Chapter 5 Results and Discussion --- Forest Team

5-1 Baseline study on forest, forest policy, and land systems*

*Note: This section was based on the report by Misa Masuda, short-term JICA expert, on September 1998

5-1-1 Data collection

Baseline survey on forest policy was carried out through interviews and secondary data collection at Forestry Department and Forestry Commission in Accra and Regional Forestry Office in Kumasi as well. Since available time was so limited, however, and forest policy in Ghana itself was in transition**, second data collection could not be done sufficiently.

**Note: The new revised forest policy of Ghana on 2000 was attached on the last page of this section.

The term of land system implies both land tenure systems and land use patterns. When the preliminary survey was carried out on Pumpunyao river basin proposed as the project site on F/D, it was found that the settlement inside the basin consist of only two categories: (1) settlements along Sunyani road in progress of urbanization, and (2) scattered small hamlets of cacao caretakers. Adujama and Potrikrom can be categorized to the former, which populations are recorded to be 1,923 and 940, respectively, in the report of preliminary socio-economics survey carried out in 1996/97. As for Adujama, actually it can be estimated to reach 3,000 including *zongo* area and satellite hamlets scattered in the vicinity.

Comparing with the purpose of baseline survey to find the aspects of land system in rural communities, and also constraint of time, both Adujama and Potrikrom seemed not suitable for study sites because of their sizes and natures as semi-urbanized societies. When only several weeks are available, population of a small village is preferably not over 300.

Another issue to be discussed here is how to determine the unit of sampling. When the family system in a region concerned is based on nuclear family concurrent to household and house as well, family / household / house can be used as a basic social unit. A random sampling method can be easily applied when the population size is enough large, so far as a list of households / houses are ready to use. The result of preliminary interview, however, implemented in 1997 to a house of medium size at Adujama shows where plural nuclear families as a unit of economy form an extended family as a unit of dwelling. More in detail, that traditional quadrate house consisted of eight bedrooms and two kitchens surrounding an open-air courtyard on the center. Five nuclear families and two individuals dwelling in seven rooms, and they are all relatives of the house owner. The rest was rented out to an outsider family.

Based on these conditions, upper part of Biem river basin, adjacent to Pumpunyao River, was added for RRA on number of houses and population, since more settlements in wider varieties of size are found. As a result, Biemtetrete was neglected for the site of baseline survey on land system because of the desirable population size compared to available time for survey. Open-ended interviews on place of origin and land tenure to all houses were carried out for one week during the first visit in 1997, and for two weeks in 1998. As for land use, interviews to key information are applied, supplemented with aerial photographs taken by Inland Valley Consortium in March 1997 and topography maps made in 1972.

5-1-2 General setting of forestry in Ghana

The forest policy in Ghana had been long based on An Ordinance for the Protection of Forests and the constitution and Protection of Forest Reserves, or Forest Ordinance as a short title commenced in 1927. As shown in the title, forest management of Ghana is based on forest reserves created through certain procedures such as appointment of a reserve settlement commissioner, notification on the gazette, and final demarcation after the interim period to regulate disputes.

Demarcation of forest reserves was almost completed in 1989, accounting for 20.4 percent of high forest zone and 5.6 of savanna zone. In 1993, however, it was estimated that around 80 percent of timber harvest were provided from outside forest reserves [FD, 1995:9].

For the present, the legal status of natural stands outside forest reserve cannot be clearly explained here because of insufficient data collection. Supposing from Trees and Timber Decree, 1974, and Forest Fees Regulation, 1976, together with the result of interviews to forest officers, lands outside forest reserves belong to *stools* or other resemble customary systems, while natural stands on the same lands are not necessarily so. Timber concession is applied to the areas outside forest reserves and royalty is imposed to the harvest. Yet felling activity without government permission is commonly observed in the secondary forests. Those woods are sawn at the site by chain saws and used for local consumption such as housing and small-scale furniture industry.

Local people collect non-wood forest products and fuel-wood from outside forest reserves also without control by the government. Unlike oil producing countries such as Nigeria and Indonesia where energy resources have been replaced to petroleum and gas particularly in urban areas, demand on fuel-wood in Ghana is still increasing not only at villages but also urban areas for domestic use and industrial purpose as well. Only difference between rural and urban sectors is the source of fuel-wood. In rural areas, branches and small-diameter including withered cacao trees particularly in Ashanti region are collected by women, while charcoal is preferred at urban households, which is made from large-diameter wood felled and burnt by professional groups. This activity is also done outside forest reserves without any government permission.

At the project site, mainly Sissala people from Tumu, Upper West region, engaged in charcoal production. According to interviews to the people burning charcoal inside bush, the species used for charcoal is only *denja* with large-diameter, scattered on cacao farms. When they find a tree, first make negotiation with the owner of the land on compensation for surrounding cacao trees that can be damaged at the time of felling, and employ chainsaw operators for felling and cross-cutting. Then the round woods are covered with lower layer of grasses or twigs and upper layer of soil, and burnt. It takes more than a month to complete all the process.

From the aerial photographs and ground observation, large diameter trees only remain on cacao farms but some useful species such as *denja* and *wawa* are being exhausted. People recognize *kwaie* (primary forests that are never cultivated) is now only found on forest reserves but not on communal lands any more.

5-1-3 Land system at Biemtetrete

As already mentioned, here the term of land system implies land tenure and land use. In 1997, direct interviews were first conducted to all the households of Biemtetrete to get a collect figure of total population and to classify the residents into natives / migrants and landlords / tenants. During the second visit in 1998, the same questions were made to find the natural and social population mobility. Interviews on land tenure and source of income were also conducted to both men and women. The reason to include women is, particularly in Ashanti region, they are not always economically dependent to their husbands, and owing to matrilineal inheritance system, many of women hold their own lands that were not incorporated to the properties belong to their husbands. Since data analysis has not yet been completed, here only general aspects can be described.

5-1-3-1 Land tenure

Biemtetrete is a settlement under control of Omanhene (paramount chief) at Adanwomase; a town lies 17 miles north of Kumasi. According to information from elderly people, several families originated from Adanwomasehene (chief of Adanwomase) acquired some square miles of land from Achanpemhene who ruled this region at that time, and started to migrate. Now most part of the vicinity is possessed by the descendants, which from both resident landlords still hold kinship and houses at Adanwomase and often go and back.

Table 5-1. Caregories of farmers (tentative data collected in 1997

	Landlord peasant	Peasant	Peasant tenant	Tenant	Others	Total
Ashanti	9	24	1	-	7	41
Migrant	-	1	3	49	9	62
Total	9	25	4	49	16	103

Table 5-1 shows tentative data collected in 1997. The number of adult counts 103, which definition is not based on unreliable figure of age but on economically independent individuals and married couples. Landlord-peasant means landowners who cultivate some parts of the lands by themselves and rent out another parts at the same time. Peasants are those who own the lands and manage by themselves Peasant-tenant means those who engaged farming on both owned lands and rented lands. Others consist of the people, mostly women, whose main sources of income are not farming but non-agricultural sectors.

The irregularly distributed patches of cacao farms mixed with natural stands are derived from the land tenure system. Absentee landlords prefer to convert their lands to cacao farms rather than renting them out to tenants for food crops. As a result, concentric circles pattern of land use, that is, from the most intensive pattern to extensive ones in accordance with the distance from a settlement, are not formed and even the lands adjacent to the settlement still remain as cacao farms because some lands are owned by absentee landlords.

Various forms of contracts are found for cacao farm establishment. Formerly *abunu* system was adapted, but owing to land scarcity, almost disappeared in the region near Kumasi. It is a long-term contract to let a tenant plant cacao trees on their own expenses, and after they start fruiting, the trees together with the land are divided into two, half belong to the landlord and the other to the tenant. For maintenance of cacao farms, caretaker system is widely adapted, in which a tenant can get one-third (*abusa*) or half (*abunu*) of the cacao harvest in exchange of their labor of weeding, harvesting and processing.

It was remarkable that around 60 percent of the adult population was migrants mainly from Upper East, Upper West and Volta regions. Some are even from outside Ghana, Burkina Faso and Togo. The living strategy of such migrants differs between northerners and those from Volta. Most of the northerners make their living on the combination of cacao caretaking and rice farming, while the latter have a tendency to supplement their cash income from cocoa with palm wine tapping as for men and food processing for women, as Adanwomase is one of the centers of *kente* industry.

Compared to the result in 1998, certain social mobility of population to different directions is observed. The most obvious one is coming and going of migrants between Biemtetrete and their hometowns. Another is found between the village and Adanwomase, which is only found among the natives. Most of migrants answered they wish to go back their hometown as soon as can earn enough amount of money. Because of long history migration, however, combined with expansion of cacao farm, now the second generation of the migrants who were born in Ashanti is growing. How to locate such people is necessary to be discussed, not only for general consideration but also for the design of this project.

5-1-3-2 Land use pattern

As shown in Figure 5-1 (Adujama area), Fig.5-2 (Biemtetrete area) and Fig. 5-3 (Mmonroben area), land can be basically categorized into *wura* (lowland) and *etineso* (upland). Land use patterns of *etineso* consist of *aduyanifuo* (farm of food crops, mixture of cassava, cocoyam maize and plantain), cacao plantation, *nfofuo* (bush of forest fallow), and *kwaie* (primary forest). Though *kwaie* can be found only on forest reserves, secondary forests still look abundant in the vicinity of Biemtetrete from aerial photographs. Few of high trees distribute on *nfofuo*, however, but the most only remain as shade trees of cacao farms, forming two-story forests.

The rotation found in wura is after rice cultivation for a season, one or at most two years fallow period is kept. In contrast, fallow period in etineso is longer. Mix cropping of cassava, cocoyam and plantain, sometimes with maize is done during the first year, and the former three crops can remain normally up to two years. The follow period depends on their land area, from two years to five years. One native informant answered to keep a fallow four years for his *aduyanifuo*.

Migrants first look for opportunities to become caretakers. The contract starts from weeding during season and ends after harvest in dry season. *Abusa*, two third of harvest landlords and on third for caretakers, is the common share system, and occasionally *abunu*, dividing to halves, is applies for young or degraded cacao farms. The reason why tenants are resigned to advantageous share system to landlord is the caretaker can find rooms for their *aduyanifuo* on the cacao farms under their charge, which can be free from rent. According to the opinion of a landlord, another incentive is the patron-client relation. Especially for newcomers, it is also important to be supported socially and economically by the landlords. On the other hand, however, there is the possible to create constant debtors.

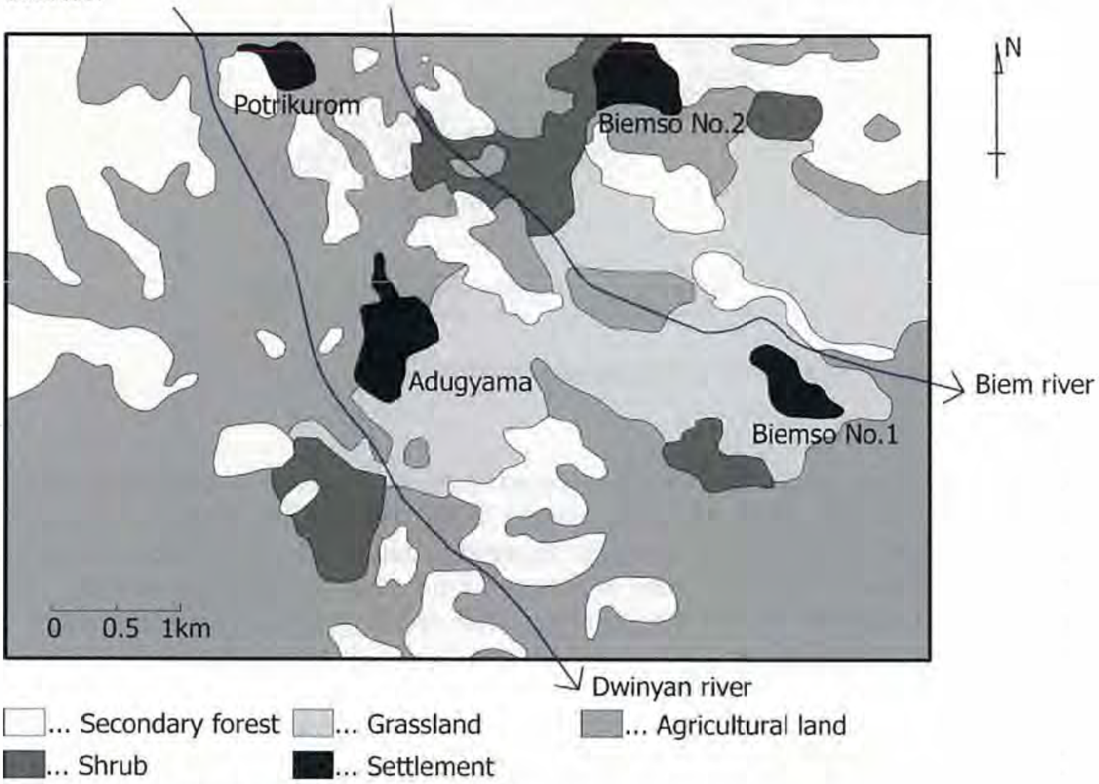


Fig. 5-1. Land use patterns around Adujama.

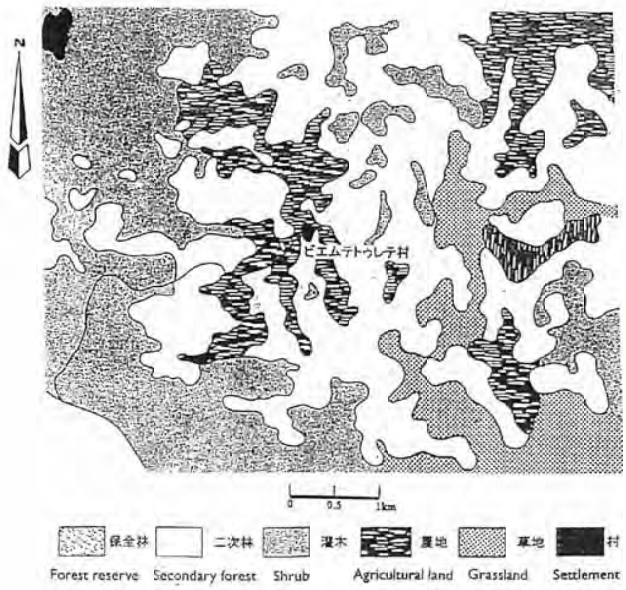


Fig. 5-2 Land use patterns around Biemtetrete

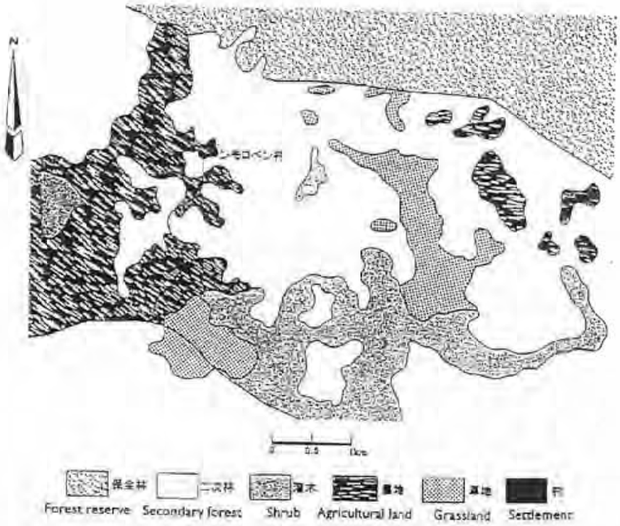


Fig. 5-3 Land use patterns around Mmoroben

Rent of rice farm is fixed before land preparation. It is generally paid after harvest, normally it cash but sometimes in the form of harvested rice. The tenant of *aduyanifuo* consists of both fixed rent and so-called *taungya* system. In the latter form of contract, tenants have to sow seeds of cacao in between food crops or transplant seedling of oil palm. Cacao seeds are provided by tenants, while seedling of oil palm are provided by landlords.

5-1-4 Appendix:Proposal for the Revision of Ghana National Forest Policy at by Ghana Forestry Commissionby Ghana Forest Service, Ministry of Lands and Natural resources and Ministry of Environment Science and Technology

5-1-4-1Preamble

A policy to guide forestry development in Ghana was adopted in 1948. Since then significant changes have occurred in the policy environment. Besides, the forest itself, by nature and design, is dynamic and is continually evolving and changing. The major changes in these two respects relate to: (1)changes in the nature of the forest resource – particularly, the serious reduction in the area under forest cover, which has been brought about by increased human populations, non-sustainable farming systems, an increase in uncontrolled wild fires, and the over exploitation of some commercially popular timber species, (2) the greatly increased demands on the forest resource for fuelwood, timber, non-timber products and environmental benefits, (3) advances in science, technology and knowledge, (4) institutional changes including changes in the Policy itself as applied in practice, in legislation and in the institutions concerned with policy formulation and implementation; and (5) changes Resulting from biological processes and natural disasters.

Consequently, a review of both the policy objectives and the strategies to meet the objectives has become necessary.

5-1-4-2 Background

(1) The forest of Ghana are considerable importance to the economy, environment and welfare of the nation. The forests: (i) provide energy for domestic and industrial use. Wood fuels account for over 75% of total national energy consumption and an overwhelming majority of the people in both rural and urban areas depend on fuel wood and charcoal for their household energy; (ii) provide a variety of non-timber products which are important in the daily lives of the majority of Ghanaians. These include pharmaceutical products; canes and rattans, fodder for castle, sheep and goats; bush meat, fruits, mushrooms and other foods, as well as fibre, gums and other chemicals;(iii) constitute a priceless eco-diverse resource, protecting soil and water resources, controlling floods, storing and recycling nutrients, providing habitats for wildlife and acting as a reservoir of valuable genetic resources; (iv) provide industrial wood products which account for between 5% - 65 of total Gross Domestic Products, support the home constructional industry, and rank third next to cocoa and minerals among export commodities;

(2) About 16% of the total land area of the country, made up to 11% of forest reserves and 5% of wildlife reserves, have been legally set aside and constitute as a permanent forest and wildlife heritage. Inadequate financial human and other resources have, however, not always made the effective management and conservation of this heritage possible.

(3) Outside the perment forest lands, National Policy has formerly been to progressively utilize the forest resources without replacement, prior to their destruction by conversion to other forms of land use. High population growth rates with their accompanying demands for food and other resources, have led to the removal and destruction of most of these non-reserved forests. The processes of deforestation and forest degradation have been accelerated by mining activities, also by over-grazing, the incidence of uncontrolled bush fires and selective logging which concentrates on a few choice species. The revised policy needs to address the development of forest resources particularly outside the forest estate.

(4) The participation and involvement of individuals, communities, community organization and Local Authorities is essential to the effective conservation and development of forest resources and to deriving optimum benefit from their utilization. The majority of the population have not shown sufficient appreciation of the importance of forests and the necessity for the management and conservation of forest resources. Public education and the promotion of measures to increase public participation are therefore essential to successful forest management and conservation.

(5) The forest estate should be managed in such a way that productivity is optimal yet sustainable in the long-term while biodiversity is also maintained.

(6) Research data in all technical branches of forestry are required for effective forest policy formulation, sound forest management decisions and efficient utilization of the forest resources. Research capacity therefore requires to be built up and maintained.

(7) Appropriate forest industries need to be encouraged to utilize efficiently the resources of the forest. Emphasis needs to be placed on the development of value-added products, the economic uses of wood residues and the expansion of the utilization base.

(8) Adequate numbers of trained manpower of all categories are required for the forest based industries and the institutions concerned with the implementation of the policy. Such staff need to be properly motivated and remunerated.

(9) There is a continuing necessity for co-operation in land-use planning by all interested agencies and for the harmonization of efforts at environmental conservation and economic development by such agencies.

5-1-4-3 The Policy Statement

Ghana's Forest Policy shall be, to:
(1) Maintain, protect, enlarge and develop enough forest land including plantations to ensure that; (a) sufficient forest and tree cover exist to meet fuel wood, fodder and forest produce requirements of the people; (b)a sustainable wood bags is developed to support domestic needs and provide produce for export; (c) soil and water resources are sustained and the environment enhanced; (d) adequate tree cover is maintained, and where necessary restored to protect environmentally sensitive areas such as steep hills and water courses; (e) flora and fauna are conserved in the different ecosystem; (f) the existing natural forest estate is prevented from further degradation in species diversity and reduction in area; (g) sites for trees and forests are incorporated in all land use planning and human settlements; and (h) amenity and recreational needs are met.

(2) Manage the forest estate so as to optimize environmental and economic benefits by ensuring: (a) the control of soil erosion and desertification; (b) that harvesting of forest resources are based on principles of sustainable yields, environmental conservation and enhancement of biodiversity; (c) control of exploitation of the forest resources to avoid serious ecological damage, (d) the development of losses due to pests, diseases, fire and human encroachments; (e9 conditions favourable to agricultural productivity; and (f) that Environment Impact Assessment of developments and other projects consider forestry aspects and are referred to the appropriate forestry agencies for comment before the execution of the projects.

(3) Provide support to forest-based industries: (a) to encourage a fuller utilization of the forest resources through the increased harvesting of the lesser used species; (b) to stimulate the development of more value-added products by promoting diversification of wood-based industries; (c) so that the harvesting and conservation of forest resources is carried out efficiently and waste minimized; (d) to stimulate the development of appropriate wood-based industries whose capacities will be commensurate with resource availability so as to achieve optimal resource utilization; but no large forest-based enterprise should be permitted in the future unless it has been first cleared after a careful scrutiny with regard to assured availability of raw material. (e) to develop economic uses for wood residues; (f) to integrate the forestry sector into the national economy to promote rural development and provide employment; and (g) to ensure efficient management.

(4) Encourage Private and Social {Community/Rural} Forestry by: (a) public education aimed at promoting an understanding of the role and value of trees, forests and wildlife; (b) involving the participation of the local people in forestry decision making and implementation through local institutions; (c) integrating forestry and tree planting into development planning at the grass root level; (d) assisting individuals, organizations

and communities to grow, protect, manage and utilize their own trees, forests and wildlife; (e) removing obstacles to tree tenure; (f) giving increased support to participatory forestry programmes; (g) supporting forestry development initiatives that benefit rural communities; (h) encouraged the development and practice of agroforestry; (i) the provision of physical incentives for private and community plantations; and (g) requiring Non-Governmental Organisations (NGO's), Privte Voluntary Organizations (PVO's) and other related bodies with interest in tree planting and other forestry related activities to liaise with appropriate forestry agencies and harmonise their activities with National Forestry Programme.

(5) Enhance the conservation and development of wildlife occurring in the forested and savannah woodland ecosystems outside the 'special' wildlife conservation areas.

(6) Ensure availability of trained manpower for the implementation of this policy by: (a)developing technical schools, specialist training and apprenticeship schemes that bear on forest management, utilization and industries; and (b) co-operating with any other institutions, local and international with relevant programmes.

(7) Maintain a research capability to improve monitoring, provider information and develop technology for policy formulation and decision-making and to permit better management, sustainable exploitation and efficient utilization of the forest resources through: (a) the maintenance of a strong Forest Research Institute; (b) the establishment of a Forestry Advisory Board drawn from Forestry, Agriculture and institutions concerned with forest-related activities to get priorities and review research programmes for execution by the Forest Research Institute and other interested researchers; (c) the execution of research, giving priority to research required for policy formulation, management and utilization of the national forest heritage investigations which provide information of general usefulness to the private sector and are in consonance with national priorities with also be given due attention; (d) co-operation with agriculture to evolve appropriate farming systems to ease pressure on the forest

(8) Develop, strengthen and maintain sectional efficiency through adequate motivation and remuneration of staff as well as the co-ordination of progrmmes and funding of the institutions required to implement this policy.

(9) Co-operate with their interested bodies, both national and international to harmonize efforts at environmental conservation and economic development.

(10) Establish a special fund(s) to ensure the achievement of the objectives of this policy.

(11) Enact appropriate legislation to implement this policy

(12) Ensure a periodic review, not less than 10 years, of the policy to reflect changing socio-economic conditions and/or availability of new information.

5-1-4-3 ACTION PROGRAMME

The Action Programme for the attainment of government's objectives set out in the Forest Policy of Ghana has seven components:

(1) Development of Forest Resouces:
(2) Management of the Forest Estate
(3) Conservation of the Forest Ecosystems;
(4) Development of Forest Based Industries
(5) Research; and
(6) Extension and Public Education
(7) Institutional Development

Based on the concept of multiple use and in dealing with the same resources one action aimed at a particular goal, of necessity also has implications for other objectives. Thus, the seven components of the Action Programme do overlap in many respects; the categorisation proposed is therefore only for convenience

It is recognized that wood fuel has hitherto been the most important source of energy for the majority of Ghanaians and that for a very long time to come, this dependency will continue. Nonetheless, the role of the forest as a major source of energy both for industry and households is not treated separately in the Action Programme; rather, fuelwood plantations and woodlots are considered under the Development of Forest Resources whilst efficient production and conversion of wood energy are treated under the Development of Forest based industries.

(1) Development of Forest Resources

The development of forest resources will essentially be carried out through privates and community forestry with support by public institutions and NGO's. The strategies will be as follows:
(I) The system of protected areas made up of forest reserves, protected environmentally sensitive areas, traditional protected areas and other natural forests permanently protected and managed by local authorities and communities will be increased from 16% to cover at least 20% of the total land areas by the year 2000. Together with industrial plantations, social, urban and other forests, at least 30% of the land surface area will by that time be covered by forests.
(II) Industrial plantations will be established by appropriate industries for specific end uses in appropriate places. These will include plantations for brick and title, iron and steel smelting, tobacco curing, match factories, pulp and paper mills and the mining concerns.
(III) Land use zoning in urban and rural settlement will provide sites for trees and green-belts
(IV) Encouragement will be given for the local development and domestication of non-timber forest resources, especially medicinal and food plants.
(V) Communities will be encouraged and assisted to grow multi purpose trees.
(VI) The support by Non-Governmental Organisations (NGO's) to tree planting will be encouraged within a National Forestry Programme.
(VII) The Forestry Department will enhance the provision of planting materials and technical support services to individuals and communities.
(VIII) To ensure a regular supply of seeds, Seed Centres will be developed at strategies locations.
(IX) Capability to raise seedlings and nurseries will be developed
(X) Adequate incentives will be made available for the tree planting programme.
(XI) Tree crops of short rotation will be promoted

(XII) Approval for the establishment of industries that depend on fuel wood will only be granted after adequate proof that the particular factory will not depend solely on the natural forest for fuel.
(XIII) For the long-term, there will be a programme to encourage all major institutions which use fuel wood for cooking to convert to other sources of energy.
(XIV) As a conservational measure, efficient wood fuel energy convertors will be developed and promoted to reduce the quantity of wood fuel required for domestic use
(XV) People will be helped to develop the habit of tree planting and protection.

(2) Management of the Forest Estate

The following strategies will be adopted to achieve the management objectives set out in the policy:
(I) continuous inventory will be undertaken to monitor the forest growth and dynamics to help institute the appropriate management plans
(II) in deciding on the appropriate forest management options, all forest resources shall be taken into consideration including wild life
(III) the legal basis for acquiring rights to exploit forest resources will be reviewed to evolve a system which involves the District Assemblies and is consistent of long term economic benefits.
(VI) Harvesting will be guided by silvicultural and environmental considerations especially to ensure regeneration.
(V) The national allowable cut will be spread over as many species as possible and monitoring of logging activities intensified.

