FINAL TECHNICAL REPORT

FOREST FIRE MANAGEMENT IN GHANA

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1. ABSTRACT

The increase in forest fires in the high forest zone of Ghana during the past two decades seriously threaten the survival of some of the nation's forest reserves. The annual loss of revenue from merchantable timber to fire is currently estimated at $24 million. There was an urgent need to develop an understanding of causes and effects of forest fires in order to find effective means to prevent fires in forest reserves. This project therefore aimed at providing vital baseline information as well as procedures and programmes for effective forest fire management in Ghana. The development objective of the project is to enhance sustainable forest management in Ghana and the specific objective is to reduce current rates of natural forest depletion by developing efficient fire management systems.

Scocio-economic studies were conducted using Rapid Rural Appraisal (RRA) methodologies to gather the perceptions and views of local people on the causes and effects of forest fires. These included focus group discussions, community fora, consultative meetings, household and key informant's interviews. Assessment of fire control needs and ecological studies including burning experiments were also performed to investigate the effects of forest fires on flora and fauna and options available for controlling fires. Four Forest Reserves, namely Afram Headwaters, Worobong South, Pamu Berekum, Tain II in two forest types with recent history of fires were selected for the project. The sites were selected for their relatively short fire–return interval and variation in ecology.

The results of the project show that forest fires are strongly linked with livelihoods and impacts negatively on sustainability of agricultural and forest land use. It was also revealed that the ecological status of the forest brought about by previous use is a recipe for more fires. Forest degradation resulting from fires was found to have had significant effect on the distribution, abundance and diversity of forest plants and animals.

A forest fire prevention and awareness programme was initiated through the development of a fire prevention communication plan and improvement in the programme content of antibush fire campaign in collaboration with Ghana National Fire Service.

The project identified three viable options (Green firebreaks that prevents re-entry of fire, tree planting and forest aggradation as means for rehabilitating fire-degraded forests). These options however need to be pursued through collaborative mechanisms with appropriate and sustainable incentive schemes.

The methods and procedures identified for effectively controlling forest fires in Ghana included fuel treatment, fire detection, institutionalisation of fire reporting, and training of fire volunteers. All these are to be pursued through a well coordinated forest fire management programme owned and executed by the Forestry Commission.

2. INTRODUCTION

In Ghana fire has been shown to be the single most important agent responsible for reducing productivity and depleting the genetic diversity of forests (Hawthorne, 1994). Over 4 million cubic meters of exportable timber have been lost to fire following the 1982-83 drought (Hawthorne, 1994). Forest fires in Ghana have been estimated to cause an annual loss of 3% of GDP during the past 15 years. Forestry Department (Now Forest Services Division) records and news reports also show a steady increase in the incidence of forest fires during the same period. By 1993, the total area of forest reserves in the high forest zone affected by fire was 0.917 million hectares, more than half the total area of reserved forest. The increase in forest fires during the past two decades seriously threatens the survival of some of the nation's premium timber species notably, *Pericopsis elata* (Afrormosia), *Milicia* spp. (Iroko) and *Entandrophragma* and *Khaya* spp. (African Mahogany) among others.

Fire continues to erode the value of Ghana's forest reserves in a climatic zone, which has a great potential for substantial timber production. Without an effort to rehabilitate, these reserved lands will remain unproductive, as they cannot legally be used for purposes other than forestry. The Government of Ghana initiated a programme to prevent and control forest fires. Which culminated in the enactment of bush fire Laws. Additionally, the Ministry of Lands and Forestry (MLF) acting within the broad guidelines of the 1994 Forest and Wildlife Policy encouraged the Forestry Department to create a Forest Fire Prevention and Control Unit (FPCU) at the then Planning Branch in 1995. The FPCU was set up with support from the Department for International Development (DFID), U.K. and mandated to develop programmes aimed at reducing forest degradation through effective forest fire control.

However, the effectiveness of all these measure has been heavily hampered by lack of information on which to develop cost efficient forest fire management system and forest fires continue to plague the country. Apart from the development of effective fire prevention and control there was the need to identify options for rehabilitating the fire-degraded forests.

It therefore became quite urgent to collect baseline data for use by policy makers and forest managers in developing programmes to reduce forest fires.

This project therefore aimed at providing vital baseline information for developing procedures and programmes for effective forest fire management in Ghana. The development objective was to enhance sustainable forest management in Ghana and the specific objective was to reduce current rates of forest fires by developing efficient fire management systems.

The project had four main outputs namely; causes and effects of fires understood, effective forest fire control systems developed, mechanisms for rehabilitating fire-degraded forests developed, effective wildfire prevention, education and awareness programmes instituted.

The project had a strong collaboration, involving research institutions, implementation institutions and forest dependent communities. The Forestry Research Institute of Ghana, which is the main implementation agency, worked in close collaboration with the Ghana Fire Service, Forest Service Division, and local communities. External consultants from the University of Aberdeen, U.K., Ministry of Forest, British Columbia and United States Forest Service provided technical support to the project.

3. MAIN TEXT

PRESENTATION AND ANALYSIS OF DATA

Output 1 Causes and effects of fires understood

Managing forest fires is a complex task due to a wide range of issues bordering on prevention, presuppression and suppression/control. Preventing forest fires is much more cost-effective than suppression/controlling them and bearing the resulting losses and negative impacts. The causes and effects of forest fires, and the underlying reasons for them need to be determined before effective prevention methods can be developed and applied. The general public through their lifestyle or livelihood activities is an important cause of wildfire in Ghana possibly due to a lack of understanding of the importance and value of forest and the negative impacts of fire.

Activity 1.1 conduct sociological survey of local people's use and perception of fire

Introduction
Forest fires in Ghana are anthropogenic in origin and can be avoided to a large extent if local people are effectively educated on the threats forest fires pose to their environment. In spite of the impacts of the fires on the rural economy the use of fire is still an integral part of the traditional farming and rural livelihoods. In line with this any programme to prevent the spread of fires need to look at the level of fire usage and the perception of the local people on fire. In addition indigenous knowledge of the local people needs to be incorporated into scientific knowledge in an effort to solicit local community support in fire prevention and control.

Methodology
The project conducted surveys in three districts, namely Begoro, Dormaa-Ahenkro and Sunyani to gather information on the local communities' indigenous knowledge of fire usage. Five hundred respondents were interviewed in 54 communities. Twenty village meetings and ten focus group discussions were also held.

Findings
The study revealed that the use of fire has not changed much over time and is closely linked to livelihood activities. These activities are farming, palmwine tapping, and hunting.

In farming fire is used to remove biomass from cleared land, get rid of unwanted residue, manage shade and also for cooking food on the farm. Fire is used to control pest, prevent rottenness of the palm tree, and ensure better taste and to increase yield of the wine during palmwine processing. In hunting fire is used to smoke out the game, to remove animal hair, roast the meat and light cigarette to keep hunters awake.

The study showed that there are laid down procedures for the use of fire for the activities mentioned but some local people go contrary to the laid down procedures and this results in incidence of fires.

According to the respondents fire usage has obvious advantages and disadvantages. The advantages include, ability to clear large plots, increased crop yield, improvement of soil fertility, reduction in labour cost, easiness in tilling the soil, and control of harmful insects and pests. Other advantages are suppresion of weed regrowth, easy organization of farm and the natural regeneration of cocoyam(a staple food in the forest zone).

In spite of these advantages the respondents indicated that the continued use of fire poses some problems namely, the influx of new weeds, reduction of moisture content of soil and destruction of forest vegetation. There is also the problem of increasing workload when the debris does not burn properly and the tendency of fires getting out of hand resulting in destruction of property.

Respondents identified some existing alternatives to slash and burn namely 'Proka' (farmer sows or plants in mulch of cut slash), use of weedicides and windrowing. However these are associated with high labour cost. Besides not all crops can be grown using these methods. The alternatives to slash and burn do not therefore appear alternatives at the moment.

Certain conditions: Strong winds, excessive drying of cleared vegetation, presence of dead lying wood, high temperature and long drought are perceived to facilitate the spread of fire beyond intended target. Respondents indicated that these conditions need to be taken into consideration before using fire.

Respondents use their indigenous knowledge to ensure that some of these conditions are kept under control. For example wind direction is checked at the site of burning by throwing soil into the atmosphere or watching the movement of leaves to ensure the suitable wind condition for burning. The leaf flush of *Moris mesozygia* (a forest tree) and the first two rains after the dry season are clues used by local people to identify the time for save burning.

The respondents use whistle and shouting to transmit fire warning and call firefighters in case of fire outbreak.

It was evidently clear that local people have some indigenous knowledge of forest fires, which is reliable but remaining to be tapped and processed into scientific knowledge to enhance its effectiveness.

Activity 1.2 Determine the frequency and distribution of fire risk

Introduction
The ability to predict fire risk is an effective tool to reduce the occurrence of accidental fires. The personnel, vehicles and other resources that are necessary to implement

legislation designed to prevent accidental fire are very limited given the magnitude of the forest frontier. Predictions of the severity of fire risk in different parts of the fire-prone forest reserves could help government agencies decide where to invest their scarce resources, and when additional resources are needed.

Various environmental and human factors are known to influence the frequency and distribution of vegetation fires. Environmental factors such as human population density, settlement and house density, Land use (forest reserves - plantation and natural forest, farms & farm fallow, industrial, commercial farms, mines), tarred and untarred roads, vegetation types, vegetation biomass, climate, topography, soils and geology influence the frequency and distribution of vegetation fires. An in-depth analysis is needed in order to determine the relationships among these environmental factors and fire.

