Forest depletion in Ghana: the empirical evidence and associated driver intensities

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Abstract

Purpose – This study seeks to provide a robust piece of evidence of forest depletion in Ghana and its associated driver intensities to inform national policy decisions towards achieving Sustainable Development Goal (SDG) 15 and beyond.

Design/methodology/approach – Using a representative sample size of 733 households, which was obtained with the aid of a structured questionnaire, a descriptive analysis is used to show the evidence of forest depletion. For robustness purposes, the geographic information system (GIS) is used to provide a piece of remote sensing evidence to substantiate the claim. In addition, an ordered probit regression model is estimated given the ranked nature of the responses to determine the drivers of forest depletion.

Findings – The results provide evidence that the urban forests in the Greater Accra Region (GAR) of Ghana have been depleted. Overall, 44% argued that the depletion of the forests is high, 30% indicated that the depletion is moderate, while 26% indicated that the depletion is low. Consistent with the literature, the ordered probit regression results show that human behaviour, climate change and institutional failure are the driver intensities of forest depletion in the Region. Besides, the authors find an increasing order effect for all three drivers. Using a descriptive analysis, majority of the respondents posited that human behaviour is the main driver intensity, followed by climate change and then institutional failure. This study recommends the need for education and advocacy, community participation, law enforcement, resource mobilization, modern adaptation strategies and internalization of externalities as a way of controlling the drivers of forest depletion.

Originality/value – The study uses remote sensing techniques to provide empirical evidence of protected forest depletion in the GAR, Ghana. In addition, an ordered probit regression is used to identify the driver intensities that explain the depleted protected forests in the region.

Keywords Driver intensities, Climate change, Human, Institution, Forest depletion, Ghana

Paper type Research paper

1. Introduction

The importance of forest and forest resources are enormous. Forests and trees have significantly supported the survival of mankind, biodiversity and ecosystem services. Forest resources have been a source of food, medicine, etc. for billions of the world's population. For those who live in forest and savannah areas, about 250 million of them depend on forests and

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trees for their livelihood and food security. Unfortunately, human and non-human activities have contributed to the shrinking in the Earth's forest areas. From 2000 to 2015, evidence from the 2018 Sustainable Development Report shows that the Earth's forest areas shrunk by 100 million hectares. In addition, from 2015 to 2016, the financial support for biodiversity in the form of bilateral official development assistance (ODA) fell by 21%.

In most urban areas, forest protected areas are reserved essentially for biodiversity conservation. It is considered "…[t]he only hope we have of stopping many threatened or endemic species from becoming extinct" (see Dudley, 2008, p. 2). However, demand for urban space has compromised some protected areas in many developing countries, especially those with lax legislation on protected areas.

In Ghana, there are two main types of forest reserves, namely the production forest reserves and protected forest reserves. The former constitutes about 80% of total forest reserves, and it is mainly exploited and used as timber. The latter constitutes about 20% of total forest reserves which is kept for conservation purposes. In terms of depletion, Hawthorne and Musah (1993) have reported that about 50% of reserved forests are "either mostly degraded or in worse conditions". Against this background, the government of Ghana through policy instruments has demonstrated commitment towards ensuring that the forests are protected. For instance, in 1994, Ghana launched the Forest and Wildlife Policy document as a replacement of the Forest Policy of 1948. Subsequently, the government through the Ministry of Lands and Natural Resources launched the 2012 Ghana Forest and Wildlife Policy as a replacement of the 1994 Forest and Wildlife Policy.

In addition, in 1999, the Forest Plantation Development Fund was established to support the private sector with funding for commercial forest plantation investment. In 2002, the public sector was included in forest plantation development. A year before this amendment (2001), the National Forest Plantation Development Programme (NFPDP) was launched. This was relaunched in 2010 with the aim of promoting tree planting of about 30,000 ha per year in all administrative municipals of Ghana.

In spite of the local, national, regional and international efforts towards preserving Ghana's forest resources (see Mensah *et al.*, 2016), it is estimated that net forest depletion which was valued at US$1.578 bn in 2010 has risen to US$3.134 bn in 2017 (World Bank, 2019). This shows a net forest depletion of over 98% from 2010 to 2017. In line with meeting the Sustainable Development Goals, this trend provides a worrying situation that needs urgent attention. This study therefore seeks to provide empirical evidence of the depletion for specific forests as well as unveiling its perceived driver intensities.