(3) Conservation of the Forest Ecosystems

The conservation of the forest ecosystem will be undertaken through the maintenance and protection of special conservation areas for fauna and flora, and of areas critical to the conservation of soil and water. The following Action Plan will be used:
(I) Maintain large representatives of areas of natural tropical forests and wood lands. Increase substantially forest/tree cover in the country through massive afforestation, community/social forestry programmes.
(II) There will be a continuous monitoring of flora and fauna to assess their conservational status. Damage to forests from encroachment, fires, etc. should be arrested.
(III) All endangered species of flora and fauna will be protected.
(VI)Environmentally sensitive areas such as hilly areas, water courses, and swamps will be declared conservation areas.
(V) Diversion of forests lands for any non-forest purpose should be subject to the careful examination by specialists from the stand point of social and environmental costs and benefits.
(VI) Mining concessionaires will be required to repair and rehabilitate their concession areas in accordance with established forestry practices.
(VII) Headwaters of rivers will; be kept permanently under forest cover
(VIII) Traditional authorities will be strengthened to protect scared groves and other traditional conservation areas which will be legally constituted as such.
(IX) District authorities shall ensure that where necessary, suitable trees are planted on sites earmarked fore tree cover such as critical hilly areas, water courses, open parks or

nature reserves; they shall further ensure that uses incompatible with the maintenance of tree cover are discouraged.

(4) Development of Forest Based Industries

The following strategies will be adopted to encourage the development appropriate industries and efficient processing of the forest resources:

(I) Every effort will be made to broaden the species utilization base of the forest through research efficient exploitation and processing to enhance sustainability of the resource.

(II) Emphasis will be placed on thew secondary and tertiary processing of forest produce. Viable value-added products will be identified and promoted.

(III) Industries based on non-timber forest produce will be promoted to benefit rural communities.

(IV) Industries that use forest and mill residues will be promoted.

(V) Efficient wood fuel stoves will be developed and promoted.

(VI) Charcoal making methods will be improved to reduce waste.

(VII) Special attention will be paid to the training of technical manpower and the development of managerial capability for the Timber Trade and Industry.

(VIII) Forest Products Industries should assume increasing responsibilities for afforestation and protection of their concession areas, and thereby help to maintain a renewable supply of quality produce.

(5) **Research**

To meet the research needs of the forestry sector, the following strategies will be adopted

(I) Research programmes will be directed at solving priority problems of the sector, and will be reviewed periodically

(II) Linkage between research, industry and forestry practitioners will be strengthened

(III) Forestry practitioners, industry and the universities should also be encouraged to carry out some aspects of forestry research.

(IV) Dissemination of research findings should be made an integral part of research programmes.

(6) Extension and Public Education

To deal with the inadequate public appreciation of the importance of forests and the need for its sustainable utilization, and to strengthen capability for private and community forestry development and efficient exploitation and utilization of the forest resources, the following strategies will be adopted.

(I) All Forestry Sector Institutions shall maintain strong social relations outfit, and effective Extensions Units

(II) A sustained public education programme shall be launched

(III) Forestry will be included in the curricula for first and second cycle education institutions.

(7) Institutional Development

The Action Plans discussed under this broad heading cover matters pertaining to Forestry Sector institutional arrangements, manpower training and development, funding and legislation. The specific Action Plans are as follows":

(I) The Forestry Commission will be restructured to function as a National Forestry Authority responsible for advising on the formulation and review of national forest policy, and the coordination, monitoring and harmonization of policies and programmes of the sector institutions

(II) The Commission will have strong liaison with any other institutions whose work has a bearing on the forest and forest lands including other institutions responsible for manpower training for the sector.

(III) Restructuring of Forestry Sector Institutions to forage greater cooperation and joint participation in decision-making in the sector

(IV) There will be a progressive training scheme for all personnel of the Forestry sector

(V) Adequate support will be provided to the Institute of Renewable Natural Resources to properly carry out its approved objectives of research and training at under graduate and post-graduate levels. Post-graduate training will be expanded to provide high calibre personnel for the sector especially the Timber Industry.

(VI) The School of Forestry at Sunyani will be supported in the training of technical/sub-professional

(VII) A Forest Industries Training Centre will be set up to provide both vocational and technical training to cope will advanced technology in the Wood Processing Industries.

(VIII) Advisory Boards will bet set for all institutions training manpower for the sector to ensure that the needs of the sector are met and standards maintained. Membership of the Boards will include representation from the sector.

(IX) Forests should not be looked upon solely as a source of revenue. The full contribution of forests are not easily quantified especially in maintaining essential ecological processes and life-support systems and in preserving genetic diversity.

Conservation and management of forest resources is the sovereign responsibility of the national government to give adequate support to forestry institutions and their activities.

(X) Funding and investment in the forestry sector will be given due priority to ensure effective and efficient implementation of the policy.

(XI) In addition to the normal budgetary allocations to the sector, a special Forest Fund will be established into which revenues from the sector including levies, excise and export duties will be paid. The fund will be established prior to the coming into force of the policy and will be used for forestry development, management, research and training as well as other activities of the Sector Institutions.

(XII) User-agencies of research findings, particularly the industry, will contribute to the special Forest Fund.

(XIII) Other sources of revenue for the fund may include donations, grants, bequests and the like

(XIV) The Fund will be administered by a Board of Trustees made up of representatives from among the Sector Institutions, Industry and related government agencies

(XV) Develop a master plan for dynamic development of the forestry sector

(XVI) The appropriate legislation will be enacted to implement this policy

(XVII) Existing legislation will be reviewed and subsequent ones enacted to ensure that they harmonise with the Forest Policy of Ghana.

5-2.Integration of Trees into Watershed for Sustainable Sawah Development in Ghana

5-2-1 Introduction

In the area where the project was implemented people are generally doing subsistence farming. They clear the fallow vegetation by traditional slash and burn method and they grow rice in lowland and several other crops such as cassava, plantain, maize and cocoyam in upland area. But when we look at the practice of clearing vegetation, invariably that practice leads to a loss of important nutrients such as nitrogen, sulphur, carbon in gaseous form. That is the heat helps to convert nitrogen into the gaseous form and carbon into carbon dioxide, which are all lost into the atmosphere. You will take that out of the land. Burning also leads to destruction which otherwise could have added organic matter to the soil and organic matter is very essential in the formation of the structure of the soil. The burning and lost of organic matter in the soil also leads to damage the physical structure particularly, the structural characteristics of the soil.

This paper will first conceptualize the potential effect of trees, their integration into uplands and inland valleys, and how they will affect a sustainable Sawah development. I will also touch on the activities of forestry team and discuss their implications.

Wetland farming are known to be fairly stable because of water and nutrient accumulation in lowland. Therefore, in wetland farming you can grow several crops. You can have rice when there is plenty of water and after that you can put in vegetables, grain legumes and some crops in swamp areas. So if we want to increase food production, we need to convert our low lands or wet lands into food, especially rice, production and then put more economic and then put more economic crops like cocoa, oil palm and citrus in the uplands.

5-2-2 Role of agroforestry in watershed management

We should also put the uplands into agro-forestry that trees and trees mixed with food crops. Soils in the uplands are very fragile so the pressure we put on the lands, that is into typical arable cropping, which involves sterilizing the soil we eventually end up in a lot of degradation.

Agro-forestry has been defined in various forms by different authors but we will first look at the one that the International Centre for Agro-Forestry (ICRAF) has being using and they defined agro-forestry as a land-use system in which trees are grown in association with food crops or you can have trees in association with pasture, or you can help your cattle to have shed under the trees. Once the cattle is under the tree enjoying the shed that is also agro-forestry.

It also sustains production because of recycling the nutrients in conservation of soil that takes place. Trees can be sold or it could be use for fuel, wood, for constructing houses and by so doing, the farmer will earn extra income to support the Sawah development. Trees with their deep rooting system can capture and recycle the greater amount of nutrients and this is were the sustainability of nutrients comes in.

Trees can also be referred as ecological engineers (Fig. 5-4) and this is in the sense that when you take from one location to the other you can get the eco-system functioning. Inland valleys comprises of watershed of drainage axes in which seepage and runoff from adjacent lands coverage. Therefore outcome of nutrients element cycles should impact on fertility status of inland valley bottoms. Rainwater from the upland would sip water through vertically and laterally into the valley bottom (Fig. 5-5).

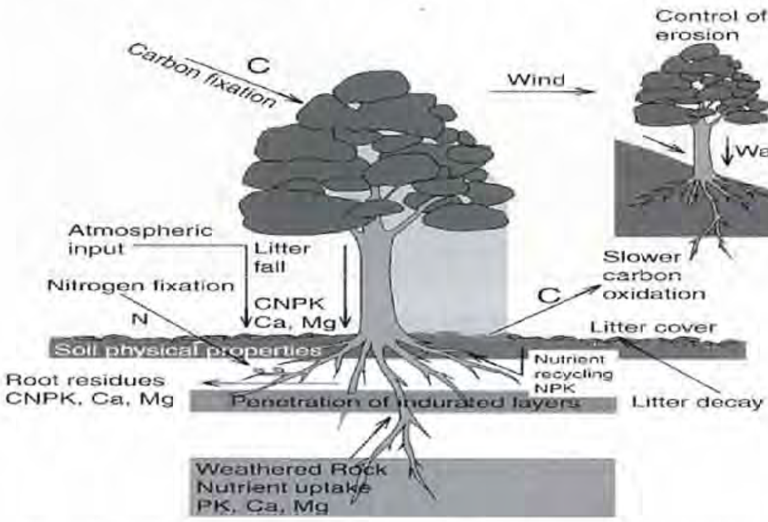


Fig. 5-4. Tree as ecological engineers (Young 1989)

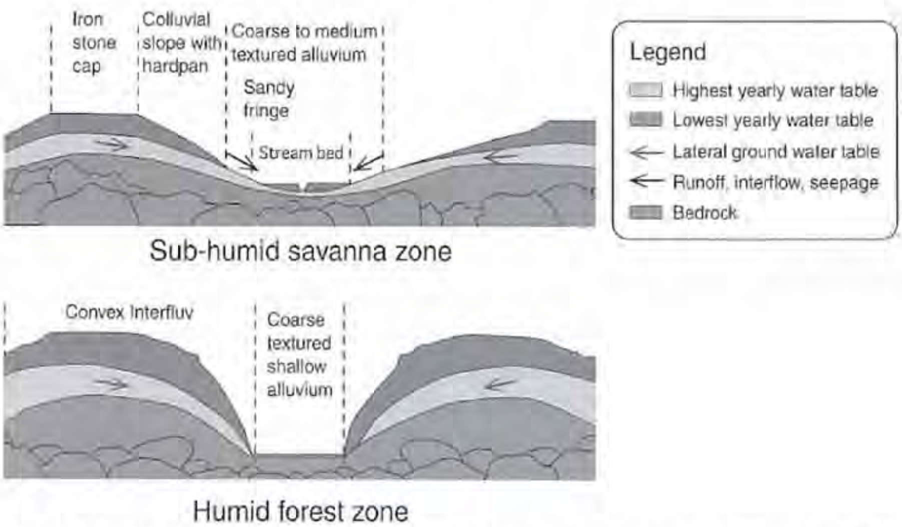


Fig. 5-5. Water movement from upland to lowland (Raunet 1985)

Humid agro-ecological zone of Ashanti regions characterized by the following land use types that is more food cropping system, plantation food crops, (cacao, citrus, oil palm), Secondary forest or fallow vegetation and the Primary forest (reserved forest) and that are managed by the forestry department (Fig.5-6). Some trees are less demanding of nutrients, therefore better of recycling available nutrient in their environment. Trees that throw large water volume of litter better at rejuvenating degraded lands. Various land-use types may differ in their influence on nutrient status of soils since they are composed of different trees.

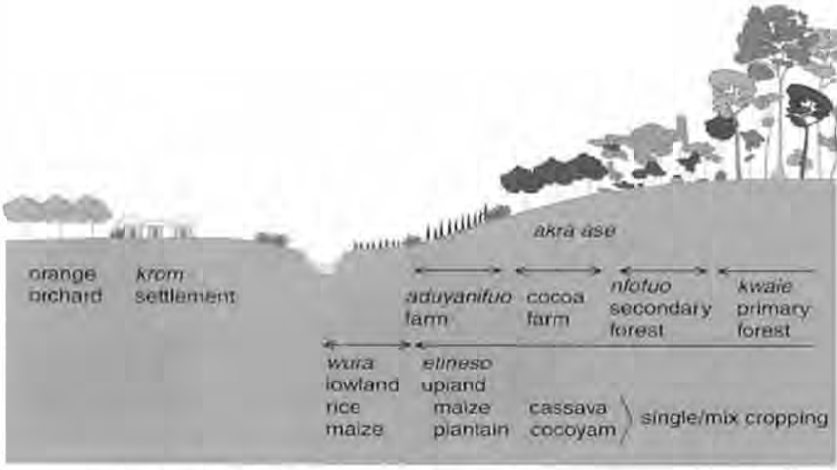


Fig. 5-6. Generalized land use Dwinyan watershed

5-2-3. Major Study Areas and Methodology

(1) Baseline studies on integration of trees into farms:
Our objective was to gather information necessary to enhance integration of trees into inland valleys. We also did
(2) Ecological studies on nutrient recycling in various land uses in our project site. Primary and secondary forests (Photo 5-1 and 5-2), cacao plantation (Photo 5-4, which including litter trap), mixed farming (Photo 5-5), fallow land(Photo 5-6), and valley bottom traditional rice field (Photo 5-7) were selected for intensive study. As described in the Chapter 3, those land uses were periodically monitored using strategic transect line survey (Photo 5-8).
Objectives were to determine 1) whether or not there are differences in quality and quantity of litter, 2) effects of various land uses on soil storage of carbon and nutrient, and 3) effect of various land uses on the extent of nutrient leaching in soil.
(3) Tree Planting for Soil and Water Conservation to Improve Quality of Land (Photo 5-9)
The objectives were to determine tree-planting arrangement, which is effective in soil and water conservation and land improvement and that of tree species, which are effective in soil and water conservation and land improvement.
(4) Wood-lots for firewood and charcoal production
Our objectives were to train or assist rural communities to produce fuelwood on sustainable basis to reduce deforestation and land degradation and also offset combustion of fossil fuels. We also demonstrated that multi-purpose tree species (MPTs) have relatively faster growth rates than indigenous species.
(5) Community or private tree nursery
Our objective was to train rural communities in techniques for raising seedlings and budding and grafting and to raise seedlings needed for deforestation and diversity income (Photo 5-10).

5-2-4. Results and Their Implications

Although latter parts of this chapter, we described major results in details, some essences of results were summarized as fallows.

(1) Base line studies

We conducted baseline studies on integration of trees into farms and where farmers prefer to plant tree species which could bring economic returns in short term and improve soil fertility. Farmers would also like to plant high value trees such as teak (*Tectona grandis*) The reason is that in Ghana we have the rural electrification project and the policy of the government is that rural electrification should be done with treated teak poles. So teak poles have value and so they realized that if they plant teak poles they will earn some money. The farmer's main problem with tree planting is lack of knowledge in propagating and establishing trees because of that the farmers suggested as a solution that they be given training in tree propagating and establishment techniques and assistance to acquire inputs.

(2) Ecological studies on nutrient cycling in various land uses

The quantity of litter trapped in each of the land use types showed gradual increasing trend from the wet season to the dry season (details will discuss in following sections of this chapter). Since the study area falls within the most semi-deciduous forest types, the observed pattern of litter accumulation is not unexpected. According to Nye and Greenland (1961) large qantity of litter (10, 500 kg/ha) accumulated in mature forest in a year. The corresponding amounts of nutriesnt returned to the soil surface from the above quantity of litter would be 200 Kg N, 7.3kg P, 68Kg K, 206Kg Ca and 45Kg Mg per ha annualy.

(3)Tree planting for soil and water conservation is to improve the quality of land

The two tree species planted, i.e., *Leucaena leucocephala* and Cassia, *Senna siaema*. Both trees exhibited very fast early growth attaining heigh of between 110cm and 150cm in 8 months. Leuceana have shown vigorous growth, however, Leucaena has grown taller than Cassia (Photo 5-9). Dry matter estimation in the second year revealed that the mixed plantings had about 40% of total dry matter in the form of leaves (Table 5-2). Therefore, for the purpose of producing dry matter for mulching and recycling nutrients mixed palntings of *Leucaena leucocephala* and *Senna siaema* should be used.

Tree planting, however, disturbs traditional slush and burn cultivation. Therefore if farmers have no clear understanding the importance of trees, they want to cut or burn such newly planted trees as shown in Photo 5-11.

Table 5-2 Percentage biomass yields of the planted species at different spacing and arrangement

Species spacing and arrangement	% dry weight	
	Wood	Leaves
C.2mx2m	80.68	19.32
C.3mx3m	94.7	5.3
C.mixed 2mx2m	59.3	40.7
C.mixed 3mx3m	58.36	41.64
L.mixed 2mx2m	64.82	35.18
L.mixed 3mx3m	86.51	13.49

C=S.(Cassia)siamea L=L..leucocephala
M=mixed species 2=2mx2m 3=3mx3m

(4) Woodlots for firewood production
The Cassia, *Senna siaem*, woodlots established in one of the communities has reached s stage where it could be harvested for firewood. However, the villagers have deciede to waite for a while to allow the trees to grow bigger. Probably the reason why the villagers are not rushing to harvest the firewood in the wood-lots is that they have another source of domestic energy which is cacao wood. Recent urbanization also accelerates the use of charcoal even in sub-urban areas.

(5) Community or Private Tree Nurseries
In one community seedlings of six tree species were produced in the nursery in 1998. However, only seedlings of two species, namely, oil palm (*Elaeis guineensis*) and cacao (Theobroma cacao) were sold out completely.

5-2-4 Conclusion

Baseline study revealed that farmers would prefer to plant trees, which can yield economic return in the shortest possible time. Farmers should also be encouraged to intercrop fruit trees with hardwood and that will be a good combination.
Since farmers want more seedlings of cacao, oil palm and citrus, then if they indulge in raising seedlings in nursery, they would earn substantial income to supplement traditional farm income.

For the purpose of producing biomass for mulching and nutrient recycling, mixed plantings of Leucaena leucocephala and Senna siamea could be used.

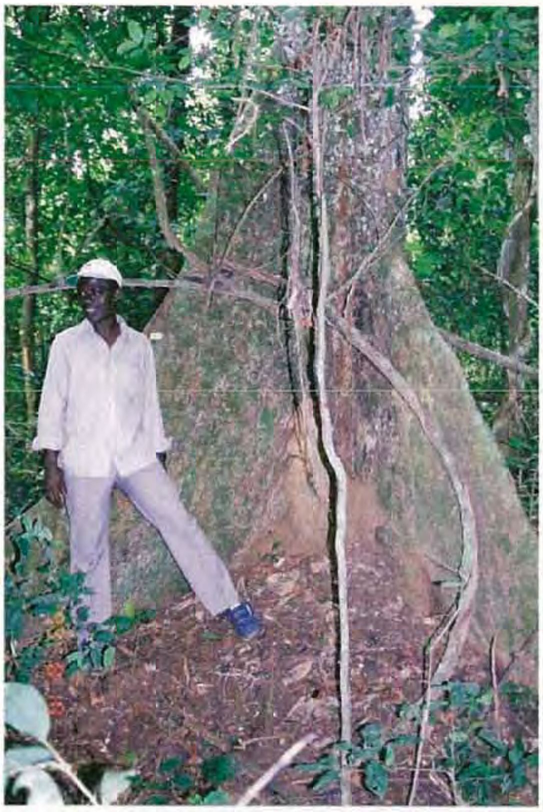


Photo. 5-1. Primary/secondary forest

Photo. 5-2. Primary/secondary forest

Photo. 5-3. Primary/secondary forest

Photo. 5-4. Cacao plantation and litter trap

Photo. 5-5. Mixed cropping

Photo. 5-6. Fallow land

Photo. 5-7. Valley bottom traditional rice

Photo. 5-8. Strategic transect line survey

Photo. 5-9. Lucaena and Cassia planting at Danyame (Gold valley) site

Photo. 5-10. Tree nusery

Photo. 5-11. Trees newly planted were burned for upland rice cultivation

5-3 Ecological studies on nutrient cycling and flows in and between various land use

5-3-1 Land Use Systems

In the study area, various land uses can be identified. These include, lowland traditional rice farming in the valley bottom, mixed cropping, cacao, citrus and oil palm plantations, fallow and forests.

5-3-1-1 Mixed cropping.

Advantages of mixed cropping are (1) It allows a fuller use of light, nutrients and water. Most crops have widely differing canopies and their combination permits a more efficient use of incident light and a favourable distribution of CO_2 (Suryatna and Hardwood 1976). There is less runoff and leaching. More transpiration occurs through plants than directly from the soil and the time with leaf cover is extended. (2) It tends to reduce the adverse conditions in the ecosystem. Disease and insect damage may be less and is likely to be more evenly distributed. Also damage to one crop may be compensated to some degree by the more vigorous development of another one (Banta and Hardwood 1973). (3) It also tends to produce less erosion than sole stands under the same circumstances and so contains an element of resource maintenance (Norman 1973). Socio-economic reasons include an increase in total output and it is also the traditional and more effective way of reducing risks. Mixed cropping usually represents a careful adaptation of the cropping pattern to topographic features. This farming systems play a significant role in the study area.

5-3-1-2 Fallow

In addition to storing soil water for the succeeding crop, fallow enhances accumulation of Nitrogen, through mineralization of organic matter and control of problem weeds , diseases and insects (Smika, 1983). Under the traditional minimal or no external input farming system, fallowing was used as the principal soil fertility restoration mechanism. This required a long fallow period of ten years or more for restoring the soil fertility that diminished during the two to four year cropping cycle. Soil reclamation during the fallow period was the result of recycling of nutrients by vegetation that pumped nutrients from the subsoil to the above-ground plant tissue. The decomposition of plant litter returned nutrients to the soil surface (Harcombe, 1977). Traditional fallow also forms part of the farming systems in the study area.

5-3-1-3 Cacao Plantation

As the largest source of revenue to the government, Cacao plays a very important part in the economy of Ghana. It accounts for about two-thirds of the value of exports from the country and provides employment for thousands of people. The cropping system is more permanent, for as long as 30 years. The most remarkable fact about the Ghana Cocoa industry is that production is controlled by peasant farmers. Cacao farms vary in size from less than 0.5 hectares to over 20 hectares, with average size being 1 hectare. During the establishment period of tree crops, it is common to intercrop with crops like plantain and cocoyam until tree canopy closes as described later.

5-3-1-4 Traditional lowland farming

The basic operational methods used by farmers in the sample area to prepare their lands for rice growing is the slash and burn method. Majority of the farmers slash the thicket with cutlass and burn the stubble. Only few use herbicides to kill weeds before planting. Majority of the farmers plant only local varieties and yields are always low. Most farmers plant their rice by dibbling randomly. There is no water management within the study area due to lack water management techniques. Most people also do not apply inorganic or organic fertilizers to their rice, therefore resulting in lower yields.

5-3-1-5 Forests

Another land use that has been identified in the study area is the forest, which has been classified into primary and secondary forests, depending on how they have been disturbed. These forests contain a high diversity of both plant and animal species. They are effective in soil and water conservation and land improvement. Due to their widely differing canopies, it tends to produce less erosion and so contains an element of resource maintenance. It is known that trees have more extensive and deeper root system and as a result, are more likely to capture and recycle larger amount of nutrients than herbaceous plants (Nair, 1993). With time, the leaves, roots and other plant materials returned to the soil will decompose and add organic matter and nutrients.

5-3-2 General description of Study Area

5-3-2-1 Geology

The soils of the area are developed over lower Birimian phyllites. These rocks consists of phyllites, greywacke, schists and gneiss. These were laid down in early geological times and consist mainly of clay deposit subsequently hardened and altered by heat and pressure. Veins and stringers of quartz injected into the phyllite break up during weathering to give stones and gravels. Due to the uneven distribution of these veins, the amount of quartz stones and gravels in the soils vary considerably and may be locally abundant.

5-3-2-2 Soils

The soils are developed from phyllite of the lower Birimian geology. They are grouped under Bekwai-Nzima-Oda compound Association (Adu, 1992). The soil association in its catena, comprise the summits and upper slopes of the uplands. They are well drained, reddish brown gravelly silty clay soil, Bekwai series (FAO Ferric Lixisol). Following the Bekwai series in the catena is Nzima series (FAO Ferric Luvisol) which occurs on the upper and middle slopes and sometimes on low-lying summits. It is moderately well-drained, yellowish brown, gravelly silty clay soil. It has morphological characteristics similar to Bekwai series but differ only in colour.

The lower slopes and the valley bottoms are occupied by Kokofu series (FAO Ferric Lixisol) which consists of moderately well to imperfectly drained yellowish, brown non-concretion or gravelly silty clay soils and the Oda series (FAO Dystric/Eutric gleysol) which consists of poorly drained grey clay soils respectively.

5-3-2-3 Vegetation

The vegetation of the area is influenced by the topography of the area. The uplands, that is, the summit and upper slopes, are covered by remnants of tropical rainforest. Plantation crops like Cocoa, Oil Palm, citrus and forb plantation which consists of mainly *Chromolaena odorata* (Siam weed/ Acheampong weed) and few scattered trees occur on the upper and lower slopes. The valley bottoms comprise rainfed lowlands, usually flooded during the rainy season. These are used mainly for lowland rice. Areas that are not flooded during the rains constitute an upland on which mixed cropping is practiced. Within the study area, the crops involved with mixed cropping are maize, cassava, cocoyam, plantain and vegetables like pepper and garden eggs.

5-3-3 Materials and Methods

5-3-3-1 Soil Sampling:

Sampling was done depending on the land use pattern of the area. These included the valley bottoms and the uplands and the corresponding land use were Valley bottom (VB) (under traditional rice production), Mixed cropping (MC), Fallow (predominated by *Chromolaena odorata* / Acheampong weed) and Cocoa plantation (CP). Sampling was also done at the gentle slope summit, which is occupied by a primary forest (PF) (Fig.4). Samples were mainly collected using core samplers. A few of the samples were taken from profile pits. Both topsoil (0-20m) and subsoil (20-40), (40-60cm) were collected. Samples were taken at selected depths because of the method adopted (core sampling), to cover a wider area.

5-3-3-2 Plant Sampling

Plant samples were also collected, corresponding to the various land use. These included fresh leaves and bark samples.

5-3-3-3 Laboratory analysis

Plants were oven dried at 60°C for 48-72 hours, ground into a powdery form and digested with Nitric acid in a high pressure Teflon vessel at 150°C for 4-5 hours. The various concentrations were then determined on the Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICPS 2000). K and Na were determined by Atomic Absorption Spectrophotometry (Thomas, 1982). Total Carbon and Nitrogen contents of the samples were determined by the dry combustion method using an N-C analyzer (Sumigraph NC-90A) as described by Geiger and Hardy (1971).

5-3-4 Results and Discussion

5-3-4-1 Soil Reaction.