In line with this the project using model builder a GIS based programme generated fire risk model, which was used to generate a fire risk map covering the project sites. Fire risk predicts the ignition potential. This will enhance prioritization of areas for fire prevention and control. Five basic layers namely towns, roads, fire occurrence zone, aspect and slope were used for the risk model (fig 1). The model can be run for just the portion that deals with a risk factor eg. Roads. The five basic layers were overlaid through the process of arithmetic overlay and a risk map (Fig 2) was produced for the four forest reserves. The darker the area on the map the higher the fire risk.

Findings

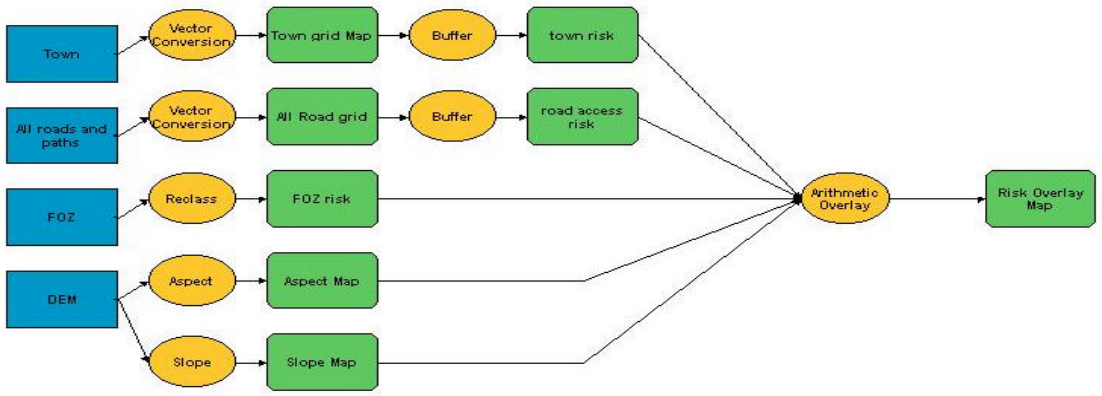

Fig 1 Fire Risk Model

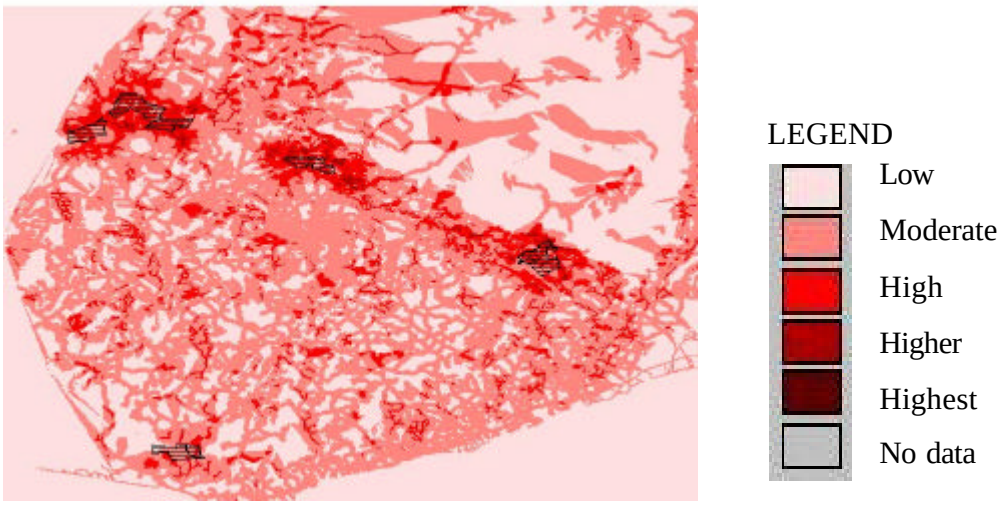

Fig 2 A fire risk map based on town, roads and past fire occurrence covering four forest reserves in the transition zone.

Activity 1.3 Determine the spatial and temporal distribution of forest fire hazard

Methodology

Two basic layers, namely vegetation zone and land cover were used to generate Fire Hazard Model through the use of Model Builder to prioritize areas of high hazard for fire prevention and control.

Vegetation zone information used for the hazard model (fig 3) was reclassified based on fuel type and vegetation zone hazard map produced. A hazard map was also produced from a Landsat derived land cover. The two maps were overlaid through the process of arithmetic overlay, which allows values to be reclassified and weights to be given to each layer and overall hazard map (Fig 4) produced.

Findings

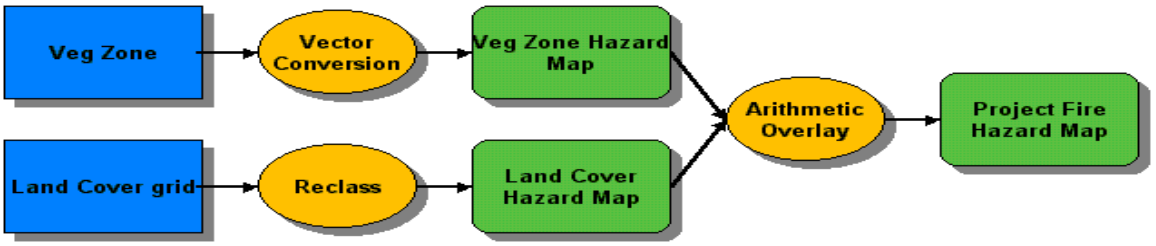

Fig 3 A fire Hazard model

The hazard model allows for more site-specific data to replace some of the layers when available. Specific sources of data to replace land cover information may include coverage of degraded areas, plantations, TUC areas, taungya and farms.

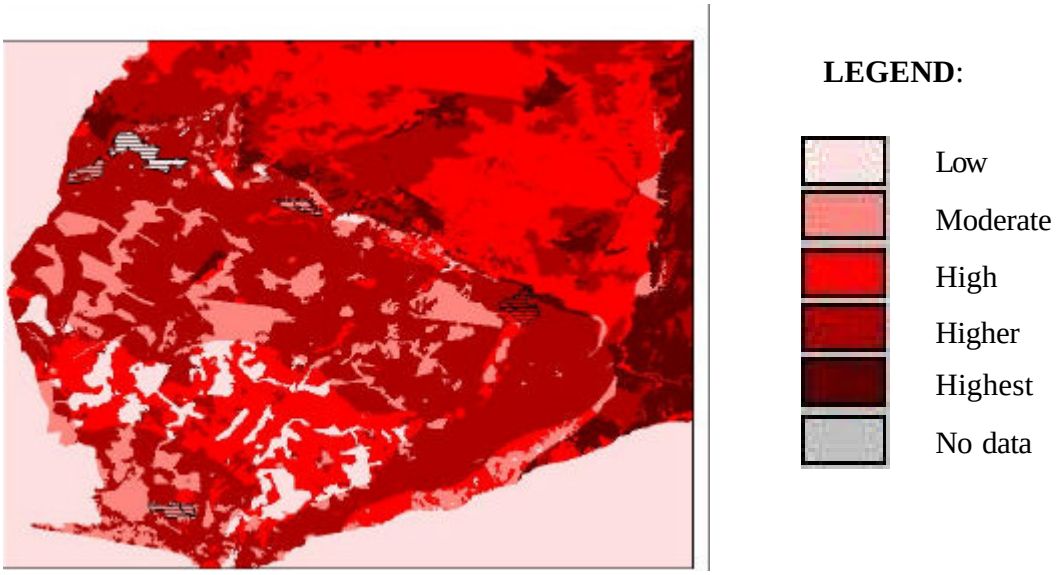

Fig 4 Fire hazard map based on vegetation zone and land cover in the transition zone

Activity 1.4 Describe forest resources at risk

Introduction

Financial and technical resources meant for forest protection are limited and will therefore have to be allocated based on forest management priorities. When setting priority in forest protection it is necessary to consider the values of forest resources at risk of destruction by a particular cause of degradation, in order to determine the appropriate level of protection justifiable economically and environmentally. It was therefore deemed necessary to provide a general overview of the forest resources in the high forest zone of Ghana, likely to be lost to fire in the near future, based on the present fire-risk distribution pattern. Strictly speaking forest resources at risk of degradation may be grouped into plant and animal species in general (biodiversity), economically important plants and animals, vulnerable landscape units, local climate, sacred forests, small forest islands and the ecosystem as a whole (Hawthorne and Abu-Juam, 1995). This study could not provide a detailed description of these resource categories but tried to generalize how valuable the forests in the fire-prone zone are in terms of the above forest benefits.

Methodology

Using satellite imagery, ground observations and forest inventory and botanical survey reports, this activity sought to highlight the values of the North-west subtype of the Moist Semi-decidous and the Dry Semi-deciduous forest which are the two main types of forest whose resources are most vulnerable to fire damage (Swaine et al., 1995). The moist forests are presently significantly impacted by fire but still, contain good forest vegetation whilst the dry forests have virtually been reduced to little fragments of closed canopy forest surrounded by large expanse of seriously burnt and degraded forests. These fragments will be completely lost to fire if protection measures are not implemented

immediately. Forest reserves in the two forest types are shown in Figure 5 as mostly degraded.

