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Full Length Research Paper

Influence of age and cropping system on tree population structure in South West Ghana

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Timber tree recruitment and retention was assessed within cocoa farms and mixed perennial farms of varying age classes in south western Ghana. The rationale was to be able to understand the pattern of change in timber tree populations within farms, as well as identify the extent to which farm management activities explain these changes. Each farm was sub-categorized according to farm age into Phase I (farm age < 5 years), Phase II (farm age > 5 years) and Phase III (abandoned farms). Density and species richness of mature trees, that is with diameter at breast height (DBH) above 5 cm and regeneration (DBH of 5 cm and below) were determined while height, DBH and crown area were measured for only mature trees. About 96 farmers were also selected from 16 communities in the study area and interviewed. Results show that regeneration was most vigorous during the phase III (abandoned farms) compared to active cropping stages. Mixed perennial farms retained much less of recruits and if efforts are made to retain much of the recruits, timber supply could be largely augmented from this system. Within cocoa based cropping system, it was also observed that mature tree populations do not reflect the vigour of regeneration during the early stages (Phase I) of farm growth and this was attributed to the influences of farm management activities. Sustainable production of timber tree species from farming areas must take into account variations in tree densities and species richness among cropping systems as well as overtime (age classes) within a cropping system.

Key words: Cocoa based cropping system, mixed perennial cropping system, timber tree species, correlation test.

INTRODUCTION

Timber production takes place within production areas (natural forest reserves and plantations) with augmentation from non production areas (e.g. farm lands, fallow areas etc). In Ghana, this augmentation in supply of timber from non production areas was about one third to two third of total timber harvested in the 1990s (Mayers et al., 1996; Agyeman, 2001). But this has however declined in recent times attributed to a number of factors including over harvesting, developments like agricultural technology and shifts in choice of cropping systems. It was also speculated that the decline in off reserve tree resources might be a reflection of farmers' response to an inequitable policy, that provides no incentive for managing trees on farms (Amanor, 1996; Anim-Kwapong, 2003).

In order to solve the issue of timber decline in off reserve areas however, it would be important to understand the dynamics of trees on farms and to know the extent to which farmer activity influences these dynamics. Previous studies conducted (Amanor, 1996; Asare, 1999; Osei- Bonsu et al., 2000) suggested that if policies regarding equitable benefit sharing of tree resources on farms were changed in a way that improves farmer benefits, farmers would be better motivated to protect trees on their farm. But without understanding the changes in tree populations on farms

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and the various considerations that affect farmers' decision-making on trees, simply changing policy might not result in the desired impact. An appreciation of the recruitment and de-population dynamics of trees would better inform any policy modification or changes.

Quite apart from that, one of the major factors of biodiversity loss has been blamed on traditional shifting cultivation and rotational agriculture (Mkanda, 2002) . This system of farming (that is shifting cultivation and rotational agriculture) however, being rural based does not only feed major rural populations but also serves as a source of income for major rural based communities (e. as reported among the Phunoy ethnic group in Phongsaly district of Laos by NAFRI, 2005). An understanding of the changes in tree populations among different cropping systems and age classes will therefore contribute to understanding the pattern of biodiversity loss and recovery as a result of shifting cultivation activities. The main objective of the study was therefore to understand the influence of age and cropping system on tree population structure and also to find out how farm management activities explain or influence these dynamics. The study specifically sought to answer the following questions: How does regeneration diversity vary with age of farm? How do mature trees change in density and species richness with farm age? How does regeneration capacity reflect in mature tree populations? And to what extent do farm management activities explain these observations?

MATERIALS AND METHODS

Description of study area

The study was carried out in the Goaso District which is geographically located in the south western portion of Ghana covering a total land area of 3,250 km^2. The area encompasses three administrative districts including Asunafo North, Asunafo South and Asutifi districts and located between latitude 6°47´48´´N and 7°06´44´´N and longitude 2°17´53´´W and 2°38`45``W. In terms of forest type classification, the district lies within the moist semi deciduous zone of the tropical high forest with rainfall ranging from 1500 to 1750 mm and annual mean temperature range of 26 to 29°C. According to the Goaso Forest District Profile (2008), some of the trees that are home to the district include *Triplochiton schleroxylon*, *Ceiba pentandra*, *Terminalia superba*, *Entadrophragma* sp and *Afromosia elata*.