Soil pH: Mean soil pH of the watershed under different land use systems are presented in Table 5-3. In general, the mean pH was moderately to slightly acid. The topsoil values for the various land uses were: Valley bottom (VB) 5.5, Mixed cropping (MC) 4.9, Fallow 6.4, Cocoa plantation (CP) 6.1 and Primary forest (PF) 6.2. With the exception of VB, soil pH generally decreased with depth. MC recorded the lowest pH. Profile distribution of soil pH for CP, Fallow and PF showed a sharp decrease from the topsoil to the subsoil. That of MC showed a gradual decrease from the topsoil. With regards to VB, there was a gradual increase from the topsoil to the subsoil.

Exchangeable Acidity :Mean levels of exchangeable acidity of the study area was very low. With the exception of the valley bottom soils, exchangeable acidity generally increased with depth. Distribution of exchangeable acidity was in the order MC > PF > VB > CP > Fallow. Mean topsoil levels as shown in Table 2 were VB 0.13, MC 0.59, Fallow 0.02, CP 0.05 and PF 0.22.

Table 5-3 Means of Soil pH, Ex.acidity, eCEC&Base saturation of Inland Valley watersheds in the Ashanti region of Ghana

	Depth	Land use				
	(cm)	Valley bottom	Mixed Cropping	Fallow	Cacao	Primary forest
Soil pH	0-20	5.5(5.0-5.8)	4.9(4.2-5.5)	6.4(5.7-8.1)	6.1(4.8-7.7)	6.2(5.4-7.0)
	20-40	5.6(5.3-6.0)	4.8(4.3-5.4)	5.6(4.5-8.1)	5.4(4.8-7.4)	5.7(4.7-6.8)
	40-60	5.6(5.3-6.0)	4.7(4.2-5.3)	5.5(4.7-8.0)	5.4(4.7-7.3)	5.5(4.6-6.6)
Exchangeable acidity [cmol(+)/kg]	0-20	0.13(0.0-0.3)	0.5980-1.2)	0.02(0-0.1)	0.05(0-0.2)	0.22(0-1.2)
	20-40	0.3(0.1-0.5)	1.3(0.1-2.4)	0.21(0-0.4)	0.21(0-0.6)	0.54(0.1-2.2)
	40-60	0.32(0.1-0.6)	1.23(0.1-2.0)	0.35(0-0.7)	0.31(0-0.6)	0.66(0.1-1.6)
eCEC [cmol(+)/kg]	0-20	7.18	6.07	11.75	14.08	14.56
	20-40	4.55	3.6	4.31	6.03	4.59
	40-60	3.6	3.49	4.13	5.21	4.41
Base Saturation[%]	0-20	98	90	99	99	98
	20-40	83	62	95	96	88
	40-60	91	64	91	93	85

5-3-4-2 Exchangeable Bases, eCEC and Base Saturation

Exchangeable Potassium, Calcium, Magnesium, and Sodium,

Mean exchangeable K levels of the study area are also shown in Table 5-3. Levels were highest in the topsoil and generally decreased with depth. With the exception of the mixed cropping soils, there was a general decrease of K levels down the profile. Distribution of the cation was in the order PF > Fallow > VB > CP > MC. Mean topsoil levels recorded were PF 0.46, Fallow 0.37, VB 0.36, CP 0.23 and MC 0.15. Though the mean topsoil for PF was higher, VB was however comparable to the other upland sites.

Mean exchangeable Ca levels were higher in the topsoils and generally decreased with depth. With the exception of the mixed cropping soils, there was a general increase of Ca levels along the toposequence, that is, from the valley bottom to the primary forest, which corresponds to the lowlands, through the slopes and to the summit. Distribution of exchangeable Ca was in the order PF > CP > Fallow > VB > MC. Observed mean topsoil levels were PF 11.57, CP 9.81, Fallow 8.75, MC 4.02 and VB 4.58.

The topsoils recorded the highest levels of mean exchangeable Mg levels and there was a general decrease down the profile. With the exception of the mixed cropping soils, there was a gradual decrease of the cation down the toposequence. The cation levels was however, higher in the Cocoa plantation and the fallow which corresponds to the slopes of the inland valley than the summit and the lowlands. Distribution of the exchangeable cation was in the order CP > Fallow > PF > VB > MC. Recorded topsoil levels were CP 3.94, Fallow 2.40. PF 2.16, VB 1.92 and MC 1.23.

The distribution of exchangeable Na did not follow any general pattern. For soils of VB, MC and CP, there was a gradual increase of the cation levels with depth. Parent material may play a major role in its distribution. For the Fallow and PF, there was a gradual decrease of the levels with depth. In general, there was fluctuations of the cation levels with depth. VB levels of this cation was however comparable to the upland sites. Observed mean topsoil levels were VB 0.19, MC 0.08, Fallow 0.21, CP 0.05 and PF 0.15.

Effective Cation Exchange Capacity (eCEC) and Base Saturation

Effective CEC and base saturation of the study area is also shown in Table 5-3. This parameter followed the same trend as the exchangeable cations, with the highest level being recorded in the uplands and decreased down the toposequence. The highest levels were recorded in the topsoils and decreased sharply with depth. Distribution of eCEC was of the order PF > CP > Fallow > VB >MC. Since the exchangeable acidity of the study area was low, the higher levels of eCEC might be due to the higher levels of exchangeable cations especially Ca and Mg. Apart from the contribution of parent material through weathering and sedimentation, higher organic matter and clay content in the uplands which bind the cations enabling them to leach could account for the distribution of eCEC.

Due to the low levels of exchangeable acidity within the study area, the base saturation values were very high with the mean topsoil values ranging between 90 and 99%. With the exception of MC which recorded the lowest value, all the other sites along the toposequence were comparable. Base saturation also decreased with depth. This parameter is known to be dependent on pH and with the lower depths decreasing in pH, they're corresponding base saturation also decreased. Little leaching of cations resulting in higher accumulation in the topsoils, may explain this trend.

5-3-4-3, Total Carbon (C) and Nitrogen (N) and Carbon/Nitrogen ratio (C/N)

Mean total C and N and C/N levels for the study area are shown in Table 5-4. Total C levels were however higher throughout the study area. The topsoils recorded the highest levels, decreasing sharply down the profile. The uplands had the highest concentration and gradually decreased down the toposequence. The valley bottom, therefore, recorded the lowest concentration. Distribution was of the order PF > CP > MC > Fallow > VB. The denser vegetation cover played a major role in the TC distribution. The total N levels of the study area was quite high with the topsoil recording the highest level and decreasing sharply down the profile. The uplands recorded the highest levels and decreased gradually down the toposequence. Its distribution was of the order PF > CP > MC > Fallow > VB. The denser vegetation cover, litterfall and mineralization, which is highest in the uplands and releases N could account for this trend of distribution. With the exception of Fallow and Mixed cropping, C/N ratio decreased sharply with depth. Distribution was of the order PF < VB < MC < CP < Fallow. Total C of the study area was quite high with corresponding high Total N and this may account for the observed trend of distribution.

5-3-4-4 Available Phosphorus (P)

Mean levels of available P (Bray No.1) of the study area are also presented in Table 5-4. The topsoil levels were relatively high and decreased sharply with depth. Among the macro elements determined, available P had a differing distribution trend, with the highest levels recorded in the valley bottoms and decreasing along the toposequence, that is, moving from the valley bottom to the uplands. Distribution was of the order VB > MC > PF > CP > Fallow (Fig 5-7). Mean available P of inland valley topsoils of West Africa was 3.9ppm that was less than half of that of Tropical Asia. The level was close to one tenth of that of Japanese Sawah (Issaka and Wakatsuki 1997), therefore, the level of available P in our study site was slightly higher than the mean of inland valley of West Africa.

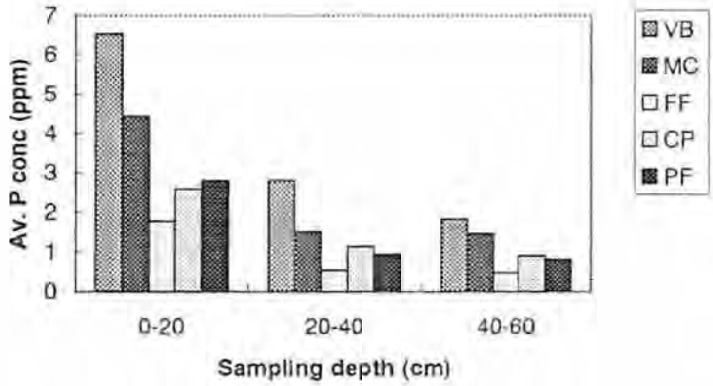


Fig. 5-7. Available-P

Table 5-4 Means of Total Carbon, Total N, C/N ratio & Available P of Inland Valley

	Depth (cm)	Land use				
		Valley bottom	Mixed Cropping	Fallow	Cacao	Primary forest
Total Carbon [g/kg]	0-20	19.5(10.1-35.3)	29.6(12.2-46.8)	27.5(17.5-41.1)	34.22(2.6-47.5)	36.62(0.1-45.3)
	20-40	6.4(3.7-8.3)	11.5(7.4-15.5)	9.0(6.9-14.0)	12.4(6.8-13.8)	13.3(8.5-20.9)
	40-60	2.8(1.7-3.9)	11.7(7.9-17.7)	8.4(6.7-10.3)	8.5(5.3-12.4)	12.9(9.5-20.2)
Total N [g/kg]	0-20	2.20(1.4-5.0)	2.96(1.4-5.0)	2.65(2.0-3.6)	3.44(2.4-5.3)	4.40(3.1-8.8)
	20-40	0.90(0.4-1.4)	1.46(0.8-2.4)	1.04(0.8-1.5)	1.47(0.7-3.5)	2.05(0.9-6.19
	40-60	0.5(0.2-0.9)	1.50(0.9-2.4)	0.92(0.7-1.1)	1.26(0.5-3.3)	2.1(1.0-6.9)
C/N ratio	0-20	9	10	10	10	8
	20-40	7	8	9	8	6
	40-60	6	8	9	7	6
Available P [mg/kg]	0-20	6.53(1.96-13.05)	4.43(2.56-10.49)	1.78(1.13-2.94)	2.58(1.34-5.409	2.79(1.22-5.40)
	20-40	2.80(1.18-5.59)	1.51(0.83-2.52)	0.54(0.18-1.23)	1.14(0.70-2.67)	0.96(0.22-2.07)
	40-60	1.83(0.73-4.49)	1.47(0.70-2.80)	0.48(0.22-0.99)	0.91(0.45-1.65)	0.81(0.18-1.92)

5-3-5 Discussion

5-3-5-1 Degradation of lowland soils in the site

The exchangeable cations especially, Ca, Mg and K was comparatively richer in the uplands than the lowlands. The Primary forest recorded the highest levels followed by Cocoa plantation and fallow. Relatively high organic matter in soils of the uplands, accounted for the larger retention of the basic cations compared to the lowlands. Higher clay contents of the uplands also partly explain the accumulation pattern of these exchangeable cations. Sandy nature and low organic matter content of the lowlands could account for the low levels of accumulated cations. Effective Cation Exchange Capacity (eCEC), an important fertility parameter, followed the distribution pattern of the various exchangeable cations, being higher in the uplands than the lowlands. Vegetation plays a major role in Total Carbon (TC) and TN distribution. TC and TN was highest in PF and CP and decreased down the toposequence.

General low fertility of lowland soil in the study area is the very characteristics of present non-sawah based traditional rice farming showing the degradation of lowland soils. If lowland soils are used in sawah based farming such as in Asia and Japan, normally soil fertility is very higher in lowland than in upland, especially for eCEC and exchangeable Ca, Mg, and K. Organic carbon and nitrogen level may be the highest in the primary forest and the lowest in the soils of upland cultivation. Sawah soils are always higher than those counterpart soils of upland soils (Kyuma and Wakatsuki 1995). However this is not true in our study site. The necessity of the introduction of Sawah systems in the lowland, is, therefore very clear.

5-3-5-2 Some selected micro-nutrients
Available Zn, Fe, Mn, Cu and Ni were first extracted by the DPTA method (Norvel and Lindsay, 1978). The concentrations of the various elements were then determined by the Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICPS 2000).

Available Zinc (Zn):Mean levels of available Zn in the study area are shown in Fig.5-8. In general, with the exception of available Mn, the micro-nutrients determined showed a trend which differed from the distribution of the macro-nutrients but similar to available P. Topsoil mean available Zn level was highest in the valley bottom. Distribution was of the order VB > CP > PF > Fallow > MC. With the exception of the Fallow, there was a sharp decrease of available Zn level with depth

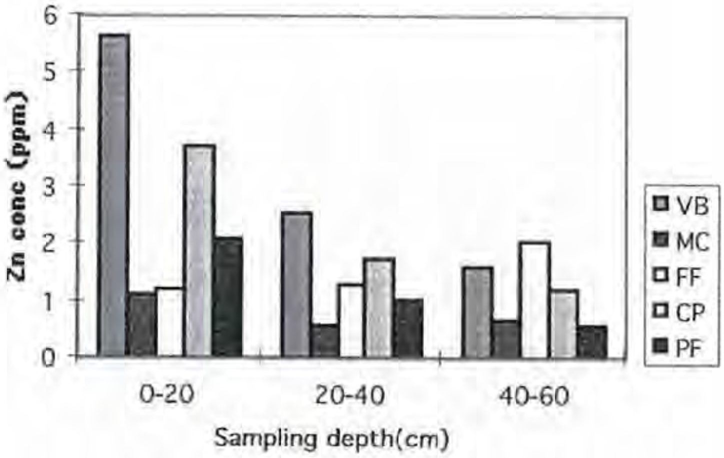


Fig. 5-8. Available Zn

Available Iron (Fe): Similar to that of available Zn, the highest topsoil mean levels was recorded in the valley bottoms and decreased towards the uplands. There was a general decrease of available Fe levels with depth. Distribution therefore was VB > MC > PF > Fallow > CP (Fig 5-9).

Available Copper (Cu): The highest topsoil mean level was recorded in the valley bottom. With the exception of available Mn, this showed a similar trend to the micro-nutrients already mentioned. With the exception of PF, there was a general increase of the levels with depth. Distribution was therefore in the order VB > CP > PF > Fallow > MC (Fig 5-10).

Available Nickel (Ni)
Nickel that has only recently been added to the list of elements shown to be essential to higher plants, was also studied and its available levels is as presented in Fig. 5-11.
In conformity with the micro-nutrients studied, available Mn exempted, the highest available Ni levels was recorded in the valley bottom and decreased towards the upland. There was a gradual decrease of the levels with depth. Available Ni distribution was in the order VB > CP > MC > Fallow > PF.

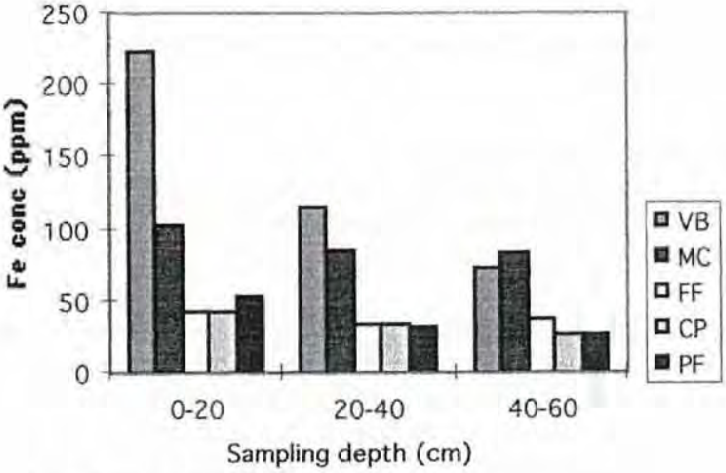


Fig. 5-9. Available Fe

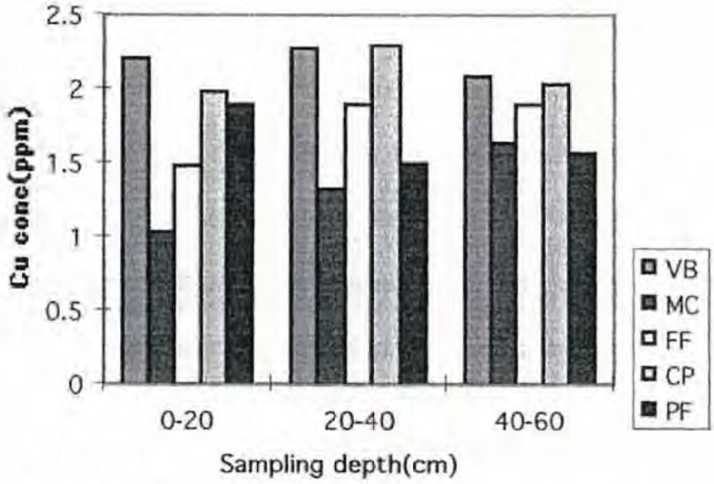


Fig. 5-10. Available Cu

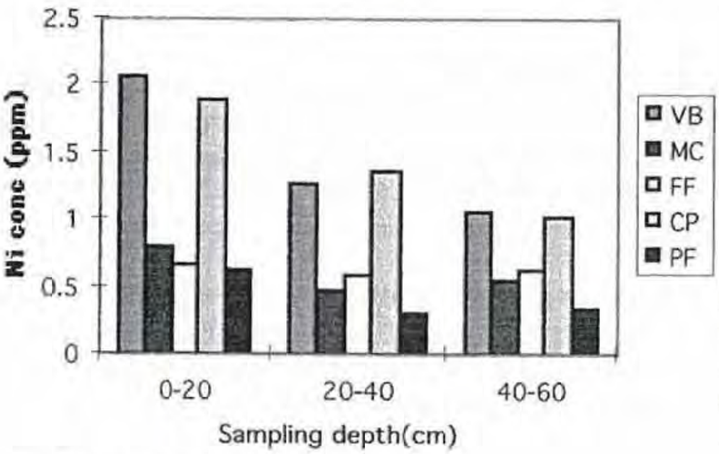


Fig. 5-11. Available Ni

5-3-5-3. Results of plant analysis

Characterization of the plant species and their nutritional characteristics in the various land use were therefore determined. Fig5-12, 13, 14, and 15 show families of the plant species found along the various land uses. The different families observed show the diversity of plants along the toposequence, that is, from the valley bottom to the primary forest. For the tree species, that is, primary forest and Cocoa, the elemental composition of leaves was compared with the result of bark analysis. The concentration range of various elements in the leaves and bark of the different land use and their mean topsoil fertility are presented in Table 5-5 a, b, and c.

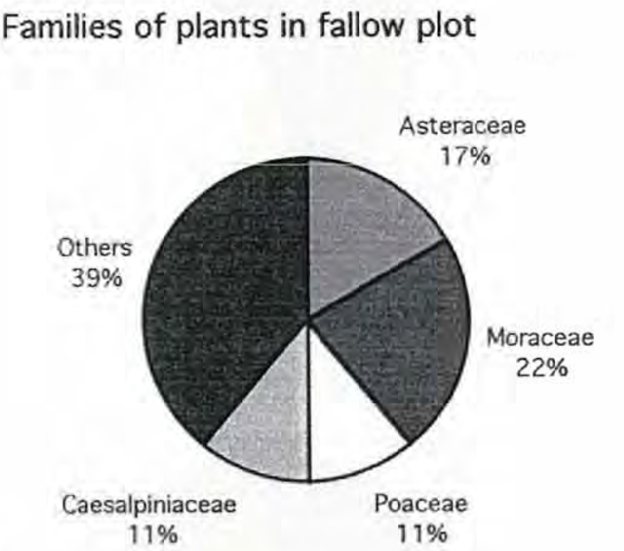


Fig. 5-12. Plant families identified at the fallow plot

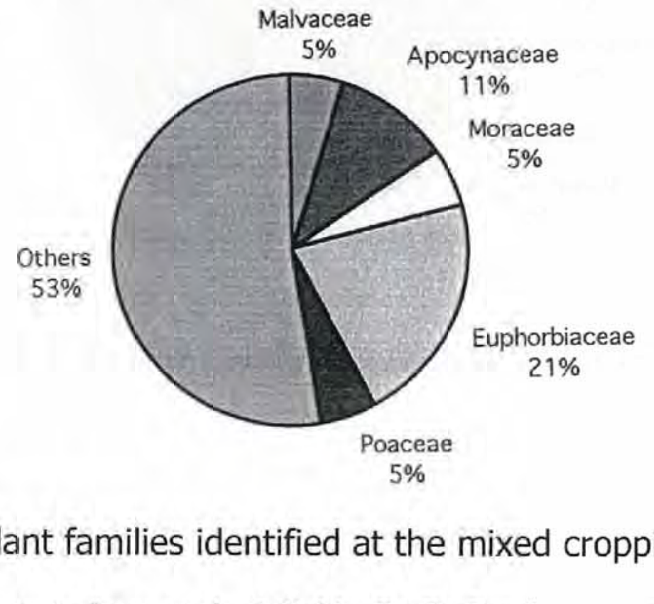


Fig. 5-13. Plant families identified at the mixed cropping plot

It was found that, elements, for example, S, K, Mg, Cu, Fe, P and Zn were higher in leaves than bark. However, some elements, for example, Ca was found to be much higher in bark than in leaves. The wide variation in nutritional characteristics in terms of elemental concentration and distribution in leaves and bark reflect the diversity of species in this area. The results of this work have shown that Ca tended to accumulate more in the bark than in the leaves. For the elements like P, Mn and Zn, the highest levels were recorded in the VB plants, though the other plant species from MC and Fallow were comparable.

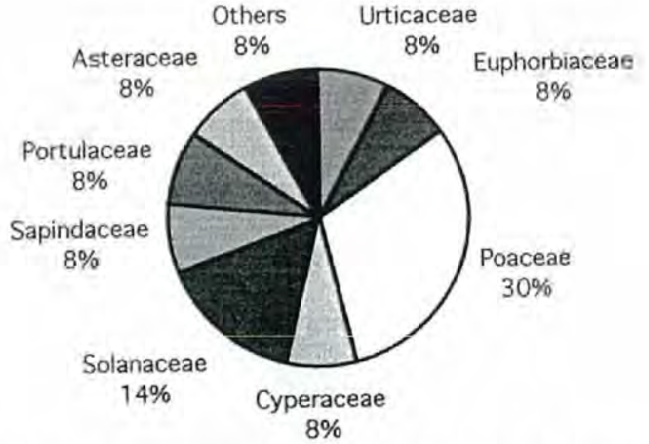


Fig. 5-14. Plant families identified at the valley bottom plot

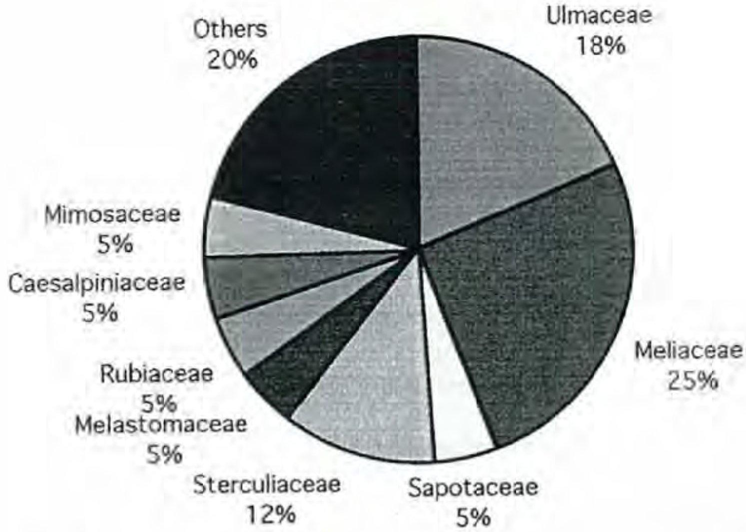


Fig. 5-15. Plant families identified at the primary forest plot

Table 5-5a Comparison of nutrient concentration of plants (leaf) of the various land use

Land use	S	Ca	Mg	K	P	Cu	Fe	Mn	Zn
	g/kg					mg/kg			
PF	1.3-6.5	2.1-63.1	1.6-5.3	4.2-39.5	0.2-2.3	0.5-80.5	88.7-528.4	0.1-762.0	8.0-407.3
Cacao	1.5-2.8	2.2-27.5	2.7-15.8	3.7-29.5	0.1-2.6	3.8-89.7	86.4-647.4	34.0-1120.0	25.6-140.7
Fallow	0.2-1.9	0.7-31.1	1.4-6.8	1.1-50.6	0.3-3.9	0.5-94.6	56.2-773.3	17.3-303.0	6.3-69.3
MC	0.6-4.7	4.5-27.0	14.0-7.4	2.2-46.5	0.3-3.7	0.7-10.6	155.0-421.5	4.1-734.0	2.4-58.2
VB	0.8-5.6	0.8-16.2	0.3-45.3	11.3-50.8	1.9-38.9	0.3-32.7	115.2-701.9	8.7-2066.0	10.0-102.4

Table 5-5b Comparion of bark nutrient concentration of Primary forest and Cocoa trees

Land use	S	Ca	Mg	K	P	Fe	Mn	Zn
	g/kg					mg/kg		
Primary forest	0.4-6.2	11.6-67.4	0.03-4.3	2.1-14.4	0.15-0.97	0.1-195.2	0.2-173.68	0.04-82.0
Cacao	1.2-1.4	47.7-52.7	4.33-5.08	21.1-28.4	0.19-0.26	95.0-258.6	0.01-0.02	56.1-67.9

Table 5-5c Mean topsoil fertility levels of the various land use

Land use	TN	TC	K	Ca	Mg	Avail.P	Cu	Fe	Mn	Zn
	g./kg					mg/kg				
PF	4.40	36.60	0.47	11.60	2.20	2.79	1.90	53.50	58.33	2.10
Cacao	3.40	34.20	0.33	9.80	3.90	2.58	1.98	42.78	97.88	3.73
Fallow	2.70	27.50	0.37	8.80	2.40	1.78	1.49	42.47	44.45	1.19
MC	3.00	29.60	0.15	4.00	1.20	4.43	1.04	103.45	24.06	1.10
VB	2.20	19.50	0.36	4.60	1.90	6.53	2.21	223.81	39.09	5.64

5-4 Woodlots for firewood and charcoal production

5-4-1 Woodlots for fire wood and charcoal production

This study is being carried out with the aim to (I) train rural communities in woodlot establishment and management practices (ii) assist rural communities to produce fuelwood on sustainable bases to reduce deforestation and land degradation and also offset combustion of fossil fuels, (iii) demonstrate that multi-purpose tree species (MPTs) have relatively faster growth rates than the indigenous fuelwood species.

An experimental/demonstration woodlot plot using cassia (*Senna siamea*) has been established in one of the communities. The spacing was 2m x 2m and the planting stocks were potted seedlings and stumps. In order to make the experiment/demonstration a truly participatory venture, the women's group in the community was assisted to plant cassava on the entire plot. Half of the plot was planted to improved cassava variety and the other half to a local variety. The women on their own decided to intercrop further with pepper.

Raising polypotted and bare-rooted seedlings and grafting citrus; (ii) assist rural communities to raise seedling needed for reforestation and soil fertility restoration and also to diversify income sources; (iii) demonstrate the effect of soil ameliorates (e.g. poultry manure) in enhancing growth and vigour of seedling in nursery.