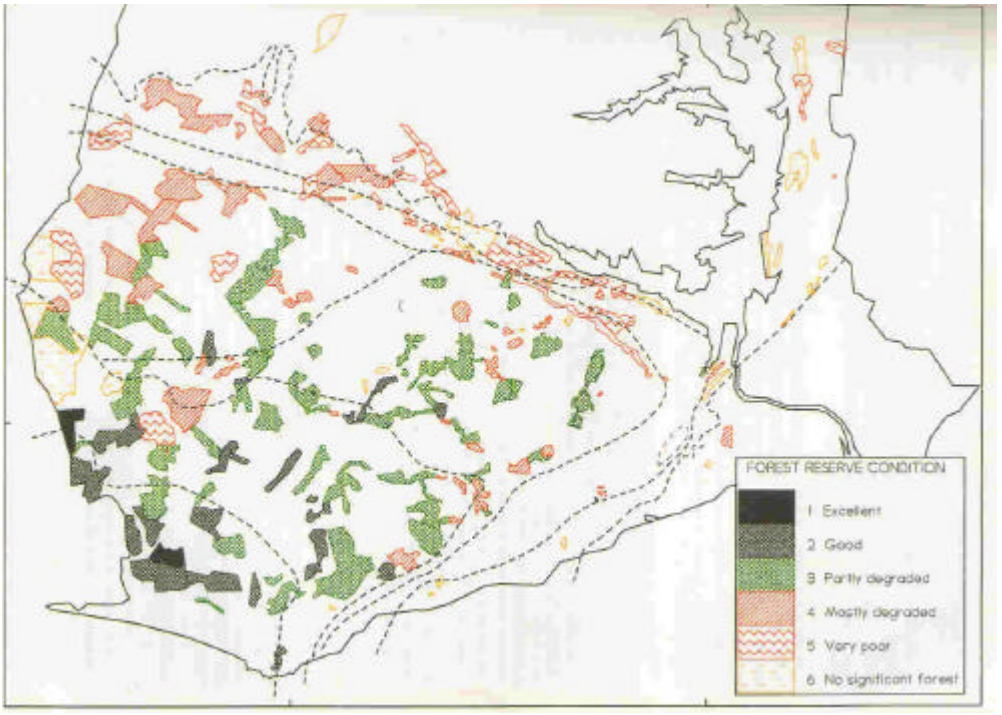

Fig 5 Map showing forest reserve condition
Source: Hawthorne and Abu-Juam, 1995

The forests in the Volta Region as well as those located in the Southern Marginal and South-east Outlier forest types were not considered in this study although fires are no less a threat in these forests than elsewhere. The main reasons are their low timber value and already existing special protection measures being implemented for them.

Findings

Since 1983 forest fires have crossed the dry forest into the moist forest zone thus establishing a new fire frontier further down south. Consequently most forest reserves in the North-west subtype of the Moist Semi-deciduous Forest type are subject to occasional burning contrarily to the general observations prior to the fire insurgences into the forest reserves. At the time of forest reservation the western part of this subtype had very little human population and the Forestry Department was therefore able to obtain a number of large forest reserves. There are some 25 forest reserves with a total area of 3567km^2 located here (Hall and Swaine, 1981). Due to bad logging and fires especially since 1983, less than 2% of the forest reserve area is considered as good without any signs of degradation. Most parts of the reserves are either partly degraded (30%) or mostly degraded (40%) whilst about 28% of the area is either very badly degraded or contains no

significant forest vegetation. This state of degradation predisposes the forests to fire irrespective of their location in the moist zone.

Considering timber resources the zone has made significant contribution to the overall timber volume harvested in the country and still contains a good number of commercial timber species in significant quantities. This forest type is part of the most productive area of the forest zone and its present state of degradation can be attributed to the abundance of most of the popular traditional timbers that made logging very attractive to timber contractors in the 1970s and 80s. Trees here are the largest and probably have the highest increments in the country. Having been logged heavily in the past majority of compartments in various reserves are not due for another round of harvesting but one still observes logging here and there. Conservation wise the area is home to a number of tree species like *Pericopsis elata, Khaya anthotheca, Argomuellera macrophylla*, and a few others which are either rare or completely absent elsewhere in the Ghanaian forests (Hall and Swaine, 1981). Two of the recommended forest protection measures (provenance protection and convalescence protection) to safeguard the long-term interest of the timber industry are most prominent in this forest subtype. The highest population of elephants in the forest zone used to be located here even as late as the mid eighties and were driven further south by loggers and probably farming of the unreserved forests. Although the prospects of the elephant stock building up again remain rather obscure, this account and other facts show the utilization and conservation value of the forest. Forest plantations here are less extensive though healthier than those in the dry forest zone. Attempts to grow indigenous timbers in plantations are more widespread than in other forest types but success has been rather low (Hawthorne and Abu-Juam, 1995). There are a number of interesting hills within forest reserves in the subtype for cultural and environmental reasons notable among which are Bosomkese, Kwamisa and Tinte Bepo.

The reserves in the Dry Semi-deciduous Forest type were strategically demarcated to protect the rest of the forest zone from further southward advancement of the open savanna vegetation. Numbering close to 40 with a total area of 3575km^2 a lot of these reserves can no longer be called forest except for the legal status of the land they occupy. In 1995 the best part of the reserves was classified as partly degraded and this was only 0.2% of the total area (Hawthorne and Abu-Juam, 1995). Years after, the forests have further declined in condition including portions of sacred groves that had full protection status. So one is likely to wonder what is in these forests to protect and what they are valued for.

In this forest type one of the resources at risk may be the forestland itself, which has been progressively degraded to an extent that it bears a closer resemblance to savanna rather than forest in most areas. Forestlands are not only useful for the vegetation they carry but also for non-botanical forest qualities. Sacred areas, steep slopes, river banks, watersheds, swamps and local climate are issues that have dominated forest protection in Ghana and they are unlikely to be abandoned in favour of others even though the practices on the ground often question the commitment of forest officers to these forest values. Even in its present state of degradation the forest offers better protection to these interests than other land-uses can do. Again these degraded lands have the potential to recover through an

aggradation system if properly protected from further abuse (Section 1.5.1.). Although one must distinguish the potential for forest recovery from the opportunities that exist for recovery to occur, it is hoped that with commitment and possibly pressure from civil society groups the Forestry Commission may do better than allow this asset to fall into non-forest land uses.

Another resource at risk comprises small forest patches with significant tree cover especially in areas fringing streams and rivers. From a professional point of view these patches should deserve attention for maximum protection but on the contrarily a lot of them have been creamed of the few valuable timber trees under a dubious unofficial timber salvage system further diminishing the need for protecting these fragments. However they are still valuable to deserve protection as they contain the last remnants of this forest type, besides any natural regeneration of the remaining forest may derive its strength from the few mother trees still lingering on in these patches. Degraded, as it is Tain II Forest Reserve for instance has 1.19% of its land area serving as provenance for *Milicia excelsa, Aningeria spp* and *Ceiba pentandra.* This may not reflect the reality on the ground but it shows the conservation value of the forest even in its degraded state. Probably the highest conservation value is due to the presence of the Black star species *Talbotiella gentii* which is endemic to Ghana and found in some of the reserves here.

One particular forest type where sacred patches and therefore cultural values are high is the Dry Semi-deciduous forest where rocky scarps and bovals are often accorded local reverence probably because of their distinctive and abrupt features. In Tain II Forest Reserve 1.65% of the total area (8.4km2) is a cultural site housing the shrine of the Nsoatre community. Such social values are some of the resources at risk of devaluation due to fire.

The above discussion of the dry forest is generally towards safeguarding the future of the forest, nonetheless, even in terms of present roles and values there is a lot to protect the forest for. Forest management in Ghana is becoming more financially sensitive and therefore revenue generation more critical. In terms of returns to forest managers in the immediate future the teak plantation stands in this forest type are the resources that easily come to mind. Most of these have been thinned carelessly in the past but they still contain valuable wood for poles and lumber. Recent surveys show a good coppice population from the thinned stands, which if managed well will constitute a cheap source of replacement crop.

The Ghanaian forest resources at risk of fire damage and total destruction are huge in terms of total forest coverage and values thereof. Most of the benefits for which tropical forests are managed, ranging from timber to socio-cultural values are found in the fire-prone forest belt and all face a high risk of further damage from fire. It is worth noting that even in the extreme degraded forests the resources still available are valuable enough to warrant reasonable levels of protection.

Activity 1.5 Determine the impacts of fires of varying intensity on timber tree species and biodiversity

1.5.1 Determine the impacts of fires of varying intensity on birds

Introduction
Birds in forests play important ecological roles as predators (on invertebrates and seeds) and seed dispersers. Very little work has been done to understand how these processes are altered in patches lacking a large fraction of the native avifauna. Forest fire is involved in both the causes and effects of fires. As a causative factor, pursuit of wild game incites some hunters to burn forests to flush animals into more open areas, and to attract them to the herbaceous regrowth in newly burned areas. Although this short-term benefit involves a long-term cost (the cumulative effect of annual fires eventually destroys the forest), little is known about how hunters perceive their role in the fire problem. The more profound impact on animals' follows from which type of plant community follows in the wake of repeated fires in high forest.

Methodology
As part of a broader effort to understand birds response to forest fires the study surveyed birds on 2.5ha transects in Afram Headwaters and Worobong South Forest Reserves. Secondly, questionnaires were administered to local hunters and farmers in around these forests.

This study was restricted to bird species that were expected to be associated with forests, and that could be censused reliably. In all ninety-eight diurnal species that at least two of four previous studies considered to be strongly associated with forests in Ghana (Grimes 1987, Holbech 1996, Dutson and Branscombe 1990) or neighboring Cote d'Ivoire (Gartshore et al. 1995) were first identified. Of these ninety-eight species, eighty-three species had songs distinctive enough to allow auditory detections; these became the focal species for this study; forty-nine of these species were detected on at least one transect.

All surveys were completed during 0550-1050. On each transect, an observer walked the assessment line, and listened and looked for birds up to 50m on each side of the line, spending 6 minutes on each 50-m segment of the line. Each species was marked as present if it was detected by song or sight anywhere in the transect area during the visit. No attempt was made to determine the number of individuals of each species on a transect. Each transect was visited twice, with at least 4 weeks between visits. The first visit was during Feb 27-April 13 (late dry season), and the second visit was during April 21-June 1 (early rainy season). A species was considered present if it was detected in the 2.5-ha transect area on either visit. On the second visit the detectability of 28 focal species was increased by whistling imitations of their songs or broadcasting recorded songs.