Land use in the Goaso Forest District is mainly forests found in forest reserves and in patches outside reserves and also agricultural land located outside the demarcated reserves (Bih, 2007). Data from the Ghana forestry commission shows that off reserve revenue from timber resources in the Goaso district was the second largest among all districts in the country for the period of 2003 to 2006, making it an important site for studies on off reserve tree dynamics.

Cropping systems

The study was carried out within two major cropping systems namely cocoa based cropping systems and mixed perennial cropping systems. Cocoa based cropping systems are farms where cocoa trees constitute the major crop; all management activities are directed towards the maintenance of this tree crop. The West African Amelonado cocoa was the first to be introduced and commonest variety of cocoa in Ghana. But due to poor yield and susceptibility to swollen shoot disease, new varieties (hybrid) were developed (Edwin and Masters, 2005; Thresh et al., 1988), which currently dominate the study area. Cocoa is the most important crop in the area and it accounts for about 70% of income in the district (Ardafio-Shandorf et al., 2007). But since cocoa is not an annual crop (that is it does not fruit in the first year of planting), most farmers usually intercrop cocoa with staple food crops which are usually seasonal to annual in nature. After the clearing of a forested/fallow area, cocoa seeds/seedlings are planted and then food crops intercropped. While cocoa takes a couple of years to mature, the annual and seasonal food crops are harvested much earlier and provide subsistence for the family. Intercropping continues until the cocoa canopy is closed, in which case it becomes a cocoa monocrop. One aspect of the tree inventory therefore investigated the life cycle of cocoa-based cropping systems looking into tree recruitment and depopulation along the life cycle of cocoa.

Also common in the study area, were land areas set aside for cultivation of only food crops. In these farms, cocoa or other cash crops were not planted. These farms were locally called “didifuo” which translates literally as feeding farm, implying they are mainly for household subsistence. Very common intercrops include cassava-cocoyam-plantain, cassava-vegetables (e.g. pepper, garden egg etc) plantain etc. This category of farms is referred to in this study as mixed perennial cropping systems. One similarity between mixed perennial and cocoa based cropping systems is the fact that, these farms are maintained for several years (perennial) and there are tree populations within them even though the numbers or specific species as well as the needs drawn from them might differ overtime and between the cropping systems. The major difference between these two systems is the presence of cocoa. In the former cropping system, cocoa is the major crop throughout the growth cycle and all farm management activities were directed towards the maintenance of this crop. In the latter however, there is no cocoa tree but rather a mixture of seasonal, annual and perennial food crops.

Sampling design

The study had two components, an inventory of trees within selected farms and a social survey in which farm managers (farm caretakers, farmers and landowners) were interviewed. Both components were carried out from March to June of 2008 in the Goaso Forest District (Figure 1) of Ghana. The tree inventory component was carried out through a stratified and purposive sampling approach. The entire study site (Goaso Forest District) was stratified into four (4) geographic zones namely North East (NE), North West (NW), South East (SE) and South West (SW) and sampling was done in each zone. Within each zone the two major cropping systems were studied. The idea to stratify the region geographically was to verify if location had reasonable impacts on tree populations. It was however observed that irrespective of geographical location the trend of timber tree recruitment and retention was same ($p>0.01$). Consequently, observations within zones were used as replicates(Anyomi, 2008).

