CURRENT WORLD ENVIRONMENT

ISSN: 0973-4929, Vol. 17, No. (1) 2022, Pg. 99-112

Current World Environment

www.cwejournal.org

Agroforestry as an Agro-Ecological Pathway to phase-out chemical Fertilizer Application in Smallholder Farms in Cameroon: State-of-the-Art and Policy Implications

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Abstract

Man and ecosystems are highly threatened by the abusive application of chemical fertilizers in a bid to enhance soil fertility and improve crop productivity. These chemical fertilizers pose serious health risks to farmers and the population at large and contribute to short and long-term soil degradation. Thus, this study was initiated to examine how agroforestry can contribute towards phasing out chemical fertilizers application in smallholder farms in the south west region of Cameroon. Data collection was done from secondary and primary sources and analyzed using inferential and descriptive statistics. Microsoft Excel 2013 and SPSS version 17 were used to run the descriptive and inferential statistics. It was found that silvopastoral, agrosilvopastoraland agrosilvicultural systems were the most dominant agroforestry systems,with different agroforestry practices like coffee-based agroforestry plantations, cut and carry fodder, home gardens, trees/shrubs on farmlands, cocoa-based agroforestry plantations, live fences, improved fallows and home gardens with livestock characterizing these three agroforestry systems. These agroforestry systems provided different ecosystem services to agroforestry practitioners with the most common being food, fuelwood, finance/income, and climate moderation. Besides food and soil fertility enhancement, very limited or no chemical fertilizer was used to obtain the other ecosystem services. There was an inverse relationship ($p<0.05$) between ecosystem services of agroforestry systems and chemical

Article History
Received: 10 April 2021
Accepted: 18 December 2021

Keywords
Agroforestry;
Cameroon;
Chemical Fertilizer;
Ecosystem Services;
Farmers;
Soil Fertility.

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Doi: http://dx.doi.org/10.12944/CWE.17.1.9

fertilizer application, demonstrating that chemical fertilizers are not needed to enhance the ecosystem services of agroforestry systems. There was equally an inverse relationship ($p<0.05$) between agroforestry systems and chemical fertilizer application, indicating that farmers' practice of agroforestry reduces chemical fertilizer application on farms. Agroforestry is therefore recommended as a sustainable pathway to limit and/or eradicate farmers' application of chemical fertilizers.

Background

Declining fertility of the soil is a major challenge to agriculture worldwide.[1,2,3,4] Studies have shown that a direct relationship exists between crop productivity and soil fertility.[5,6] This implies that crop yields increase as soil fertility increases and decline as soil fertility declines – all with major implications on food security.[7,8] Kopittke *et al*.[9] demonstrated that the application of chemical fertilizers on hybrid crop varieties could raise crop productivity by three to five times. Although this approach has helped to increase crop yields in Asia and Western countries in particular and other parts of the world in general, it has suffered from a lot of setbacks. These setbacks have been caused by factors such as the high cost of producing and purchasing fertilizers, as well as the high rate of environmental degradation caused by the application of chemical fertilizers.[8,10] Other setbacks have included declining yields even after the application of chemical fertilizers owing to deficiencies in micronutrients or physical degradation of the soil. Moreover, most farmers are poor and simply cannot afford to purchase fertilizers and other inputs.[1] Even farmers who have resorted to using chemical fertilizers have found that their crop yields increase only after they have spent a lot on chemical fertilizers.[10] On the basis of economic analysis, this type of agricultural system (depending a lot on chemical fertilizers) cannot besustainable or profitable.[10,11,12,13] There is therefore the need for suitable cultivation methods that will increase crop yields while decreasing inputs (especially chemical fertilizers) which will go a long way to improve the natural fertility of the soil.The use of nitrogen fixing and fast growing trees in agroforestry systems could contribute enormously towards increasing biomass and organic matter content in the soil which goes to increase soil fertility.[7,8,10,13] This is because tropical soils for example, in most cases lack nitrogenwhich is an essential element for crop growth and productivity.[10]

The former practice of increasing nutrient deficiencies by simply adding mineral fertilizers to the soil has given way to the new approach of integrated fertility management because liming and appropriate fertilization are constrained by socio-economic aspects in tropical Africa forcing developmental research innovations oriented towards better use of local nutrient sources.[2,10,14,15] To improve the fertility of the soil as well as its capacity to improve productivity and support crop growth, there is absolute need to implement more integrated soil fertility management practices. The double impact of this approach is to support micro and macro-nutrients for crop growth and build up the soil'snutritional status.[7] Soil erosion has continued to be a major driver of soil infertility in the tropics. Coupled with other environmental threats like climate change, soil erosionhas serious repercussions on farmers especially on crop yields– which have been declining consistently.[7] Climatic elements like rainfall and wind are the major drivers of soil erosion. Wind and rainfall are the main climatic elements that influence soil erosion.Energy coming from rainfall or wind sets in motion different processes that drive erosion.[7] Soil erosion and leachinglead to the depletion of vital soil nutrients like phosphorus (P) and nitrogen (N) as well as potassium.[16]

Continuous crop cultivation especially in areas prone to population pressure has led to declining soil fertility resulting from soil degradation or natural loss of the soil. Continuous cropping (with short or no fallow periods) also reduces exchangeable Ca and Mgas well as pH levels in soils tremendously.[14,16] For farmers to continuously cultivate their farmlands, they mustimplement sustainable practices capable of rendering the soil fertile all year round even if they cultivate. Soil acidification, loss of soil organic matter and compaction have been singled out as the main causes of declining crop yields under continuous cultivation.[16] Studies have also shown that tillage practices associated with continuous cropping trigger a rapid drop in soil organic matter.[14] Complex interactions between physical, biological and chemical components of the soil determine the productive capacity of soils. The interaction of these different components ensures a suitable balance between soil organic matter, soil microbial activities and soil structure.[14] Soil decline apart from erosion is directly linked to a drop in soil humus when fertilizers are in appropriately used.[15] Another cause of the fall in crop yields is low farm inputs, and poor farm practices that lead to the loss of soil macro and macro-organisms which help to aerate the soil and make it more fertile.[17] Farmers lack enough capital to procure good farm inputs and this also leads to poor yields.[18] Thus, farmers need to apply agricultural practices that will conserve and increase the little available nutrient levels in the soil.