A semi-structured questionnaire was administered to 55 hunters in personal interviews. Of the team of 5 interviewers, 1 interviewer participated in each survey. A Participatory Rural Appraisal (PRA) approach was adopted to allay suspicions and explain the

potential benefits of the survey to the local hunters. Nonetheless most hunters approached for the survey declined to participate. Those who did participate were cooperative.

Findings

The results of the transect survey indicated that the indirect effects of fire on wildlife include forest modification as a result of the fire and invasion by the exotic weed *Chromolaena odorata*. In heavily degraded portions of the forest the original forest birds have been replaced with savanna species.

Results of the hunters questionnaire survey showed that hunters overwhelmingly believed that bush fire was the main factor responsible for a perceived decline in game species over the past decade. Hunters do understand the long-term consequences of fire, and realize that in the long term bush fire is a detriment to game populations and hunting success. Whereas respondents in Worobong think that no wildlife species benefit from bush fire, those in Afram were of the view that species such as the Giant rats (*Cricetomys gambianus*), Grasscutters (*Thyonomys swinderianus*), Red river hogs (*Potamochoerus porcus*), Bush bucks (*Tragelaphus scriptus*) and Giant forest squirrels (*Protoxerus stangeri*) do benefit from bush fire. The wildlife species recorded in different status in this study could mean that, certain wildlife species depend upon periodic destruction and renewal of the forest, with various species occurring at different stages in succession.

Hunter-farmers think that species like the Grasscutter and Giant rats do benefit from forest fire, whereas, others such as Monkeys, Reptiles, Duikers, Red river hog and other slow moving terrestrial animals (e.g. Tortoise) are killed by fire. In short, real forest species seldom survive forest fire in most times. They die out of burns or smoke inhalation. Although many hunters were of the view that birds were not affected much, however, in an extensive or completely burned areas birds' abundance distribution may change because real forest birds are habitat specific. The wildlife species recorded in different status in this study could mean that, certain wildlife species depend upon periodic destruction and renewal of the forest, with various species occurring at different stages in succession.

Almost all farmer–hunters in both forest areas interviewed agreed that hunting success has diminished as a result of bush fire, over-exploitation of wildlife and the widespread of the "Acheampong" weed (*Chromolaena odorata*) in recent times. *Chromolaena odorata* is an invasive exotic weed of forest opening in West Africa which has spread steadily through the forest zone in the 1980's following extensive degradation of forest cover by fire.

Forest fire in the short-term makes hunting easier although, hunters are of the view that a lot of time and energy is required, with uncertain and infrequent success whenever there is bush fire. Bush fire also promotes the fast spread of the "Acheampong" weed (*Chromolaena odorata*) which modifies the forest to suit generalist and opportunistic wildlife species, especially rodents rather than real forest species that seldom survive in fire-climax communities. The information generated from this study will inform, and also, become a resource for forest managers. It is high time forest managers did

everything within their means to create a suitable environment for the entire array of plant and animal species that occur in their reserve.

The effect of forest fire on wildlife is more difficult to predict in this study because, this often depends on the type of fire and type of vegetation. Findings in this study may although be limited, in that information from interviewees gave little indication of how particular species were affected directly or indirectly by bush fire, nevertheless, using hunters knowledge on forest animals, in the tropics are undoubtedly essential for their future conservation.

1.5.2 Determine the impacts of fires of varying intensity on timber tree species

Introduction

Forest fires in Ghana are now recurrent, so that their history is complex. Oral and documented records of burning can be used to reconstruct the increasing effects of recurrent fires on forest structure and composition. Whereas the moister forests of tropical West Africa appear to have maintained some integrity under recurrent fires, the drier forests have been more severely affected (Swaine, 1992). Only in the tropical rain forests of the Brazilian Amazon has some account been made of the effect of recurrent fires (Cochrane & Schulze, 1999). It has been suggested that to understand the ecology of tropical forest fires, we must know what is burning, how often and when (Cochrane, 2003).

Methodology

In other to know what is burning, how often and when, eight 0.25 ha plots (totalling 2 ha) were demarcated at different locations within 1-5 km radius in Tain II Forest Reserve. Four plots were randomly chosen and subjected to Early Burn treatment, and the remaining four, to Late Burning. Four sub-plots or quadrats, each measuring 5 m x 5 m (=25 m^2), were randomly located in each 0.25 ha plot, on which seedlings (defined here as all young trees < 10 cm dbh) were enumerated. The initial cohorts of seedlings were tagged with numbered metal tags and their response to fire followed throughout the experimental period. Seedlings that emerged later on were monitored alongside the initial cohorts. In Worobong South Forest Reserve, however, two contiguous 1 ha blocks, separated by a 10 m wide strip, were used in place of eight 0.25 ha plots. One of the blocks was randomly chosen and subjected to Early Burn and the other to Late Burn treatment. Initial seedling enumeration and subsequently the assessment of seedling response to fire was done on four 2 m x 100 m transects due to the lower seedling density. As in Tain II Forest Reserve, the initial cohorts of seedlings in each transect were tagged and monitored throughout the experiment. Seedlings that emerged in the course of the experiment were likewise monitored.

Findings

The experiment indicated the presence of all species guilds. There were no clear patterns of site preferences for the various guilds although the percentage of savanna species, appear to increase with canopy openness. Species diversity was quite high among trees at all stages of fire degradation except in the heavily degraded stand of Worobong South.

Despite the influence of fire there is at least 92% probability that any two trees >5cm dbh chosen at random from any of the stages of degradation within the two forest reserves would be different species, except the heavily degraded stand in Worobong South.
Mean basal area (BA) of live trees (dbh ≥ 5 cm) showed similar patterns in Tain II and Worobong South Forest Reserves in relation to fire history. Within each forest reserve, basal area was significantly different (ANOVA, df = 2, $P<0.001$), declining from slightly degraded through partially degraded to heavily degraded forest stands. Live tree basal area also differed significantly (ANOVA, df = 1, $P<0.05$) between the two forest reserves, with Worobong South showing much greater loss of basal area due to fire. This is indicated by a highly significant interaction (ANOVA, $P < 0.001$; df = 2) between forest reserve and degradation in live tree basal area.

Mean basal area of standing dead stems (dbh ≥ 5 cm) for the two forest reserves, like that of the live trees, followed similar pattern within both forest reserves and was negatively correlated with live tree basal area (Pearson correlation coefficient = -0.51; df = 22; $P<0.05$). Nearly all the standing dead trees, as well as downed woody material, in these stands have been consumed by fire. Only the large, charred dead stems remain standing, mostly in the heavily degraded stands, clearly indicating that what is presently grassland (Worobong South Forest Reserve) and *Chromolaena*-dominated areas (Tain II Forest Reserve) previously carried forest.

Fire has exerted considerable influence on total stem densities in the two forest reserves. Within forest reserves, total stem density of trees ≥ 5 cm dbh are significantly different across stages of degradation (ANOVA: $P<0.001$; df = 2). Interaction between stage of degradation and forest reserve is also highly significant ($P<0.01$; df = 2). However, the difference in stocking of trees ≥5 cm dbh between the two forest reserves is not significant. Similar results were for total stem density of trees ≥10 cm dbh.

Percentage canopy openness was lowest in the closed canopy forests and highest in the heavily degraded stands, and was correlated negatively with basal area of live trees (r=-0.90) and positively with basal area of standing dead trees (r=0.55). There was also a poor negative correlation (r=-0.25) with forest floor litter biomass. Mean canopy openness for the closed canopy stand was 6.5% and 9.5% for Worobong south and Tain II forest reserves respectively. These increased to between 17.6 – 18.5 for the partially degraded sites whilst in the worst degraded areas Tain II had 53.3% and Worobong South 83.3% canopy openness respectively.

Total biomass (dry matter content) of forest understorey (or ground layer), excluding trees ≥ 5 cm dbh for Worobong South Forest Reserve increased consistently along the fire degradation gradient from slightly degraded to heavily degraded stands and was negatively correlated with live tree basal area ($r = -0.51$, df = 22, $P < 0.05$) but positively with canopy openness ($r = 0.55$, df=22, $P < 0.01$). However, in Tain II Forest Reserve, the heavily degraded stand had the highest ground layer biomass, because of the dominant *Chromolaena*, followed by the slightly degraded and partially degraded stands in that order.

Differences in forest floor litter biomass was highly significant (ANOVA: $P < 0.001$, $df = 2$) among stages of degradation; and was correlated positively with basal area of live trees ($r = 0.83$, $df = 22$, $P < 0.001$). However, there was no significant difference in litter biomass between the two forest reserves, and there was also no significant interaction between forest reserve and stage of degradation. The decline in litter with increased fire damage is a reflection of reduced vegetation biomass, and therefore parallels the differences in stand basal area.

Five plant life-forms, including climbers, forbs, grasses, shrubs and trees, were represented at all three stages of degradation in both forest reserves. Trees dominate the life-form spectra in all the samples (Fig. 6).

Species richness declined with increasing fire damage, more strongly in Worobong South Forest Reserve. The slightly degraded stand at Worobong South has notably higher richness than that of Tain II Forest Reserve.

