Land Cover Change Impacts on the Abundance and Composition of Flora in the Densu Basin

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Abstract

The Densu Basin is one of the most intensively cultivated river basins in Ghana, giving rise to a complex mosaic of land cover categories with concomitant alterations in the floristic composition of the area. Both cocoa cultivation and farming of staples have contributed significantly to both qualitative and quantitative degradation of the hitherto rich floristic composition. In comparison, the plant community of existing pockets of forest, though patchy and much disturbed, possess a much higher population density of larger/bigger trees and are more species diverse than the vegetation associated with the cocoa or food crop farms. The observed vegetation degradation is worst on fields put to food crop cultivation. To improve the ecological integrity of the basin for sustainable agriculture, tree-based agrosystems that are locally adaptable to the soils of the area may have to replace the current system of arable farming.

Introduction

The Densu Basin forms part of the Southern Forest-Savanna Transition frontier and transcends eight administrative districts, namely East Akim, Suhum-Kraboa-Coaltar, New Juaben, Akwapim North, Akwapim South, Asamankese, Awutu- Efutu-Senya and Ga districts (Fig. 1). The area constitutes one of Ghana's most productive agro-ecological ecotones (Gyasi *et al.*, 1994). Lying between latitudes 5° 55' and 6° 10' N and longitudes 0° 25' and 0° 15' W, the area was once the cradle of Ghana's cocoa industry and still remains an active zone for the cultivation of the crop, though production is progressively on the decline. In addition to the cultivation of cocoa (*Theobroma cacao*) and oil palm (*Elaeis guineensis*), the inhabitants are sustained economically by the cultivation of such food crops as maize (*Zea mays*), cassava (*Manihot utilissima*) and plantain (*Musa paradisiaca*).

In the recent past, agricultural activities in the area have not only been intensified but also become pervasive to the extent that most of the landscape has been dramatically transformed in the process into a complex mosaic of land cover classes (Attua, 1996), Also, a study by Agyepong & Kufogbe (1996) indicated that the trajectory of land use and cover changes in the basin have progressively shifted from cocoa cultivation to food crop farming. Unknown, however, are the ecological implications of this progressive change in land cover characteristics, particularly on the abundance and composition of flora in the basin. As succinctly encapsulated in a joint report by the International Geosphere-Biosphere Programme (IGBP) and the Human Dimensions Programme (HDP) on the relationship between land use and cover change, such alterations in land use and cover characteristics have significant implications on the abundance and composition of vegetation (IGBP/HDP, 1993).