Each farm visited was further identified and classified by age into phase I, II or III. Phase I implies farms with age less than five years since cropping started, that is age of cocoa or dominant food crop. Phase II farms are those with farm age greater than 5 years. The selection of age 5 to differentiate phases I and II was due to the fact that, farm canopies usually close at age 5 and for cocoa farms specifically, most trees begin to seed at this time. Farm tending

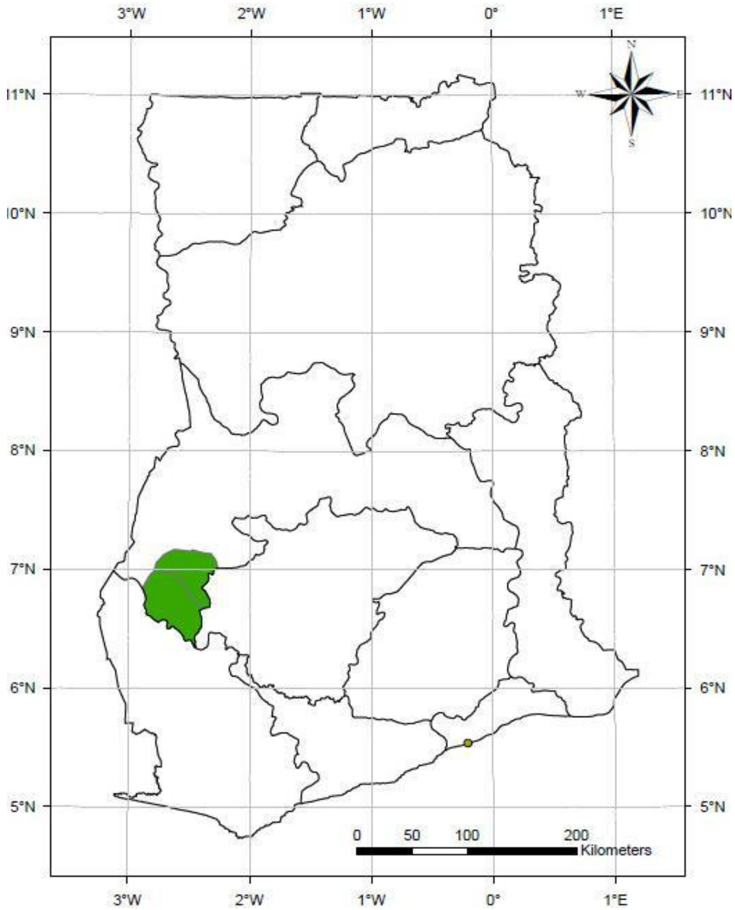

Figure 1. Research site (shaded area). Small dot is Accra (capital city).

activities within the first 5 years of farm establishment therefore differ after 5 years. Phases I & II can be described as active referred to as phase III. Farms get abandoned for several reasons including incidence of fire, disease and pest infestation which made the enterprise unproductive. Other farms were also abandoned because of ageing leading to higher costs in farm maintenance than yield. Time since farms were abandoned ranged from 2 to 5 years. Age of farm was obtained from farm owners and experienced farmers selected from the community who accompanied the team to the farms. They could tell the age of the farm by observing the major food crop. The categorization by age was for all farms earlier on identified as both cocoa-based cropping systems and mixed perennial systems. The rationale was to be able to reconstruct farm cycle overtime, so as to understand recruitment and retention of timber tree species within different age classes. For each system, farms were carefully selected, so as to minimize variation within phases and by so doing differences in tending activities between phases and their effects on timber trees could be distilled out.

Sixty (60) farms were in all selected for the study. Twelve (12) farms representing each of the two active cropping phases (that is phases I and II) within each of the two cropping systems (cocoa based and perennial systems) . This gives in all forty eight (48) farms while another twelve (12) were selected to represent the third phase that is abandoned farms. Within each farm, a main plot of size 30 x 30 m (0.09 ha) was demarcated. Two sub-plots each of dimension 10 x 10 m (0.01 ha) were demarcated within each of the main plots diagonally in opposite corners for assessing regeneration density and species richness. The social survey component was carried out through a three stage (multi-phase) stratified sampling procedure along demarcated zones as described earlier. Four communities were selected in each of the four zones giving sixteen (16) communities in the entire district (Figure 1) including; Nfama, Dominase, Fianko, Gambia I, Obengkrom, Kenyasi I, Ataneata, Donkorkrom, Akrodie, Pesewokrom, Ampemkrom, Manhyia IV, Asumura, Tipokrom, Nakete and Fawohoyeden. In each community, six (6) individuals were interviewed using semi structured questionnaires. The six individual respondents were carefully selected to comprise of two (2) farm caretakers, two (2) landowners and two (2) farmers. Each category wilds different power over the farm and has quite perculiar responsibilities and it would be interesting to know, if any differences existed along the different power lines.