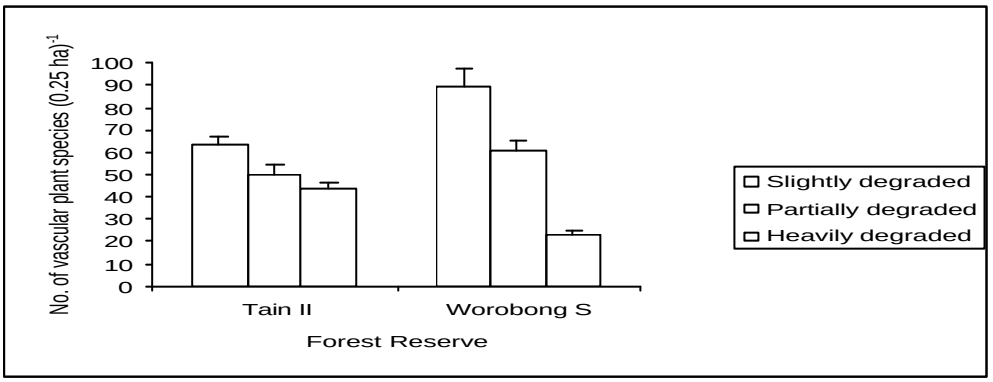

Fig. 6. Mean Number of vascular plant species $(0.25\ ha)^{-1}$ recorded at three stages of degradation in Tain II and Worobong South F.Rs., Ghana. Error bars = ± 1 se

In summary although Worobong South Forest Reserve has higher rainfall compared with Tain II Forest Reserve, the combined effects of fire and logging in a forest on shallow, sandy soils has caused far more degradation than in Tain II Forest Reserve. The *Chromolaena odorata* that has invaded the understorey of Tain II Forest Reserve is possibly less pernicious than the grasses at Worobong as it appears to allow the development of some shade-bearing tree species which could eventually allow the forest to recover in the event of the fires subsiding.

Activity 1.6 Evaluate effects of fire on local and national economies

1.6.1 Effects of forest fire on Farming System Dynamics in the Transition Zone

Introduction
Forest fires do not destroy forest in Ghana but also agricultural fields. The Food and Agriculture Organisation (FAO) Assessment during the 1982-1983 fires in Ghana showed that about 35% (154, 000 metric tonnes) of standing crops and stored cereal were destroyed by bush fire (Ampadu-Agyei, 1988). There was therefore the need to identify major changes in farming systems attributable to fire and evolved responses by farmers. This will allow for better management of fire in farming and the annual incursions of fires into forests.

Methodology
The study was carried out in eight communities around four forest reserves, namely Pamu Berekum, Tain II, Afram Headwaters and Worobong South Forest Reserves to identify major changes in farming systems attributable to fire and evolved responses by farmers. A total of 120 respondents were selected randomly in the communities. The target group was farmers who have been in farming for ten years and above. Structured questionnaires were used to interview the respondents together with informal discussions with opinion leaders and chiefs. Direct observations on farms were also made.

Findings
Results showed that there have been changes in farming system driven by fire. A notable change is a shift from the growth of cash crops mainly cocoa (71% of respondents) and other perennials to the growth of annuals especially maize and cassava (62.2%) in the Dry and Moist Semi-deciduous forest zone. In the past plantain, cocoyam and cocoa dominated the Semi-deciduous Forest Zone (Wills, 1962). Most farmers (62.2%) prefer cassava and maize because they claim the present soil conditions, the vegetation, the high market demand, short rotation and cassava's ability to re-sprout after fire favour their growth.

The declining interest in the cultivation of cocoa by farmers may reduce its contribution to the Gross Domestic Product, which currently stands at 14% and also affect income levels of farmers since cocoa and other cash crops have been the backbone of the rural economy. In addition depressed yields recorded by farmers (84.7%) in the face of increased labour and high cost of farm inputs puts the farming system in crisis especially in the studied area and other farmers at the edge of the forest zone boundary (Amanor, 1994). This situation may perpetuate poverty since about 54% of Ghana's poor are food crop farmers (MOFA, 2001).

The collection of Non Timber Forest Products NTFPs from the forest and certain fallow crops on fallow lands play an important role in the rural economy. However as a result of fires NTFPs notably snails, bushmeat and even fuel wood which were readily available in the past are presently scarce (Table 1). The scarcity of these resources is affecting income levels of farmers. This is because some farmers claim to earn more money from

bushmeat trade than farming but maintains the interest in farming because it is more secure and provides a greater variety of their needed products.

Table 1 Changes in NTFPs and fallow crop availability. Total sample size: 119

NTFPs and Fallow Crops	Percentage of Respondents	
	Scarce at present	Readily available in the past
Fuel wood	13.0	23.3
Bush meat	26.4	25.8
Wrapping leaves	9.2	12.5
Medicinal plant	6.3	12.8
Chewing stick	5.6	5.5
Snails	27.5	14.0
Avocardo	7.7	0.5
Mushroom	0.7	3.5
Sponge	0.4	0.3
Canes	1.1	0.5
Pistles	2.1	1.3

In response to these changes farmers have adapted strategies (Table 2) to manage fires. These strategies are farm management practices, precautionary measures and prevention education. However these strategies have not been evaluated for their effectiveness and have therefore not been incorporated into scientific procedures for safe burning.

Table 2 Present strategies in response to forest fire

Category	Strategies in response to wildfire	Percentage of farmers
Farm management	Preservation of trees on farms	13.8
	Constant weeding all year round	4.4
	Cultivation of cassava	1.3
Precautionary measures	Non use of fire in the farm during dry seasons	14.4
	Change in time of burning slash	33.8
	Change in ignition method	11.9
	Construction of clean fire belt	10.6
	Use of fire volunteers	2.5
Prevention education	Institutionalised cautioning by chief during the dry season	7.5

1.6.2 Determine the total economic cost of forest fire management

Introduction

To address the forest fire problem in Ghana some measures have been taken to protect the forest from forest fires. These measures generate some costs to the economy, which have not been studied. Such costs can be used as guide for subsequent planning of forest

fire management in Ghana especially if that can be put in a form suitable for use in the Fire Economic Evaluation System (FEES). There was therefore the need to develop economic cost model and use it to estimate the total economic cost of fire management programme, which can be updated and compatible to fire management efficiency analysis required for long-term planning.

Methodology

Four main fire management inputs were used by the study. They included the Ghana National Fire Service, Forest Services Division, anti-bush fire volunteer groups and community members or farmers involved in green firebreak projects. Seven cost components were identified. These included equipment, facilities and implements, materials, wages/salaries (payments), travel and transport allowance (T & T), subsistence allowances/per diem allowances, and operational cost. Cost estimation was based on Mcketta *et al* Cost Aggregation Model. Many techniques were used to measure the cost components of the various activities. For the components, which were paid for, the expenditures were used. In the case of those not paid for, the study used the imputed values with the aid of hedonic and contingent valuation methods. Also opportunity cost methods were used to estimate the value of time spent by various categories of people in the fire management.

Findings

The results of all the estimated cost are summarised in Table 3 and 4.

Table 3: Summary of cost estimates on fire management programme incurred by fire management input units from the four forest reserves (Cedis per hectare)

FR	FIRE MANAGEMENT INPUT UNITS	FIRE MANAGEMENT PROGRAMME			
		PREVENTION	PRESUPPRESSION	SUPPRESSION	TOTAL
PAMU BEREKUM	GHANA NATIONAL FIRE SERVICE	61.79 (0.012)			61.67 (0.012)
	ANTI-BUSH FIRE VOLUNTEERS	2,658.83 (0.511)		3,957.04 (0.761)	6,615.87 (1.272)
	FOREST SERVICES DIVISION	65.58 (0.013)	579.69 (0.112)		645.27 (0.124)
	GREEN BELT FARMERS		14,442.01 (2.777)		14,442.01 (2.777)
	TOTAL	2,786.20 (0.536)	15,021.70 (2.889)	3,957.04 (0.761)	21,764.94 (4.186)
TAIN TRIBU. BLOCK II	GHANA NATIONAL FIRE SERVICE	22.7 (0.004)			22.7 (0.004)
	ANTI-BUSH FIRE VOLUNTEERS	1,054.42 (0.203)		1,901.97 (0.366)	2,965.38 (0.569)
	FOREST SERVICES DIVISION	25.43 (0.005)	67.33 (0.013)		92.76 (0.018)
	GREEN BELT FARMERS		2,172.29 (0.418)		2,172.29 (0.418)
	TOTAL	1,102.55 (0.212)	2,239.62 (0.431)	1,901.97 (0.366)	5,224.14 (1.008)
AFRAM HEADWATERS	GHANA NATIONAL FIRE SERVICE	65.71 (0.013)			65.71 (0.013)
	ANTI-BUSH FIRE VOLUNTEERS	3,060.61 (0.589)		5,388.83 (1.036)	8,449.43
	FOREST SERVICES DIVISION	64.61 (0.012)	25.59 (0.005)		90.20 (1.625)
	GREEN BELT FARMERS		2,908.44 (0.559)		2,908.44 (0.559)
	TOTAL	3,190.93 (0.581)	2,934.03 (0.564)	5,388.83 (1.036)	11,513.78 (2.214)
WOROBONG SOUTH	GHANA NATIONAL FIRE SERVICE	84.79 (0.016)			84.79 (0.016)
	ANTI-BUSH FIRE VOLUNTEERS	4,365.53 (0.839)		8,982.30 (1.727)	13,347.83 (2.567)
	FOREST SERVICES DIVISION	53.07 (0.01)	20.62 (0.004)		72.7 (0.014)
	GREEN BELT FARMERS		2,743.48 (0.528)		2,743.48 (0.528)
	TOTAL	4,502.30 (0.866)	2,764.10 (0.532)	8,982.30 (1.727)	16,248.80 (3.125)

Note: Figures in parentheses are in Dollars per hectare and Foreign Exchange Rate at the time of study was ¢5200:$1(March, 2000)

Cost difference between fire management input units

The cost incurred by the Fire Volunteers was consistently the most significant in all Fire Management Inputs, except in the Pamu Berekum Forest Reserve where the highest was Green Belt Farmers. The cost by the Fire Volunteers was more than 50% of total economic cost of fire management programme. In the cases of Afram Headwaters and Worobong South it was 73.39% and 82.15%, respectively. However, these costs were imputed and not noticed by the ordinary people. Green Fire break farmers followed it and the last was Ghana National Fire Service. It was quite clear that there were differences in the costs of various fire management input units. This therefore shows the extent of participation in fire management by the various management inputs. The trend is similar to the other three forest reserves under consideration. Strangely enough, the least participated management-input units, with the lowest cost for all the reserves were the governmental institutions; Ghana National Fire Service and Forest Services Division.