In the Greater Accra Region (GAR), there are very few forest covers compared to other regions such as the Eastern and Western regions. The region is predominantly a coastal savannah belt with a flat landscape. Weather conditions are usually extreme with severe rain and sunshine recorded at various times in the year. It is the second largest region in terms of population, with population growth among the highest in the country. Population growth with accompanying demand for infrastructure development, energy consumption and agriculture are putting undue pressure on these limited resources. The gradual depletion of these forests has both short- and long-term effects on well-being. The study focuses on the three largest resources among the few forest resources in the GAR.

The study is organized in five sections. Section 1 presents the introduction and background. Section 2 provides the literature review. Section 3 outlines the methodology while Section 4 presents the results with discussion. Section 5 concludes the study with policy recommendations.

2. Literature review

The forest transition theory explains the mechanism in which forest cover undergoes transformation through industrialization and urbanization (Rudel *et al.*, 2010; Mather and

Needle, 1998). The process of economic development brings about industrialization and urbanization, which draws active population from rural to urban locations. At the early stages of economic development, society is characterized by high forest cover and low deforestation rates. At the middle stage, there is an increase in deforestation, reducing forest cover. An advanced stage of development leads to a slower rate of deforestation, eventually bringing stabilization and recovery of forest cover. This pattern is influenced by human population density, level of development, the structure of the economy, global economic forces and government policies.

As per the forest transition theory, one would expect most developing countries which are in their early stages of economic growth and development to have high forest cover and low deforestation. Unfortunately, this has not been the case. For example, Ghana is a *lower-middle-income* country that has not yet attained a *middle-income* status. Nonetheless, it has already started experiencing a rapid rate of deforestation in levels that can be likened to middle-stage countries. This rise has been driven mostly by exports of timber, rapid population growth and a corresponding increase in domestic demand for wood for purposes such as fuel, furniture and construction. Also, bush fires in the 1980s, climate change and poor enforcement of laws have been influential. The most severe and identified drivers of deforestation are the synergy among human activities, institutional factors and changing climatic conditions (see Geist and Lambin, 2002).

Unfortunately, the environmental literature has not provided a conclusive definition of the drivers of deforestation and degradation of the forest. Hosonuma *et al.* (2012) provide four forest degradation drivers (timber/logging, uncontrolled fires, livestock grazing in forest and fuelwood/charcoal), and five deforestation drivers (commercial agriculture, subsistence agriculture, mining, infrastructure and urban expansion). In line with these drivers, this study reclassifies the drivers into human behaviour/activity, climate change and institutional failure for an empirical review.

2.1 Human factors

This simply suggests that the depletion of the forest is caused by human need for settlement space, commercial and subsistence activities for survival among others. In the environmental literature, several models and theories have been developed to explain the link between human environmental knowledge, human behaviour and environmental (forest) degradation or deforestation or depletion. Recent strand of literature in environmental and energy economics focuses on energy consumption decisions of firms and households in developing nations (see Gertler *et al.*, 2016). About 58% of the energy supply in Africa comes from fuelwood and charcoal (Specht *et al.*, 2015). The demand for fuelwood for cooking and heating is often cited as the most important cause of deforestation, ahead of other demands for forest products such as furniture and paper.

Fuelwood collection, charcoal production and to a lesser extent livestock grazing in forests are the most important proximate drivers of deforestation in Ghana. Deforestation and forest degradation in Africa remain dominated by small-scale processes (Fisher, 2010). Fuel wood is expected to remain a major source of domestic energy for some time, while the demand for charcoal is likely to increase due to an expected increase in urbanization, as urban inhabitants use more charcoal than those in the rural areas. Other underlying drivers of forest change such as population and demand for agricultural products are all expected to increase (Hofstad *et al.*, 2009).