The objective of this study, therefore, was to comparatively examine and quantify the aggregate effects of this agricultural
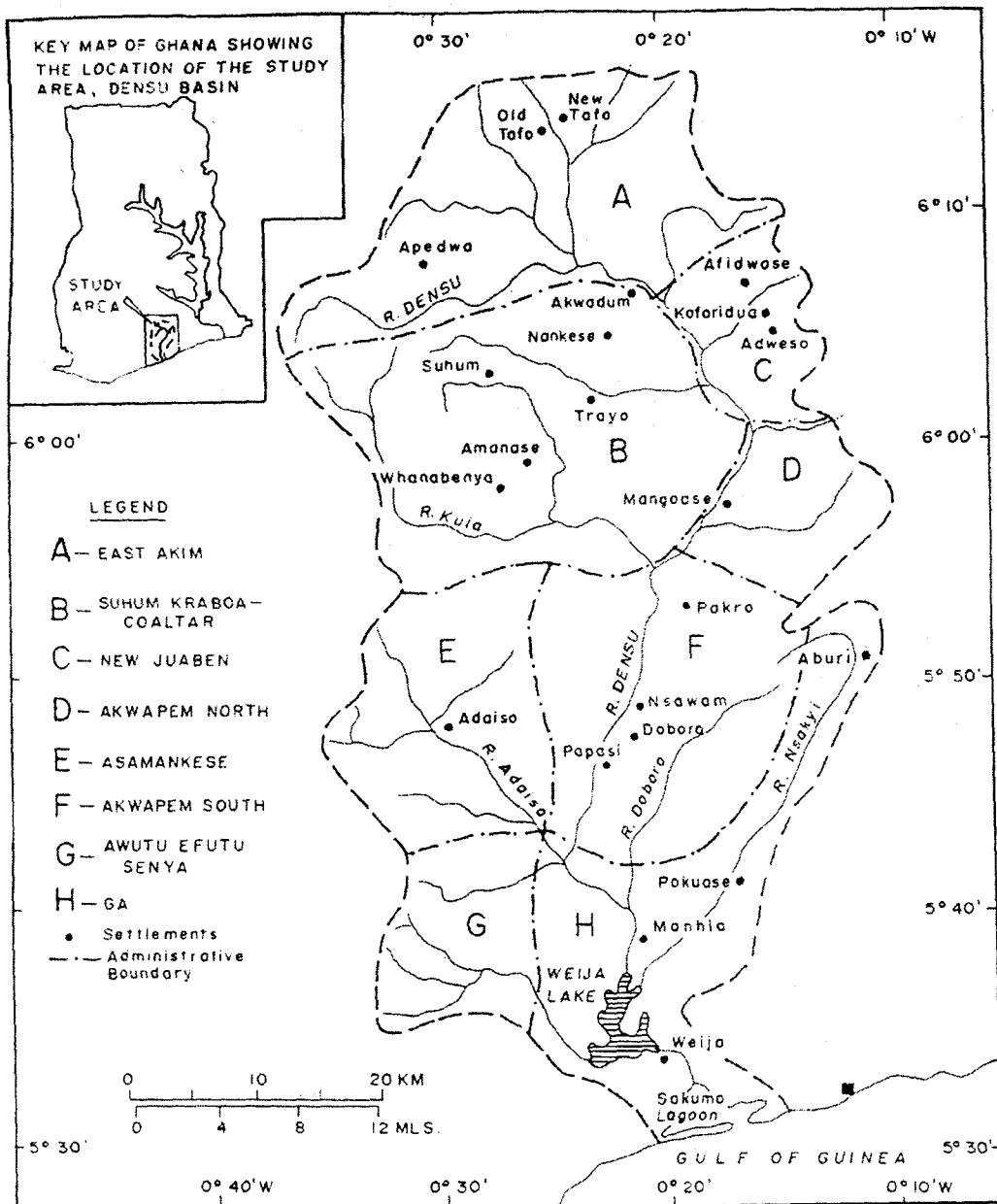
Fig. 1. Administrative districts of the Densu Basin

land cover change as reported by Agyepong & Kufogbe (1996), on the abundance and composition of plant communities of the three most dominant land cover categories in the basin – food crop farms, cocoa farms under tree cover and forests. The floristic parameters investigated were basal area, mean inter-plant distance, relative density, relative dominance and species diversity of the plant communities associated with these land cover types.

Materials and methods

The in-depth field study was concentrated at three sites, namely Whanabenya, Amanase and Trayo (Akote); all in the Suhum-Kraboa-Coaltar District of the Eastern Region of Ghana. Fig. 1 shows the relative geographical locations of these study sites. Each site comprises a cluster of farming communities inhabited predominantly by settler farmers of Akwapim and/or Siade-Shai ethnicity. The relief is generally gently rolling with slopes lying between 8-16% (Dickson & Benneh 1988; Benneh & Agyepong, 1990; Adu & Asiamah, 1992). The area is drained by the tributary rivers of the Densu River namely Suhum, Mame and Abeasua. Also present are seasonal streams that are only a few metres wide. The basin lies within the bimodal rainfall belt, with a mean annual rainfall of about 1260 mm. The major rainy regime begins from April and ends in July; peaking in June. The minor season is from September to November. December and January are dry months with high ambient temperatures during the harmattan season (Dickson & Benneh, 1988; Benneh & Agyepong, 1990; Adu & Asiamah, 1992).