Cost difference between fire management programmes

From Table 3 the cost incurred on presuppression programme was the highest among the three programmes identified by the study in Pamu Berekum and Tain II Forest Reserves. The costs on presuppression were ¢15,021.70 (69.02 %) per hectare and ¢2,239.62 (42.71%) per hectare for Pamu Berekum and Tain II, respectively. They were followed by cost on Suppression programmes; ¢3,957.04 (18%) per hectare and ¢1,901.77(36.27%) per hectare for Pamu Berekum and Tain Block II, respectively. The last programme was prevention. However, in the Afram Headwaters and Worobong South Forest Reserves, the programme that had the highest cost was suppression. It was ¢5,388.83 (46.80%) and ¢8,982.30 (55.28%) for Afram Headwaters and Worobong South, respectively. The next higher programme was prevention, which was estimated to be ¢3,190.93(27.71%) per hectare and ¢11,513.78 (27.71%) per hectare for Afram Headwaters and Worobong South Forest Reserves, respectively. The programme with the least costs was presuppression.

From the analysis, there is a unique trend of the importance given to the various fire management programmes in the reserves. Whereas Green Fire break activities dominated in Pamu Berekum, and Afram Headwaters, in Worobong South, on-fire fighting by fire volunteers dominated. In the Tain Block II it appears that fire management programmes are not keenly taken up, especially, considering the large area of the reserve yet the low cost quoted for fire management.

Activity 1.7 Conduct literature and policy reviews

Over thirty-two publications including peer-reviewed journal articles on forest fire management in the tropical forest regions of Africa, South America and Southeast Asia have been reviewed. In addition, extra-sectoral policies that have an influence on wildfire and forestry development have also been reviewed together with indigenous knowledge on wildfire. This served as input into the refinement of project strategy and development of questionnaires for the various studies under the project.

Activity 1.8 Establish fire weather data base

Weather data was collected from the Meteorological Service Department (MSD) to cover the project sites. This has been developed into a database. Critical weather elements have been found to be temperature, relative humidity, and wind speed. A combination of these elements will be used to assess a fire risk danger rating system for the Royal Netherlands Embassy (RNE) Funded Wildfire Management Project being executed by the Forestry Commission.

Activity 1.9 Set up forest fire database

Fire incidence reporting constitutes a major aspect of forest fire management. Fire incidence report is used for contingency planning as well as forecasting the probability of a fire starting in the future. Forest fires in Ghana are reported to have various anthropogenic sources. However, fire reporting has mostly been through verbal communication and where documentation is done (usually by the FSD staff) no standard format or procedures are used. This makes it difficult to use such uncoordinated information to make any meaningful management decision.

Under this Project, a system of fire reporting was instituted to enable relevant and coordinated fire reporting from both the Forest Services Division and the Ghana National Fire Service through the Village Volunteer Fire Fighting Squads. This system was piloted in five forest districts namely Offinso, Bechem, Begoro, Dormaa and Mampong to look at the causes of wildfires in these districts, the size of fire and the fire fighting capabilities in these districts. A database has been set up at Resource Management Support Centre (RMSC) of the Forestry Commission where fire reports are entered after every fire season.

In addition fire reports were collated from the five districts between 1975 and 2000 for analysis. The results of the analysis show that in all the five districts, unknown source of fire rank first (74%), followed by farming activities (17%,), hunting 4%, honey taping (2%), palm wine taping (2%), and Charcoal burning (1%).

In conclusion as the database grows through addition of annual data it will form the basis from which Ghana can build a highly modern and effective fire management system.

Output 2: Effective forest fire control systems developed

Forest fires are seriously eroding Ghana's forest reserves. If the forest reserves are to survive the onslaught of fire it is critically essential that effective fire control be instituted as soon as possible. The first step in any programme to combat forest fire is prevention. However, the most ambitious and successful of prevention programmes will not remove wildfire from the landscape. There are many accidental and willful ignitions, which will continue to cause extensive wildfire in spite of the best prevention efforts. For this reason it is necessary to have a comprehensive fire control system that encompasses prevention, detection and suppression. There is therefore the need to establish a detection and

reporting network capable of spotting, reporting and monitoring wildfires within and adjacent to the forest reserve areas.

Activity 2.1 Determine appropriate fire detection systems for high fire threat areas

In order to deal effectively with a fire, fire crew need to find out a fire exists as quickly as possible. This can be done from Satellite Infrared Imagery, air patrols, ground patrols, and lookout towers. These methods may be used singularly or in combination with one another. Each method has its applicability and drawbacks.

A consultant evaluated the four detection methods for their suitability to high fire threat areas and found lookout towers to be suitable offering a tried and proven method of detecting fires. Although they are "low tech" they still remain highly effective with reasonable developmental and maintenance costs. They also operate on the principle of "smoke spotting" and as such offer the quickest method of alerting fire staff to the occurrence of an incipient wildfire.

In addition to the fire detection function of a tower, this method offers employment opportunities at the local community level. If local labour and materials are used to construct and operate the towers, initially all the expenditure will be directed towards the local economy.

The suitability of using lookout towers was assessed in the Pamu-Berekum Forest Reserve. A cursory examination of contour maps covering the PAMU-BEREKUM Forest Reserve has indicated that the first (test) tower could possibly be located near ASUNSO #1. Two hilltops nearby, one at 1350 ASL and another at 1285[1] ASL, and located approximately at $7^{0}23^{1}$N and $2^{0}53^{1}$E, should be examined from the air for suitability.

The project could not test the lookout towers because of the high cost involved. However, the RNE Funded Wildfire Management Project will test the lookout towers at the recommended locations.

Activity 2.2 Determine effective fire break systems

Introduction
One of the major ways of managing forest fires is to develop cost effective prevention methods that will minimize the risk of fire occurrence in the agricultural and forest landscape.

The objective of fire prevention is to reduce the number of human caused fires. Fires are prevented by reducing both the agent that causes the fire to start (fire risk) and the material through which the fire travels (fire hazard). Fire prevention programmes comprise education to influence the behaviour of people, law enforcement, fire prevention engineering and fuel management to reduce flammable vegetation. Most of the above components that go into fire prevention programmes have been tried in Ghana

but with disappointing levels of success. Unlike the others, fuel management is an old and familiar practice in Ghana and appears to be relatively successful. However, traditionally, only one (bare ground firebreaks) of the many fuel management options has been used. This is even limited to local farmers who try to prevent fires from escaping from small burning fields.

Any programme to prevent forest fires in Ghana should therefore explore the possibility of developing appropriate fuel management methods around which the other components of fire prevention could be built. Although managing fuels especially in forests is a complicated process it is essential and indispensable in situations where other prevention methods appear to be so far ineffective.

The Forestry Commission established green fire breaks popularly known as green belts with the collaboration of forest fringe communities around fire-prone forest reserves in the mid 90s. Activity 2.2 was undertaken to evaluate the potential of the green fire breaks and other firebreak systems in the protection of forest reserves from fire damage.

Methodology
The study was conducted through a desk study that sought to determine the applicability of the various firebreak systems in the context of the Ghanaian local situation. A detailed field- work was also undertaken to evaluate some silvicultural and socio-economic aspects affecting the achievement of project objectives of the green firebreak in one of the Forestry Commission's pilot sites. The fieldwork involved administering of questionnaires for information on the socio-economic aspects of the green belt whilst the silvicultural evaluation was done through the direct determination of tree survival and growth as well as the ability of the species to suppress weedy undergrowth.

Findings
The various fire break systems identified in the study with potential use in Ghana were bare ground fire breaks, controlled grazing, close canopy forest strips as fire barriers and green fire breaks. Of these, green firebreak was found as the best. The field evaluation shows that on the basis of silvicultural characteristics, *Cassia siamea*, appears as the best of the six candidate species (Table 4), however it should not be planted around natural forest due to its invasive nature.

Table 4: Growth performance of two year-old trees, in a green fire break trial in the Pamu-Berekum Forest Reserve. Also included is the mean weight of live vegetation and litter sampled on 1 x 1 plots under the trees.

Species	Mean diameter in cm (n=5)	Mean crown radius in meters (n=20)	Mean weight of undergrowth (g)
Ficus sp	10.2	1.15	4.3
cassia siamea	8.8	2.69	5.0
Cordia mellinii	7.8	1.48	5.3
Alstonia bonei	5.8	1.44	4.5
Blighia sapida	2.0	0.59	1.6

The local people's participation in the trials was good and balanced in terms of gender. Plot sizes were considered too small for high economic reward to farmers but enough to ensure trees are properly planted and tendered. The green belt concept is fulfilling a very important role not only in terms of forest protection but also in satisfying land hunger and improving livelihoods.

Activity 2.4 Assess effects of early burning practices on fire control

Introduction
With the current trend in fire incidence, it looks uncertain that the fires would stop, and therefore ways to protect and rehabilitate the forests need to be devised. Existing research on fire management in Savanna near the high forest zone of West Africa (Charter & Keay, 1960; Mensbruge & Bergeroo-Campagne, 1961) suggest that early burning allows forest species to invade.

It is not known how the fire-degraded forest reserves in the dry and moist forest zone would respond under early burning, however, early burning could potentially reduce the damaging effects of late fires and form the beginning of the recovery process of these degraded forest reserves. In the absence of the regular late fires, it is anticipated that these fire-degraded forest reserves would recover, probably at time scales dependent on the degree of degradation.