At the start each of the participating communities was given a set of garden tools to clear the site of any vegetation and to construct the seed and transplants beds and also fill polybag with topsoil. A technical officer from the Forestry Research Institute of Ghana (FoRIG) educated the communities on the rudiments of nursery practices and assisted to sow the seeds supplied to them

The multipurpose trees species use in the woodlot experiment / demonstration, cassia (Senna siamea) is growing vigorously. Barely one week after planting, the stumps started sprouting profusely. However later some sprouts died. Drawing on previous experience with *Senna siamea* in the derived savanna agroecological zone, then at age two years after planting Senna siamea will be 5.90m in height and 6.0cm in diameter at breast height (Cobbina and Owusu-Sekyere, unpublished data). At that stage the trees could be clear-felled and sold to be used as fuel directly or after conversion to charcoal and thereby earn extra income which could be used to purchase inputs for rice production.

5-4-2, Cacao: agroforestry in the forest zone*

*This section was cited from 'Cacao, agroforestry in the forest zone' by Azusa Ochiai, which is appeared in "Restoration of Inland Valley Ecosystems in West Africa", edited by H. Hirose and T. Wakatsuki, Norin Tokei Kyoukai, Tokyo, 2001.

5-4-2-1 Introduction

Traditional agroforestry is often arranged ingeniously in the point of contact between the natural environment and an artificially created environment. In the case of sheanut, agroforestry is used as the method for utilizing effectively a useful tree that has already grown just as seen in some rice fields in northeastern Thailand, where trees are growing.

On the other hand, agroforestry of cacao observed in the project site, forest zone in Ghana is an example where a newly introduced tree crop is well incorporated into the existing farming system.

While it is not known when cacao planting was started in Ghana, there are several theories about its introduction. According to one of the theories, Tetteh Quarshie, a blacksmith belonging to Ga, one of the ethnic groups in Ghana, took back a cacao tree from a small island in the Gulf of Guinea in 1879, which started cacao growing in the country (Manu, 1995, p.9). It is not clear whether or not this theory is correct but Ghanaian farmers now call cacao tetteh quarshie.

The colonial government in Ghana had placed great emphasis on the cultivation of new commodity crops in British colonies in West Africa. After introduction of cacao, it distributed young cacao trees to farmers in 1887 to encourage them to grow this tree. Because the temperature and precipitation conditions of forests in southern Ghana resembled those of South America, the home of cacao, the land suitable for cacao growing in Ghana was almost all opened up and planted with cacao by about 1900. In 1970, the cultivated area of this tree reached about a half of the country's total acreage under cultivation. In 1947, to secure stable producers' prices, the country created a government agency for cacao purchase named Cocoa Marketing Board (CMB). This agency helped small cacao farmers in the country enlarge their farms further (Huq, 1989, p.109).

A variety of factors will lie behind the fact that no large cacao plantations were created in Ghana, but one important reason is probably that this crop was well built into the existing shifting cultivation system that farmers had already employed before the introduction of cacao. This is because cacao production in Ghana is almost all carrying out by small farmers. Unlike plantations operated by large companies, this cacao growing system by small farmers does not try to maximize the yield and profit of a single crop. Instead, it combines various strategies, such as crop arrangement for securing both the supply of materials for daily life and cash income and such techniques and management scales as may be covered by family labor. As a result, an agroforestry-like farming system was created.

The figures and tables shown below in this section are the results of the two surveys conducted in 1997 and 1998 in the State of Ashanti whose capital is Kumasi, Ghana's second largest city. Three villages were selected according to the distance from Kumasi (location): Adujama, a village about 40 km north-northwest of Kumasi facing a trunk road that was rapidly urbanized; Biemtetrete, about 4 km back from the section of a trunk road about 4 km north from Adujama; and Mmoroben about 20 km from a trunk road.

5-4-2-2 Characteristics of the farming system

How was cacao introduced into the traditional cycle of shifting cultivation, then? First of all, farmers clear a natural forest leaving trees too big to cut down and burn the undergrowth. After burning, they plant such food crops as maize, cocoyam, cassava and plantain first and then plant young cacao trees in the spaces under these crops. As the cacao trees grow taller and begin to shade the land with branches and leaves, they stop growing food crops and the land gradually turns into cacao woods. Young cacao trees need shades in the early growth stage and these shades are provided by the un-felled trees and the food crops grown that play the role of shelter woods (Figure 5-16).

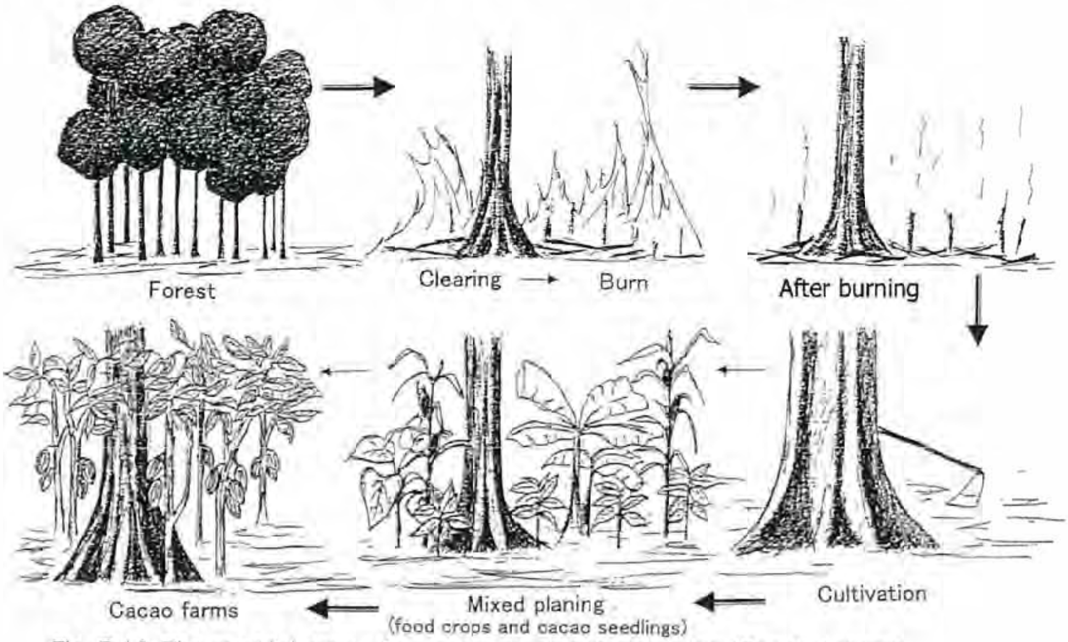


Fig. 5-16. The establishment of cacao groves in Ashanti region (The first stage).

After cacao woods are established, if new gaps are made as a result of, for example, the felling of big trees remaining in the woods by woodcutters or the withering of trees due to a disease or aging, farmers grow food crops in the gaps again and plant young cacao trees between the rows of food crops. Finally, cacao woods are renewed (Figure 5-17). This process is repeated thereafter in newly made gaps (Ochiai /et al., 1998).

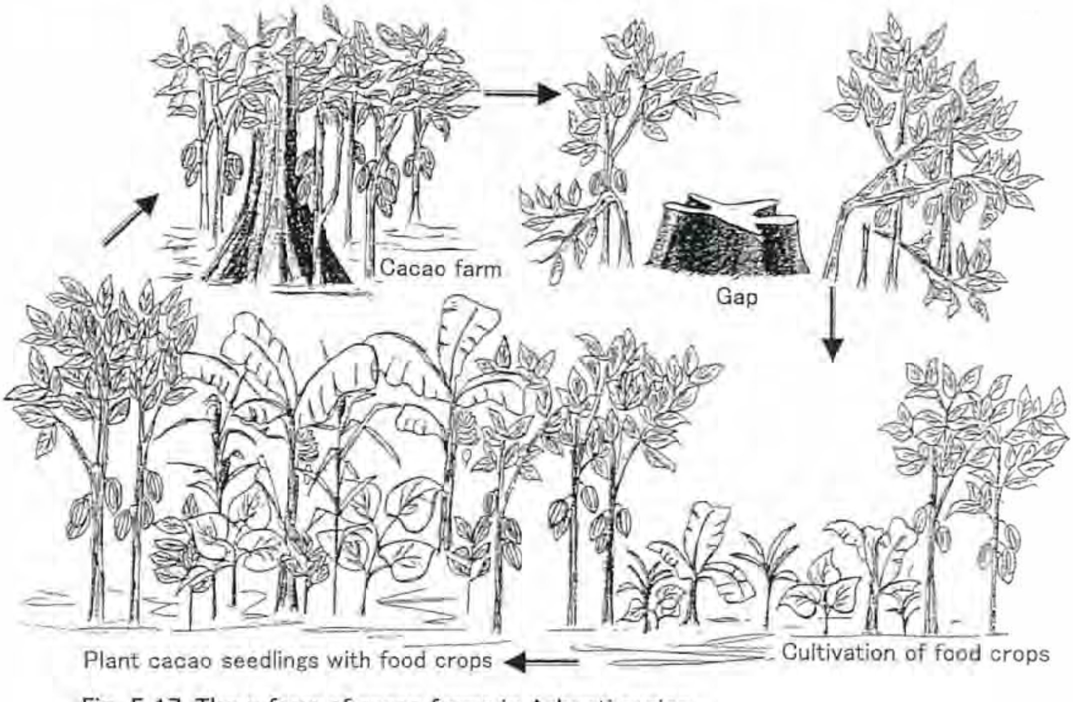


Fig. 5-17. The reform of cacao farms in Ashanti region.

The land use is shown in Fig. 5-18. The land surrounding near the village is used for agricultural fields, then the outer part is used for cacao farms or secondary forests. The land use system corresponds with the method how firewood is produced and sold. In Biemtetrete village, the cacao farms and secondary forests surrounding the village are mixed up (Fig.5-2), so firewood is gathered anywhere within area. In Adugyama village, land use patterns are relatively clear and there is little secondary forest (Fig 5-1.), most of the firewood are obtained from the agricultural and cacao fields. In Odeneho-Kuradaso village, people purchase firewood which are brought from villages facing the main road like Adugyama villages, or wastes from sawmills in Kumasi where most sawmills are located (Fig. 5-19)

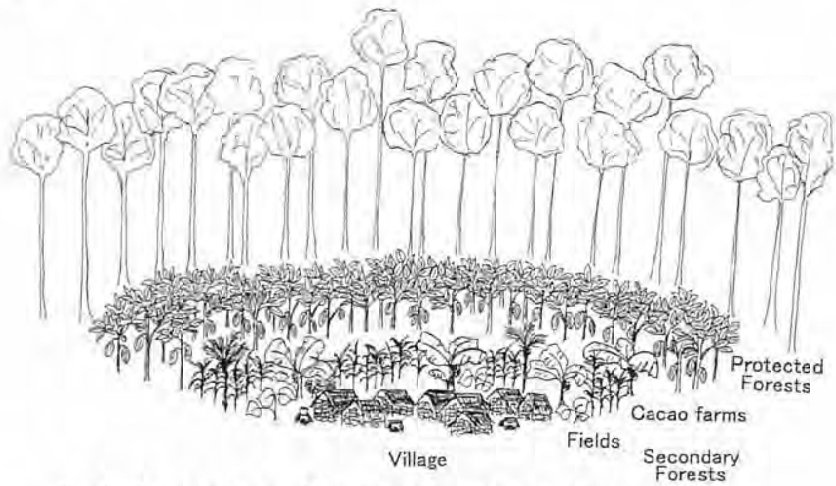


Fig. 5-18. The land use of Biemtetrete and Adujama villages.

5-4-2-3 Multipurpose character of cacao agroforestry

(1) Multipurpose use of cacao itself

Cacao seeds are dried and sold to the cacao-purchasing firm in each of the villages. They are mostly exported. The flesh around the seeds is eaten raw in some cases. Caustic soda is made by burning cacao shells; this is used as the material of soap together with palm oil lees and is a valuable source of cash income for women in the villages. It seems that tree crops like cacao have been regarded as "crops" for seed production and that their role as firewood has been considered less important though they are "trees." But the function of cacao as fuelwood is very useful.

In 1997 and 1998, an investigation on household fuels was conducted in the three cacao producing villages. Figure 5-20 shows the ratio of possessive number of furnace for firewood and stoves for charcoal in the three villages surveyed. Fig 5-21 shows the ration of cacao to the total weight of firewood the families in Biemtetrete. While some families had no stock of cacao, the percentage of cacao was 100% in two households. The ratio of cacao to the total firewood stock in weight of all households in the village was 42%. A similar tendency was observed in Adujama and Mmoroben, too. Considering that the stock of

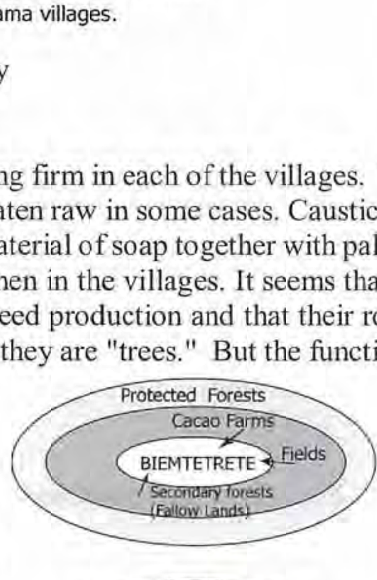


Fig. 5-19. The flow of firewood

fuelwood other than cacao is composed of multiple tree species, these figures suggest how important part cacao plays as firewood.

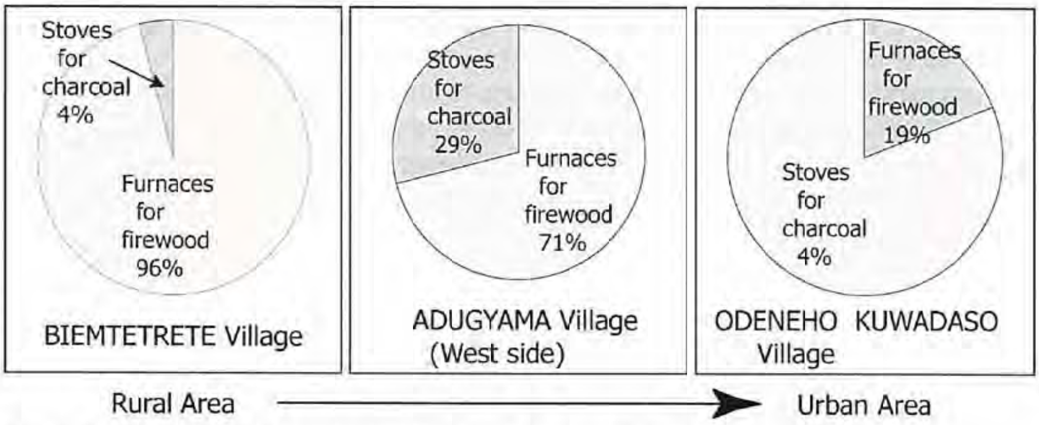


Fig. 5-20. The ratio of possesive number of furnaces for firewood and stoves for charcoal in each village (%)

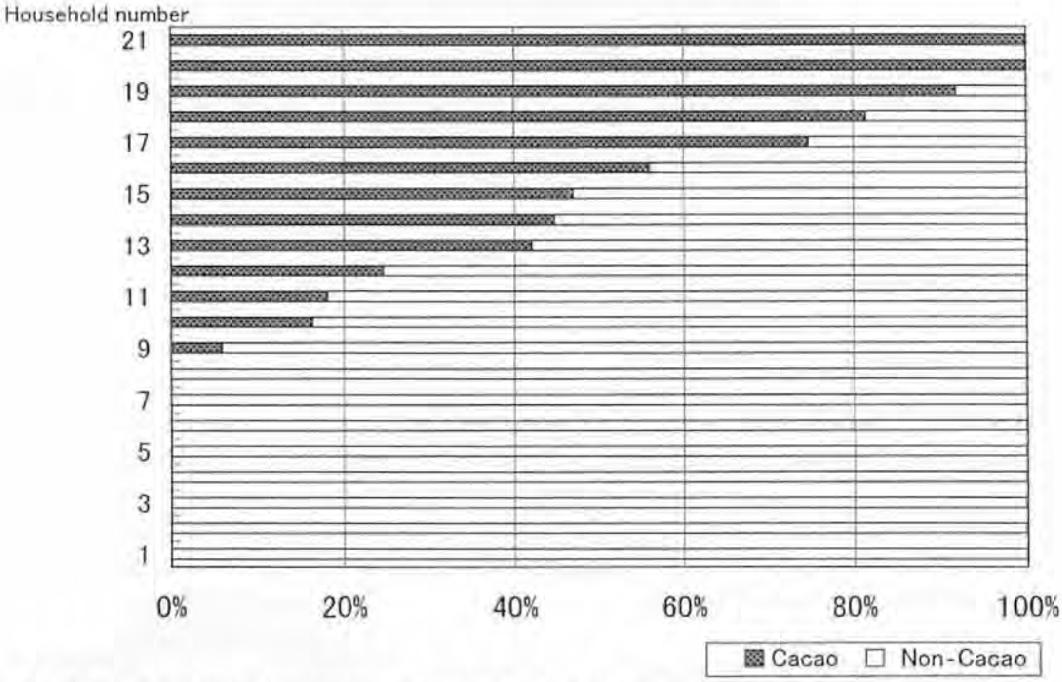


Fig. 5-21. The ratio of cacao account for all firewood, Biemtetrete (%)

It had been supposed that residents in Mmoroben would use other trees more than cacao as firewood because the village is adjacent to a forest reserve and there are non-cacao forests where they could gather wood for fuel. But the survey revealed that they used cacao as much as residents in Biemtetrete and Adugyama, who are far away from the forest reserve. Table 5-6 is the result of the investigation as to the consumption of fuelwood in which two households randomly selected from Biemtetrete (B) and Adugyama (A) were asked to use only cacao as fuel. As a result, it was found that each household used 0.08 m/3 per week on average. Based on this figure, the yearly fuel consumption is estimated at about 0.6 m/3 per person. For the calculation, FAO's mass conversion equation (kg/cubic metre = 725) was used.

To estimate how much fuelwood is taken from cacao woods, six plots of 20 m x 20 m were established in the cacao woods of native and improved species and the number of cacao trees planted was counted in each of the plots. In addition, ten of the cacao trees that would be cut down as fuelwood soon (that is, those which were laid aside or stood dead) were felled and their weight was measured (Table 5-6). The values obtained from the plots and weight measurement were averaged and figures per ha were estimated. The number of trees was 1,291 per ha and the volume of fuelwood materials that could be obtained from cacao trees was 0.08 m/3 per tree on average.

Table 5-6 The consumption of firewood and charcoal in Biemtetrete(B) and Adugyama(A)

Family	Adult	Children	The mean number of people/ meal	The mean number of cookin/day	The consumtion (m3/household/week)		The consumption/capita (m3/person/year)	
					Firewood	Charcoal	Firewood	Charcoal
B1	2	3	7	2	0.08		0.83	
B2	3	5	11	2	0.10		0.65	
A1	2	4	11	2	0.04		0.36	
A2	2	3	7	3	0.08		0.80	
B3	2	2	9	2		0.05		0.65
A5	2	1	3	2		0.07		1.22
A6	2	4	10	3		0.04		0.35
Ave.	2	3	8	2	0.08	0.05	0.66	0.74

*1 Only cacao wood for firewood

Supposing cacao trees were renewed in a 30-year cycle and those reaching 30 years were consumed as firewood, about 233 cacao trees would be needed to meet yearly demand for fuel per person. These cacao trees are equivalent to about 0.2 ha of cacao woods. This means that one cacao tree could supply fuel to one family of two adults and three children for a week and those cacao woods of 1 ha could meet one household's daily demand for fuel.

(2) Food supply function

As already noted, young cacao trees need to be shaded at their early growth stage and because of this, are planted in the shade of food crops. Thus it may be said that cacao trees have the function of food supply for a certain period of time. By the same method used in estimating the volume of firewood cacao woods could supply, the food supply quantity of crops grown on the floor of cacao woods was measured. The crops investigated were cassava, cocoyam and plantain; these crops are the main ingredients of fufu (prepared by steaming starch crops, making them into rice cake-like stuff and then putting soup on it), the main meal eaten almost every evening in Ashanti, the survey site, and are usually planted together with young cacao trees.

In Table 5-7, it was estimated that in Ashanti, about 0.2 ha of cacao woods would satisfy yearly demand for firewood per person. Thus it was supposed that each of the residents owned 0.2 ha of cacao woods. From these woods, they could reap about 56 kg of cassava, 63 kg of cocoyam and 59 kg of plantain a year. Supposing these harvests were all "fufu," they could eat about 178 kg of "fufu" a year. According to the survey conducted in this region in the same period, the yearly consumption of the three crops used for "fufu" is about 194 kg per person (estimated assuming that each person eats "fufu" once every day). This means that they can get about 90% of the three crops from their cacao woods. Needless to say, the harvest will change year after year owing to weather conditions, availability of farm hands and other factors and it will be impossible to meet almost all of demand with crops from cacao woods. But cacao woods can supply a considerable volume of crops and play a very important role in the supply of food crops.

Table 5-7 The potential volume of cacao for firewood (m^3) and the area of cacao farms for demand (ha)

Area of cacao forms *2 in Ashanti reagion (ha)	Densitiy of *3 cacao farms (Number /ha)	The mean volume of *4 firewood /cacao tree (m^3)	Annual comsumption (m^3/person/year)	Necessary number *5 of cacao/year Number/person/year	Area of cacao farms for demand/person (ha/person)
16,598	1,291	0.08	0.66	248	0.19

*1 Atlas for Ghana, Organization of African Unity 1995
*2 1995/96 Annual review report Ashanti reagion, Cocoa services division,1996
*3 This was setimated from the mean number of cacao trees in 6plots (20mx20m) (Number/ha)
*4 The mean weight of 10 cacao trees which have been intended to fell for firewood (kg)
*5 Cacao trees will be replaced every 30 years.

5-4-2-3 Considerations for gender and the existing systems

Worldwide, preparing meals, farm work for the cultivation and harvesting of crops needed for cooking and collection of firewood consumed in the kitchen are considered to be mainly the tasks of women. We have discussed the roles women play in cacao woods, and these functions have very good effects on women who take charge of these tasks.

Whether non-cacao forests where firewood can be gathered are near or far, the ratios of cacao trees to the total stock of fuelwood are roughly the same in the three villages surveyed. This is partly because cacao is a suitable firewood material but also because cacao woods (that are both the sites for wood collection and those for food crop production) are scattered on a small scale within the sphere of women's activities. Cacao woods give them an important physical advantage: after farm work and reaping of food crops for daily consumption, women can collect firewood, too. This is very important factor in reducing women's working hours and workload.

While shortage of fuel materials is posing a serious issue in the savanna zone in general, it has not attracted much attention in the forest zone because it is usually considered that this zone has a sufficient stock of wood fuel. It may be true that the forest zone has more fuelwood resources than the savanna zone. But what is more important in considering the question of fuel materials, especially that of a lack of firewood for household use, is access to resources rather than the entire stock of resources existing in the area, and an increase in forest areas will be no solution to the problem of fuel materials. To overcome a shortage of fuelwood, emphasis should be placed not merely on measures to increase resources (development of new fuelwood forests, etc.) but also on how to reduce the labor and time of those engaged in firewood collection work.

Ghanaian people succeeded in incorporating cacao, a newly introduced tree crop, into their traditional farming system and created a new system that can be used for many purposes, cacao agroforestry. Only within one century, a very short time compared with their long history, they adopted the new farming system to their life as their own one. Their ability to introduce what they need into their environment in an appropriate form and the diverse and reasonable land use methods they established as a result are really outstanding.

As seen from the case of cacao agroforestry in Ghana, the "existing" system is not anything unchanged for a long time but the one established through adaptation to various circumstances. Ghanaian people have accepted new technology and knowledge and have used them to build up what is appropriate to their environment. It is no bad thing to introduce new techniques and tree species. But in development aid projects aiming at increasing fuel material production, consideration should be given not only to early-growing species from abroad but to the "selection of appropriate trees to the area," including native trees and tree crops, as well. Instead of just trying to increase woody resources by a large-scale project, the "selection of forest sizes" should be made properly and the project site should be chosen in consideration of gender. What is more important will be the recognition that newly introduced elements are no separate and independent ones but are those to be built in the already existing system, to which adequate attention should be paid, too.

5-5 Development of Community and Private Tree Nurseries

5-5-1 Overview of the Development of Community and Private Tree Nurseries

5-5-5-1 Results of Base Line Survey

The overall objective of the baseline study was to gather information necessary to enhance the integration of trees into upland farms in inland valleys and also for the development of tree nursery. The relevant information was gathered through interviews and discussion with farmers some of the issues discussed included farmland ownership, location, and use pattern. Fig. 5-22 shows an example of the questionnaire for the nursery. The other preferred trees for planting on farmlands, reasons for the preference, and problems associated with tree planting on farmlands.

Fig. 5-23 shows the four sites of nursery trials in this project. Fig. 5-24 shows the distribution of private nurseries and the water pump in Biemso No. 1 village.

Most of the timber trees on farmlands occur naturally in widely scattered form and have been preserved mainly for the purpose of soil fertility improvement provision of wood for medicine and to provide shade to young cacao seedlings. Some timber trees which farmers claim are compatible with agricultural crops include *Ceiba pentandra, Milicia excelsa* and *Pycnanthus angolensis*. Those tree species farmers identified as contributing to soil fertility restoration include *Ceiba pentandra, Terminalia ivorensis,* T. superba Triplochiton scleroxylon and *Blighia sapida*.

Tree species farmers prefer to plant on their farms are those that could bring economic returns in the short term and also those, which will improve the soil fertility. Farmers would also like to plant high value timber and pole species such as teak (*Tectona grandis*). Farmers' main problem with tree planting on farmland is lack of knowledge in propagating and establishing trees. For solution to the above-mentioned problem, farmers suggested that they be given training in tree propagation and establishment techniques and also some assistance to acquire requisite inputs.

1. Do you have your own nursery? Yes No

If yes, to questions 2-6, if no, to questions 6-10

2. Why did you make your nursery?
   To use seedling in your fields
   To sale seedlings as business
   Both
   etc...

3. When did you make it? How did you know the nursery management skill?

4. What kind of seedling do you make?
   (Cacao, Oil palm, Citrus and Teak etc... ( )
5. How many seedlings do you have?
6. How did you get seeds?
7. Have you involved in nursery work?