Field work

Sampling plots were located on the basis of the three major agricultural land use/cover classes as follows (Attua, 1996): food crop farm (three plots), cocoa farm (three plots) and forest (open-canopy type). For difficulty in locating forest in accessible terrain, only one plot was sited. In the study, it was assumed that the forest represented a near-natural and ecologically more stable condition and that, except for cultivation, the other cover types would have been forests. The data obtained from the forest was, therefore, used as the baseline information for comparison. All study plots were sited on well-drained, gentle and undulating ground. On each location, a square plot of side 100 m was randomly laid down with the help of measuring tapes and poles (to save time no technique of randomization was used). With measuring tapes and wooden pegs, each plot was subdivided into five strips, each of 20 m × 100 m and lying side by side. This was to facilitate the listing of low growing plants and increase the chance of including most, if not all available species, in samples (Hawthorne & Musah, 1993).

A species list was made of each plot to include trees, climbers, shrubs and herbs. Non-vascular plants were, however, ignored. Species were identified as far as possible on site and those of unknown identity were collected as whole plants and/or parts, and pressed for later identification at the Ghana Herbarium, Department of Botany, University of Ghana, Legon. Plants of girth 20 cm or more on each plot were identified, listed, counted and girthed, each species separately. All girths were measured at breast height (gbh) of about 1.3 m above ground, except for trees with buttresses, where measurements were made just above the buttresses, using a measuring tape. For

plants with irregular-shaped stems, three girth readings were taken around the stem of each individual of a species and averaged. Climbing was done to measure the girth of some trees with buttresses high above ground. From the data, a girth class distribution of species on each plot was prepared.

The relative density, relative dominance, diversity and basal area of a given species were computed from the formula below (Hopkins, 1974; Magurran, 1988):

$$\text{Relative density of the } i^{th} \text{ species (\%)} = \frac{n_i \times 100}{N}$$

$$\text{Simpson's diversity Index, D} = \sum \frac{n_i (n_i - 1)}{N (N - 1)}$$

where n_i is the number of individuals of the ith species and N is the total number of all individuals per plot. The reciprocal of D was taken to ensure that the value of the index increased with increasing diversity (Magurran, 1988).

Basal area of an individual tree, BA_i (in m^2) was computed as

$$BA_i = \frac{1}{4} \pi (d_i)^2$$

where d_i is the girth of an individual tree in metres. The total basal area of an ith species was obtained by the summation of the basal area values calculated for all individuals of the ith species per plot. The relative dominance of an ith species (Rd_i) was computed as

$$Rd_i = \frac{\text{Total basal area of the } i^{th} \text{ species}}{\text{Total basal area of all individuals}}$$

Using the quadrant approach (Hopkins, 1981), the mean distance for the ith species (D_i), with girth of 20 cm or more, was calculated in metres as:

$$D_i = \frac{\text{Sum of all distances measured}}{\text{Number of distances measured}}$$

The density per hectare of species with girth of 20 cm or more, was calculated per plot as:

$$\text{Density of species} = \frac{10,000}{D^2}$$

where D is the mean inter-plant distance of all plants of 20 cm girth or more on a plot.

Sampling of smaller plants (trees less than 20 cm girth at breast height, shrubs and forbs) was done by demarcating each sampling plot into five strips, each of dimension 20 m × 100 m and lying side by side. A 1- m^2 wooden quadrat was used to take 20 random throws over each strip and at each point the plant species enclosed were noted and counted. This approach was to increase the chance of including most species present on the plots in samples (Hopkins, 198; Hawthorne & Musah, 1993).

For each quadrat throw, the enclosed plants were identified on the field where possible. Unfamiliar species were, however, collected as whole plants and/or their parts, pressed and brought to the Ghana Herbarium in the Department of Botany, University of Ghana, for later identification. The species were each counted, one at a time and recorded. Using a pair of callipers (in the absence of a diameter tape), the diameter of each individual of a species was obtained as close as possible to the ground. The diameter recordings of all individuals of a particular species were then averaged. For species that were very abundant (> 100 individuals), averaging was done with only the first 100 individuals. Clumped plants of

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the same species were tied together and treated as an individual. From the collected data, the frequency, basal area, relative density and relative dominance were calculated from the formulae.