Methodology
One ha each of two forest reserves namely, Tain II Forest Reserve, of the Dry Semi-deciduous forest type and Worobong South Forest Reserve, of the Moist Semi-deciduous forest type, were subjected to experimental Early and Late Burn treatments for three and two consecutive annual burnings respectively, and their seedling response to fire monitored.

In Tain II Forest Reserve, eight 0.25 ha plots (totalling 2 ha) were demarcated at different locations within 1-5 km radius. Four plots were randomly chosen and subjected to Early Burn treatment, and the remaining four, to Late Burning. Four sub-plots or quadrats, each measuring 5 m x 5 m (=25 m^2), were randomly located in each 0.25 ha plot, on which seedlings (defined here as all young trees < 10 cm dbh) were enumerated. The initial cohorts of seedlings were tagged with numbered metal tags and their response to fire followed throughout the experimental period. Seedlings that emerged later on were monitored alongside the initial cohorts.

In Worobong South Forest Reserve, however, two contiguous 1 ha blocks, separated by a 10m wide strip, were used in place of eight 0.25 ha plots. One of the blocks was randomly chosen and subjected to Early Burn and the other to Late Burn treatment. Initial seedling enumeration and subsequently the assessment of seedling response to fire was done on four 2 m x 100 m transects due to the lower seedling density. As in Tain II Forest Reserve, the initial cohorts of seedlings in each transect were tagged and monitored throughout the experiment. Seedlings that emerged in the course of the experiment were likewise monitored.

Findings
The results showed that, percentage survivorship is higher under Early Burning in both forest reserves than under the Late Burn treatment. Conversely, annualised mortality rates were higher in the Late Burn plots in the two forest reserves, and the plots showed evidence of progressive degradation. There was, however, little net change in seedling density in the Early Burn plots. Nonetheless, seedling basal area remained constant under both Early and Late Burn treatments in the two forest reserves, suggesting that the survivors were growing bigger. All tree seedlings less than one year are killed in early burnt plots.

Against the backdrop of generally declining growth rates, one pioneer species, *Malacantha alnifolia*, had positive increment in absolute and relative height growth rates under Early Burning in Tain II Forest Reserve, and showed the least decline under Late Burn treatment. Although this species has no timber value, it is abundant in Tain II Forest Reserve and may therefore play a significant role in increasing woody cover in Tain II Forest Reserve.

In summary the study showed that there are good prospects in early burning as a fire management tool but its use may be limited to forest still with some canopy due to heavy ground litter in the very open forest that makes early burning even very destructive.

Activity 2.5 Prepare a manual of procedures for fire control

Implementing a sound fire management strategy is a prerequisite for protecting and rehabilitating forest resources to maintain healthy ecosystems and provide forest products in the future. This project therefore developed a manual of procedures for fire control.

District Managers have the primary responsibility for the success of fire management planning and operations. They need to minimize the level of damage that will occur in those reserves under their charge by directing the resources they have in terms of manpower and equipment to those areas defined as critical; and by taking practical steps to control the spread of fire through early detection, appropriate response to stop unwanted fire spread, and the establishment of fuel breaks complemented by early burning.

The Manual has been written to guide district-level forest officers who are responsible for ensuring the protection of forest reserve areas on fire management procedures. It may also be of value to other partner agencies and stakeholder groups outside of the Forest Service, particularly the resource owners and District Assemblies. It represents an effort to establish standardized procedures to guide implementation of forest fire management strategies for the Forest Services Division. Information presented in this document provides a broad overall framework for District Managers to develop their own Fire Management Plans suited to their particular situation and needs. It is hoped this document will provide them the necessary guidance to manage forest and prescribed fires under their authority.

Output 3: Effective wildfire prevention education and awareness programmes instituted

Forest fires may be minimised if the necessary investments and plans are made in fire prevention whenever risks of accidental fires are high. The first rule of fire prevention and control is that it is much easier and cheaper to prevent accidental fires from occurring than to put them out once they escape the limits of the intended burn area. Small, strategic investment made in fire prevention can thus avoid the need and the expense of assembling large groups of people and equipment to combat fires under emergency conditions. Results of output 1 have also shown that the long-term impacts of wildfires on vegetation and the environment are not fully known by the wider community. Education on forest fire must therefore embrace awareness creation, detailed training and general building of capacity amongst the general public, land users and associated public agencies.

Activity 3.1 Consult local communities on prevention methods

Introduction
As the number of forest fires increases, conventional fire prevention measures have increasingly come under question. Indigenous knowledge of fire prevention methods has received little attention and remains to be tapped by government institutions responsible for defending public interest in the forest reserves. There was the need to explore a more pro-active approach to fire prevention, which takes into account the concerns of the communities on fire prevention methods.

This activity sought to do that by consulting fifty-six opinion leaders in 28 communities to know their views. Focus group discusions were also held for four categories of stakeholders namely, hunters, farmers, palmwine tappers and fire volunteers. Focus of the discussions centered on the preferred methods of carrying out prevention messages, resource persons within the community to be used for prevention and suitable time for receiving fire prevention messages.

It was revealed that prevention messages should be communicated to the local communities through the use of mobile vans; talk shows; screening of documentaries on responsible use of fire on televisions, and regular village meetings to review and remind the community about the dangers of fire outbreaks during dry seasons.

Activity 3.2 Develop public awareness training material

In consultation with the local community and a wide range of people from various institutions namely, Forest Services Division, Wildlife Division, Ghana National Fire Service, and media experts the project developed a Forest Fire Prevention Communication Plan. Forest Fire Prevention Communication Plan is a first step in the creation of a nation-wide prevention campaign. The overall purpose of this Plan was to outline the principal messages and audiences, that need to be addressed to accomplish the goal of reducing or eliminating unwanted human-caused bush fires by discouraging the

illegal use of fire and by encouraging the use of proper burning procedures for legal occupational fire use. A secondary emphasis was on encouraging community members to do their part in reporting and fighting bush fires. The specific strategies for implementing these objectives were to be developed at the local level using the guidance provided in this Plan and the Manual of Procedures for fire control(Activity 2.5).

Activity 3.3 Train fire volunteer teams in prevention techniques

Basic training in fire prevention and local fire fighting organisation is essential for successful control and management of forest fires. A number of the communities in and around the project sites have established Fire Volunteer Squads, which have been involved in fire prevention and suppression activities. However, they lack the requisite training in prevention and suppression techniques to enable them carry out their duties effectively. The project therefore offered training to the Fire Volunteer Squads. The Ghana National Fire Service with the cooperation of the Forestry Commission carried out the training.

A total of four hundred and twelve village fire volunteers (Table 11) were trained in fire crew organization, forest fire detection procedures, fire monitoring and establishment of green fire breaks.

Table 11 Number of trained fire volunteers in project sites

Community	Number of volunteers trained
Akrofoa	68
Asempaneye	71
Asuboi	77
Ahomahomaso	50
Kumfere	30
Ntesu	30
Otuate, Agave	32
Akumeresu	34
Agave	20
Total	412

The training offered to the Fire Volunteers sharpened their skills, improved their confidence level and above all increased their response rate to forest fires.

Activity 3.4 Training of trainers programme for project staff

Quality data is a pre-requisite for any meaningful socio-economic and ecological research. Unless field staff are properly trained data may be collected that are inappropriate for the objective of the study, and subsequently excluded from analysis. This increases project costs and time. To ensure that appropriate data is collected the project organised a training of trainer's programme for the project staff at the project secratariat to sharpen their skills in data collection.

Twelve research scientists and technical officers were trained in field measurement, data collection techniques, data entry and management and interview techniques at the project secretariat.

Activity 3.5 Test education and awareness creation programmes in selected communities

A durbar was organised for twenty communities in and around the four selected forest reserves to educate the rural people on the causes and effects of wildfires, raise general awareness and to warn of specific high-risk periods. The durbar was captured by the media and was used for Adult Education Programmes on Ghana's National Television (GTV) to raise awareness on the dangers of forest fires. These programmes improved the awareness on the causes and effects of wildfires of the general public. Presently the communities around the four forest reserves are well aware of the dangers of wildfire. These durbars have worked well as there were generally a large attendance at each of them.

Activity 3.6 Develop community incentive schemes to reduce fires

Introduction
Forest fringe communities are in the best position to support the prevention, suppression and control of forest fires in forest reserves. For an effective and efficient forest fire prevention and control all institutions and individuals involved should be well motivated so that their interest can be sustained. Fire Volunteer Squad and other community-based organisations have contributed to the reduction of forest fires but the lack of rewards for their efforts have led to a reduction in their enthusiasm in this regard. One way of motivating stakeholders is therefore to provide them with requisite incentives. This activity therefore identified the incentives required by different groups in the various communities in the prevention and control of forest fires.

Methodology
The study was carried out in Begoro, Offinso and Dormaa districts. Series of consultations were held to design the study plan. Literature search was carried out to gather information from secondary sources. Surveys were also conducted to determine the incentive requirements of the communities.

Findings
The study identified two main types of incentives namely; innovative incentives through facilitation of access to goods and services and direct incentives through provision of cash or material rewards.

It was also revealed that incentives vary with different groupings. Each group has its own specific incentive requirements. Farmers require fertile land through the Taungya plantation and technical advice on the proper use of fire on farms. Hunters on the other hand require appropriate and affordable equipment and breeding stock of domesticated animals. Palm wine tappers require sanitizing chemicals. The Fire Volunteer Squads

require contract jobs like boundary weeding, seedling production, plantation establishment and patrolling.

The communities have given indication that the incentives they hope to derive from their involvement in forest fire management would motivate them to readily participate in forest fire prevention and control programmes. Some of these incentives are citing of development projects and the offer of scholarships to wards in communities where forest fire prevention and control are successful. Given the appropriate incentives the various groupings in the communities as identified above would participate actively in the management of forest fires.