Agroforestry has been proven by different studies as having the capacity to ameliorate soilfertility while contributing towards crop productivity enhancement.[1,8,11,13] This implies that, ceteris paribus, agroforestry practicing farmers make use of limited chemical fertilizers than non-agroforestry practicing farmers. At present, there is limited literature examining the role agroforestry can play towards reducing chemical fertilizer application in smallholder farming systems. Thus, this study sought to provide answers to some burning questions that have remained unanswered. To do this, some attainable objectives were set which were: to identify different agroforestry systems and their associated practices; to identify ecosystem services of different agroforestry systems; to examine the relationship between ecosystem services and chemical fertilizer application; and to assess the relationship between agroforestry practice/non-practice and chemical fertilizer application. The main hypothesis of the studyis that agroforestry contributes towards reducing chemical fertilizer application on farms due mainly to the myriad of ecosystem services of agroforestry systems.

Methodology

Study area

The study was carriedout in Cameroon –more precisely in Mbelenka, Lebialem division, South-West Region of Cameroon (Figure 1). This area lies longitudinally and latitudinally between 10° 2'E to 10° 4 E and 5° 37' to 5° 39 N respectively. Climatically, there are two main seasons – the wet/rainy season between April and October and the dry season between November and April. The mean annual temperature is 18°C although temperaturein the months of December to January sometimes go below 18°C.[19] Savannah grassland is the most dominant vegetation interspersed with xerophytic tree species.[13] The area is equally drained by different streams and rivers which take their rise from the surrounding hills. Mbelenka is inhabited mainly by the Bangwa people who are a major ethnic group in Cameroon.[13]

Agriculture is the backbone of the local economy.[13,20] As the main economic activity of the environment, traditional agricultural practicesthat were often practiced have been modernized. This explains why people in this area no longer cultivate for personal consumption but for commercialization. It is because of this that there are small, medium and large scale farms. The involvement of these peasants in agro-pastoral activities has enabled the creation of many common initiative groups and a cooperative society known as "M'mock Union of Potato Producers and Seed Multiplication" (MUPPSEM) that facilitates access to potato seeds and aid from the government. The potato subsector program also offers technical assistance and inputs to farmers through these common initiative groups. Potato is grown mainly in the sole cropping system by farmers.

Crops like carrots, onions, leeks and garlic are harvested and commercialized without keeping seeds. For potato, farmers always select bigger ones for commercialization while the average and smaller ones are kept for seeds.

Mbelenkahas an undulating topography made up of hills, valleys and gentle terrain with an average elevation of 2200 m. There are recurrent landslides owing to the hilly nature of the environment.[19] The soils are mostly made up of mollisols and andosols which by nature are supposed to be very fertile. However, due to the recurrence of soil erosion and leaching, the soils have completely lost their fertile nature – leading to a decline in crop productivity. The high elevation of Mbelenka fosters cool weather conditions which favour market gardening crops. Market gardening in Mbelenka is largely done through chemical fertilizers and pesticides application.

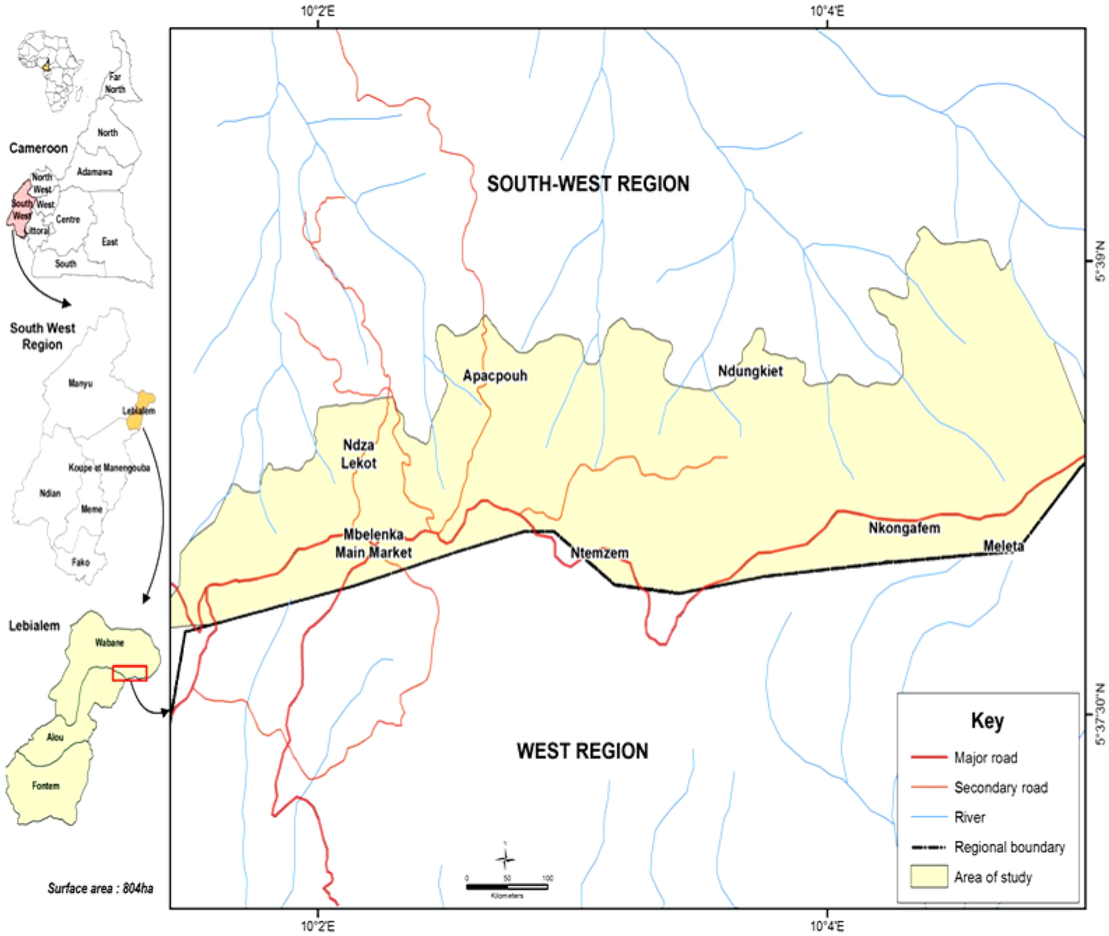

Fig. 1: Map showing location of the study area

Although Mbelenka lies in the transitional area between the savannah grassland and the forest zone – having characteristics of both vegetation types, grassland savannah vegetation predominates. With the increasing population in Mbelenka,the limited forest found in the area has been cleared giving way to grassland vegetation which has severe repercussions on the hydrographical network of the area – which has decreased sharply leading to water scarcity.