8. Is that who's nursery?
   Your family, Your friends, etc... ( )

9. Have you bought seedlings? What kind of seedling did you buy?
   Yes, No Cacao, Oil palm, Citrus, etc... ( )

10. Where did you get it?
    In Biemso No.1, Another place ( )

Fig. 5-22. The format of questionnaire for nursery

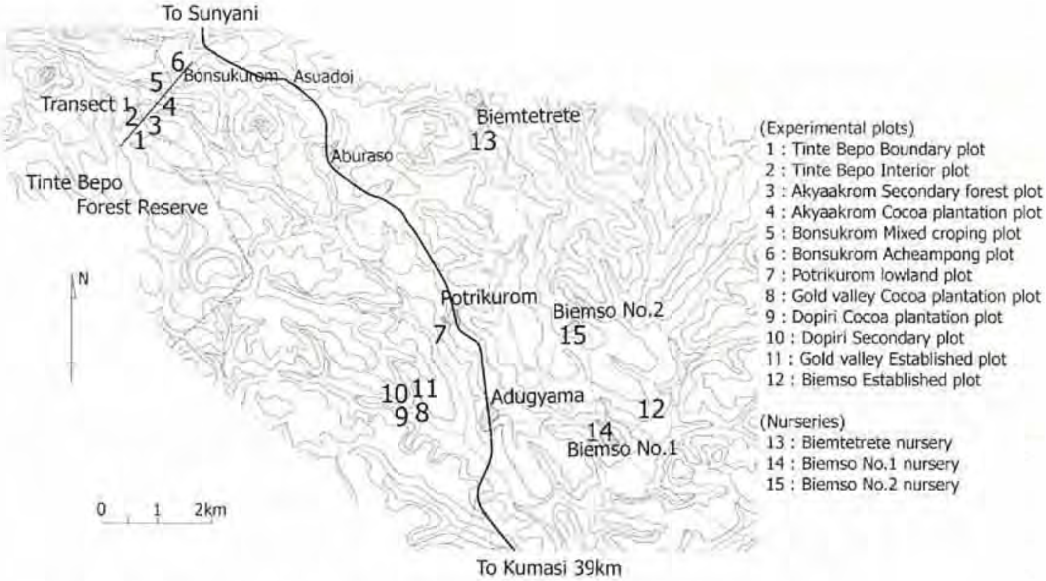


Fig. 5-23. Research sites of F-team (Experimental plots and nurseries)

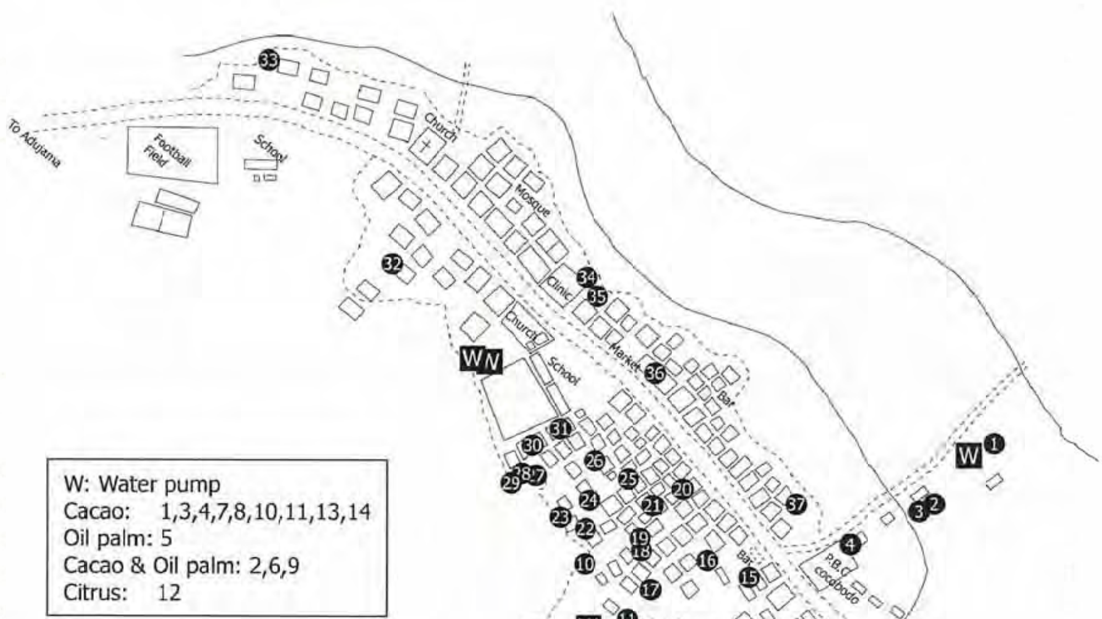


Fig. 5-24. Private nurseries in Biemso No.1

5-5-5-2 Results of the Nursery Trials

In one of the two communities (Biemtetrete) the nursery was established on a land provide by the chief. This nursery was truly a community undertaking with a greater number of the residents (both men and women) participating. A nursery management committee was elected and it is still functioning as at the start of the 1998 cropping season, the Bientertrete nursery had produced 800 Cassia (*Senna siamea*), 200 Teak (*Tectona grandis*), 100 Wawa (*Triplochiton scleroxylon*). 200 Pampina (Albizia adianthifolia), 175 oil palm (*Elaeis guineensis*) and 2240 Cocoa (*Theobroma cacao*) seedlings as shown in Table 5-8. By mid August 1998 all the cacao seedling had been sold out at a price of ¢50.00 seedlings^{-1} whilst the oil palm seedlings were sold for ¢1,000.00 seedling^{-1}. In contrast, the Senna siamea, Triplochiton scleroxylon and Albizia adianthifolia seedlings have not been bought. The Club "C" members at Adujama have been re-organized to carry out nursery activities and it is in progress. Cocoa pods and oil palm germinated nuts have been distributed to the communities for nursing as follows; Biemso No1, 500 seeds and 200 germinated nuts; Biemso No2, 800 seeds and 200 germinated nuts; Biemtetrete, 500 seeds and 300 germinated nuts; Adujama, 1000 seeds and 200 germinated nuts respectively in the third year. Survival rates are as below: Biemso No1, 84.5% for cocoa and 80% for oil palm; Biemso No2, 88% and 56.3% Biemtetrete, 85.7% and 80% and Adujama, 88.5% and 70% respectively. Adujama nursed teak seeds and germination is 40%, which is poor.

Table 5-8 Production of tree seedlings in community nursery at Biemtetrete

	Quantity of seedlings	
Tree species	Produced	Amt realised(cedies)
Elaeis guineensis	175	175,000
Theobroma cacao	2,240	112,000
Senna siamea	800	None
Tectona grandis	200	None
Triplochiton scleroxylom	100	None
Albizia adianthifolia	200	None

※Exchange rate: US$1= Cedies 2,340.00

It became apparent that even those people who owned land and can grow trees were not enthusiastic about planting hardwood trees. Some argued that the hardwood trees take exceptionally too long a time to mature. Besides, they were of the opinion that timber tress still belong to the government who only has the right to allocate the area to timber contractor. But the fact of the matter is that under the new forestry act, as described in the section 5-1-4 of this chapter, anyone who plants a tree has the right to dispose of the tree. There is therefore, the need to embark on extensive campaign to educate rural people on the provisions of the new forestry act so that they will be motivated to take tree planting as a business.

At Biemtetrete, barely two years after starting the community nursery, two men started their private nurseries in the village where they raised cacao seedlings. It is inferred from these developments that to transfer a complicated technology such as raising seedlings in nursery to rural people, the entire community will have to be taken on board. With time, as people acquire the techniques they will decide to try it on their own.

5-4-2 Participatory Approach for the Development of Community and Private Tree Nurseries*

*This section was based on the JICA expert report by M. Masuda on September 1998

5-4-2-1 Background

Tree planting normally starts from nursery establishment. Former JICA projects aiming at social forestry had a tendency to start from construction of large-scale nurseries together with other accompanying facilities such as building for management and research as well. Once those are established with heavy equipment, distribution of seedlings, which consist of fast growing species, and training are provided to farmers through extension network.

Such centralized nurseries, however, cannot fit for the forestry component of this project, as the basic concept is to find out a course of rural development with a bottom-up approach. In addition, without well-developed extension networks in the field of forestry, or without certain economic conditions to allow farmers to prepare means of transportation by themselves, large-scale nurseries can work only for large-scale tree plantation either by governments or by private enterprises.

Therefore, it seems necessary to find alternatives of applicable and sustainable nursery systems in order to encourage farmers to arrange more trees on their environment. The conditions of such nurseries can be summarized as follows:

- small scale
- scattered arrangement
- designed and managed by farmers themselves, either on communal basis or by individuals
- based on available resources for farmers
- proper intervention by extension or research organization

In addition, careful attention should be also paid for site selection, as nurseries require watering throughout the year.

5-4-2-2 General settings of the project site

As already mentioned, Ashanti region is characterized by peculiar customary laws relating to land tenure, which is called stool system. The whole land fundamentally belongs to Asantehene (king of Ashanti) and is divided to *omanhene*. The direct rules of each portion of land are families of recent individuals who acquired land trough inheritance, donation or purchase.

Expansion of cacao farm combine with continuous migration from the north and Volta region has given rise to tenancy agriculture. From such background, rural settlements of Ashanti region can be tentatively classified to the following categories:

Category 1

Settlements developed in large scale based econo-geographical location

- Ruled by Ohene (chief)
- Consist of various occupations including those of non-agricultural sectors

Category 2
Settlements of relatively small scale
- Ruled by Odikuro (sub-chief)
- Mainly consist of farmers, both natives and migrants

Category 3
Hamlets of cacao caretakers, consisting of only one r some houses, scattered all over the region

Among Category 1, participatory approach cannot be easily applied because of the population size and various sources of cash income reduce their interest in small-scale activities. In addition, sites suitable for nurseries are limited to where water is always available, and potential of such lands as riverbanks cannot afford to accept everybody. For the purpose of village nursery development, it seems better to take Category 2 as the target.

The reasons why Biemtetrete was selected not only for baseline survey but also as a trial site of village nursery development are: (1) size of population, (2) geographical location to be rather far away from commercial centers, and (3) existence of well organized community works.

5-4-2-3 Process of the first stage, 1997/1998

Step 1. Negotiation
Besides baseline survey, negotiation was done with key persons such as the chief and other opinion makers. To assure impartial opportunity for all the members, both natives and migrants, development of community nursery was suggested from the project side, and after discussions, the key persons agreed it.

Step 2. Site preparation
Through Step 1, the chief offered a part of his land near Biem River. Water can be supplied from Biem River during the rainy season, and as for two months when the river dried up, water supply from bore hall well is available.
It took two days for weeding, uprooting and hoeing to make nursery beds by communal work. Only men participated in these works and a technician from FoRIG guided the work.

Step 3. Selection of species
It resulted in a compromise of farmers' request and suggestion from the project side. Farmers preferred to plant hybrid cacao, citrus and oil palm, while the project put emphases on timber and fuelwood species, in this case, *Cassia siamea, Tectona grandis* and *Triplochiton scleroxylon*.

Step 4. Management organization
As various committees have already existed at Biemtetrete such as community development committee, farmers association, and PTA of elementary school, it did not take time to organize management body or nursery, which consists of chairman, secretary and treasury. Then all of the adult members were divided into six groups and ordered to be responsible on watering of the assigned date.
It should be pointed out here, however, that even through imposed the same duties,

migrants were excluded not only from the committee member but also from the discussions.

Step 5. Maintenance
It cannot be traced at this moment, but is summarized in the attached report by Dr. J. Cobbina, leader of F-team. Anyhow the nursery could be maintained by the villagers themselves without intervention by the project throughout the dry season.

5-4-2-4 Suggestions to the activities of the second stage, 1998/1999

A review meeting after one year was held on 24 July 1998. To encourage open discussions, the villagers were divided into three groups: landlords, migrants, and women. Based on the results that most of cacao and oil palm seedling could be sold out, the following tropics are suggested for further discussions between villagers and the project:

(1) Management system
As the buyers of seedling are only landlords, it seems further development of the village nursery at Biemtetrete can be directed toward not on communal basis but on individual efforts. Rental of nursery beds to individuals can be taken into consideration. If the villagers prefer existing system of communal basis, how to secure accountability, especially on the financial aspect, should be carefully discussed.

(2) Marketing and planning
Many of the landlords claimed cacao seedling provided during the first stage were far less than the demand. Together with the result that some could be sold to outsiders, marketing research and planning as well seem essential for the next step of village nurseries. Comparison of survival rates between bare-root and polypot seedlings are also required. To realize higher additional value and to find out broader market of produce from village nurseries, technology transfer of grafting, budding, and cutting, especially of fruit trees is suggested. For example, seeds of mango are available from the trees grown everywhere but grafted seedlings of mango are sold at 3,000 cedis in Kumasi.

(3) WID aspect
Through the meeting with women, it was pointed out that the involvement of women in community nursery was limited to fetch water for the nursery. Some of them were even not informed any about what was going on. Therefore, separated activity only by women was suggested and accepted at meeting. Combinations of vegetable farming with tree crops seem to be an alternative.

5-6 Integrated agroforestry for sustainable development in small inland valleys in Ghana.

5-6-1 Establishment of Forest Plots for Integrated Agroforestry

5-6-1-1 Introduction

This is being carried out with the objective to determine: (1) whether or not there are differences in the quantity and quality of litter thrown the various land uses, (2) effect of various land uses on extent of nutrient leaching in the soil profile and (3) movement under different land-use condition on a toposequence, upland to lowland. We established 12 plots at typical land uses (primary and secondary forest, cocoa plantation, fallow, mixed cropping field and lowland, which are shown in Photo 5-1, 2, 3, 4, 5, 6, and 7 respectively) during April, 1999 to March, 2000 as shown in Fig.5-24.

(2) Plant community

Tinte Bepo Boundary and Interior plots (dry semi-deciduous forest) and 28 years old secondary forests were identified and selected as study sites in Tinte Bepo forest reserve near Bonsukurom. In order to gain a fair knowledge of the level of plant species diversity in the two forest types, an inventory of plant species and canopy measurement were carried out. A total of 435 trees whose diameters exceeded 5.0cm measured at breast height (dbh) were identified from a plot size of 4,500m^2 in the Tinte Bepo Interior plot as shown in Fig. 5-25 a and b. Fig. 5-25 c and d showed tree location and topographical map. Fig. 5-25 e showed subplot diagram. Species identification and some plant nutritional characteristics were studied, too. A total of 26 plant families are represented out of which Rubiaceae dominates (15.9%) followed by Sterculiaceae (10.1%), Papilionaceae (9.9%), Meliaceae (9.7%) and Ulmaceae (8.5%). The least represented families are Anacardiaceae, Burseraceae, Combretaceae, Irvingiaceae and Ebeneceae (0.2%) as shown in Fig.5.

We established two secondary forest plots. Akyaakrom secondary forest plot was located beside upper site in transect 1 and Dopiri secondary forest plot was located on left ridge of Gold valley. Both plots are divided into three small plots in upper, middle and lower site, each on the slope as shown in Fig.5-26 and Fig.5-27. In those plots, total of 158 number of tree above 5.0cm dbh were identified in Akyaakrom forest and 118 trees in Dopiri forest. The dominant families in Akyaakrom secondary forest are Meliaceae (21.5%), and Moraceae (12.0%) Apocynaceae (11.4%), Euphorbiaceae (10.8%), Mimosaceae (9.5%) and the least are Rhamnaceae, Rutaceae, Rubiaceae and Olacaceae (0.6%). In Dopiri, a total of 18 plant families were represented and the highest occurring families are Moraceae (18.6%), Mimosaceae (17.8%), Euphorbiaceae (14.4%), Meliaceae (9.3%) and Rubiaceae (8.5%). The least are Ulmaceae, Anacardiaceae and Annonaceae (0.8%) as shown in Fig.9 in page19.

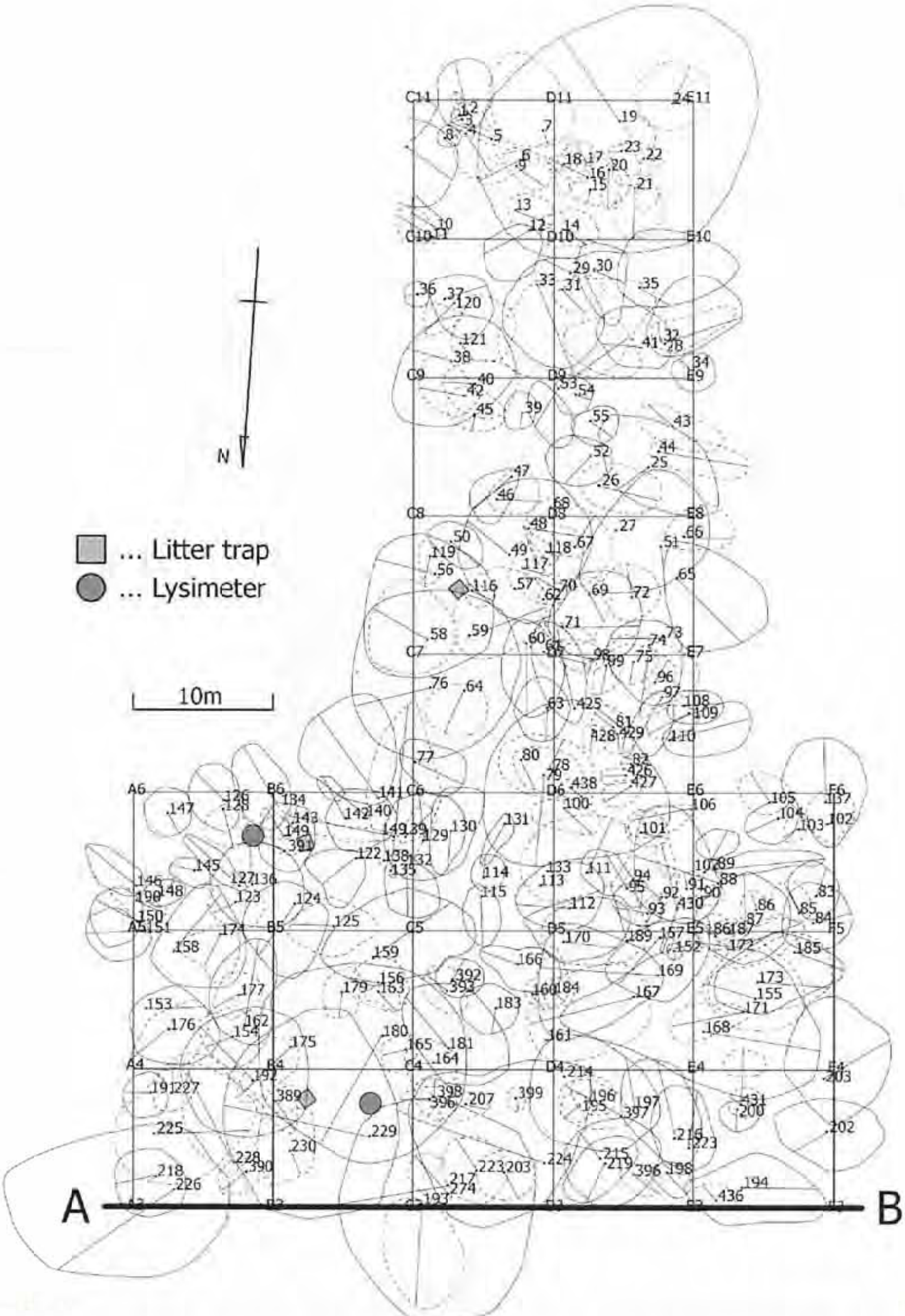


Fig. 5-25a. Canopy projection in Tinte Bepo Forest Reserve plot (Sub-plot No.1-25)

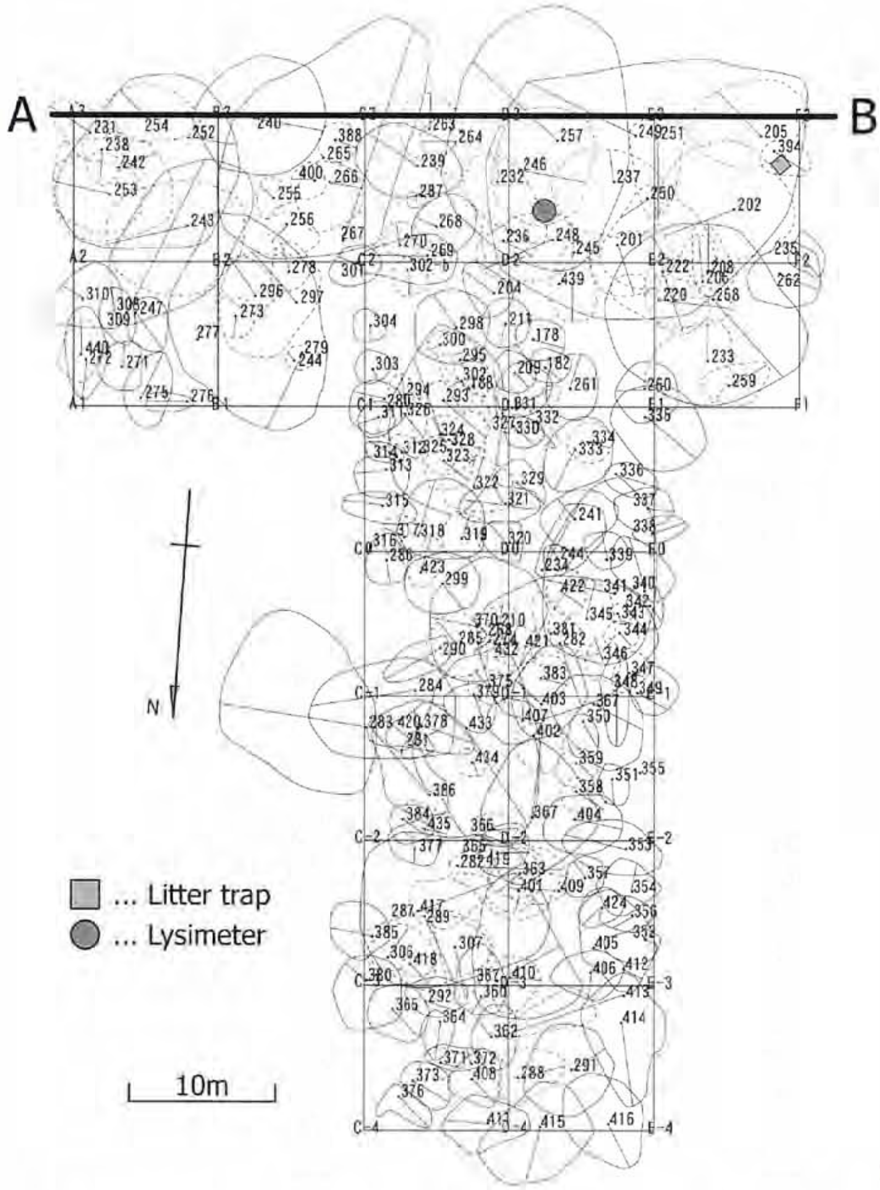


Fig. 5-25b. Canopy projection in Tinte Bepo Forest Reserve plot (Sub-plot No.26-45)

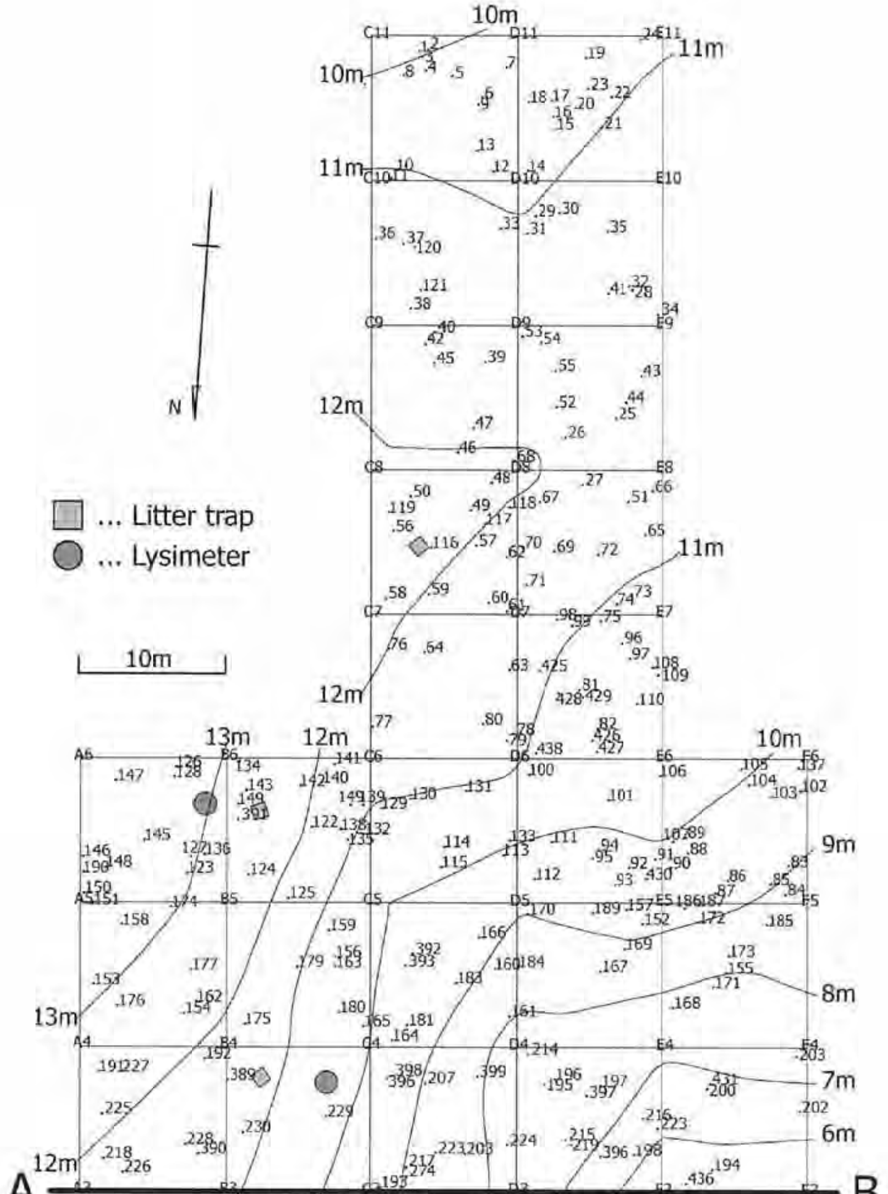


Fig. 5-25c. Tree location and topographical map in Tinte Bepo Forest Reserve plot (Sub-plot No.1-25)