Output 4: Mechanisms for rehabilitating fire-degraded forests developed

Fire is a dominant source of destruction in the forests of Ghana. As Hawthorne and Abu-Juam (1995) observed fire has been degrading huge areas of the Dry Semi-deciduous forest type and the drier sub-type in the north-west of the Moist Semi-deciduous zone. This means that the natural position of the forest-savanna boundary may be advancing towards the forest zone southwards. The rehabilitation of these forests, therefore, is a matter of high priority. Embarking on any successful forest reserve rehabilitation programme demands the execution of effective strategies to prevent encroachment of forest fires.

Activity 4.1 Select tree species and planting techniques

Introduction
Different plant species as well as the different stages in the development of a plant have variable degrees of fire tolerance. Plants that can tolerate or survive fire have certain traits that afford them protection against fire. To effectively rehabilitate fire degraded forests, careful research is needed to select the right species for planting. This is because survival through the seedling stage of the life cycle is critical for future success of species.

This activity was carried out to identify seedlings of forest tree species that have traits or characteristics likely to confer some reasonable levels of fire tolerance on them and to find out which of these traits best explains the distribution of tree species in fire-prone forest.

Methodology
Seedlings of thirteen Ghanaian forest tree species representing a wide range of ecological types, were raised under a shed, and tested for seedling traits related to fire tolerance such as relative dry weight growth (relative biomass gain), relative diameter growth, root length, root volume, root/shoot ratio, moisture content and leaf surface area per dry weight ratio. The species chosen were: *Antiaris toxicaria, Blighia unijugata, Celtis zenkeri, Cola gigantea, Malacantha alnifolia, Mansonia altissima, Milicia excelsa, Myrianthus arboreus, Nauclea diderrichii, Nesogordonia papaverifera, Tetrapleura tetraptera, Trichilia prieuriana and Triplochiton scleroxylon.*

Findings
Milicia excelsa showed consistent dominance for all the traits tested than any other species. It was followed by *Antiaris toxicaria.* Thus, these species are likely to be better fire tolerants than the other species. Pearson's Correlation Matrix test revealed that there was a positive correlation between relative biomass gain and relative diameter growth, root length, root volume, root/shoot ratio, moisture content and leaf surface area per dry weight (Pearson correlation coefficients: $r = 0.940$, 0.852, 0.799, 0.683, and 0.557 respectively, $P < 0.05$). However, growth rate, root length, root volume and root/shoot ratio showed the most consistency in the rankings of species. It was found that seedlings that had characteristics likely to confer some level of fire tolerance on them had a good representation of adult populations in the dry and moist forests in Ghana.

Activity 4.2 Implement collaborative forest fire management (CFFM)

The reality is that forest fires will succeed or fail according to the degree of involvement by local communities. Communities have managed forest fires in many ways, ranging from fire prevention to fire fighting. Any programme of fire management must mobilise community members to supply knowledge, labour and social control. This is because it is the communities that start fire, prevent fires, suppress fires and modify fuels that can cause wildfires.

The Collaborative Forest Management Unit of the Resource Management Support Center has instituted various initiatives since 1993 aimed at encouraging local people and other stakeholders' participation in forest management. This programme has been successful to a large extent. However, not much had been done in terms of initiating collaborative programmes for fire management as of 1999.

Using the format established by the Collaborative Forest Management Unit of the Resource Management Support Centre, the potential for collaborative forest fire management was investigated. Five hundred respondents were interviewed in fifty-four communities to know the perception of the local communities on forest fires. Fifty-six opinion leaders in these communities were consulted to assess the needs of community.

In addition two hundred and seventy seven participants participated in three district level workshops to validate results obtained from interviews and consultations of the local communities.

Summary of Workshop Deliberations
There was a general consensus at the workshops that forest fire management programmes must be built around the already existing fire volunteer squads concept so that they become community based and avoid any tendencies towards a top down approach.

The workshop came out with guidelines on how to involve the forest fringe communities in fire management which included the involvement of traditional leaders in decision making and education; education campaign on the responsible use of fire; the

introduction of some form of incentive package; and the need for wildfire management policy.

The workshops agreed that communities could play significant roles in fire management, especially in areas where most local fires originate. There are many different ways for communities to participate in fire management, ranging from simply providing labour to making major decisions on how fire could be managed in the community. Community interest and involvement are most active when people develop a "sense of ownership" over fire management programmes. Communities cannot do everything, however, their strength lies in fire prevention, control, monitoring, joint suppression activities, fire education and establishment of green fire breaks.

Activity 4.3 Investigate the potential for local community collaboration in rehabilitating denuded forests areas

One of the factors militating against the implementation of rehabilitation of degraded forest programmes has been the lack of adequate funds. It is believed, however, that adopting a collaborative approach involving communities, investors and the Forestry Commission will considerable reduced the envisaged costs.

Activity 4.3 therefore sought to discover the potential for local community collaboration in rehabilitating fire degraded forest areas.

Methodology
The activity was carried out in Begoro, Dormaa Ahenkro and Sunyani Districts. Focus group dscussions, community meetings and household interviews were used to gather the perceptions and reactions of the local people.

Findings
The potential for collaboration among the community members was found to be high. Most of the community members contended that the availability of NTFPs has dwindled drastically because of the extent of degradation of the forest reserves in their localities and were therefore willing to collaborate in rehabilitating them.

On the strategies to be adopted, most respondents mentioned taungya plantation while a few mentioned contract plantations. Those who mentioned taungya plantation argued that it has been piloted in those areas and it was effective. In areas such as the Begoro district where access to land is very limited almost all the communities opted for the taungya plantation system.

To whip up interest in the rehabilitation programme, all the communities expect the Forestry Commission to give them incentives such as Wellington boots, hand fork, cutlasses and hoe. A respondent in Koradaso in the Dormaa Ahenkro district located in Pamu Berekum Forest Reserve suggested that individuals participating in the rehabilitation should be grouped and the group that does a good job should be rewarded.

Community members exhibited adequate knowledge about the threat posed by forest fires to forest reserves in their localities and were ready to share their knowledge on possible collaborative strategies in rehabilitating degraded Forest Reserve with the research team. This may probably be due to the fact that seasonal forest fires have been a major constraint to the socio-economic development of these areas. Apparently, as evidenced by the people's responses, there exists strong desire in all the visited communities to collaborate in rehabilitating denuded Forest Reserves in their localities.

3.2 CONCLUSIONS

Forest fires in Ghana are caused mainly by human activities and can be prevented to a large extent if the local population is effectively educated on the threats posed to their environment and property. Fire will continue to be an important phenomenon in the landscape for a long time because of its linkages with rural livelihoods. Most people are aware of the causes of forest fires and their economic and ecological impacts but find it difficult to change their attitudes towards fire usage. The safe use of fire must therefore be the primary objective of any fire management programme to be instituted. A wide variety of education and publicity materials for target groups should be used to raise general awareness and to warn people of specific high-risk periods and sites. The fire prevention communication plan developed by the project will play a key role here.

The forests have become more vulnerable to fire due to intensive logging and recurrent annual fires resulting in higher levels of fuel loading and dryness.

Effective control system involving fuel treatment, detection, fire reporting, and training of fire volunteers was deemed necessary in reducing fire incidence.

For effective fire prevention education and awareness creation programmes, fire prevention communication plans must target the key audiences with appropriate messages.

Viable mechanisms for rehabilitating forests exist but their success depends on effective collaboration between all forest stakeholders especially rural communities.

3.3 RECOMMENDATIONS

The project has generated baseline data and tools for further development of effective forest fire management programmes in Ghana.

The project recommends the following for implementation:

- Village Fire Volunteers need to be motivated. The levels of motivation should depend on the situation on the ground.
- Incentives/motivations for fire volunteers and other stakeholders should be staggered in such a way that monetary incentives would be withdrawn with time. The staggering should also go hand in hand with education.

- Develop incentive packages that are sustainable and focused on non-monetary considerations like, billboards, rebates, etc. for fire free communities and other collaborators other than the public sector agencies.
- Piloting of forest fire prevention communication plan for subsequent implementation
- Hold stakeholder consultation on the implementation of the manual of procedure

The project further recommends the following areas for future research:

- The impact of fire on biodiversity should be expanded to cover issues like plant and soil relations, and general ecosystem dynamics.
- Continue research on economic implications of forest fires.
- The economic model on fire management cost needs to be validated using the data collected by the Dutch/GoG project, which has just taken off.
- There should be further research to refine results on burning trials.

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PROJECT STAFF

Name	Position	Institution
Dr. Victor Agyeman	Project Leader	FORIG
Dr. Kyereh Boateng	Lecturer/ Ecologist	IRNR, KNUST
Dr. T. Kwesi Orgle	Forest Ecologist	MLF, Accra
Mr. Richard Ninnoni	Forest Fire Mgt Specialist	RMSC
Mr. Alex Asare	Participatory Forest Mgt Specialist	RMSC
Mr. Godfred Ohene-Gyan	Social Scientist	RMSC
Mr. Joseph Acquaah	Metro Fire Officer	GNFS
Mr. Michael Ekow Amoah	Resource Economist	FORIG
Kennedy Owusu Afriyie	Forest Conservationist	FORIG
Mrs. Lucy Amissah	Project Administrator	FORIG
Mr. Opoku Nyame,	Technical Officer	FORIG
Mr. Anthony Osei-Fosu	Economist/Lecturer	KNUST

EXECUTING INSTITUTION

Forestry Research Institute of Ghana
University Box 63, Kumasi, Ghana.
TEL: 233-51-60123/ 60373
FAX: 233-51-60121
E-Mail: director@forig.org

COLLABORATING INSTITUTIONS

Resource Management Support Centre, Forestry Commission

Ghana National Fire Service (GNFS)

USDA Forest Service (USDAFS)

University of Aberdeen, United Kingdom