The population ofMbelenka is diverse with the Bangwa people in the majority. Other ethnic groups living in Mbelenka include: the Bamileke, the Mundani, and the Mbororos who lead a nomadic lifestyle. TheBangwaare the natives of Mbelenka and oral history hold that they migrated from the forest zone of Cameroonand settled in the Mbelenka area. Other ethnic groupshave equally migrated and settled in the areadue to the huge agricultural potentials found in Mbelenka. There is peaceful co-existence between the different ethnic groups living in Mbelenka.

Sampling and Questionnaire Design

Following an exploratory investigation, two of the major clans in Mbelenka (M'Muock-Leteh and M'Muock-Fossimondi) were selected purposively owing to the presence of different agricultural systems in the area especially agroforestry as well as their reputation for high crop productivity and rapidly depleting soils. After the purposive selection of these two clans, six villages were selected from both clans with the help of extension officials based in these communities (i.e. three villages per clan). Using semi-structured questionnaires, household surveys were conducted in thesix selected villages. These household surveys were complemented through interviews withkey informants and focus group discussants. Questionnaires were designed to attain the study's objectives. The main data collected were on different chemical fertilizers applied by farmers on their farms, the frequencyand rate of application of chemical fertilizers by farmers on their farms, the impact of chemical fertilizer applicationon ecosystem services of agroforestry; and the link between chemical fertilizer application and farmers' agroforestry/non-agroforestry practice.

Collection and Analysis of Data

To identify the different farming practices in Mbelenka especially the different agroforestry systems and the plausible factors influencing soil fertility decline (e.g. soil erosion), direct field observations were carried out. In each of the six villages (Ntemzem, Ndungkiet, NdzaLekot, Meleta, Nkongafem and Apacpouh) found in the M'Muock-Leteh and M'Muock-Fossimondiclans of Mbelenka, focus group discussions were conducted. This was done with the assistance of key informants (quarter heads/chiefs) as well as agricultural extension officials working in these villages. The identification of resourceful farmers for interviews, as well as other key informants (agricultural extension officials and engineers and other major agricultural/environmental stakeholders in the community) was done during focus group discussions which allowed the researcher and his team to get a general overview of the situation in Mbelenka as far as chemical fertilizer use, agroforestry practices, and levels of soil fertility of the soils are concerned. In the six villages, six focus group discussions were conducted and interviews were conducted with 26 key informants. Longevity in agricultural activities especially agroforestry practices as well as the degree of expertise/knowledge in agroforestry, ecosystem services of agroforestry and chemical fertilizer application were the main bases for choosing key informants.

Concerning household surveys, semi-structured questionnaires were administered to farmers (i.e. 120 questionnaires to 120 farmers made up of 48 men and 72 women) in the six villages chosen for study. The questionnaires administered per village were in direct proportion to the population size of that village. Mostly women were surveyed because farming activities are largely carried out by the female folk. In the two aforementionedclans of Mbelenka where the study was carried out,we administered sixty semi-structured questionnaires in each of the two clans giving a total of 120 questionnaires. The questionnaire was designed to acquire information on the soil fertility level in the area; typology of agroforestry systems and practices, chemicalfertilizers applied; frequency and rate of application of chemical fertilizers; impact of chemical fertilizer application on ecosystem services of agroforestry; and the relationship between chemical fertilizer application and agroforestry practice/non-practice.

Data obtained from the field was coded and imputed into the Statistical Package for Social Sciences (SPSS version 17.0) as well as Microsoft Excel 2013 spreadsheets for inferential and descriptive analysis. Percentage indices and frequency tables were the main descriptive statistics while inferential statistics were Spearman rank correlation, Kruskal-Wallis test statisticand regression analysis. Kruskal-Wallis test statistic analyzed the level of variation in ecosystem services and chemical fertilizer application across different agroforestry systems while correlation and regression analyzed the direct and inverse relationships existing between explanatory variables and farmers' application of mineral fertilizers.

Results and Discussion

Results

Agroforestry Systems and Associated Practices

From the analysis of empirical data, it emerged that, three agroforestry systems (agrosilvicultural, silvopastoral and agrosilvopastoral) were predominant. Each of these agroforestry systems had different practices (Figure 2). For the agrosilvopastoral system, there were two practices (home garden with livestock, and fodder trees/shrubs on croplands) with the most common practice being home garden with livestock (60%). For the silvopastoral system, two main practices (trees on pastureland, and cut and carry fodder) were the most dominant, with the most common practice being cut and carry fodder (10%). The agrosilvicultural system had the highest number of practices (shrubs/trees on croplands, coffee-based plantation, home garden, live fences, improved fallows, windbreaks, slash and burn, cocoa-based plantation) with the most common practices being shrubs/trees on croplands

(40%), home garden (30%), coffee-based plantation (20%), live fences (20%), and the cocoa-based plantation (15%).

Agroforestry systems are therefore made up of diverse practices with the agrosilvicultural system having the greatest number of practices.

