.4.

Table 3.4

Descriptive statistics for the selected variables used for factor analysis in the study.

Variable	Mean	Maximum	Minimum	Standard deviation
AHH (years)	51.65	91	23	13.34
SHH	11.19	35	2	6.54
FOW	3.88	1	20	2.81
DFF (km)	4.39	0	35	5.64
FIRR	0.90	0	10	1.44
FSW	0.56	0	6	1.06
SOLE	1.53	0	7	1.75
NAN	1.74	0	4	1.13
NTOO	3.27	1	7	1.16
NINT	3.19	0	10	2.24
SUS	0.34	0.09	0.94	0.18

Some of the variables collected in the study area were very closely related and had to be eliminated after preliminary analysis.

The correlation coefficient of all pairs of the variables is shown in Table 3.5.

The highest number of correlations were recorded with the number of farm plots owned by the household (FOW) followed by the sustainability score (SUS) and the number of companion crops used in intercropping (NINT) while the least number of correlations was between the distance of the furthest farm plot from the homestead (DFF) and the other variables. The number of significant correlations in Table 3.5 suggested that a multivariate approach to data reduction was productive.

Table 3.5

Simple correlation coefficients for the variables studied in the study area

Variable	AHH	SHH	FOW	DFF	FIRR	FSW	SOLE	NAN	NTOO	NINT
AHH										
SHH	0.26**									
FOW	-0.27**	0.21*								
DFF	-0.08	-0.05	-0.01							
FIRR	-0.37**	0.03	0.32**	-0.03						
FSW	-0.01	0.06	0.33**	-0.10	0.36**					
SOLE	-0.27**	-0.04	0.13	0.04	0.35**	0.20*				
NAN	-0.09	0.21*	0.22*	0.13	0.05	0.13	0.02			
NTOO	0.14	0.17	0.10	-1.11	0.09	0.12	0.19*	0.13		
NINT	-0.05	0.20*	0.19*	-0.25**	0.06	-0.04	0.14	0.19*	0.36**	
SUS	0.28**	0.07	-0.27**	-0.07	-0.39**	-0.24**	-0.23**	-0.08	-0.17	-0.22*

*and ** represent significance at 5% and 1% probability levels respectively.

The factor analysis extracted four factors (Table 3.6) from 10 explanatory variables initially identified (see Table 3.4) with eigenvalues greater than one.

Table 3.6

Results of principal components factor analysis and varimax rotation of the first three factors.

Variable	Factor 1	Factor 2	Factor 3	Factor 4
AHH	0.09	-0.05	-0.83	-0.06
SHH	0.37	0.27	-0.45	0.32
FOW	0.18	0.59	0.21	0.35
DFF	-0.39	-0.20	0.20	0.70
FIRR	0.06	0.61	0.50	0.01
FSW	-0.06	0.86	-0.04	-0.08
SOLE	0.26	0.22	0.60	-0.05
NAN	0.25	0.18	-0.17	0.71
NTOO	0.71	0.10	-0.03	0.00
NINT	0.84	-0.08	0.14	0.05
Eigen value	1.68	1.67	1.64	1.23
% variance	16.79	16.67	16.42	12.67
% Cum. Var.	16.79	33.46	49.88	62.15

These four factors explained 62.15% of the total variance. The signs of the factor loadings provide information on how these variables relate when representing the common factor. It is observed that the most important variable in the first component is the number of companion crops used in intercropping (NINT) and its influence is positive in the component. The other important variable which exhibits a positive influence on the first component is the number of farm tools owned by the household (NTOO). The second component is positively influenced by the number of farm plots in swampy areas owned by the household (FSW), the number of total farm plots owned by the household (FOW) and the number of irrigable farm plots owned by the household (FIRR). The third component is negatively influenced both by the age of the head of the household (AHH) and the size of the household (SHH) and positively influenced by the number of crops produced under sole cropping (SOLE). The fourth factor is positively influence by the distance of the furthest farm plot from the homestead and the number of animal species raised by the household.

3.3.3 Relative importance of the factors influencing the sustainability of the farming system

Table 3.7 shows coefficients and statistics of models relating sustainability scores with the latent variables for the study area.