Data collection and analysis

All trees within demarcated square plots and with diameter at breast height (DBH) above 5 cm were enumerated, that is identified by species, DBH, height and crown area. DBH and height were determined using diameter tape and Suunto Clinometer respectively. Crown area for each tree was obtained by estimating the average of two projected ground diameters (d1, d2) of the crown and then computing the crown area from Equation 1:

$A = D^2 /4$……………………………………………………..(1)

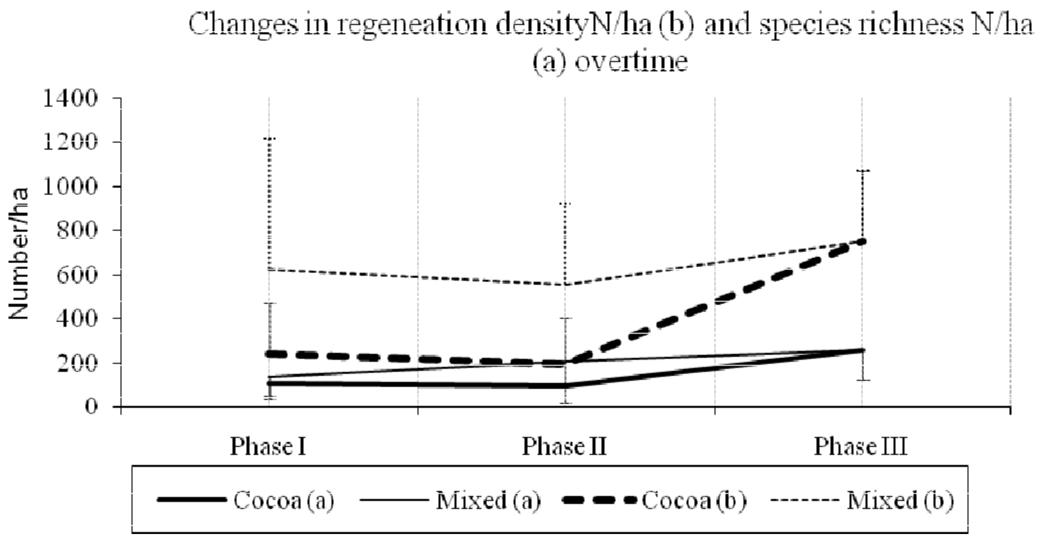

Figure 2. Changes in regeneration density (b) and species richness (a) within cocoa and mixed perennial system. Error bars represent standard deviations; north pointing bars on density mean values and south pointing bars on species richness mean values.

Where A is the crown area and D is the average of two projected ground diameters of the crown, that is $D = (d_1+d_2)/2$

Within each sub- plot of a main plot, regeneration number and species richness were determined. Regeneration number was determined through counting of all recruits with DBH below 5 cm while species richness referred to the number of different species within a defined area. Mean regeneration densities were computed at the main plot (combining the two subplots; 0.02 ha) level using Equation (2) and then for each cropping system using Equation (3):

$_{ijk} = n_{ijk}/A$……..………………………………………….………..(2)

$_{ik} = \quad _{ijk}/N_{jk}$ …………………….……………..……………..…………(3)

Where $_{ijk}$ is e.g. regeneration density observed in the i_{th} plot at the j_{th} phase of the k_{th} cropping system. n_{ijk} refers to the number of individuals (e.g. regeneration) in the i_{th} plot at the j_{th} phase of the k_{th} cropping system. A is the area of the plot (0.02 ha for regeneration density and0.09 ha for mature tree density). $_{ik}$ is mean parameter (e.g. regeneration density, height etc) at the j_{th} phase of the k_{th} cropping system. N_{jk} is the number of plots at the j_{th} phase of the k_{th} cropping system (that is 12 plots). Arithmetic means were computed for tree DBH, height, crown area, densities of regeneration and mature trees as well as species richness using Equation (3).