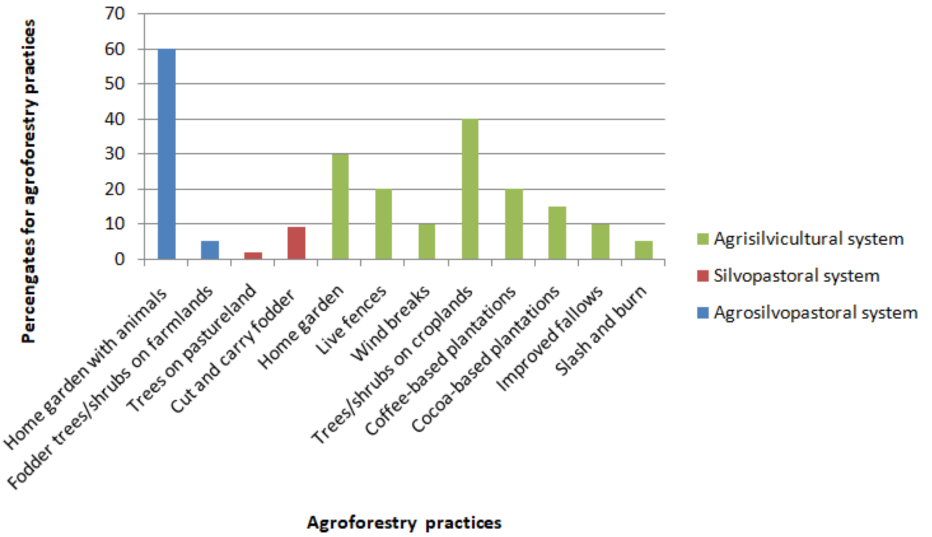

Fig. 2: Agroforestry systems and associated practices

Ecosystem Services of Agroforestry Systems

The different agroforestry systems provided diverse ecosystem services to farmers (Figure 3). The agrosilvopastoral system provided mainly ecosystem services such as food (100%), fuelwood (60%), soil fertility enhancement (70%), traditional medicines (60%), finance (100%), erosion control (50%), and climate moderation (60%). The silvopastoral system on its part provided mainly ecosystem services like fodder (80%), food (40%), finance (40%), and climate moderation (50%). The agrosilvicultural system provided mainly ecosystem services like food (100%), income/finance (70%), climate moderation (70%), erosion control (60%), fuelwood (50%), soil fertility improvement (50%), building materials (40%), traditional medicines (50%), and protection from wind (50%).

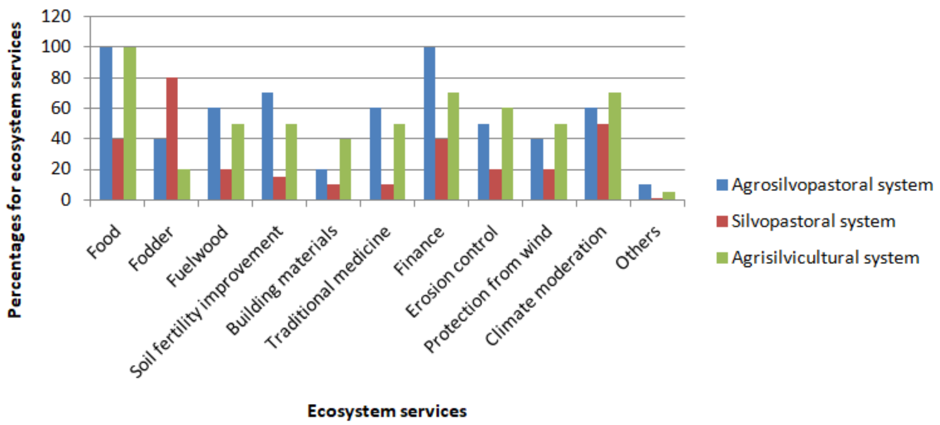

Fig. 3: Ecosystem services of agroforestry systems

Thus, the most common ecosystem services farmers derive from the three agroforestry systems were food, fuelwood, finance, and climate moderation.

Table 1: Ecosystem service variation between agroforestry systems

Agroforestry system	H-test statistic	p-level
Agrosilvopastoral Silvopastoral Agrosilvicultural	127.645	0.000*

* Significant at 5% probability level

Variation in Ecosystem Services between Agroforestry Systems

The H-test (Kruskal-Wallis test statistic) showed the existence of high levels of variation in ecosystem services between different agroforestry systems. Statistics from the H-test ($X2= 127.645$, $p<0.05$), indicated that, ecosystem services provided by the agrosilvopastoral, silvopastoral, and agrosilvicultural systems varied tremendously (Table 1).

Quantity of Fertilizer used to Obtain Ecosystem Services

Based on empirical data analysis, it was found that, apart from some ecosystem services including food, soil fertility enhancement, and finance wherein over 40% of agroforestry practicing farmers used moderate to little amounts of chemical fertilizer, for other ecosystem services such as fodder, fuelwood, building materials, indigenous/traditional medicines, erosion control, windbreak/protection from wind, climate moderation, and others such as crop pollination, over 80% of the agroforestry practicing farmers used no chemical fertilizer (Figure 4). This goes to show that, to obtain ecosystem services from agroforestry systems, there is little or no need to use chemical fertilizers.

Relationship between Ecosystem Services of Agroforestry and Chemical Fertilizer Application

Ecosystem services of agroforestry systems and chemical fertilizer application on smallholder farmshad a significant relationship (Table 2). For ecosystem services likefood, soil fertility enhancement, and finance, there was a significant direct relationship between these ecosystem services and the use of chemical fertilizer. Mean while for ecosystem services like fuelwood, fodder, building materials, traditional medicines, erosion control, protection from wind and climate moderation, there was a significant inverse relationship between these ecosystem services and agroforestry farmers' use of chemical fertilizer. Thus, most of the ecosystem services of agroforestry systems have an inverse relationship with the application of chemical fertilizers on agroforestry practicing farmers' farm plots.