Table 3.7

Coefficients and statistics of multiple regression models relating sustainability with the latent variables identified for the three villages.

Intercept	Factor 1	Factor 2	Factor 3	Factor 4	R2	P>F
0.32 (0.02)[a]	-0.03 (0.02)	-0.04 (0.02)	-0.06 (0.02)	-0.02 (0.02)	0.23	0.001

[a] Numbers in parenthesis are standard errors of the estimates.

All the latent variables had negative coefficients indicating that they are all negatively related to the sustainability score.

3.3.4 Main constraints influencing agricultural production in the study area

The constraints faced by the farmers are summarized on Table 3.8.

Table 3.8

Percentage of farmers' priority of agronomic production constraints

Constraint	Bafou	Baleveng	Fongo-Tongo	χ2
Poor yield	71.1	75.5	77.8	Ns
Poor road infrastructure	55.6	36.7	68.9	**
Problems with crop pests	60.0	64.6	64.4	Ns
High cost of inputs	82.2	79.6	73.3	Ns
Low price of outputs	62.2	38.8	57.8	Ns

**significant at $p < 0.01$, ns not significant

Except for their views on road infrastructure, all the other constraints were similar for farmers in all the villages.

3.4 Discussions

3.4.1 Relationship between agricultural production variables and the different villages

Households in all the villages studied showed a similar interest in both crop and livestock production. Livestock production was valued as the second most important activity after crop production. Animals were used mainly for social events such as payment of dowry, guests' reception and ceremonies (wedding, funerals etc.). Cash crops produced were vegetable crops concentrated around the higher altitudes and irrigable lands. The most important of these crops were potatoes, cabbages, carrots, leeks, beetroots, onions, and tomatoes which were cultivated by sole cropping. The vegetable crops were principally for the market. These crops consumed huge amounts of off-farm chemical inputs (fertilizers, insecticides, fungicides, and herbicides) and employed a significant number of wage labourers for all the production stages (from land preparation to harvesting and transportation). Farmers produced an average of more than two crops a year especially where irrigation was feasible. Food crop production was concentrated at the lower altitudes and was principally produced by intercropping. The major crops found in the multiple cropping fields included maize (usually in the first season), beans, aroids, plantains, sweet potatoes, groundnut, and assorted leafy vegetables.

More wage labourers were needed in the high input vegetable production system common in the area which explained the importance of this practice in the three villages studied. Baleveng was least dependent on off-farm chemical inputs and hence the lower number of wage labourers employed. This could be due to the fact that high altitudes favourable for cool-season crops that are highly dependent on chemical inputs are not available in Baleveng. As a result farmers in Baleveng were not greatly involved in cool-season vegetable crops. Labour type and requirement in the study area depended on household size; number of farms owned and the size of adult household members. Labour is the primary instrument for increasing production within the framework of traditional agriculture. Amaza *et al*. (2009) found that fertilizer and hired labour were the major factors associated with changes in the output of food crops in the Borno state, Nigeria. In their study they found that chemical fertilizer and hired labour had significant positive effects on output. This is similar to the results of this study as the use of off-farm inputs and hired labour explain the differences among the villages studied in the same manner.

The fact that the head of many households had at least finished high school was an encouraging sign as it implied they were forward-looking and open to the idea of change. Many studies have revealed that the level of education is a factor in helping farmers to use production information efficiently (Hayami, 1969; Lockheed *et al*., 1980; Phillips, 1994; Wang *et al*., 1996; Yang, 1997). Education also influential when it comes to making use of opportunities available to improve livelihood strategies, enhance food security, and reduce the level of poverty. It affects the level of exposure to new ideas and managerial capacity in production as well as the perception of the household members on how to adopt and integrate innovations into the household's survival strategies.

Females who headed households in our research site were mostly widows. Female headship is often believed to increase the likelihood of the household being poor but World Bank data indicated that while this may be true in Asia and Latin America it is less obvious in Africa (Chant, 2003). In the WHC, many women compete well with men in nearly all activities. However the rural-urban division of labour has required women to undertake all the agricultural tasks, thus curtailing the extent to which they can participate in the labour market as also noted by Gwaunza (1998).