With regards to the social survey, data was collected on farmer characteristics (demography), that is the educational background, age class, owner status (that is whether he/she is a landowner, farmer and caretaker), family size, nativity etc. Data was also collected on dominant tree species retained; their names, approximate numbers per farm area, as well as the reasons for retaining such trees. Interviews were not segregated along cropping system (farm type) lines neither were they categorized by age as was the inventory. One reason was the difficulty in identifying farmers with only cocoa farms or with only mixed perennial farms. It was observed that farmers often had cocoa farms mostly as source of cash to support their family expenses and also mixed perennial farms to provide daily supplement to diet. The interview data therefore only supported (explained) observations from the inventory.

TEDB (1994) and Hawthorne (1990) were consulted in translating local names to scientific names and economic tree species (species exploited for commercial timber) were identified using TEDB (1994) and Parren and de Graf (1995). Non- parametric tests (Mann-Whitney, Kruskal Wallis, Chi square and spearman correlation) were conducted as normality and homogeneity of variance could not be ascertained (e.g. from Levenes test for equality of variance conducted) to determine if mean parameters differ significantly. Mann-Whitney and Kruskal Wallis tests were performed to compare mean parameters (DBH, height, crown area, densities of regeneration and mature trees as well as species richness) at various cropping phases. Spearman correlation test was used to investigate the linear relationships between characteristics of farm manager (that is demography) and responses to questions collated during the interview. For the inventory data, correlation tests were applied to determine if any associations existed between regeneration intensity and economic tree densities and species richness. The linear relationship between tree densities at the various phases was also tested using spearman rank correlation and chi square tests.

RESULTS

How does species richness and density of regeneration vary with age of farm?

Mixed perennial farms were more species rich and also had higher densities of regeneration compared to cocoa farms for all two active phases. Higher values for both species richness and density of regeneration were observed (Figure 2) during the phase III compared to active cropping phases within both cocoa and mixed perennial farms. Correlation test results show an insignificant difference in the mean densities of regeneration between phases I and II ($p=0.590$, $p=0.843$; respectively for cocoa and perennial farms), but a

Table 1. DBH, Height and Crown area of trees within cropping system and phases.

Cropping system	Cropping phase	Parameter					
		DBH (m)		Height (m)		Cr Area (m^2)	
		Mean	std	Mean	Std	Mean	Std
Cocoa	I	0.207	0.092	8.242	5.257	45.863	42.481
	II	0.387	0.427	9.010	10.257	131.880	160.401
Mixed perennial	I	0.177	0.272	5.150	4.995	48.070	120.064
	II	0.186	0.251	4.450	3.958	72.954	173.737
Abandoned farm	III	0.466	0.193	14.165	6.736	118.455	72.103