Results and discussion

A comparison of the floral characteristics of the study area revealed that, generally, shrubs and herbaceous species showed preponderance over trees on all study plots. Throughout the study, 5,100 individual plants from 44 botanic families, 77 genera and 90 species were included in the samples. Tables 1 and 2 show the number, basal area, mean inter-plant distance, density and diversity indices of the plant species associated with the three different land cover types studied. Of the 5,100 individual plants enumerated, only 106 or 2.08% were of girth ≥ 20 cm. These belonged to 14 families, 26 genera and 29 species; 26 being trees. The remaining

bulk of 4,994 plants (97.02%) were smaller plants; of which only 36 were tree species. This large bulk of small plants belonged to 37 families, 55 genera and 58 species; made up of 55 dicotyledons and three monocotyledons. The predominant plant families were Papilionaceae, Moraceae, Sterculiaceae, Euphorbiaceae, Sapindaceae, Mimosaceae, Meliaceae, Apocynaceae and Compositae. Papilionaceae, Moraceae, Sterculiaceae, Euphorbiaceae, Sapindaceae, Mimosaceae, Meliaceae and Apocynaceae were the most dominant families among plants of 20 cm girth or more. Among the smaller plants, Papilionaceae, Euphorbiaceae, Compositae, Sapindaceae and Moraceae were most predominant. Papilionaceae had the widest distribution and occurred on all plots, among both the larger and smaller plant populations.

Fig. 2 is an illustration of the girth class distribution of plant species of girth 20 cm or

TABLE 1

A comparison of number, inter-plant distance, basal area, density and diversity of plant species ≥ 20 cm g.b.h. on different land cover.

| | | Land cover | |
Parameter	Forest	Cocoa farm	Fallow
Total number of individuals	50	45	11
Mean inter-plant distance (m)	6.75	4.18	13.96
Total basal area (cm²)	49,846	9,610	1,646
Density per hectare	231.81	444.67	55.92
Species diversity ($1/_D$)	8.22	3.08	2.50

TABLE 2

A comparison of number, basal area and diversity of plant species < 20 cm g.b.h. on different land cover types

| | | Land cover | |
Parameter	Forest	Cocoa farm	Food crop farm
Total number of individuals	1,044	646	3,304
Total basal area (cm²)	274	986	319
Species diversity ($1/_D$)	24.21	7.03	2.20

more on the different land cover classes. Fifty individual plants were identified as having a girth of 20 cm or more on the forest plot. These belonged to 10 families, 16 genera and 18 species. The majority (62%) of the plants were of girth ranging between 20 and 70 cm. The cocoa farm recorded 45 individuals from 11 genera, 11 species and seven families; with most of them having a girth range of 20-50 cm. Only 11 individuals from four different families and genera were counted on the food crop farm. Girth class distribution of larger plants on study plots indicated a reduction in population at increasing girths. For both the food crop and cocoa farms, the trends of girth distribution showed that more than 50% of all observations in each case fell between the girth range of 20 cm to 50 cm. Conversely, of the forest, the pattern showed the presence of almost all girth classes probably indicative of a more matured, resilient and relatively unperturbed plant community.

From Table 1, the heaviest loss of larger plants was on the food crop farm and the least was on the cocoa farm. Averagely, the inter-plant distance of the larger plants was greatest on the food crop farm and least on the cocoa farm. The forest followed the latter closely. The approximate plant densities per hectare, consequently, followed a similar pattern. The most diverse plant community was the forest, with diversity index of 8.22; the cocoa and food crop fields recording very low figures of 3.08 and 2.50, respectively. Additionally, the forest had a greater number of larger plants, consequently giving it an exceptionally high basal area value of 49,846 cm^2 as against only 9,610 cm^2 and 1,646 cm^2 for the cocoa and food crop farms, respectively.