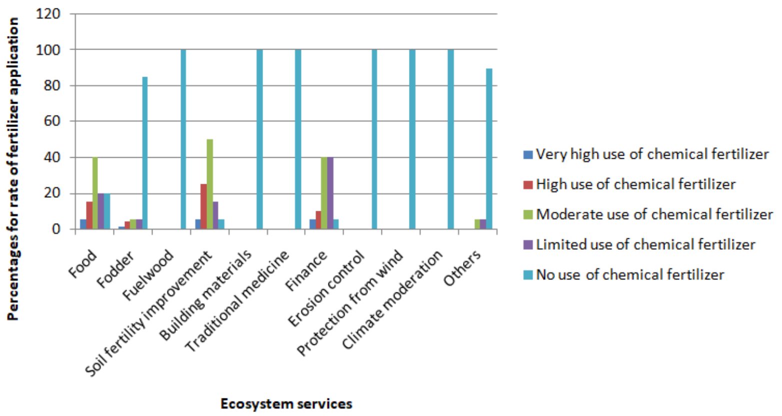

Fig. 4: Fertilizer use for different ecosystem services of agroforestry systems

Agroforestry Systems and Chemical Fertilizer Application

Chemical Fertilizer Application In Different Agroforestry Systems

Agroforestry practitioners made either little or no use of chemical fertilizer in their farm plots (Figure 5). Most farmers practicing the agrosilvopastoral system (75%) and the agrosilvicultural system (60%) made very limited use of chemical fertilizer meanwhile most farmers practicing the silvopastoral system (85%) made no use of chemical fertilizer. For all the three agroforestry systems, very few farmers (less than 10%) made high use of chemical fertilizer.

Variation in Chemical Fertilizer Use Between Agroforestry Systems

For the three agroforestry systems, there was no significant variation in the quantity of chemical fertilizer used (Table 3). The H-test statistic (X2 = 7.284, $p<0.05$) was statistically insignificant, implying that, the quantity of chemical fertilizer used was almost the same across all three agroforestry systems.

Relationship between Agroforestry Systems/ Practices and Chemical Fertilizer Application

Agroforestry systems/practices and farmers' application of chemical fertilizer had a relationship (Table 4). For the agrosilvopastoral system, there was a significant inverse relationship between two agroforestry practices (home garden with livestock and fodder trees/shrubs on farmlands) and farmers' application of chemical fertilizer. For the silvopastoral system, there was a statistically significant inverse relationship between two main agroforestry practices (trees on pastureland, and cut and carry fodder) and farmers' application of chemical fertilizer. Concerning the agrosilvicultural system, there was on the one hand, a significant direct relationship between three agroforestry practices (live fences, windbreaks, trees/shrubs on croplands) and farmers' application of chemical fertilizer; and on the other hand, a statistically significant inverse relationship between five agroforestry practices (cocoa-based plantation, home garden, improved fallows, slash and burn, and coffee-based plantation) and farmers' application of chemical fertilizer.

Table 2: Relationship between application of chemical fertilizerand different ecosystem services of agroforestry systems

Ecosystem service	r	p-value	β	p-level
Food	0.827*	0.027	1.731*	0.000
Fuelwood	- 0.659*	0.039	- 0.844*	0.019
Fodder	- 0.714*	0.042	- 0.932*	0.008
Soil fertility enhancement	0.858*	0.019	1.946*	0.000
Finance	0.688*	0.048	0.825*	0.026
Building materials	- 0.745*	0.044	- 1.374*	0.000
Indigenous/Traditional medicine	- 0.741*	0.046	- 1.286*	0.000
Erosion control	- 0.692*	0.049	- 1.055*	0.000
Windbreak/Protection from wind	- 0.806*	0.018	- 1.349*	0.000
Climate moderation	- 0.892*	0.007	- 1.711*	0.000
Intercept			- 9.174*	0.000
Pseudo R^2			0.531	

* Significant at 5% probability level

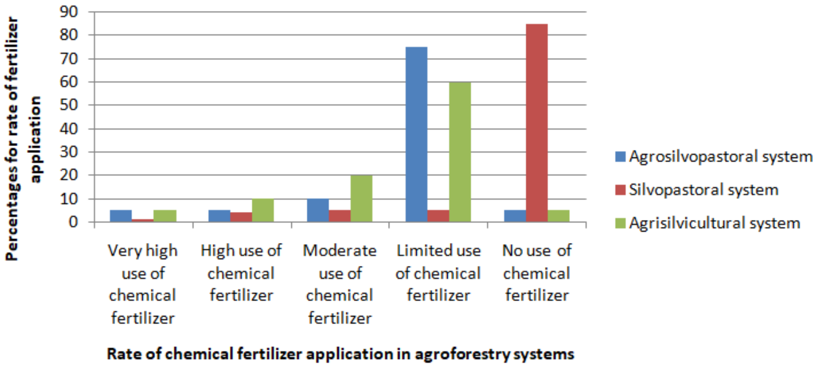

Fig. 5: Use of chemical fertilizers in different agroforestry systems

Table 3: Variations in chemical fertilizer use between agroforestry systems

Agroforestry system	H-test statistic	p-level
Agrosilvopastoral Silvopastoral Agrosilvicultural	7.284 ns	0.391

ns Not significant at 5% probability level

On the whole, there was an indirect relationship between farmers' agroforestry practices and chemical fertilizer application.

Discussion

Agroforestry Systems and Associated Practices

Silvopastoral, agrosilviculturaland agrosilvopastoral systems were the most common systems practiced by agroforestry practitioners. These systems were made up of different agroforestry practices with the agrosilvicultural system having the highest number of practices.Agroforestry systems have generally been classified based onsocio-economic characteristics,structure, function, and ecology into several types of systems.[11,21] However, this study found three main types of agroforestry systems i.e. agrosilvicultural, silvopastoral and agrosilvopastoral. Although, studies have found that agroforestry is made up of different practices,[8,13,22,23] this study went further by categorizing the different agroforestry practices based on the agroforestry system in which they belonged, and it was found that agroforestry practices classified under the agrosilvicultural system were the most widespread.