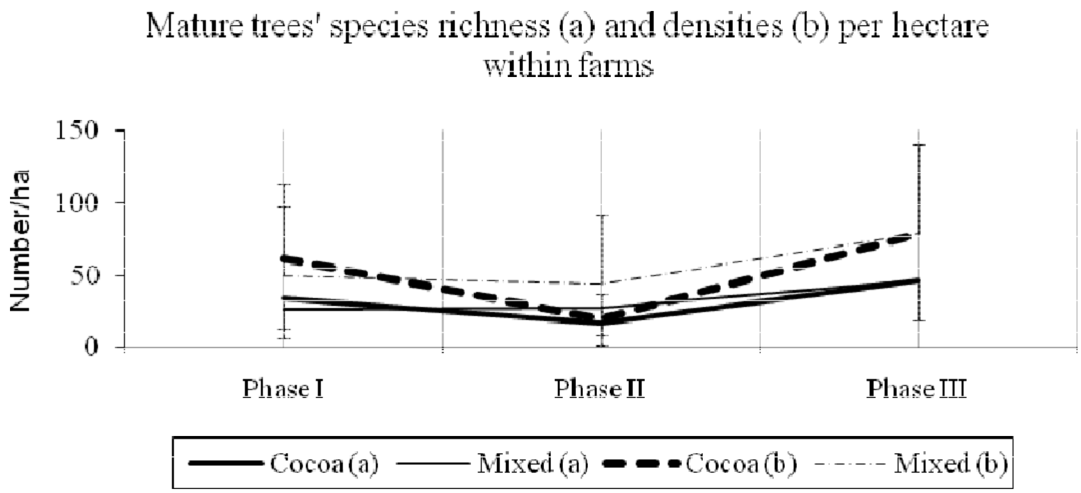

Figure 3. Changes in mature tree species richness and densities overtime. Error bars represent standard deviations; north pointing bars on density mean values and south pointing bars on species richness mean values.

significant difference between II and III (p=0.000) within cocoa farm. Regeneration species richness was similar (p=0.590) for phases I and II within cocoa farms but significantly different (p=0.000) between II and III. Even though there was a gradual and continuous increase in regeneration species richness from phase I through II to III (as illustrated in Figure 2) within perennial farms, differences between various phases was observed to be minute (p=0.2666).

How do mature trees vary with time in terms of density and species richness?

As illustrated in Table 1, trees within cocoa farms had much higher mean DBH, height and crown sizes, compared to mixed perennial farm trees. A closer look at the temporal variation in tree characteristics (Table 1) revealed that DBH, height and crown area increased gradually with age classes from phase I to II and III for both cropping systems. It was however striking to realize that mean height of trees in phase II (4.450 m STD: 3.958) was lower than that in phase I (5.150 m STD: 4.995) for perennial farms. Density as well as tree species richness was significantly lower at the phase II compared to phases I and III for both cocoa and perennial farms (Figure 3). Within cocoa cropping system, tree density and richness for all three phases differ significantly, indicating that retained trees at the different phases of cocoa growth was not similar. Within perennial farms however, both species richness and densities were observed to be similar for phases I and II while between phases II and III significant differences (p=0.031, p=0.025; for density and species richness respectively) were observed.

In a correlation test to investigate the association between mature trees at each growth phase (that is between trees in phases I, II and III), it was observed that for perennial farms, tree species richness and density in the phase II had a significant positive correlation (Table 2) with that of phase III. But, between the phases I and II however, an insignificant correlation in species richness

Table 2. Density and species richness relationships among farm phases.

Variables	rho	N	P value
*Tree species richness in phase II and III	0.638	12	0.026
*Tree density in phase II and III	0.748	12	0.005
Regeneration and mature trees within phase I	0.10	8	0.815
Regeneration and mature trees within phase II	0.80	8	0.018
Regeneration and mature trees within phase III	0.78	8	0.023

*Correlation results of tree density and species richness within perennial farms.

and density was observed. None of the tree characteristics (DBH, height and crown area) show a strong association between one phase and the next higher phase (that is I to II and II to III), an indication of the peculiarity or uniqueness of trees at each growth phase.

How does regeneration capacity translate into mature tree populations?

Within cocoa farms, a major association was observed between density of regeneration and mature tree densities specifically within phase II and also within phase III as illustrated in Table 2. This was an indication of the linearity of the relationship between number of recruited species and the retained mature tree numbers within phases II and III. This observation was made only within the cropping phase II and also, phase III of the cocoa based cropping system and not within phase I.