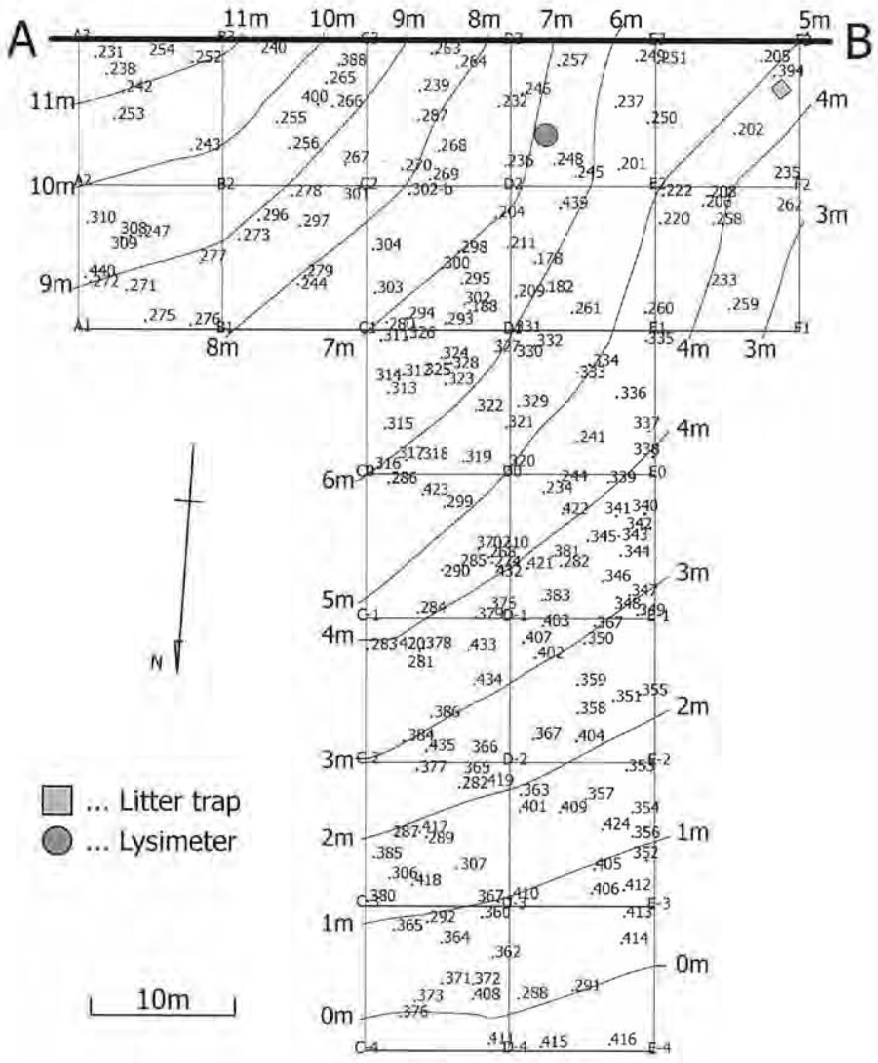


Fig. 5-25d. Tree location and topographical map in Tinte Bepo Forest Reserve plot (Sub-plot No.26-45)

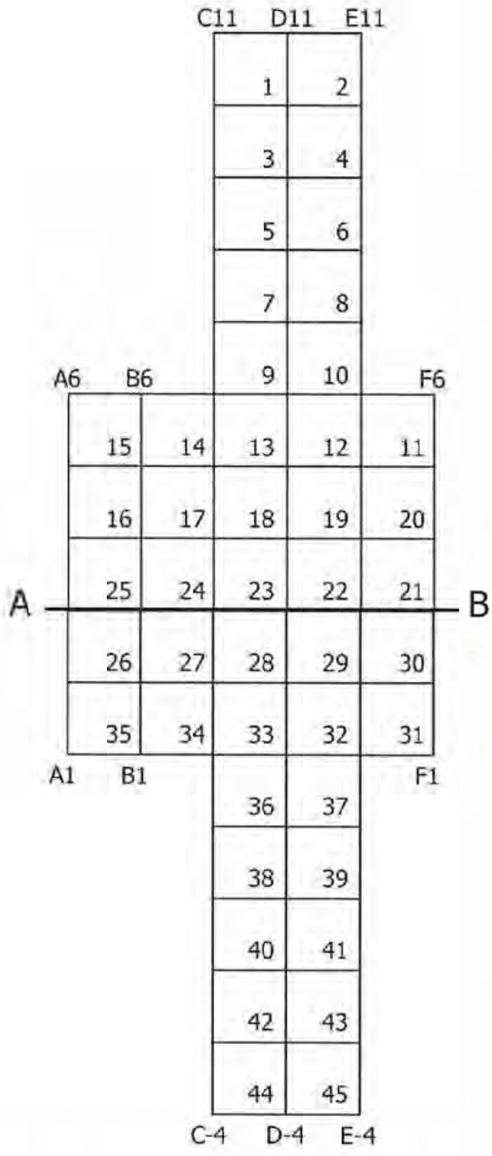


Fig. 5-25e. Sub-plot diagram in Tinte Bepo Forest Reserve plot

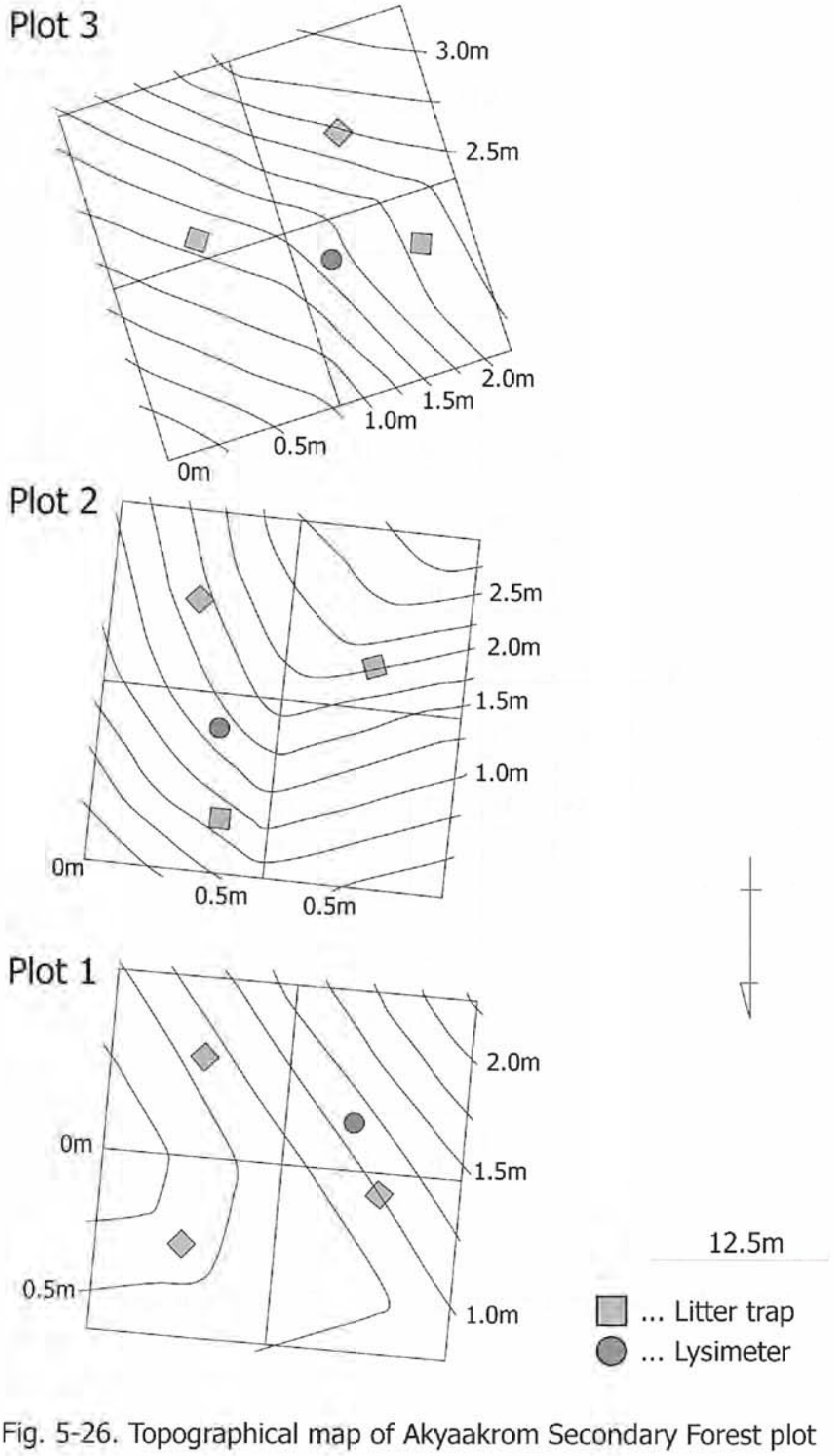


Fig. 5-26. Topographical map of Akyaakrom Secondary Forest plot

5-6-2. Decomposition and Nutrient Release Patterns of Leaves Litter from Primary Forest Reserve in Dwinyan watershed

5-6-2-1 Introduction

Tinte-Bepo Forest Reserve (T-BFR), a primary forest is rich in terms of plant species diversity including timber resource in Ghana. It is a tropical moist semi-deciduous dry forest type. The annual turnover of litter thrown could be very high especially in the drier months. Litter contains a considerable amount of nutrients necessary for plant growth (Songwe *et.al.* 1995). Through the biological processes of plant nutrition, leaves play major roles in the manufacture of food. It is the vital tissue for plant growth and survival. However, the leaves become old and senescent. They often drop to the forest floor within the vicinity of the parent plant or are carried by wind and other agents further away. Once on the ground, decomposition of the leaf material starts. In order to release the stored up nutrients, the litter must be broken down. Microorganisms and fauna in soil and forest floor carry out litter breakdown and mineralization (Swift *et al.,* 1979). The decomposer community, the physiochemical environment and the litter resource quality regulate the rate of decomposition (Anderson & Swift, 1983).

Plant materials with high nitrogen content such as legumes are considered to be of high resource quality to decomposer community and thus, decompose faster (Millar *et. al.,* 1936; Schofield, 1945; Handley, 1961; Weeraratna, 1979; Swift *et. al.,* 1979). Tenney & Waksman (1929) and Melillo *et. al.* (1982) identified that plant materials with high lignin content however, decompose more slowly. Swain (1979) stated that polyphenolics could also retard decomposition by forming resistant complexes and inhibiting enzyme activity. Decomposition and mineralization in tropical forest have not so often been investigated probably due to the great heterogeneity of the ecosystem and the consequent difficulty in selecting species to investigate for a meaningful approximation of the decomposition rates for the whole forest (Songwe *et.al.* 1995). The contribution of leaves to total litter fall have been recorded to be between 80 and 86% (Klinge and Rodrigues, 1968), 72% (Gong et. al, 1983) in various tropical forests.
Leaves decompose relatively faster than the other litter types. Mineralization supposed to be rapid. In this experiment, leaves were therefore considered for the decomposition and mineralization studies of two major tree species and other species in Tinte-Bepo Forest Reserve (T-BFR) in order to obtain a basic information of T-BFR ecosystem.

5-6-2-2 Materials and Methods

(1) The Study Area
Tinte-Bepo Forest Reserve in Ashanti Region of Ghana is located between latitudes 6° 33'N and 7° 03'N; longitudes 1° 55'W and 2° 06W. The average elevation is about 365.76m above mean sea level. The total area of the reserve is about 11,554 hectares and the Eastern Block covers 2934.5ha. The reservation was first constituted in 1949 under the Kumasi Native Authority Rules and now protected under the Forest Protection Law, 1986, (PNDCL 142) (Forest Management Unit 36). It lies in the drier part of moist semi-deciduous forest type (Hall & Swaine, 1976) and agrees fairly closely in range with the Celtis-Triplochiton Association of Taylor (1960).

The soils are mainly composed of Ferric Acrisol, Bekwai series and pH is slightly acidic (5-7). The area is characterized by two peak rainfall periods i.e. June and October, with a

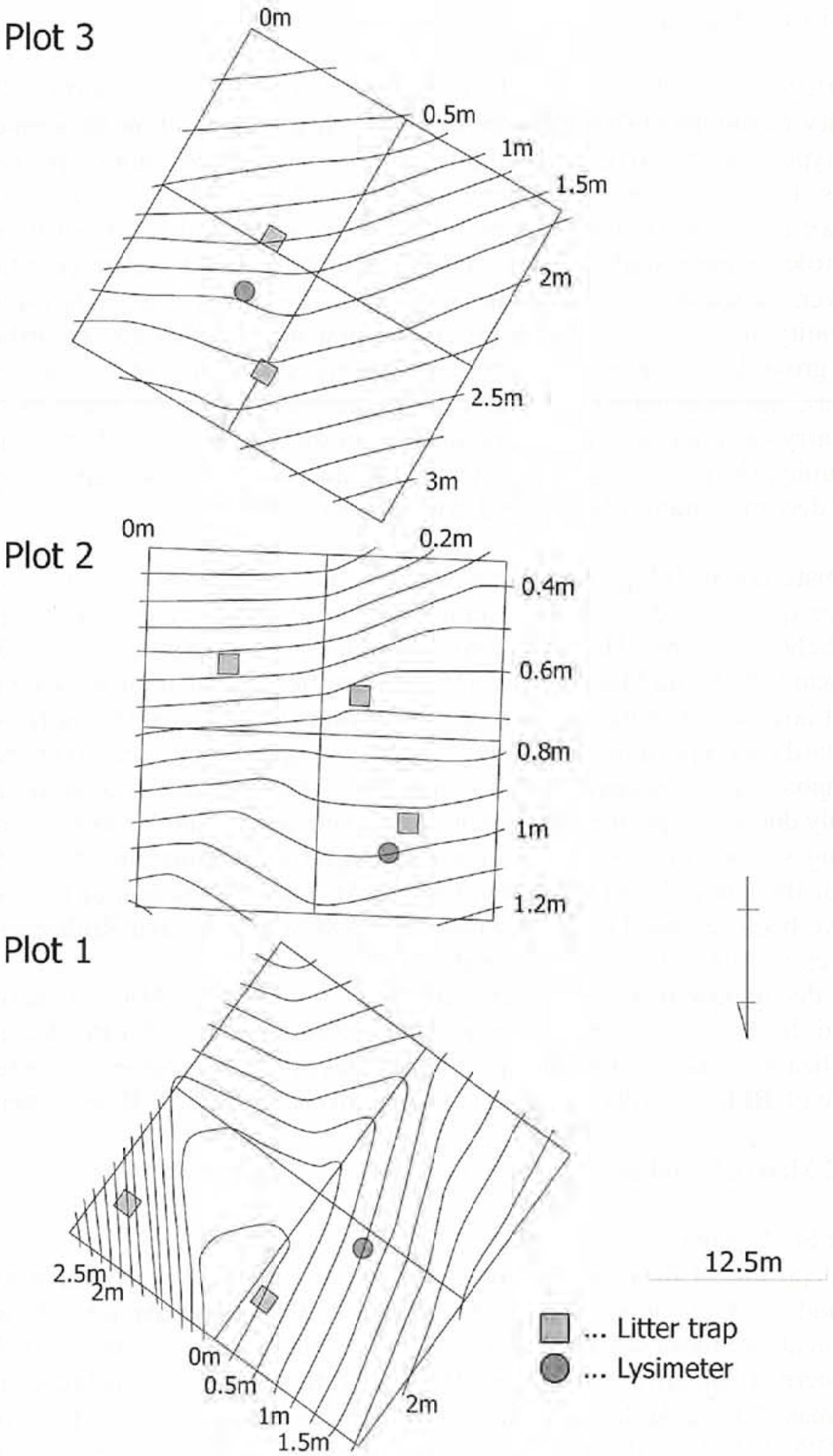


Fig. 5-27. Topographical map of Dopiri Secondary Forest plot

mean annual rainfall of 1243mm. Prevailing winds are southwesterly during the wet season and northeasterly during the dry (harmattan) season. The annual temperature ranges between 20-30°C. The reserve is under concession and previous exploitations coupled with annual bush fires have reduced quantities of some tree species. However, the present state of the forest is described as being significantly disturbed but reasonably healthy as primary forest.

(2) Litterfall collection
0.45 hectare plot was demarcated for this study in Tinte-Bepo Forest Reserve (TBFR) in the eastern block after a reconnaissance survey of the block had been conducted (Fig 5-25 a, b, c, d and e). The elevation is 305m above sea mean level in the direction of N25°E and the slope is 12°. Ten (10) litter traps were made of square wooden frame measuring 1.0m x 1.0m (inner surface dimension) and 2mm nylon mesh size were secured on the frame and allowed to sag below but not touching the forest floor to collect falling litter. The traps were raised on peg support 1.0m above the forest floor. They were randomly erected in February 1998 in the 0.45 ha plot (Fig. 5-25 a, b, c and d).

The fallen litter in each trap was collected every 14 days. The leaf portion was sorted out from the trapped litter and used for this investigation. The leaves collected at each time were sealed in paper envelopes and dried in the oven at 60°C for 72 hours. Dry weights for each trap were recorded and stored in a dry cool place. Thus, collections for the 12 months period (one-year cycle i.e., February 1997 to January 1998) were stored. The paper envelopes containing the dried leaf litter for each month were sampled and used to identify the tree species. The collections continued in 1998 through to September 2000 and the average quantities leaf litter thrown in a year was assessed on dry weight basis.

(3) Field experiment on Litter decomposition
Three sets of observations were carried out on decomposition and nutrient release from freshly fallen leaves of TBFR tree species. The fallen leaves litter was sorted out according to species from each trap. The sorted leaves belonging to each species were grouped together and percentage contribution from individual tree species to the total leaf litter (by weight) for the year was computed. The leaf litter of the same species constituting more than 40% *Celtis* sp. (Ulmaceae), *Trichilia prieuriana* (Meliaceae)) was pooled and subjected to decomposition separately. The species contributing to about 20% *Baphia nitida* (Papilionaceae), *Corynanthe pachyceras* (Rubiaceae), *Ricinodendron heudelotii* (Euphorbiaceae), *Alchornea cordifolia* (Euphorbiaceae) and *Ficus* sp. (Moraceae)) of the total trapped leaves were selected, mixed proportionally and decomposed. Mixed leaf litter containing all species leaves trapped and in their proportions (as collected from the field) was also subjected to decomposition.

Square decomposition boxes made of Melicia excelsa wooden frames (20.0cm x 20.0cm (surface inner dimension) x 2.0cm deep and 0.5cm thickness) were used. Galvanized 1.0mm wire mesh size was passed around the wooden frames to exclude larger decomposing organisms and minimize loss of leaves after fragmentation. Ten (10g) grams of oven-dried leaves under each observation were enclosed in the decomposition boxes and sent to the field in September 1998. There were 36 boxes for each treatment and fresh samples were kept for initial chemical analysis. Three 12.0m x 12.0m blocks were pegged out in the study plot and each block was subdivided into three quadrats (4.0m x 4.0m). The ground was cleared of previously fallen litter to enable the decomposition boxes make direct contact with the forest soil. The treatments (observations) were randomly distributed in each quadrat. For each observation, three boxes were sampled (one observation per block) every 28 days beginning October 1998. The sampled boxes and the contents were taken to the laboratory. The partially decomposed leaves litter was carefully separated from the soil particles, plant roots and other materials and oven-dried at 60°C for 72 hours.

(4) Laboratory analyses and field monitoring
The residual leaf litter samples for each observation collected periodically were pooled together, milled using vibrating mixer mill (MRK-Retsch, Mitamura Riken Kogyo). Nitrogen (N) and Carbon (C) concentrations were determined by dry combustion method (Sumigraph N-C 90A Analyzer, Sumitomo Chemical). Residual decomposed leaf materials were digested for other total elemental concentration determination by wet oxidation (HNO_3) method under pressure (Teflon container placed in the oven at 150°C for 4 hours). Concentrations of calcium (Ca), magnesium (Mg) and phosphorus (P) were determined using the Inductively Coupled Plasma Spectrometer (ICPS-2000, Shimadzu). Potassium (K) and sodium (Na) concentrations were determined by Atomic Absorption Spectrometry (AAS 170-70, Hitachi). Total extractable phenols (TEPH) were determined using the acetone extraction method

Monthly rainfall, relative humidity mesured by the open-pan method, soil moisture (Theta meter, Daiki), soil and air temperatures using soil thermometers and wet and dry bulb thermometers, respectively, were recorded within the period of this study.

(5) Data analyses
Monthly dry weights of the litter collected was computed for each year and averaged. The monthly litter fall was related to the monthly rainfall and presented in a histogram (Fig 5-28). The monthly decomposition trends was also presented in a graph (Fig 5-29).

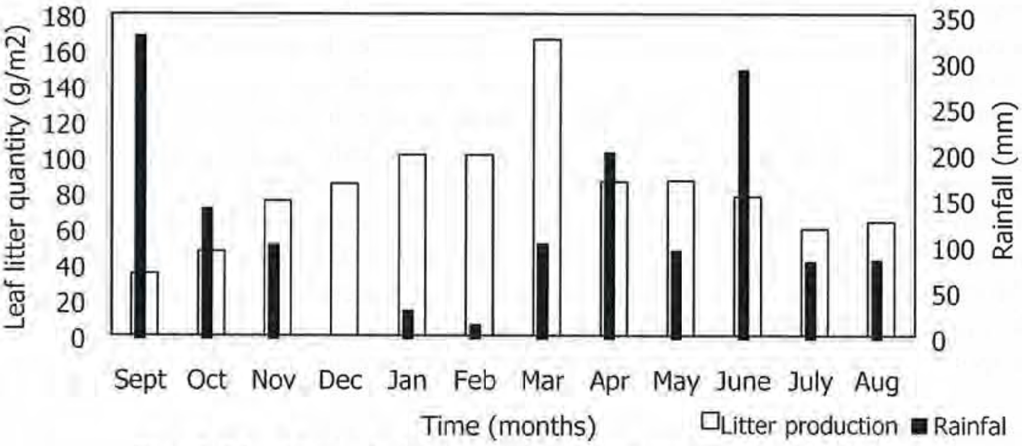


Fig. 5-28. Monthly leaf litter production and rainfall.

The changes of nutrient elements in litter types were calculated at 0-month (fresh leaf litter), 3-months and at half-life (50% of material decomposed) and presented in a table. The equation used for the calculation was: Nutrient Released or accumulated = $(X_0-X_t)/X_0 \times 100$; where X_0 is "fresh or initial leaf litter (no decomposition), X_t is residual leaf litter at the decomposition time (t) (Fig 5-30).

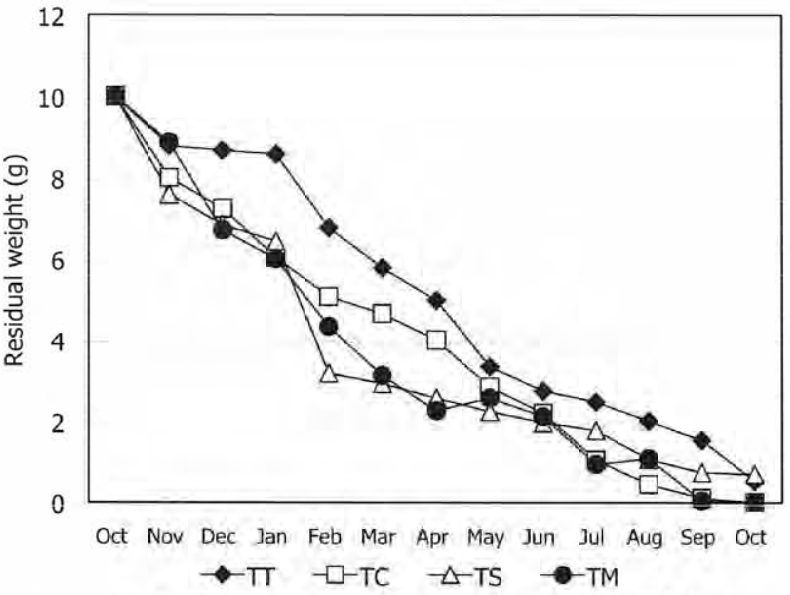


Fig. 5-29 Decomposition of four types of leaf litter

Nutrient release patterns of leaf litter for 6 months for TM, 8 months for TT and TC, and 9 months for TS in Fig.5-31 were obtained by the following calculation based on the equation 1 at each month.

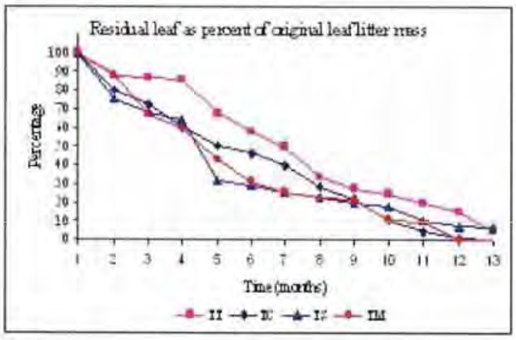
(eq.1): Residual weight of leaf litter (g) x Nutrient concentration in residual leaf litter (mg g^{-1}).

Nutrient flux (g m^{-2} $month^{-1}$) from leaf litter of TM (mixture of total leaves) for each month in Fig.5-31 was estimated as follows. Rates of nutrient release from leaf litter of TM in Fig.5-30 were assumed to be same for leaf litter produced in each month. Nutrient release of 6 consecutive month originated form leaf litter produced in each month could be obtained by following equation 2.

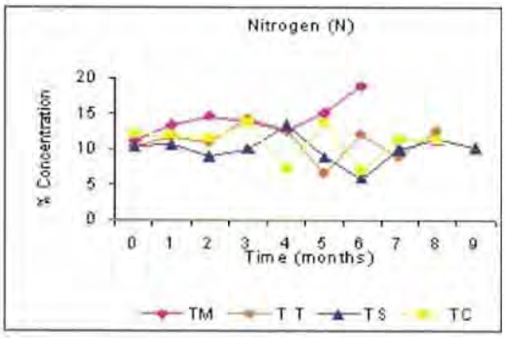
(eq.2): Nutrient release (mg $10g^{-1}$ leaf litter at 1^{st} to 6^{th} month) x Leaf litter production (g m^{-2} $month^{-1}$).

Then, 6 nutrient release values originated from 6 different months were obtained for one month and were sum up. In terms of N, nutrient release was mostly under estimated due to the shortage of data of TM shown in Fig.5-30 in which N was not fully released during the observation. Although amount of N release might be higher, no correction was done for Fig.5-31.

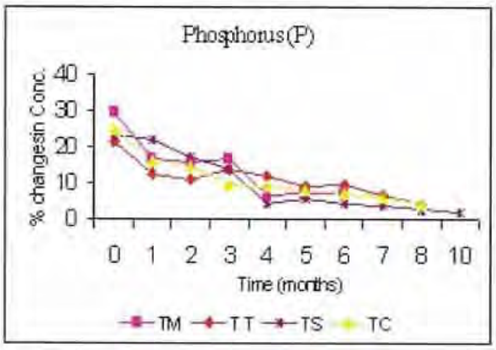
Fig. 5-30. Percentage changes of original leaf mass and N, P, K, Ca & Mg, concentrations in residual leaf litter.



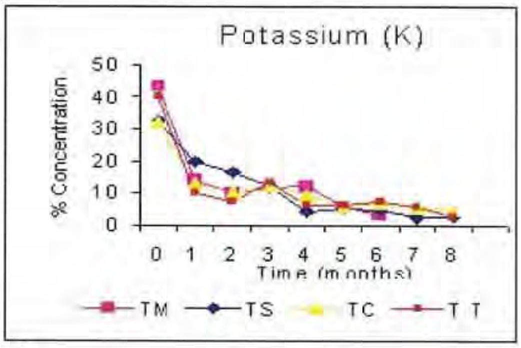
a.



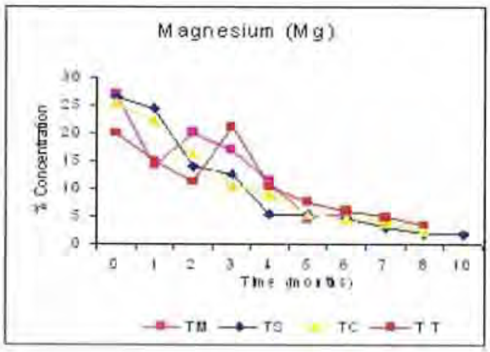
b.



c.



d.