The characterization of the smaller plant species indicated that 1,044, 646 and 3,304 individuals were included in the samples taken from the forest, cocoa farms and food crop farms, respectively. Of the number from the forest, there were 30 species from 28 genera and 19 botanic families. Of the cocoa farms, on average, 51 species of smaller plants from 47 genera and 29 families
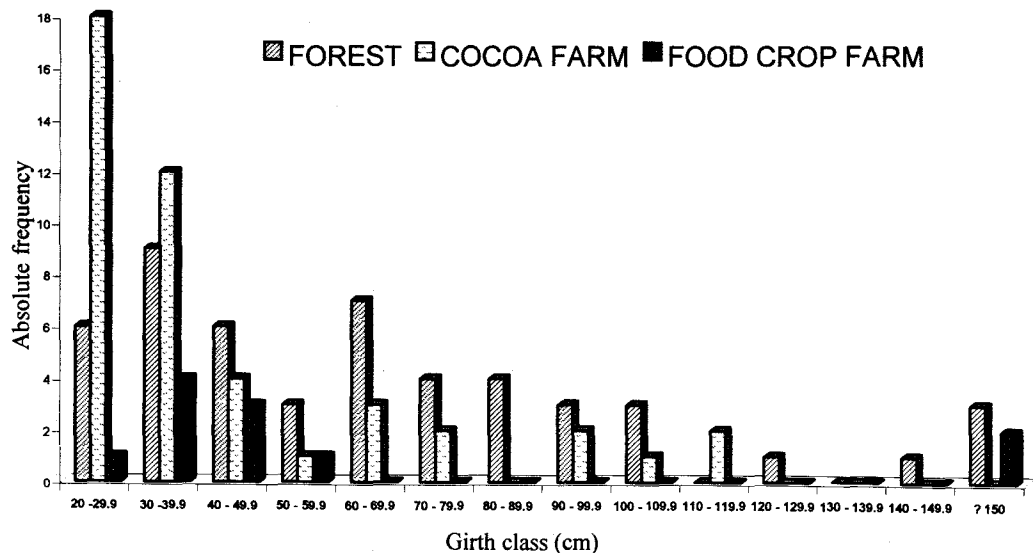

Fig. 2. Girth class distribution of trees with girth of 20 cm or more on different land cover types

were encountered. The food crop farms recorded 24 species belonging to 22 genera and 19 families. The plant populations, basal areas and species diversity scores for these plants on the respective land cover groups are shown in Table 2. Though the food crop farms recorded the largest number of individual smaller plants, the diversity index of 2.2 compared to the 7.03 and 24.21 of the cocoa farms and forest, respectively, indicates that these plants were from a few botanic species. This low species diversity score of the food crop farm could probably point to it as the most ecologically disturbed of the three plant communities.

Conclusion

From the preceding analyses, the agricultural activities in the Densu basin has not only transformed the physical landscape but also impacted negatively on the biological community of plants in the area. The impact of arable agriculture, particularly the growing of staples, has been very severe on the plant resources of the basin by reducing significantly the population of larger plants, including rare and economic tree species. In their place is the preponderant occurrence and vigorous growth of many herbaceous life forms and an aggressive invasion of savanna grasses as well as many noxious farm weeds. The rich floristic diversity, reminiscent of the forest and other less humanly disturbed plant communities, described by Hall & Swaine (1981) has been terribly eroded to a significantly low level, through traditional farming practices. Though cocoa farming impacts negatively on floristic diversity of the area, the practice of retaining some trees and growing some others to provide needed shade for the young cocoa seedlings makes it a better

option for reducing floristic diversity erosion than food crop farming. Agro-forestry and other tree-based farming systems that have the potential of restoring the species-rich integrity of the basin as well as the ecological balance without denying the inhabitants their sustenance will need to be explored. Such methods must be found adatable to the local ecology and be easily acceptable to all the farming communities in the basin.

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