Farm management and tree retention

Information was collected from landowners, farmers and farm tenders with the rationale to support inventory data in explaining farm observations characteristics of respondents can be found in Table 3. Based on data from respondents, it was realized that tree numbers and species richness varied significantly (P=0.020 for tree numbers; P=0.036 for tree diversity) along age of farm. Tree numbers and diversity was higher during the first ten years of farm age (68 and 63% of all respondents respectively) . Respondents could not comment on the fallow stage (III), since at that point they did not have interest in the food crop again. When respondents were asked if any changes had occurred in tree numbers and species richness, about 80 and 60% respectively said there has been a decrease in species richness and densities overtime. Removal of trees by farmers was the main reason (73%) cited for the reduced tree numbers and diversity while natural mortality (26%) and removal by timber merchants (1%) were other reasons given.

About 88% of all respondents tend trees on their farm while 5% will eliminate them from their landscape. About 7% will either tend or remove trees depending on the situation and also their mood. The reasons for tending were mainly due to perceived benefits (91%) while for others (8%), it's just for the pleasure of it and a few others (1%) its per chance. Specific tending activities included weeding around the tree (82%) and pruning (18%) . Tending activities were carried out mostly (53%) every three (3) months. The reasons for tree removal included no perceived benefits (55%) from the trees, detrimental effects on subject crop that is cocoa trees (27%) and out of anger (18%) with timber merchants and chainsaw operators as well as with current policies.

There was significant correlation between attitude towards trees and some farmer characteristics including nativity (whether a respondent was from the farming area or not), age of respondent, relationship to the farm, gender and the educational background of the respondent. Some 91% of all respondents acknowledged that trees were useful to them. Provision of shade was the most important use mentioned while many respondents also indicated that, they use trees to raise their tree and food crops e.g. cocoa especially during tender ages. Significant correlations were also found between usefulness of trees and respondent's relationship to the farm and whether or not he is a native of the area.

DISCUSSION

How does species richness and density of regeneration vary with age of farm?

Within both cocoa and perennial farms, regeneration density and diversity was observed to be relatively low and uniform throughout the active cropping phases compared to the higher values observed for the phase III. This might be due to absence of farm management activities in the phase III, allowing natural dynamics of recruitment and retention. During the phases I and II, farm managers actively engage the farm and in the course of their cultural activities, recruitment of economic species could be prevented and/or for the successful recruits, retention might become a problem due to for instance regular weeding activities. It was therefore logical to observe higher regeneration in the phase III compared to I and II.

Table 3. The characteristics of respondents.

Parameter	Categories	Percentage (respondents)	Mann-Whitney U/ 2 –value
Sex	Male	62	MWU=1ns
	Female	38	
Age (years)	> 50	43	14.13**
	40–50	33	
	29–39	21	
	18–29	3	
Educational levels	No formal education	25	15.11**
	Basic education	65.2	
	Secondary	5.4	
	Tertiary	2.2	
	Vocational training	2.2	
Relationship to the farm	Landowners	68	7.99*
	Tenant farmers	21	
	Care takers	11	
Civil status	Married	80.4	12.09**
	Unmarried singles	4.3	
	Divorced	3.3	
	Widows/widowers	12.0	
family size/ household	6	69	9.65*
	4 – 5	21	
	3	9	
Nativity	Migrants	80	MWU=0.000*
	Natives	20	
Migrants	North (Upper East, Upper West and Northern regions)	16	MWU=0.000*
	South	84	

Ns: not significant, * significant at =5%, ** significant at =1%.

Comparing the two cropping systems under study (cocoa and mixed perennial cropping systems), regeneration of timber species was more vigorous within mixed perennial farms than cocoa farms especially during the active phases. For example within cocoa farms, mean regeneration density during the phase II was 3.9 per 0.01 ha compared to 11.08 per 0.01 ha within the mixed perennial system during the same period. Differences could be due to different light regimes within the two cropping systems. Perennial cropping systems were more open and exposed to direct sunlight, as trees were relatively shorter and crown sizes smaller (Table 1) compared to those of the cocoa farms. Consequently, much more sunlight reaches the farm floor and might be responsible for the higher recruitment densities. Previous studies (Broackway and Outcalt, 1998; Pardos et al., 2008; Swaine and Agyeman, 2008; Dai, 1996; Myaers et al., 2000) have confirmed the relationship between light intensity and regeneration density especially within closed forests and gaps. Light might therefore be the reason for the relatively higher recruitment during active phases of mixed perennial cropping system compared to the cocoa based system.