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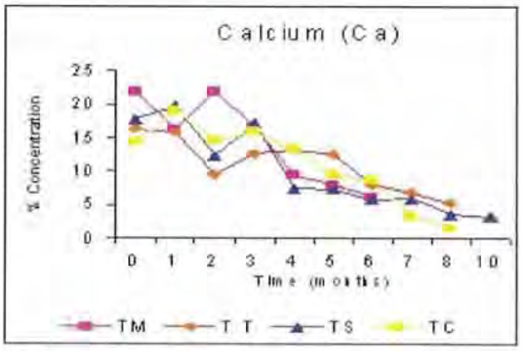

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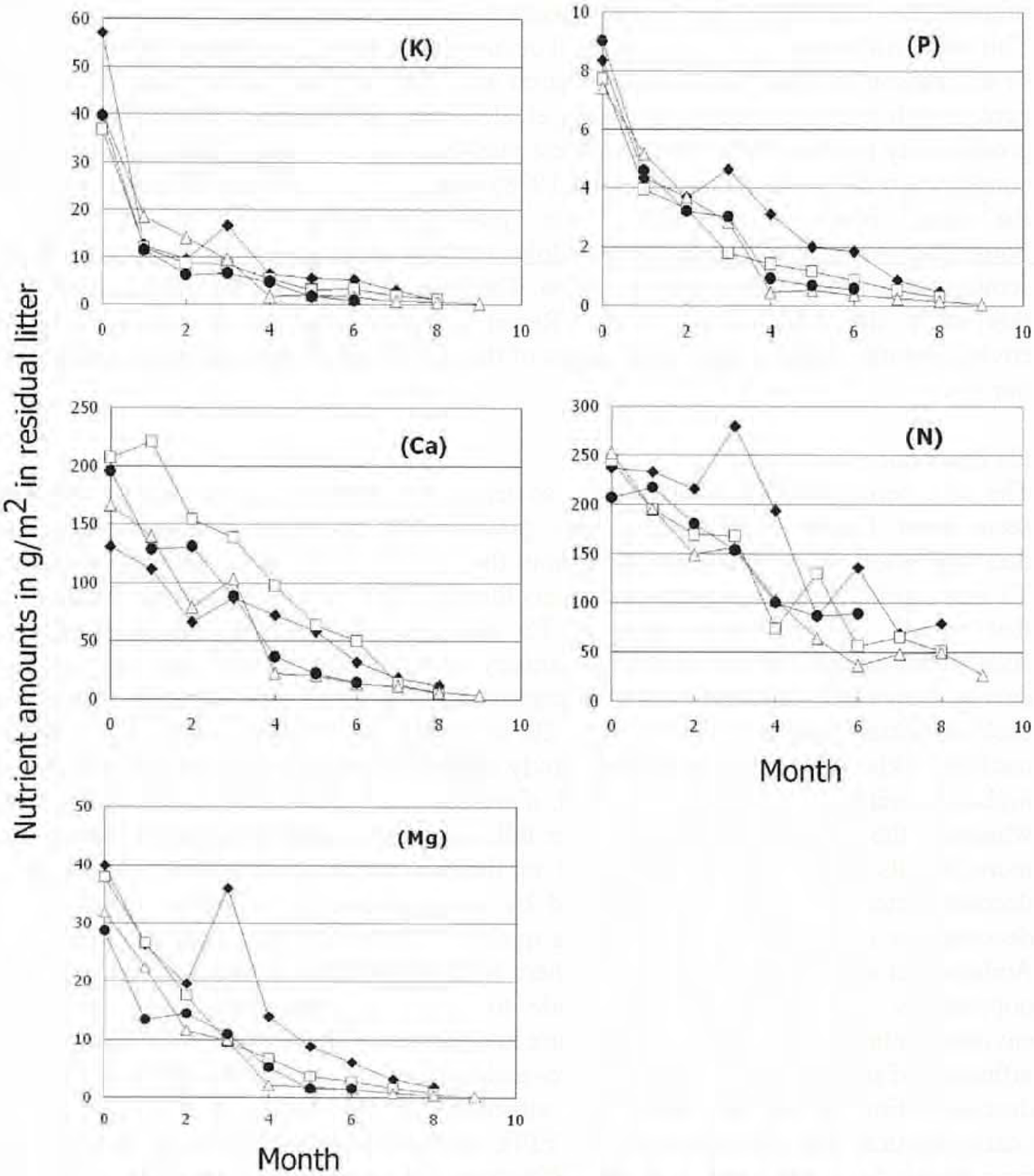

Fig. 5-31. Monthly nutrient release pattern of 4 type of leaf litter based on the nutrient amounts in g/m^2 in residual litter

5-6-2-3 Results and Discussion

(1) Litterfall

Fig. 5-28 shows the average monthly leaf litter production and rainfall during February 1998 to September 2000. Leaf litter production was the highest in March (165 g m^{-2}) and the least in September (35 g m^{-2}). Generally, leaf litter production increases from September, peaks in March (165 g m^{-2}) and lowers gradually to August (63 g m^{-2}) whilst rainfall rises from December (0 mm), peaks in June (295 mm) and September (332 mm). This pattern showed that highest leaf fall occurs when rainfall decreases. March is the end of dry season to start rainy season. March and April are the hottest months, too. This agrees with previous reports by Gong et al (1983) and Madge (1965). The leaf litter productivity in Tinte-Bepo primary forest recorded 9.8 tha^{-1} $year^{-1}$, which was very high comparing with previous reports. Lim (1978) obtained 6.4 tha^{-1} $year^{-1}$, Ogawa (1978) 6.3 tha^{-1} $year^{-1}$, Proctor et al (1983) 5.4 tha^{-1} $year^{-1}$ and Tanner (1980) 5.3 tha^{-1} $year^{-1}$ for South-east Asian dipterocarp forests. John (1973) obtained 7.4 $tha^{-1}year^{-1}$ for tropical semi-deciduous forest leaf litter in Ghana. The reason of this high leaf litter production in this study site was unclear so far. Recent climatic changes in relation to global environmental changes may some causes of the significantly high leaf litter production in our site.

(2) Decomposition

The decomposition of leaf litter was not so dependent on the pattern of monthly rainfall as seen from Figure 5-29. There was gradual but progressive fragmentation and decomposition of the leaf litter throughout the year. In terms of the decomposition rate, TT was significantly slower than the others for the first 3 months, but not for the later than that period. Decomposition rates of TS and TM were similar and seemed to be accelerated during the dry season of January to April. That of TC was less fluctuated during the period. Although some fluctuation were observed in decomposition pattern of each leaf litter type as shown in Fig.5-29, its relation to rainfall pattern (Fig.5-28) was unclear. Although our decomposition study started on October, since September was the highest rainfall and the lowest litter fall, if we start the similar study on February/March which are the driest and the highest litter fall, the results might be some difference. Such more details study may be necessary in future. Swift et al (1979) suggested that decomposition processes are regulated by three groups of variables. These are the decomposer communities, the resource quality and the physicochemical environment. Anderson et al (1983) has shown that there is no relationship of decomposition to fauna populations. Attempts have been made to relate decomposition rates on physical environmental factors mainly temperature and moisture. But this could be related to the influence of site differences on the macro-scale (Anderson and Swift, 1983). In this study, decomposition of the leaf litter was attributed to the nature of the litter or litter characteristics. The concentrations of TEPH, total extractable phenols, in each leaf litter type (Table 5-9) well explained the difference of decomposition rate among leaf litter type (Table 5-10). TEPH was the material resist to decomposition, so that decomposition of TT was delayed for the first 3months. TEPH in all the leaf litter types was remarkably broken-down for TC, TS and TM after 3 months of exposure (88%-95% breakdown), but little bit slower for TT (66%). The subsequent rapid disappearance of TEPH contributed to the faster loss of leaf litter materials as Swain (1979) reported. The difference of residual weight of leaf litter among the types became much small after April (7th month) than before through, and then the leaf litter of all the types were almost fully decomposed at the 12th month (Fig.5-29).

Table 5-9. Nutrient concentrations (gkg-1) of fresh (t0) & t1/2 (5.0g dry wt) leaf litter types from Tinte-Bepo Forest Reserve (T-BFR)

Nutrient Element	Concentrations (gkg^{-1}) of fresh leaf litter (t0)				Concentrations (gkg^{-1}) at 50% of residual leaf litter (t1/2)			
	TT	TC	TM	TS	TT	TC	TM	TS
K	5.71	3.67	3.97	4.01	1.09	1.19	0.91	2.04
Ca	13.10	20.75	19.54	16.64	7.61	21.30	19.48	11.58
Mg	3.99	3.79	2.87	3.18	2.25	2.43	2.15	1.69
P	0.83	0.77	0.90	0.74	0.42	0.46	0.48	0.54
N	23.67	24.44	20.64	25.18	24.86	23.34	26.78	21.80
TEPH	1.86	0.81	1.06	0.59	0.66	0.09	0.12	0.03

Table 5-10. Nutrient and TEPH* concentrations in fresh and decomposed leaf litters at 0 and 3rd month stage.

litter type	residual weight (g)	K	Ca	Mg (g/kg)	P	N	C/N (%)	TEPH (g/kg)
at 0 month								
TT	10	5.71	13.10	3.99	0.83	23.67	21.19	1.86
TC	10	3.67	20.75	3.79	0.77	24.44	17.90	0.81
TS	10	4.01	16.64	3.18	0.74	25.18	17.23	0.59
TM	10	3.97	19.54	2.87	0.90	20.64	21.99	1.06
at 3rd month								
TT	8.58	1.09	7.61	2.25	0.42	24.86	12.13	0.66
TC	6.04	1.19	21.30	2.43	0.46	23.34	15.09	0.09
TS	6.44	2.04	11.58	1.69	0.54	21.80	6.44	0.03
TM	6.00	0.91	19.48	2.15	0.48	26.78	14.10	0.12

* Total extractable phenols

(3) Nutrients release pattern from leaf litter

Table 5-9 showed nutrient concentration of fresh litter and the residual leaf litter at 50% decomposition. The 50% decomposition periods were 4 to 8 months depending on the litter types as shown in Fig.5-29. The nutrient concentrations of fresh leaf litter material were generally higher than those of decomposed one at 3rd month (January) in all the litter types, except for Ca of TC and N of TT and TM (Table 5-10). Fig.5-30 shows the percentage changes of original leaf mass and N, P, K, Ca & Mg, concentrations in residual leaf litter. The pattern of mean dry weights of decomposing litter after various periods over the initial dry weights is shown as percentages and presented in Fig.5-30a. The TT and TC residual quantities of litter and patterns during decomposition were similar. The mixed leaves (TS & TM) were also similar. The pattern decomposition for TS was rapid in the early months so as TM and TC. However, TT showed relatively slower rate. After the 8^{th} month, the quantities and the patterns were similar for all the litter types.

More than 95 % of the nutrient was released from all the type of leaf litter within 9 months, except for N, in following order: K > P > Mg > Ca > N. There were significant differences between litter types in the rate of mineral release and the minerals themselves in the first few months of decomposition as observed by Songwe et al (1995). The percentage decrease of phosphorus concentration was gradual and near linear and whilst potassium decrease was very rapid during the first two months of exposure as shown in Fig.5-30 c and d. During the initial four months exposure, partial immobilization and accumulation of magnesium and calcium elements were observed (Fig 5-30 c and f). Further exposure showed gradual decline of their concentrations. Generally, the mineralization of P, K, Mg and Ca follow the pattern of the disappearance of the litter.

Bernhard-Reversat (1972) reported that the mineralization of Ca related to the disappearance of the organic matter since it is used in the building of cell wall in plants and the presence of shielding substances like lignins and tannins, etc. The concentrations of total extractable phenols (TEPH) was initially high in all the litter types but were remarkably broken-down after four months of exposure. The subsequent rapid disappearance of phenols contributed to the faster loss of materials and nutrients. Swain (1979) reported this trend.

As seen from the Fig. 5-30b, N concentration in the residual litter was not decreased in all the litter types. Microbial immobilization or even some nitrogen fixation using carbon source on litter might contribute these increase of N concentration. It was highest for the total mixed species leaves (TM). The trends do not assume any particular function but a combination of linear, quadratic and cubic functions. The concentrations of P, K, Mg and Ca in the residual litter types became less as decomposition progressed as shown in the Fig.5-30 c-f. Potassium release was the fastest and was ranging 49% for TS to 81% for TT. Calcium and N were released at a slower rate of in all the litter types. The mineralization of Mg through the decomposition process was as expected, which followed that of K and P in terms of its release speed. However, it was slow for the TM. The selected mixed species released phosphorus relatively slowly. The release of P was not significantly different among the litter types.

Monthly nutrient quantities in g per m2 remained in residual leaf litter were shown in Fig. 5-31. Nutrients were generally released as decomposition progressed in all the litter types. The quantities of Ca of TC and N of TT and TM, however, increased temporally at the beginning of decomposition. This was probably due to the increase of those elemental concentrations in residual litters as shown in Table 5-10. The rate of nutrient release was generally faster than that of leaf litter decomposition rate. Even though TT was decomposed only 14% for the first 3 months, nutrients such as K, Ca, Mg and P decreased 81%, 42%, 44%, 49%, respectively. Other leaf types also showed the same trend.

(4) Nutrient fluxes during leaf litter decomposition

Based on the data of TM in Fig. 5-29, 5-30, and 5-31, cumulative nutrient release fluxes from leaf litter for each month were estimated as shown in Fig.5-32. Basically the pattern of nutrient flux was similar to that of leaf litter production in Fig.5-28. The flux was the highest in March and was the lowest in September to October, but in April to June for N. Especially for K, since 80 % of K was released in the first month of exposure, its flux pattern was almost the same to leaf litter production. There was, however, a difference among litter production and nutrient flux for the other elements. Nutrient flux tended to be high comparing to leaf litter production from April to June for Ca, M g, P and N. This was due to the continuous nutrient release from litter for several months. High litter production in March considerably influenced nutrient release in following 3 months. In terms of N release, it might be under estimation in its amount because the data of TM shown in Fig.5-31 were used to estimate N release, although N was not fully released during the observation period in Fig.5-31. In actual condition that N is fully released from

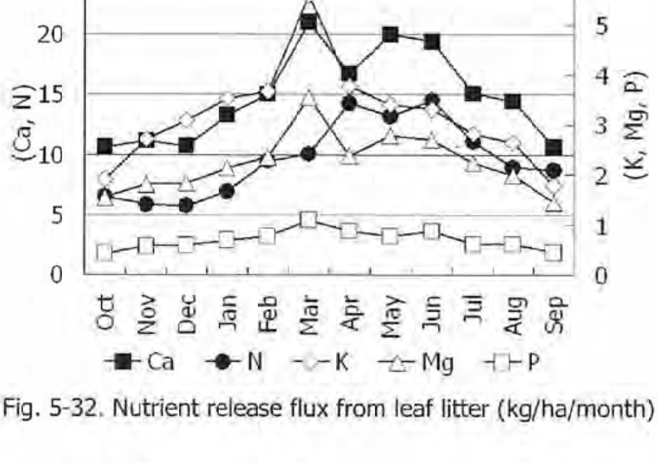

Fig. 5-32. Nutrient release flux from leaf litter (kg/ha/month)

litter, the values of N flux in Fig.5-32 would increase somewhat more for each month. However, since the data did not include the loss through denitrification. This decreases the flux.

As we explained earlier, the leaf litter fall in the Tinte-Bepo forest reserve was very high as compared to other studies in tropical African rain forests. This gave relatively large nutrient fluxes to soil through leaf litter decomposition. High litter production in March considerably influenced nutrient release in following 3 months. Environmental condition for plant growth during April to June seemed better because of much rainfall and nutrient supply. Nutrients might be, however, moved out from the forest during that period, which was another subject to study in terms of the hypothesis of geological fertilization which support sustainable rice production in inland valleys (Hirose and Wakatsuki, 1997).

As shown in Fig.5-32, monthly fluxes of Ca were 11 to 21 kg/ha, which was equivalent to 180 kg Ca/ha/year. Monthly nitrogen fluxes were 6 to 14.5 kg/ha, which was equivalent to 110 kg N/ha/year. This data, however, does not include the loss by denitrification. Monthly potassium fluxes were 1.8 to 5.7 kg/ha, which was equivalent to 40 kg K/ha/year. Monthly Mg fluxes were 1.4 to 3.6 kg/ha, which was equivalent to 28 kg N/ha/year. Monthly phosphrous fluxes were 0.5 to 1.0 kg/ha, which was equivalent to 9 kg P/ha/year.

5-6-2-4Summary

Tinte-Bepo Forest Reserve (T-BFR), a primary forest is a tropical moist semi-deciduous dry forest type. Leaves decompose relatively faster than the other litter types and mineralization may be rapid. Leaves were therefore used for the decomposition and mineralization studies to investigate decomposition and nutrients release patterns that may be contributing to support higher plant species diversity.
The fallen litter on a 1.0ha plot trapped was collected every 14 days beginning February 1998 to September 2000. The leaf litter of *Celtis* sp. (Ulmaceae) and *Trichilia prieuriana* (Meliaceae)) were decomposition separately. *Baphia nitida* (Papilionaceae), *Corynanthe pachyceras* (Rubiaceae), *Ricinodendron heudelotii* (Euphorbiaceae), *Alchornea cordifolia* (Euphorbiaceae) and *Ficus* sp. (Moraceae)) were selected, mixed proportionally and decomposed. Mixed leaf litter (all species leaves trapped) was also subjected to decomposition. Fresh litter and monthly remaining litter during decomposition were analyzed.

Highest leaf fall occurs when rainfall decreases. The leaf litter productivity in Tinte-Bepo primary forest recorded was 9.8 tha^{-1} $year^{-1}$. Decomposition of leaf litter was independent of the pattern of monthly rainfall. Weight loss of the leaf litter is attributed to the nature of the litter or litter characteristics and the fine 2.0mm mesh used for litter boxes. At $t_{1/2}$, selected mixed species leaves (TS) litter was relatively faster followed by mixture of total leaves (TM), *Celtis* sp (TC) and *Trichilia prieuriana* (TT) leaves. Immobilization and accumulation of nitrogen was highest for the total mixed species leaves (TM). Phosphorus release was gradual whilst potassium was very rapid during the first two months of exposure. During four months exposure, partial immobilization and accumulation of magnesium and calcium elements were observed. Mineralization of P, K, Mg and Ca follow the pattern of the disappearance of the litter. Polyphenols appeared to influence decomposition and nutrient releases of the litter types.

Monthly fluxes of Ca from leaf litter decomposition were 11 to 21 kg/ha, which was equivalent to 180 kg Ca/ha/year. Monthly nitrogen fluxes were 6 to 14.5 kg/ha, which was equivalent to 110 kg N/ha/year including denitrification loss. Monthly potassium fluxes were 1.8 to 5.7 kg/ha, which was equivalent to 40 kg K/ha/year. Monthly Mg fluxes were 1.4 to 3.6 kg/ha, which was equivalent to 28 kg N/ha/year. Monthly phosphrous fluxes were 0.5 to 1.0 kg/ha, which was equivalent to 9 kg P/ha/year.

5-6-3. Leaf Litterfall, Decomposition and Nutrient Release from Secondary forest Fallow.

5-6-3-1 Introduction

The most predominant farming system practiced in Ghana has been the slash and burn destroying original forest vegetation before farms are established. In the early years, fallow periods had been long over 30 years. But the rapid population increase recently has reduced the fallow period considerably from between four to ten years to less than two years in some extreme cases. This has resulted in arable land impoverishment leading to poor productivity. In the agro-ecological zone of Ghana, various land-use types such as cocoa plantation establishment and mixed food crops farming, secondary forest or fallow vegetation characterize the upland areas of the inland valleys.

It is unlikely to find over 20 years old fallow land. It is likely that the matured secondary forest vegetation will differ in their influence status of the soils for any cropping system. Each land-use depends on the nutrients available in the soil that are contributed through litter fall, decomposition followed by nutrient mineralization (Swift *et. al.* 1979) and subsequent absorption of dissolved nutrients. Most nutrient are exported from the ecosystem through erosion and leaching (both lateral and vertical) of the uplands soil (Radulovich & Sollins 1991).

The mineral nutrients (in suspension and dissolved) are captured from the sediments and organic material deposited during high water or floods, and recaptured following release from up-slope sources (Frangi & Lugo 1985). It is therefore necessary to investigate and assess the nutrient status of decomposing leaf litter that is incorporated into the soil through mineralization.

5-6-3-2 Materials and Methods

(1) The Study Area

Two (2) fallow (secondary) forests of about the same fallow age were selected for this study (Fig.5-23, 5-26 and 5-27) which are located on the same latitudes, 6° 33' N and 7° 03' N, and longitudes, 1° 55' and 2° 06' W. The Dopiri secondary forest was 27 years old covering 20 ha with mean elevation of 300 m above mean sea level and with mean slope of 9°. It lies 7.0 km south of a primary forest, Tinte-Bepo Forest Reserve.The Dopiri secondary forest is 27 years old covering 20.0ha with mean elevation of 300m above mean sea level. The major soil series is Nzema belonging to the ferric acrisol and pH is slightly acidic (5-7) (Annan 2001). The dominant tree species is *Albizia zygia* (Okro). It is about 7.0km from primary forest (Tinte-Bepo Forest Reserve), which was reported by our previous paper (Owusu et al 2001) and Akyaakrom secondary forest; 28 years fallow age, covers 30.0ha and mean elevation is 200.90m above mean sea level. It belongs to the Bekwai series of Ferric Acrisol and pH is slightly acidic (5-7) (Annan 2001). The dominant tree species is *Griffornia simplicifolia* (Atoto). It lies close (80.0m) to a primary forest (Tinte-Bepo Forest Reserve). The two secondary forests are located in the drier part of moist semi-deciduous forest type (Hall & Swaine, 1976). The area is characterized by two peak rainfall periods i.e. June and October, with a mean total annual rainfall of 1750mm and the annual temperature ranges between 20-30°C.

(2) Litterfall collection

Six plots of sizes 25.0m x 25.0m (three in each site) were demarcated (Fig 5-26 and 5-27). Eighteen (18) litter traps made of square wooden frame measuring 1.0m x 1.0m (inner surface dimension) and 2mm nylon mesh size were secured on the frame and allowed to sag below but not touching the forest floor to collect falling litter. The traps were raised on peg support 1.0m above the forest floor and three traps (i.e. nine per site) were randomly erected in each plot in September 1998 until August 2000.

The fallen litter in each trap was collected every 14 days and the leaf portion was sorted out from the total trapped litter. The leaves collected at each time were sealed in paper envelopes and dried in the oven at 60°C for 72 hours. Dry weights for each trap were recorded and stored in a dry cool place. Thus, collections for the 12 months period (one-year cycle i.e., September 1998 to August 1999) were stored. The paper envelopes containing the dried leaf litter for each month were sampled and used to identify the tree species. The collections continued in 1998 through to September 2000 and the average quantities leaf litter thrown in a year was assessed on dry weight basis.

(3) Litter decomposition

Two sets of observations were carried out on decomposition and nutrient release from freshly fallen leaves from the tree species. The sorted leaves belonging to each species were grouped together. The leaf litters of *Albizia zygia* in Dopiri secondary forest (DA) and *Griffornia simplicifolia* in Akyaakrom secondary forest (AG) contributing more than 50% to the total litter thrown at each site were pooled and subjected to decomposition, separately. Mixed leaf litter containing all species leaves trapped and in their proportions as collected in each site were also subjected to decomposition (DM and AG were used hereafter for Dopiri and Akyaakrom secondary forest, respectively).

Square decomposition boxes were prepared in the same manner of a previous paper (Owusu et al., 2001). There were 36 boxes for 12 months with 3 replications for each treatment such as DA, DM, AG and AM. Three 12m x 12m blocks were pegged out at each study plots (Akyaakrom and Dopiri) and each block was subdivided into 4.0m x 4.0m quadrats. The ground was cleared of previously fallen litter to enable the decomposition boxes make direct contact with the forest soil. The decomposition boxes were randomly distributed in each quadrat. For each treatment, 3 boxes were sampled from 3 blocks every 28 days beginning October 1998.

The sampled boxes and the contents were taken to the laboratory. The partially decomposed leaves litter was carefully separated from the soil particles, plant roots and other materials and oven-dried at 60°C for 72 hours.

(4) Data analyses

The residual leaf litter samples for each treatment collected periodically were pooled together, milled using vibrating mixer mill (MRK-Retsch Mitamura Rikon Kogyo). Concentrations of Nitrogen (N), carbon (C) calcium (Ca), magnesium (Mg), phosphorus (P), Potassium (K) and sodium (Na), and total extractable phenols (TEPH) were determined following the same analytical methods of the previous paper (Owusu et al., 2001). Nutrient release patterns and nutrient flux (g m^{-2} $month^{-1}$) from leaf litter were calculated in the same manner of the previous paper (Owusu et al., 2001).

5-6-3-3 Results and Discussion

(1) Litter fall production

Rainfall was the highest from March to November and the dry season was December to February in the study area. Leaf litter fall is high in the drier months (December to February) and least in the rainy months in both forest sites (Fig.5-33). This trend was expected in the tropical moist-semi-deciduous forest of the dry forest subtype, which agreeed with Madge (1965). But, Ogawa (1978) and Proctor *et al.* (1983) found that leaf litterfall peaked in a lowland dipterocarp forest at a time of a peak rainfall. Lim (1978) did not find any correlation between litterfall and rainfall in Pasoh. The quantity of leaf litter produced in a year from the two secondary forests, Dopiri and Akyaakrom, were 6.7 t ha^{-1} and 7.6 t ha^{-1}, respectively. These were comparable to those obtained by Nye (1961) of 6.9 t ha^{-1} $year^{-1}$ for leaf litter productivity of a 40-year-old secondary forest, or John (1973) of 7.4 t $ha^{-1}year^{-1}$ for tropical semi-deciduous forest leaf litter in Ghana. However, these leaf litter productivities were lower than that obtained in Tinte-Bepo primary forest, 9.8 t $ha^{-1}year^{-1}$ (Owusu et al., 2001).