The Bafou farmers had an edge over the other villages in their possession of a greater number of motorbikes which facilitated their farming operations. Roads and transportation facilities are essential for the sustainability of agricultural production in Sub-Saharan Africa as it positively impacts factors such as mobility (John & Carapetis, 1991), the adoption of high yielding varieties, high productivity crops and bigger farm size (Sieber, 1999). The greater involvement and higher success in agriculture of the Bafou farmers could thus be attributed to the better transportation facilities they possessed.

The low percentage of farmers whose main occupation was agricultural is characteristic of the high number of pluriactive households in the WHC. The dependence of farm families on off-farm activities as an income source is absolutely necessary, owing to the uncertainties commonly dictated by weather, market prices and attacks by pests. In sub-Saharan Africa, it is common for some farm household members to engage in other non-farming occupations to complement their earnings from farming. A study by Herbert (1996) in Burundi reveals the need of income diversification through extra-agricultural activities to complement farming.

On the whole the sustainability scores of all the sites in our study were below average due to their reliance on off-farm non-renewable inputs and the reduction of the genetic base through sole cropping. Intensive agricultural practices carried out by most farmers in the WHC necessitates transporting the inputs which it uses from more distant sources, deriving an increasing proportion of its energy supplies from non-renewable sources, depending upon a narrower genetic base and having an increasing impact on the environment. This is particularly reflected in its heavy reliance on chemical fertilizers, and pesticides, exploitation of vulnerable lands in the cultivation of the vegetable cash crops in the region, all of which contribute to environmental pollution, habitat destruction and risks to human health and welfare as observed by Hodge (1993). Amongst the three villages studied, a significantly higher sustainability score was recorded by the Baleveng village owing to the absence of high altitude areas favourable to the intensive off-farm dependent crop production system common in the Bafou and Fongo-Tongo villages. As such, farmers in Baleveng village relied less on off-farm inputs because a majority of the farmers practiced intercropping where annidation or complementarity provided appropriate growing conditions (Trenbath, 1976). Intercropping has been an agricultural practice for thousands of years (Kass, 1978), which testifies to its level of sustainability. Ofori and Stern (1987) suggested that intercropping was more efficient than mono-cropping in the exploitation of limited resources. Food challenges will be met using environmentally friendly and socially equitable technologies and methods, in a world with a shrinking arable land base (which is also being diverted to produce biofuels), with less and more expensive petroleum, increasingly limited supplies of water and nitrogen, and within a scenario of a rapidly changing climate, social unrest, and economic uncertainty (IAASTD, 2009). The only agricultural system that will be able to confront future challenges is one that will exhibit high levels of diversity, productivity, and efficiency.

3.4.2 Determinants associated with the farming systems of the WHC

There were various degrees of correlation among the determinants associated with the farming systems of the WHC. The sustainability score in the whole research area was negatively related to the number of farms owned by households (FOW), the number of irrigable plots owned by households (FIRR), the number of farm plots in swampy areas (FSW), the number of crops used in sole cropping (SOLE), the number of companion crops used in intercropping (NINT) and positively related to the age of the head of household (AHH). This indicated that the older heads of households carried out more sustainable farm practices with respect to seed source, soil fertility, crop management, pest and disease control and weed control. Household characteristics are thus important determinants of the farming system. However, Rougoor *et al.* (1998) found that the influence ofthe age of the head of the household on farm productivity was very diverse. Other studies found that age had a positive effect on productivity (Kalirajan & Shand, 1986; Stefanou & Sexena, 1988) while Adubi (1992) revealed that age, in correlation with farming experience, had a significant influence on the decision making process of farmers with respect to risk aversion, adoption of improved agricultural technologies, and other production-related decisions. Age has been found to determine how active and productive the head of the household would be. It has also been found to affect the rate at which households adopted innovations, which in turn, affects household productivity and livelihood improvement strategies (Dercon & Krishnan, 1996). All the determinants that had negative relations with the sustainability score are linked directly or indirectly to either dependence on off-farm agrochemical inputs or soil mining. Increasing numbers of companion crops (NINT) leads to less sustainability because of the intensity of land use over space by the high density of species with varied requirements as also noted by Fasching (2001).