Table 4: Relationship between chemical fertilizer application and different agroforestry systems/practices

Agroforestry system/practice	r	p-value	β	p-level
1. Agrosilvopastoral system				
1.1. Home garden with livestock	-0.984	0.000	- 2.391	0.000
1.2. Fodder shrubs/trees on farmlands	- 0.691	0.004	- 0.758	0.008
2. Silvopastoral system				
2.1. Trees on pasturelands	- 0.732	0.001	- 0.542	0.043
2.2. Cut and carry fodder	- 0.110	0.478	- 0.026	0.779
3. Agrosilvicultural system				
3.1. Home garden	- 0.744	0.001	- 0.996	0.003
3.2. Live fences	0.692	0.002	0.632	0.028
3.3. Windbreaks	0.791	0.001	0.529	0.039
3.4. Trees on croplands	0.514	0.003	0.314	0.049
3.5. Coffee-based plantation	- 0.908	0.000	- 1.439	0.000
3.6. Cocoa-based plantation	- 0.919	0.000	- 1.571	0.000
3.7. Improved fallows	- 0.987	0.000	- 2.498	0.000
3.8. Slash and burn	- 0.859	0.000	- 1.536	0.000
Intercept			- 8.172	0.000
Pseudo R^2			0.501	

Ecosystem Services of Agroforestry Systems

Agroforestry systems have been found to provide a plethora of ecosystem services to agroforestry practitioners some of which include fuelwood, food, finance, fibre, building materials, medicines, carbon sequestration, soil fertility enhancement, erosion control, protection from violent storms, climate moderation and many others.[8,13,17,21,22,23,24,25,26,27] However, this study categorized the ecosystem services provided according to the different agroforestry systems where it was found that, the agrosilvopastoral system provided the greatest number of ecosystem services which could be as a result of the many components found in the agrosilvopastoral system (trees/shrubs, crops, and livestock) compared to the other two systems (agrosilvicultural and silvopastoral systems). The most common ecosystem services in all three agroforestry systems were food, fuelwood, finance and climate moderation which could be due to the ever present tree/shrub component in all the systems.

Variation In Ecosystem Services between Agroforestry Systems

Variations in ecosystem services between the three agroforestry systems were found to be high. This could be attributed to the differences in components between the three agroforestry systems. For example, while the agrosilvopastoral system has three components (trees/shrubs, crops and livestock), the silvopastoral (trees/shrubs and livestock/pasture), and the agrosilvicultural (trees/shrubs and crops) systems had just two components. This variation in the number of components could be the reason for the variations in the number of ecosystem services provided by the different agroforestry systems. Most studies,[17,22,23,24,27,28] have simply shown that agroforestry provides ecosystem services without assessing variation in ecosystem services among different agroforestry systems, which has been done in this study.

Quantity of Chemical Fertilizer Applied to Obtain Different Ecosystem Services

Chemical fertilizer application is very widespread among non-agroforestry practitioners owing to the desire to enhance soil fertility and increase crop yields.[14,15,29,30,31,32] Studies have equally shown that, most of the non-agroforestry practitioners are market gardeners who cultivate vegetables, spices, and some food crops like potato mainly for commercial purposes[33,34,35,36,37,38] and thus apply huge quantities of chemical fertilizer in order to improve crop yields. However, in the case of agroforestry practitioners, it was found that some used chemical fertilizers in moderate quantities to improve soil fertility and enhance crop yields. However, for other ecosystem services, there was no need to use chemical fertilizers in order to obtain these ecosystem services. This goes to show that agroforestry systems have potentials to self-regulate and provide many ecosystem services owing to better nutrient cycling within the system when compared to other systems such as sole cropping.

Relationship between Ecosystem Services of Agroforestry and Chemical Fertilizer Application

From correlation and regression analysis, there was mainly an inverse relationship between different ecosystem services and the application of chemical fertilizers on agroforestry practitioners' farm plots. Besides ecosystem services such as food, income, and soil fertility which had a direct relationship with farmers' application of chemical fertilizers; all the other ecosystem services had an inverse relationship. The direct relationship existing between ecosystem services (like food and soil fertility) and chemical fertilizer application could be attributed to the mostly large family sizes of most households which demands more food, as well as the need for more income, which pushes the farmers to apply chemicals fertilizers on their agroforestry farm plots in order to meet these objectives. Meanwhile the inverse relationship existing between most ecosystem services of agroforestry and the use of chemical fertilizer could be attributed to the agro-ecological and environmentally benign nature of agroforestry which makes it unnecessary to use chemical fertilizers in the system. This shows that, agroforestry systems can contribute towards reducing the quantity of chemical fertilizer applied by farmers on their farm plots.Although, somestudies undertaken on different agroforestry systems revealed that agroforestry has the capacity to ameliorate soil fertility,[1,7,8,13,17,24] few studies have examined how agroforestry can contribute towards reducing the application of chemical fertilizersby farmers. This study by employing descriptive and inferential statistical tools to show the relationship existing between ecosystem services of agroforestry and the use of chemical fertilizers by farmers, has therefore filled a major knowledge gap.

Agroforestry Systems and Chemical Fertilizer Application

With respect to the link between agroforestry systems and chemical fertilizer application, it was found that, most agroforestry practitioners applied very little or no chemical fertilizers. There was an inverse relationship between agroforestry systems/practices and agroforestry practitioners' application of chemical fertilizer whichcould be attributed to the diverse ecosystem services of agroforestry systems which makes agroforestry a climate-smart, agroecological, and environmentally benign practice. The many ecosystem services of agroforestry make it needless for farmers practicing agroforestry to apply chemical fertilizers. Some studies revealed that agroforestry systems/practices offer diverse ecosystem services including soil fertility enhancement.[12,18,39,40,41] However, few studies have concretely examinedthe role agroforestry systemsplay towards reducingchemical fertilizerapplicationon farmers' farm plots.The non-application of chemical fertilizers contributes towards ensuring the sustainability of farming systems via a balancing of soil ecosystems, natural boosting of plant health, enhancement of the decomposition process, and limits the accumulation of heavy metals in the soil and plant systems thereby reducing pollution.This study by demonstrating that agroforestry systems can contribute towards reducing chemical fertilizers application by farmers has therefore filled a major knowledge gap.