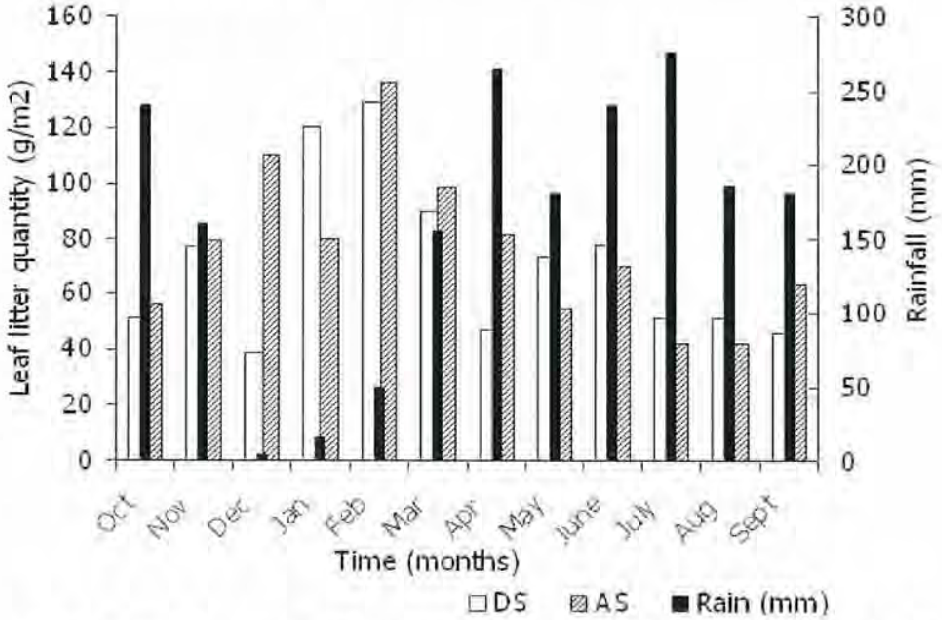

Fig. 5-33. Monthly leaf litter production in two secondary forests and rainfall pattern

(2) Litter decomposition

Figure 5-34 shows Quantity (g) of remaining leaf litter type in the secondary forests at monthly periods of decomposition beginning October 1998. From Fig 5-34, the leguminous tree species especially *Griffornia simplicifolia* (AG) (caesalpiniaceae) showed rapid decomposition in the Akyaakrom secondary forest. By the end of the 5^{th} month, AG had half of its dry weight decomposed. However, the decomposition of Mimosaceae *Albizia zygia* (DA), also a legume from Dopiri secondary forest was not significantly different from the mixtures of tree species leaves (DM) during nine months of exposure. The decomposition of DM was accounted for by the presence *A. zygia* leaf litter contributing to more than half the total species leaves litter produced. There was significant difference between the decomposition of mixed leaf litter from Dopiri (DM) and Akyaakrom (AM) secondary forests for the 1st to 3rd month and 9th to 10th month. Tanner (1981) suggested that the lower rate of decomposition in the upper mountaine as compared to lowland rain forests was as the result of lower temperature, different leaf characteristics and differences in water relations. The soil temperature recorded ranged between 22^{O}-$28^{O}C$ throughout the period of the study.

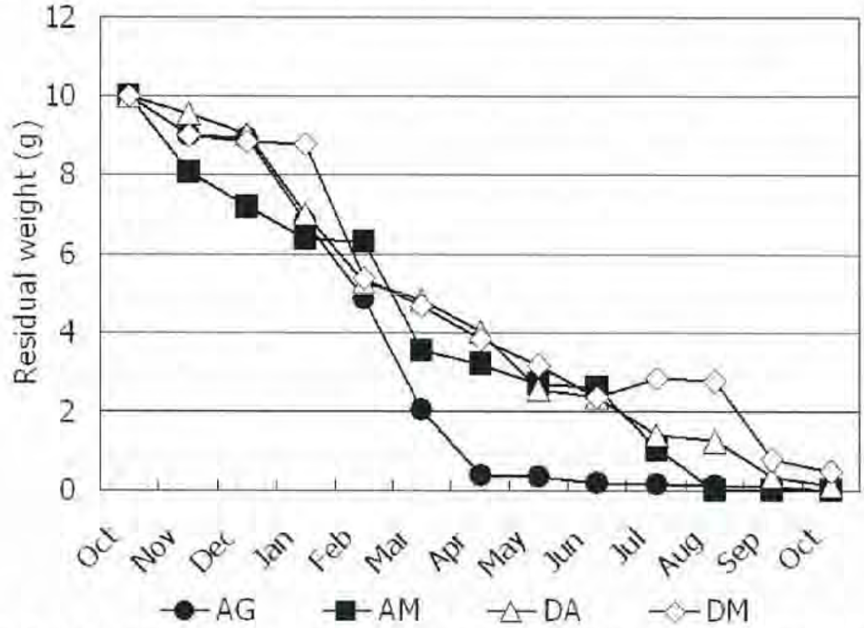

Fig. 5-34. Decomposition of four types of leaf litter in two secondaryforests

In this study, the differences in the rate of decomposition were tried to be explained by differences of TEPH concentration in leaf litter types.The fresh leaves litter contained higher total extractable phenols (TEPH). The TEPH concentration of fresh leaf litter was highest in DM (Mixed species at Dopiri), 1.86 gkg^{-1}, followed by DA(*A. zygia)*, 1.24 gkg^{-1}, AG (*G. simplicifolia)*, 0.89 gkg^{-1} and AM (Mixed species at Akyaakrom), 0.84 gkg^{-1}. At three months exposure, the TEPH concentration in AG had been broken down completely whilst concentration of TEPH in DM, DA and AM had declined by 93%, 55% and 18%, respectively (Fig.5-35 and Table 5-11). During seven months exposure, TEPH was completely broken down in DM, whereas DA and AM recorded losses of 77% and 42%, respectively. At the 9th month of exposure, only AM contained about 11% of TEPH (Fig.5-35). Rapid decline of TEPH in AG attributed rapid decomposition of its leaf litter, while slower decline of TEPH in AM and DA delayed those leaf litter decomposition. However, trends of TEPH decline (Fig.5-35) and leaf litter decomposition (Fig.5-34) did not coincide with each other. Factors other than TEPH concentration might attribute it.

Comparing the decomposition rates of DM and AM with that of mixed leaf litter (TM) in Tinte-Bepo primary forest in the previous paper (see TM in Fig.5-29, Owusu *et al.* 2001), leaf litters in the two secondary forests were decomposed faster than that of the primary forest. Half life of those leaf litters were about 4 months for DM and AM, and 6 months for TM. Turn over of leaf litter was said faster in secondary forests, which leads to faster nutrient release from those leaf litters.

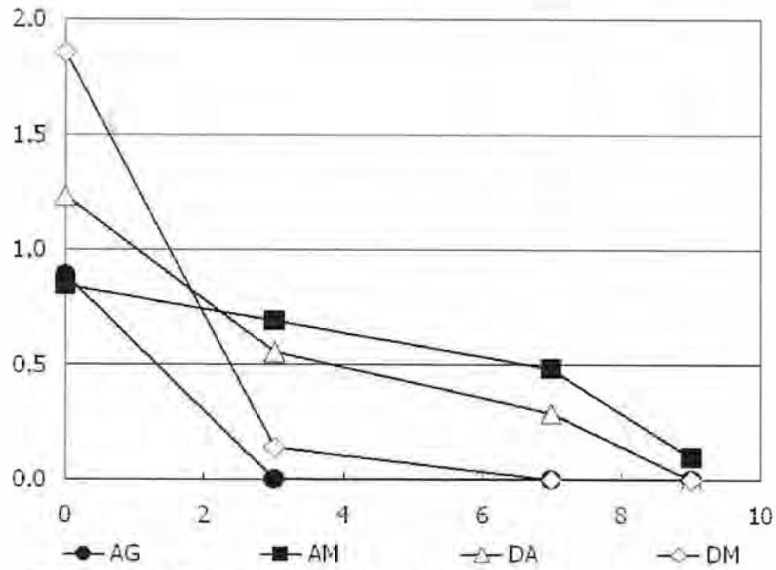

Fig. 5-35. TEPH concentration in decomposed leaf litter (g/kg)

The C/N ratios of all the litter types ranged between 14.8-22.3 % (Table. 5-11). Although fresh litters have higher C/N ratios comparing to partially decomposed litter, except for DM, no direct relationship was gained between the C/N ratios and decomposabilities. The original TEPH concentration was the highest in DM which was the lowest C/N ratios. This contradict characteristics might make the trend of decomposition rather complex in our study.

Table 5-11. Nutrient and TEPH* concentrations in fresh and decomposed leaf litters at 0 and 3rd month stage.

litter type	residual weight (g)	K	Ca	Mg (g/kg)	P	N	C/N (%)	TEPH (g/kg)
at 0 month								
AG	10	2.95	12.5	1.86	0.48	23.9	19.4	0.89
AM	10	5.52	14.6	0.24	0.69	21.1	22.3	0.48
DA	10	4.60	17.2	2.59	0.61	22.7	20.9	1.24
DM	10	1.61	19.2	5.44	0.69	30.9	14.8	1.86
at 3rd month								
AG	6.84	2.10	11.4	1.22	0.40	23.2	16.9	ND
AM	6.39	1.48	11.5	1.26	0.32	11.8	19.8	0.69
DA	8.78	2.43	12.7	1.58	0.46	14.0	17.8	0.55
DM	7.02	1.81	12.5	2.66	0.49	17.7	16.6	0.14

* Total extractable phenols

(3) Nutrients releases based on residual macro-nutrient amounts

Table 5-12 shows monthly changes of total nutrient concentration (gkg^{-1}) of N, P, K, Ca & Mg in remaining leaf litter from Dopiri secondary forest (DM, DA) and Akyaakrom secondary forest (AM, AG). Generally, there is gradual decrease in the concentrations of total macro-nutrients during the process of decomposition in all the leaf litter types except for nitrogen. Nitrogen appeared to increase in concentration during the decay process. The progressive increase of N in the remaining leaf litter collected monthly indicates that either there is immobilization and accumulation of N or the litter acted as a sink for N. Hence, the build up of nitrogen in the leaves litter and higher values obtained as decomposition progressed. Selman *et al.* (1928), Bocock (1963), Gosz et al. (1973), William & Gray (1974), Maheswaran & Gunatilleke (1988), O'Connell (1988) reported that there is build up of N and P initially in decomposing litter. Songwe *et al.* (1995) reported that addition of N from atmospheric ammonia, flora and fauna translocate and accumulate or immobilize N and P for microbial tissues build up contribute to the accumulation of these elements in decomposing litter.

Table 5-12 Nutrient concentrations (g/kg) in Residual leaf litter in Akyaakrom and Dopiri secondary forests

leaf	month	C/N	Wt (g)	K	Ca	Mg	P	N	C
AG	0	19.4	10.0	2.9	12.5	1.9	0.48	23.9	464
AG	1	17.7	9.0	2.7	17.3	2.3	0.49	23.9	424
AG	2	14.8	8.9	1.8	17.6	2.1	0.60	24.1	357
AG	3	16.9	6.8	2.1	11.4	1.2	0.40	23.2	392
AG	4	15.0	4.9	0.9	4.9	1.7	0.78	32.1	483
AG	5	14.0	2.0	0.5	0.4	0.0	0.37	24.0	336
AM	0	22.3	10.0	5.5	14.6	2.4	0.69	21.1	470
AM	1	26.1	8.1	3.8	22.0	3.3	0.60	17.5	456
AM	2	15.2	7.2	1.3	12.5	2.4	0.53	25.2	383
AM	3	19.8	6.4	1.5	11.5	1.3	0.32	11.8	233
AM	4	16.4	6.3	1.2	13.7	2.0	0.46	20.7	339
AM	5	14.1	3.5	0.7	5.4	0.7	0.49	28.9	408
AM	6	17.2	3.2	0.8	5.8	1.4	0.19	21.9	377
AM	7	12.0	2.6	0.6	6.1	0.6	0.16	28.4	342
DM	0	14.8	10.0	1.6	19.2	5.4	0.69	30.9	459
DM	1	17.6	9.0	1.3	14.0	3.9	0.51	24.6	434
DM	2	18.5	8.9	1.7	12.5	2.0	0.54	15.6	289
DM	3	16.6	8.8	1.8	12.5	2.7	0.49	17.7	294
DM	4	14.8	5.4	1.1	11.6	1.5	0.40	21.4	316
DM	5	23.5	4.7	1.1	11.2	1.4	0.33	17.3	406
DM	6	17.6	3.8	0.7	4.4	0.5	0.79	20.3	359
DM	7	22.4	3.2	0.4	8.9	0.8	0.18	11.7	262
DM	8	14.7	2.9	0.6	8.3	0.6	0.22	28.9	424
DM	9	15.7	2.8	0.5	7.4	0.7	0.18	23.4	368
DA	0	20.9	10.0	4.6	17.2	2.6	0.61	22.7	474
DA	1	21.8	9.6	1.5	15.2	2.9	0.51	18.7	408
DA	2	17.3	9.1	1.5	9.0	4.2	0.36	12.3	213
DA	3	17.8	7.0	2.4	12.7	1.6	0.46	14.0	249
DA	4	19.3	5.3	1.6	14.7	2.4	0.44	12.4	239
DA	5	13.4	4.8	0.6	8.5	1.0	0.26	28.9	388
DA	6	16.4	2.6	0.4	4.9	0.6	0.18	23.4	384
DA	7	27.0	1.4	0.6	2.0	0.3	0.10	13.1	354
DA	8	12.0	1.3	0.4	2.2	0.3	0.08	26.7	320

Comparisons of leguminous species leaf litter types from the two secondary forests (Table 5-12) revealed that nitrogen concentration in *G. simplicifolia* (AG) from Akyaakrom was higher than *A. zygia* (DA) from Dopiri. There was gradual N concentration losses in AG and DA during 3 and 4 months exposure respectively followed by N accumulation for a month. Nitrogen concentrations declined in the litter materials but DA showed accumulation after the 7^{th} month thereon. Whereas P, K & Ca were lost from DA, there was accumulation of Mg and increases of P, K, and Ca in DA for 1-2 months afterwards and then declined considerably. The pattern of phosphorus, potassium and calcium losses show linear trends in DA after the 5^{th} month. But the loss of Mg in DA after the 5^{th} month was non-linear. The increases of the concentrations of P, K, Ca & Mg in AG for the first three months were observed. The concentrations of Phosphorus and calcium were decreased in AG but the increases of K and Mg concentrations occurred between 4^{th} and 5^{th} months after which their concentrations declined relatively faster.

As shown in the Fig.5-36, the total nutrient amounts in g per m2 in remaining leaf litter decreased with time as decomposition progressed. The mineralization of calcium, potassium and magnesium was much faster at half-life in AG(*Griffornia simplicifolia*) than the other litter types. There was comparatively slower rate of mineralization of elements in the AM leaf litter type. This is due to the presence of polyphenols that inhibited mineralization of decomposing leaf litter material.

The decreasing trends were similar to the litter from each secondary forest, i.e. DA & DM, AG & AM. Nevertheless, the nutrient release trends of the legumes and the leaf mixtures differed from each of the secondary forests.

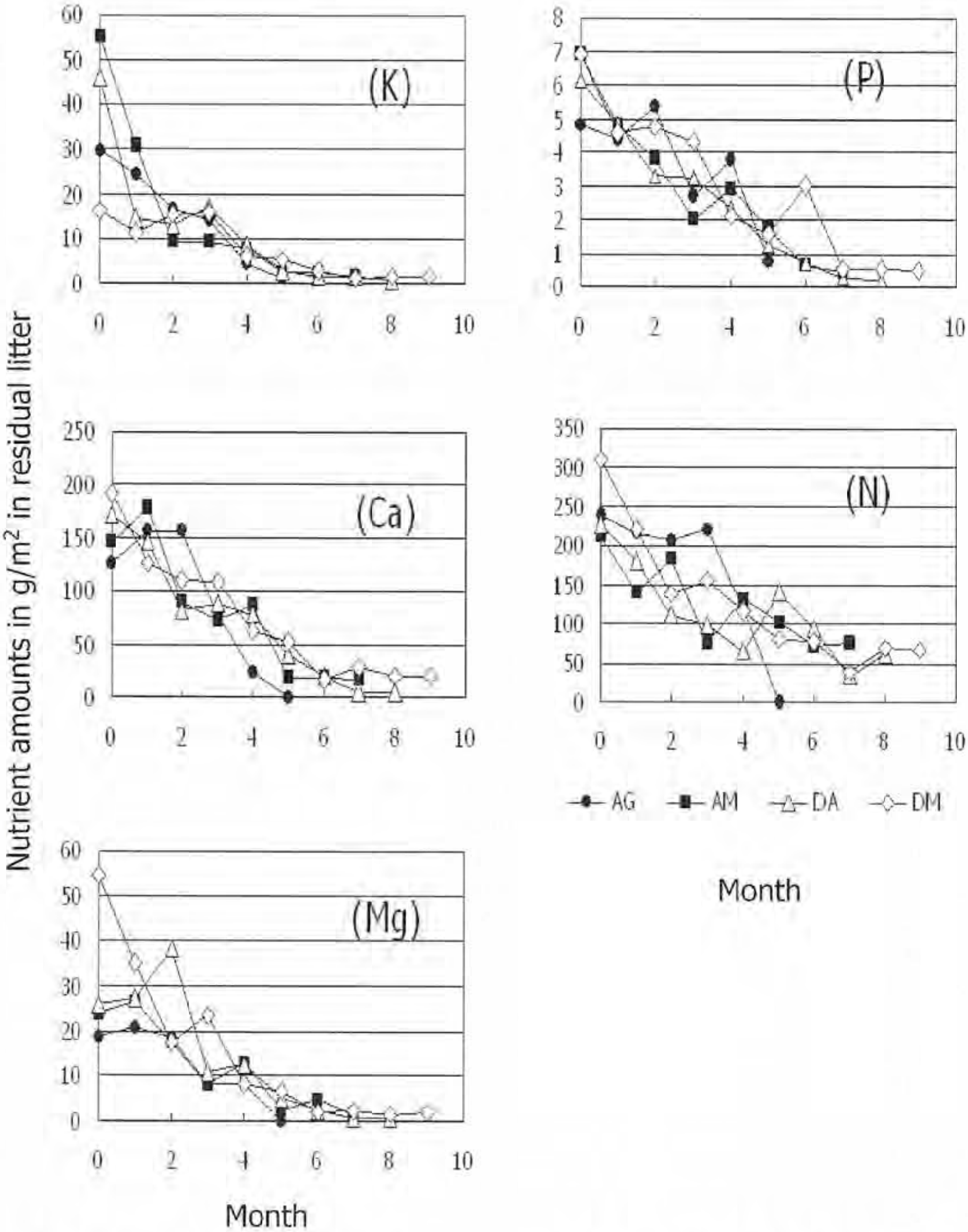

Fig. 5-36. Monthly nutrient release pattern of 4 types of leaf litter based on the nutrient amounts in g/m^2 in residual leaf litter

Nutrients from the remaining mixtures of the leaves litter types from the two secondary forests show that there was some initial build up of N in AM after one month followed by a sharp loss in the second month and rapid accumulation from the 3rd month to the 5th month. Initial loss of N from DM was followed by gradual build up after one month until the 4th month. Losses and build-ups alternated monthly in AM and DM until the end of the periods of decomposition (7 and 9 months respectively).

Based on the monthly patterns of the nutrient amounts in g per m2 in residual 4 types of leaf litter (Fig 5-36), by the 4 months exposures, nitrogen had been released in the proportions as 50%, 37%, 47% and 67% by AG, AM, DM and DA respectively. Calcium and Phosphorus were low in AG as compared to AM, DM and DA. By the end of the 3rd month, AG, AM and DA had released 29%, 73% and 47% of K into the soil environment respectively. During the similar months, the release of P was as follows; AG (17%), AM (54%), DM (29%) and DA (25%) . As shown in Fig. 5-36, because of nitrogen fixation and immobilization, monthly nutrient release was rather satble and long last in the case of nitrogen. Calcium and phosphrous follow somewhat similar relatively slow release trend. Pottassium showed the fastest release pattern. Magnesium follows the Pottassium.

(4) Nutrient fluxes duirng leaf litter decomposition

Based on the data of both AM and DM in Fig. 5-33, Table 5-12 and Fig 5-36, cumulative nutrient release fluxes from leaf litter for each month were estimated as shown in Fig 5-37 and 5-38 for Akyaakrom (AS) and Dopiri secondary (DS) forest respectively. The monthly amounts of fluxes were influenced by the monthly litter production. The fluxes were the highest during February to April in AS, but in DS the peaks were diverse between February and June.

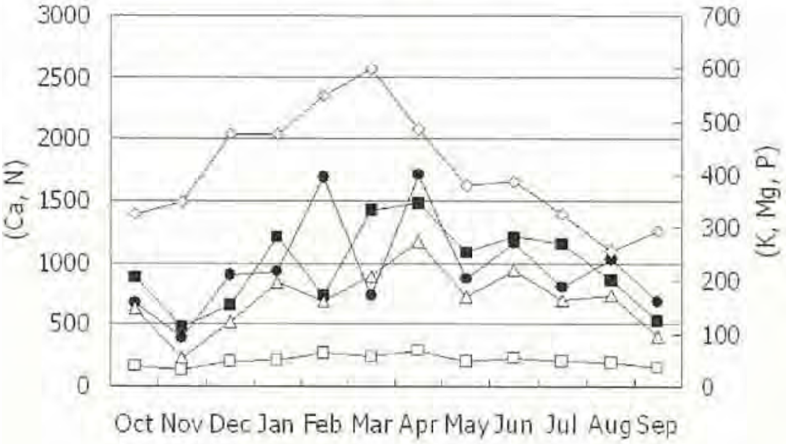

Fig. 5-37. Nutrient release from leaf litter in AS (mg/m^2/month)

Monthly nitrogen fluxes were 6.7 kg per ha in October, the lowest, and 17.1 kg per ha in April, the highest, in Akyaakrom secondary forest. If we negelect the denitrification Annual nitorgen flux from the decomposion of litter to soil was estimated to 116 kg N per ha. This is comparable to the Tinte-Bepo Forest Reserve (T-BFR) of primary forest reported by our previous report (Owusu 2001). Dopiri forest showed very high nitrogen fluxe, i.e., 209 kg/ha/year, which has monthly peak in February and the lowest in October. Annual fluxes of Ca were 117 and 145 kg/ha in AS and Ds respectively. This amounts were smaller than the T-BFR. The peak months were March, 14 kg/ha, in As and June and February, 16 kg/ha in Ds. In DS, Mg flux was followed to N and Ca. The annual flux was

45 kg/ha which has the peak month in February as 5.8 kg/ha and the lowest month in October as 2.7kg/ha. Annual flux of Mg in TBFR was 28kg/ha. But in As, K flux was followed to N and Ca. The annual flux was 49 kg/ha, which has the peak month in March as 6.0 k/ha and the lowest month was Augsut as 2.6 kg/ha. Annual fluxe of K in T-BFR was 40 kg. Annual fluxes of P were small both in DS and AS, 5.5 and 5.8 kg/ha respectively. In T-BFR the annual flux of P was 9 kg/ha, suggesting the scarcety of Phosphrous in these two secondary forests. Monthly fluxtuations were also small. But peak months were May in DS, 0.69 kg/ha, and April in April in AS, 0.67 kg/ha. The lowest months were October in DS, 0.31kg/ha, and November in AS, 0.32 kg/ha.

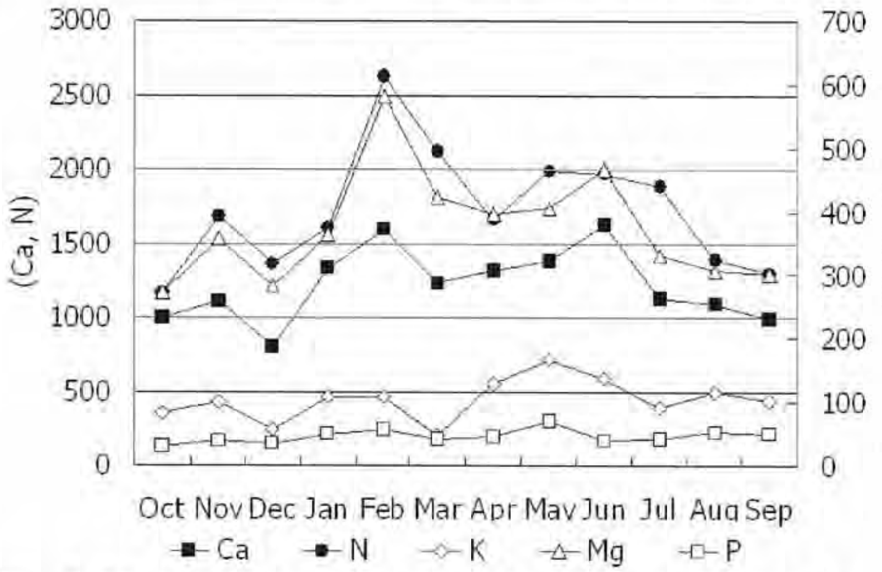

Fig. 5-38. Nutrient release from leaf litter in DS (mg/m²/month)

There is very little available information on the dynamics and cycling of nutrients in Africa's tropical forest ecosystems. Leaves decompose and release nutrients relatively faster than other plant parts. Therefore, the study into the production of leaf litter through decomposition and mineralization to the release of the held-up nutrients is important. In this study, annual leaf litterfall recorded was higher than previously recorded values in the tropics. Decomposition process was completed within a year and nutrient elements except nitrogen were released in a year. The leguminous tree species leaves litter decomposed and released nutrients relatively faster than the other leaves litter types. Nutrient release was prolonged in the mixed species leaves litter from the Dopiri secondary forest. However, N build up instead of mineralization was recorded for all the litter types. The nutrient release from the litter into the soil environment would lead to the understanding of nutrient accumulation, energy flow through the system. This would lead to the estimation of the quantity of nutrients that would have been lost if the litter materials are burnt away as practiced in slash and burn farming system in Ghana.

5-6-3-4 Summary

Two secondary forests vegetation (Dopiri secondary forest and Akyaakrom secondary forests) belonging to the moist-semi-deciduous dry forest type was selected for this study. Six plots of sizes 25.0m x 25.0m (three in each site) were demarcated. Litter traps made of square wooden were erected in the plots to collect falling litter in September 1998 until August 2000. Galvanized wire mesh (1.0mm) was passed around *Melicia excelsa* wooden frames 20.0cm x 20.0cm (inner surface dimension) x 2.0cm deep and 0.5cm thickness and used as decomposition boxes.

Dopiri secondary forest produced an average of 7.6 tha^{-1} whilst Akyaakrom secondary forest produced an average of 7.7 tha^{-1} of leaf litter per year. Leaf litter fall is high in the drier months (December to February) and least in the rainy months. *Griffornia simplicifolia* (AG) (caesalpiniaceae) showed rapid decomposition in the Akyaakrom secondary forest. The decomposition of *Albizia zygia* (DA) (mimosaceae) from Dopiri secondary forest was not significantly different from the mixture of tree species leaves from the two secondary forests (AM, DM). There was no significant difference between the decomposition of mixed leaf litter from Dopiri (DM) and Akyaakrom (AM) secondary forests. The fresh leaves litter contained higher concentrations of total extractable phenols (TEPH) and was highest in the mixed species leaves litter from Dopiri secondary forest (1.86 g/kg) followed by *A. zygia* (1.24 g/kg), *G. simplicifolia* (0.89 g/kg) and mixed species leaves litter from Akyaakrom secondary (0.84 g/kg) was the least. There is gradual decrease in the concentrations of total macro-nutrients during the process of decomposition in all the leaf litter types. The decreasing trends were similar to each litter type from each secondary forest, i.e. DA & DM (mixed species) and AG & AM (leguminous). *Griffornia simplicifolia* released nutrients rather faster than the other leaf litter types. The C/N ratios did not affect leaf material breakdown. TEPH concentrations in the leaf litter and the litter characteristics contributed to the differential patterns of decomposition leading to quantities of nutrients released into the soil environment.

Annual nitorgen fluxes from the decomposion of litter to soil were estimated to 116 and 209 kg/ha/year in AS and DS respectively. Annual fluxes of Ca were 117 and 145 kg/ha in AS and Ds respectivwly. The annual fluxes of K were 49 and 13 kg/ha in AS and DS. Annual fluxes of Mg were 45 and 20 kg/ha. Annual fluxes of P were small both in DS and AS, 5.5 and 5.8 kg/ha respectively, suggesting the scarcety of Phosphrous in these two secondary forests.