3.4.3 Influence of the determinants on sustainability

After factoring the correlation matrix by the principal component method, the first four factors explained 62.15 % variation. The first latent variable had high loadings with the number of farm tools used by the household (NTOO, 0.71) and the number of companion crops used in intercropping (NINT, 0.84). This means that both NTOO and NINT lie near the first axis. The first axis was termed *land use intensity over space* because it is most correlated with components that have to do with land use in space. The second axis was most correlated with practices that require high off-farm inputs for intensive production (FOW, FIRR, FSW); overall this axis appears to measure *the intensity of off-farm inputs*. The third axis (*household adjustment factor*) was most correlated with components that influence the household (AHH, SHH) lying near the third axis, and the number of sole crops used by the household (SOLE) lying on the opposite end of the third axis. The fourth axis was most correlated with components that have to do with the movement of the household(DFF) and the number of animals produced by the household (NAN); overall this factor appears to measure the *mobility of the household* owing to the fact that animal production is not very intensive in the area.

All the latent variables had negative correlations with the sustainability score. The negative sign for the land use intensity characterised by "plant biodiversity" (NINT) seems agronomically unreasonable as it should not decrease sustainability since it implements many different functions such as biomass decomposition, nutrient cycling, soil structure enhancement, pest regulation, pollination, detoxification, local hydrological process regulation and macroclimate control (Altieri, 1999). Having less diversity than needed can eventually lead to production and profitability problems. Adding more diversity than needed can reduce efficiency since it increases the number of crops that must be managed, handled, and marketed (Fasching, 2001). This explains why increasing the number of companion crops in intercropping will decrease sustainability. Though intercropping is envisaged as a contributor to sustainability, human efforts are required to make this happen. The suggested advantages of the intercropping system include yield stability under adverse environmental conditions, efficient use of limited growth resources, biological diversity, and potential control of pests and diseases. Many studies have shown that intercropping systems out yielded sole cropping systems of component crops (Baumann *et al.*, 2001; Lesoing & Francis, 1999; Ghaffarzadeh *et al.*, 1997; Fortin*et al.*, 1994; Mandal *et al.*, 1990).

The negative relationship between the intensity of off-farm inputs and sustainability should be obvious. Intensification and concomitant increased use of inputs in agricultural production has led to environmental pollution and low quality products (Rahman & Thapa, 1999). In order to combat this,efforts are now required to minimise off-farm inputs in order to guarantee the sustainability of farming systems. Sustainable agriculture is often viewed as low input and regenerative (Lockeretz, 1989; Reijntjes *et al.*, 1992), making better use of the farm's internal resources through the incorporation of natural processes into agricultural production and the greater use of knowledge and skills of farmers to improve their self-reliance and capacities.

The household adjustment factor had a negative relationship with sustainability. This latent variable was characterised by a negative sign for both the age of members of the household and size of the household. Taking this into account, it would mean that these components of the household adjustment factor have positive relationships with the sustainability score given that the product of two negatives is positive. The findings of this study thus suggest that sustainable farming practices in the research area are executed more by more populated households and households headed by older people. Many studies have shown the positive correlation between age and environmentally friendly agricultural practices. In Mexico, age was found to play a significant role in determining how much diversity farmers maintain. Almost 50% of the farmers growing significant numbers of traditional cultivars were over 56 years (Morales & Quinones, 2000). Wakeyo and Gardebroek (2013) postulated that in developing countries, households allocate financial resources to buying inputs after putting aside a minimum amount for household food, especially when there is a credit constraint. As such, some households exhaustively consume their harvest and are later constrained to buy inputs such as fertilizer. This attitude is positively related to the size of the household which explains the dependence on natural resources for farming by more populated household and hence the positive relationship between sustainability and the size of the household shown by the results of this study.