Conclusions and Policy Ramifications

Conclusions

Excessive chemical fertilizer application especially by non-agroforestry practitioners is a reality in Cameroon in general and the south-west region of Cameroon in particular. However, among agroforestry practitioners, the situation is different. This study found that three agroforestry systems (agrosilvopastoral, agrosilviculturaland silvopastoral) were common,made upof different practices like home gardens, cut and carry fodder, improved fallows, live fences, coffee-based agroforestry plantations, trees/shrubs on farmlands, cocoa-based agroforestry plantationsand home gardens with animals.Agroforestry practicing farmers procured different ecosystem services from their agroforestry systems with the most common being food, fuelwood, finance/income, and climate moderation. Besides food and soil fertility enhancement, very limited or no chemical fertilizer was applied in agroforestry systems to obtain other ecosystem services. The existence of a significant indirect relationship between ecosystem services of agroforestry systems and chemical fertilizer application was a testament to the fact that chemical fertilizers are not needed to enhance the ecosystem services of agroforestry systems. The indirect cause-effect relationship between agroforestry systems and chemical fertilizer application implied that the practice of agroforestry helps to limit chemical fertilizers application on agroforestry practitioners' farm plots. Agroforestry is therefore a sustainable pathway to limit and/or eradicate the application of chemical fertilizers by farmers.

Policy Ramifications

From the Study's Findings, the Following Policy Ramifications Emerge

Firstly, three agroforestry systems (silvopastoral,ag rosilvopastoral and agrosilvicultural) were common, made up of practices like cocoa-based agroforestry plantations, home gardens, home gardens with animals, shrubs/trees on farmlands, coffee-based agroforestry plantations, live fences, cut and carry fodder, and improved fallows. Policy makers should lay emphasis on these agroforestry systems and practices when formulating policies geared towards limiting/reducing chemical fertilizer application by farmers.

Secondly, agroforestry practitioners procured different ecosystem services from their agroforestry systems with the most common being food, fuelwood, finance/income, and climate moderation showing that these are the most important ecosystem services of the three agroforestry systems. Policy makers should lay emphasis on these common ecosystem services when formulating policies.

There was an inverse relationship between ecosystem services of agroforestry systems and chemical fertilizer application, demonstrating that chemical fertilizers are not needed to enhance the ecosystem services of agroforestry systems. This finding should be used bypolicy makers as a pointer to promote the practice of agroforestry especially among non-agroforestry practitioners.

Last but not the least, there was anindirect relationship between agroforestry systems and the chemical fertilizer application, demonstrating that agroforestry practices help to limit the chemical fertilizerapplication of on agroforestry practitioners' farm plots. Policy makers should strive to put agroforestry on the policy agenda as a mainstream practice owing to its ability to reduce farmers' dependence on chemical fertilizers.

Acknowledgements

We are also thankful to the farmers, agroforestry and non-agroforestry practitioners, key informants and other resource persons who provided vital information during reconnaissance and field surveys.

Funding

This study received no external funding.

Conflict of Interest

The authors declare no competing interest.

References

1. Young, A. (2002). Effects of Trees on Soils - Springer 2002, Special Supplement on Agroforestry. 5pp
2. Sanchez, P.A. (2002). Soil fertility and hunger in Africa. *Science* 295 (5562), 2019 – 2020.
3. Lal, R. (2009). Soil degradation as a reason for inadequate human nutrition. *Food Security* 1(1): 45 – 57.
4. FAO and ITPS. (2015). Status of the World's Soil Resources (SWSR) – Main Report. Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy. http://www.fao.org/3/a-i5199e.pdf
5. Gomiero, T. (2016). Soil degradation, land scarcity and food security. Reviewing a complex challenge. *Sustainability*, 2016, 8, 281.
6. Mbow, C.C.,Rosenzweig, L.G.,Barioni, T.G., Benton, M.,Herrero, M..Krishnapillai, E.,Liwenga, P., Pradhan, M.G., Rivera-Ferre, T.,Sapkota, F.N.,Tubiello, Y. andXu, Y. (2019). Food Security. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. CalvoBuendia, V. Masson-Delmotte, H.-O. Pörtner, D.C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)].https://www.ipcc.ch/site/assets/uploads/sites/4/2019/11/08_Chapter-5.pdf
7. Leakey, R.R.B. (2017). Socially Modified Organisms in Multifunctional Agriculture - Addressing the Needs of Smallholder Farmers in Africa. *Arch Crop Sci* 1(1): 20-29.
8. Awazi, N.P., and Tchamba, N.M. (2019). Enhancing agricultural sustainability and productivity under changing climate conditions through improved agroforestry practices in smallholder farming systems in sub-Saharan Africa. *African Journal of Agricultural Research*, 14(7), 379-388. DOI: 10.5897/AJAR2018.12972
9. Kopittke, P.M., Menzies, N.W., Wang, P., Mckenna, B.A., and Lombi, E. (2009). Soil and the intensification of agriculture for global food security. *Environment International* 132 (2019) 105078.
10. Raimi, A., Adeleke, R., and Roopnarain, A. (2017). Soil fertility challenges and biofertilizer as a viable alternative for increasing smallholder farmer crop productivity in sub-Saharan Africa. *Cogent Food and Agriculture* 3(1).https://doi.org/10.1080/23311932.2017.1400933
11. Nair, P.K.R. (1985). Classification of agroforestry systems. *Agroforestry Systems* 3(2), 97 -128.
12. Asaah, E.K., Tchoundjeu, Z., Leakey, R.R.B., Takousting, B., Njong, J., and Edang, I. (2011). Trees, agroforestry and multifunctional agriculture in Cameroon. *International Journal of Agricultural Sustainability*, 9(1), 110-119.
13. Tsufac A.R., Yerima, B.P.K., and Awazi, N.P. (2019). Assessing the role of agroforestry in soil fertility improvement in Mbelenka-Lebialem, Southwest Cameroon. *International Journal of Global Sustainability* 3(1): 115 – 135.
14. Chianu, J.N., Chianu, N.J., and Mairura, F. (2012). Mineral fertilizers in the farming systems of sub-Saharan Africa. A review. Agronomy for Sustainable Development 32: 545–566.
15. Kelly, V.A., and Naseem, A. (2020). Fertilizer Use in Sub-Saharan Africa: Types and Amounts. Agricultural Sciences 2: 1 – 7. http://www.eolss.net/Sample-chapters/C10/E5-24-08-04.pdf