How do mature timber tree species vary with time?

Quite differently from the temporal variation in regeneration as discussed in the previous paragraph, mature tree species dynamics reveal very low populations during the phase II compared to I and III, especially within cocoa farms. This could not have been a result of regeneration capacity, as regeneration was quite uniform throughout the active cropping phases (Figure 2). We attribute the low population of trees in phase II to farmer influences on tree retention (Amanor, 1996; Anim-Kwapong, 2003).

Within mixed perennial farms, significant positive and linear correlation in density and species richness of timber tree species between phases II and III as pointed out earlier implies that, substantial population of mature species in the phase II move on to the phase III without any significant variation in density and richness. Consequently, with an increased retention during the phase II, one could expect a rise in the phase III population as well. This was however not observed for transition from phase I to II; an indication that with high tree population in phase I, one could not necessarily expect populations in phase II to be equally high. This points to a significant loop hole or break in connection between these two phases. We therefore propose that farm management activities do not significantly influence timber tree populations in older farms (that is phases II and III) but rather within phase I.

And how does regeneration capacity reflect in mature tree populations? To what extent does farm management explain these?

Quite similar to what was discussed in the earlier section, significant positive correlations were observed between density of regeneration and mature trees within phase II and also the phase III of cocoa farms. This demonstrates that tree retention was a function of the extent of regeneration within these two phases. Thus, even if farmer activities influence tree retention within cocoa farms, the effect is not statistically significant during these phases (II and III). In other words, within phases II and III of the cocoa growth cycle, one can expect high timber tree retention per unit area with high recruitment. This was however not observed in the phase I where regeneration did not associate significantly with mature tree densities. During the interview stage, respondents observed that tree numbers and species richness had reduced overtime and that the major reason for this reduction was farmer activity. Based on these observations, we suggest that farmers exert most significant influences on timber tree retention during early stages (phase I) of farm growth.

Response from respondents show that most farm managers would tend trees on their farm due to perceived benefits of such an action. This was also the case in an earlier study conducted (Adayfio-Shandorf et al., 2007) and it thus seem logical not to spend energies on something, if one does not expect much return on it. In explaining therefore, why regeneration does not translate into mature tree population (as observed in earlier paragraphs), it can be said that farm managers at the beginning and early periods of cropping (phase I), were less motivated to retain timber trees but as the farm matures, the motivation to retain trees become greater. It might also be due to the fact that, during the initial stages of farm growth (phase I), farmers concentrate more on their food crops and use only the tree population necessary to raise their crop trees. When the major food crop becomes established (that is by the end of phase I), interest in timber trees begin to shore up and hence the improved retention of recruits.

Conclusion

This study attempts to explain farm tree population structure from an inventory point of view with supplementary data from interviews of farm managers. The study reveals that within young farms (< 5 year olds), farmers remarkably influence timber tree retention but as farm ages (> 5 years) retained tree population reflects the strength of recruitment. Mixed perennial farms exhibited higher mean regeneration densities and diversities, as well as mature tree densities and diversities compared to cocoa farms, making them potentially attractive for timber tree production.

Looking into the future, mixed perennial farms could become a major source of timber, if management activities could be channeled in a way to retain recruits.

In order to sustainably produce timber from cocoa production areas, efforts must be directed at finding ways to retain as much recruits as possible especially during the early stages of cocoa farm growth (that is within young farms). Management planning must take into account two things in producing timber from non production areas: 1) The cropping system; whether cocoa based on mixed perennial system as these retain trees differently 2) Cropping phase as retention was observed to be woefully low for young farms (phase I).

In this study we looked at tree density as a characteristic variable in comparing cropping systems and different age classes, as well as plots within different geographical zones of the study region. Another way would be to re-classify the study area by tree density and also stratification by canopy cover values. Doing this will enable an empirical measurement of light, that reaches regeneration layer with the potential of improving analysis of results.

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