With respect to the mobility component, the results of this study suggest that farmers whose farm plots are furthest from their homestead carry out less sustainable practices. This can be justified by the fact that suitable farming areas for the important cash crops of the area are located at high altitudes which are further from the homestead. The method of production of these cash crops require intensive use of agrochemical and improved seeds all of which are negative contributors to sustainability based on our assumptions. Generally crop diversity decreases with the distance of the farm plots from the homestead. In Ethiopia, Deribe (2000) showed that sorghum diversity was related to distance from the homestead: the nearer the plot to the homestead, the larger the number of varieties grown. The use of locally adapted cultivars is usually associated with limited chemical inputs and these can also serve to maintain ecosystem health and improve soil structure (Vandermeer, 1995; Wood & Lenné, 1999). Cultivars adapted to particular micro-niches are often one of the few resources available to resource-poor farmers to maintain or increase production from their fields (Jarvis *et al.*, 2000).

3.4.4 Main constraints that influence agricultural production of the area

All farmers make decisions in a complex environment in which broad contextual factors, such as markets, public policies (including regulation), and social institutions, create opportunities but also create barriers to change. With regard to farmers' priorities, households in the Baleveng village did not consider the road infrastructure as a problem simply because the tarmac road connecting the division and the region cuts across the centre of the village. This makes it fairly easy for inhabitants to move compared to other villages where the transportation of people and goods is sometimes impracticable especially in the rainy season. The problems related to poor yields and crop pests may be linked to a lack of information on improved technology. If agricultural productivity is to grow in Africa, research and extension services need to develop and disseminate science-based information about improved technologies that address the resource constraints and risks faced by the majority of Africa's farmers (Snapp *et al.*, 2003). Agricultural advisers are few and far between in the WHC which explains many of the farmer's problems. There is a need to upgrade the researcher-agricultural adviser-farmer network in the WHC. Limited adoption of recommended technologies must be expected if there is a poor connection between research, technical advisers and African smallholders (Meertens, 2003). Cameroon and many other countries have removed subsidies on fertilizers since the collapse of the coffee and cocoa markets making their affordability extremely difficult for small scale farmers. Integration of crops and livestock can lead to more efficient use of land unsuitable for crop production. It can provide a use for crop residues and by-products, provide manure, and provide a source of income, savings, and investment.

The significance of household size in farming hinges on the fact that the availability of labour for farm production, the total area cultivated for different crop enterprises, the amount of farm produce retained for domestic consumption and the marketable surplus, are all determined by the size of the farm household (Amaza *et al.*, 2009). Increasing dependence on hired labour in our study site was due to the decreasing size of households influenced by rural-to-urban migration.

3.5 Conclusion

With respect to the different variables that determine agricultural production, the results of this study show that each of the different villages studied, have much in commom can benefit equally from the same improved technologies and recommendations. Research needs to address land use intensity, off-farm inputs intensity, household adjustment factors and the mobility of the household. Common features of the farming systems in WHC are that they manage natural and economic resources and conditions that vary in time, with limited production alternatives while facing relatively low profit. Both the variation in farming systems and the common characteristics of farms lead to uncertainties about the effectiveness of decisions, from a farmer's and from a policy perspective. In spite of rapid social change, traditional hierarchical structures still influence village life so village leaders should be involved in the introduction of agricultural change. Agriculture that is truly sustainable will not mean business as usual. It will be a type of agriculture that will provide environmental, economic and social opportunities for the benefit of present and future generations, while maintaining and enhancing the quality of the resources that support agricultural production. This will not place the emphasis on maximizing yields and economic returns, but will rather focus on optimizing productivity and conserving the natural resource base. Well designed intercropping systems and the use of natural organic resources as sources of plant nutrients would benefit and satisfy both the producers and consumers in the system. Intercropping is the intensification of land and resource use in the space dimension. This can lead to: enhanced efficiency of incident light use with two or more species that can occupy the same land area and have different patterns of foliage display; different rooting patterns can explore a greater soil volume with roots of different depths; competition with weeds from a combination of species occupying two or more niches in the cropping environment can effectively reduce weed germination; a mixture of crops can provide a buffer against losses to plant diseases. In order to fill in the gaps in our understanding of the effects of emerging farming systems on sustainability in WHC, there is a real need for system-level (holistic-whole-farm approach) studies for a more detailed picture of the situation.

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