16. Amede T. (2003). Opportunities and Challenges in Reversing Land degradation: The Regional Experience. In: Amede, T (ed), Natural resource degradation and environmental concerns in the Amhara National Regional State: Impact on Food Security. *Ethiopian Soils Sci. Soc.* pp. 173-183
17. Amare, D., Wondie, M., Mekuria, W., and Darr, D. (2018). Agroforestry of smallholder farmers in Ethiopia: Practices and benefits. Small-scale Forestry, 18 (1), 39-56.
18. Atangana, A., Khasa, D., Chang, S., and Degrande, A. (2013). Major Agroforestry Systems of the Humid Tropics. *Tropical Agroforestry,* pp 49-93.
19. Wabane Council Report (2013). National Community Driven Development Program: Communal Development Plan of Wabane.
20. Nkemleke, E.E. (2019). Assessing Small-Scale Farmers' Attitudes, Practices and Vulnerability to Pesticides Use in Market Gardening Crops in M'muockngie (South Western Cameroon). *Journal of Advances in Education and Philosophy* 4(6): 295-305.
21. Nair, P.K.R. (1993). An introduction to agroforestry, Dordrecht, Netherlands: Kluwer Academic Publishers.
22. Awazi, N.P., and Avana, T.M.L (2020). Agroforestry as a sustainable means to farmer-grazier conflict mitigation in Cameroon. *Agroforestry Systems*.https://doi.org/10.1007/s10457-020-00537-y
23. Awazi, N.P., Tchamba, N.M., and Temgoua, L.F. (2020). Enhancement of resilience to climate variability and change through agroforestry practices in smallholder farming systems in Cameroon. *Agroforest Syst,* 94:687-705. https://doi.org/10.1007/s10457-019-00435-y
24. Jose, S. (2009). Agroforestry for ecosystem services and environmental benefits: an overview. *AgroforSyst* 76:1–10
25. Quandt, A.,Neufeldt, H., and McCabe, J.T. (2017). The role of agroforestry in building livelihood resilience to floods and droughts in semi-arid Kenya. *EcolSoc* 22(3).
26. Quandt, A., Neufeldt, H., and McCabe, J.T. (2018). Building livelihood resilience: what role does agroforestry play? *Clim Dev*. https://doi.org/10.1080/17565529.2018.1447903
27. Awazi, N.P., Tchamba, N.M., and Avana, T.M.L. (2019). Climate change resiliency choices of small-scale farmers in Cameroon: determinants and policy implications. *Journal of Environmental Management* 250 (2019) 109560.
28. Shidiki, A.A., Ambebe, T.F., and Awazi, N.P. (2020). Agroforestry for Sustainable Agriculture in the Western Highlands of Cameroon. Haya: *The Saudi Journal of Life Sciences,* 2020; 5(9): 160-164.
29. Dépigny, S., Wils, E.D., Tixier, P., Keng, M.N., Cilas, C., Lescot, T., Jagoret, P. (2019). Plantain productivity: Insights from Cameroonian cropping systems. *Agricultural Systems* 168 (2019) 1–10.
30. Engwali, F.D., Mbei, N.T., and Nfor, T.D. (2019). Contribution of Phytosanitary Products to the Revenue of Market Garden Farmers in Mezam Division, North West Region of Cameroon. *EC Agriculture* 5 (5): 236-247.
31. Buvaneshwari, S., Riotte, J., Sekhar, M., Sharma, AK., Helliwell, R., Kumar, M.S,M., Braun, J.J., and Ruiz, L. (2020). Potash fertilizer promotes incipient salinization in groundwater irrigated semi-arid agriculture. *Scientific Reports* 10: 3691
32. Djoufack, T.M.M., Foko, K.E.M., Kouam, E.B., Anoumaa, M., Kaktcham, P.M., and Zambou, N.F. (2020). Effect of fertilizers types on yield parameters, sweetness and nutritional quality of carrot (Daucuscarota L.) genotypes. *Int J AgricSc Food Technol* 6(1): 079-087. DOI: https://dx.doi.org/10.17352/2455-815X.00005
33. Jaza-Folefack, A.J. (2009). The substitution of mineral fertilizers by compost from household waste in Cameroon: economic analysis with a partial equilibrium model. *Waste Management & Research* 27: 207–223
34. Tsozué, D., Nghonda, J.P., and Mekem, D.L. (2015). Impact of land management systems on crop yields and soil fertility in Cameroon. *Solid Earth Discuss* 7:1761–1796.
35. Tayoh, L.N.,Kiyo, L.M.I., and Nkemnyi, M.F. (2017). Chemical fertilizer application and farmers perception on food safety in Buea, Cameroon. *Agricultural Science Research Journal* Vol. 6(12): 287– 295
36. Thuriès, L.J.-M., Ganry, F., Sotamenou, J.,

Oliver, R., Parrot, L., Simon, S., Montange, D., and Fernandes, P. (2019). Cash for trash: an agro-economic value assessment of urban organic materials used as fertilizers in Cameroon. *Agronomy for Sustainable Development* volume 39 (52) (2019).

37. Ngosong, C.,Bongkisheri, V., Tanyi, C.B., Nanganoa, L.T., and Tening, A.S. (2019). Optimizing Nitrogen Fertilization Regimes for Sustainable Maize (Zea mays L.) Production on the Volcanic Soils of Buea Cameroon. *Advances in Agriculture* 2019 (4681825), 8 pages.

38. Temegne, N.C., Ngome, F.A., Suh, C., Youri, A., andBasga, S.B. (2020). Determining Appropriate Fertilizer Scheme for Maize and Sorghum Cultivation in the Sahel Agroecological Zone of Cameroon. *Journal of Experimental Agriculture International,* 42(8), 50-58.https://doi.org/10.9734/jeai/2020/v42i830570

39. Molua, E.L. (2005). The economics of tropical agroforestry systems: the case of agroforestry farms in Cameroon. *Forest Policy and Economics*, 7(2), 199-221.

40. Smith, M.S., and Mbow, C. (2014). Editorial overview: Sustainability challenges: Agroforestry from the past into the future. *Current Opinion in Environmental Sustainability,* 6, 134-137.

41. Leakey, R.R.B. (2019). A holistic approach to sustainable agriculture: trees, science and global society. In: Mosquera-Losada, M.R. and Prabhu, R. (eds.), Agroforestry for sustainable agriculture, Burleigh Dodds Science Publishing, Cambridge, UK, 2019, (ISBN: 978 1 78676 220 7; www.bdspublishing.com)