World population is projected to reach 10 billion by 2050. This is expected to increase global pressure on the use of productive land, particularly in developing countries where a significant rise in population will occur. Deforestation, brought about by the conversion of forest land to other social needs, threatens not only forest resources, forest communities and indigenous peoples but also the diversity of life. Land-use changes result in a loss of valuable habitats, land degradation, soil erosion, a decrease in clean water and the release of carbon into the atmosphere. How to increase agricultural production and improve food security without reducing forest area is one of the biggest challenges in our present time (FAO, 2018).

Defries *et al.* (2010) have acknowledged that the forces underlying tropical forest loss are uncertain. Nonetheless, they used data from satellite-based estimates across 41 countries to identify two main drivers of deforestation in the 21st century. Using two methods of regression analysis, the authors established a positive correlation between forest loss and urban population growth, as well as exports of agricultural products. However, same evidence was not found in the case of rural population growth. This implies that in areas where human activities are enormous forest loss is inevitable.

2.2 Institutional factors

In recent times, economists lay much emphasis on the role of cultural, historical, social and institutional factors in explaining the process of development (North, 1990; Easterly, 2001; Todaro and Smith, 2015). These factors are now deemed important to achieve sustainable development sensitive to the needs of mankind and the environment. The institutional environment to enhance sustainable development consists of norms, rules of conduct and generally accepted ways of actions.

It is generally acknowledged in the economic theory that when property rights are well defined (by institutions), ownership and efficient utilization of resources are enhanced. The "legal structure and property rights" index measures a country's legal security of private ownership, including clearly delineated property rights that are protected by law. Foster and Rosenzweig (2002) observed that deforestation rates are negatively correlated with this index, as countries with weak property protection are more likely to see citizens liquidating forest stands. They also assert that a country's commitment to free market and democratic principles have a negative effect on the deforestation rate.

Policy and governance failure are other institutional factors influencing deforestation. According to Duguma *et al.* (2019), forced eviction and relocation of local communities, weak property rights, poor engagement and exclusion of local communities in forest management are among prominent reasons worsening illegal exploitation of forests by immediate local communities and residents. These conditions undermine the sense of ownership of forest resources by the communities. There is the need for a proper land use plan to guide what kind of land or land cover can be used for what purpose. Without a clearly organized administrative system at the policy level to guide this, it is virtually impossible to curb this challenge. Also, there is the need for able institutions and institutional frameworks to enforce the provisions and restrictions in the policy with regards to ownership and use of land.

Corruption control is a component of social capital which is important for sustainable forestry (Kaufmann *et al.*, 2002). Deforestation is inversely related to corruption index; less corruption enhances social development and thus improved environmental quality. Another important component of social capital is the extent to which citizens are empowered to participate in political decision-making processes. In countries with higher levels of social capital, there is more pressure on government and firms to behave in environmentally responsible ways. A country's overall literacy rate is also an important measure of empowerment. Higher levels of literacy suggest that a country is more likely to protect scarce forest resources (Meyer *et al.*, 2003).

Meyer *et al.* (2003) conducted a study on the relationship between deforestation and economic, institutional and social capital among 117 developed and developing countries. Using ordinary least squares (OLS) regression, they found that institutional, economic and social capital variables are significantly related to deforestation in the absence of income. Also, their results emphasized that countries are less likely to liquidate forest assets when the level of corruption is low.

2.3 Climatic factors

Climate change and its effect on forests over the years has become clear with the help of satellite images. Rustad *et al.* (2012) noted that human activities such as fossil fuel combustion and industrialization are driving up concentrations of carbon dioxide and other greenhouse gases in the atmosphere. Increased emissions of these gases trap heat, altering the Earth's temperature. Climatic conditions shapes and controls plant and animal life, determines our energy needs, influences the atmospheric gas and water and drives the melting of glaciers, which results in the rise in sea levels. Mild changes in climate may therefore have major effects on forests and thus for society.

Humidity in forests is greatly affected by changes in temperature and precipitation. According to Mortsch (2006), a warm temperature leads to increased water losses from evaporation and evapotranspiration which can result in reduced efficiency in water use by plants. When a warm temperature occurs continuously for a longer period, say, over a generation, severe moisture stress and drought arises. This process leads to a reduction in the growth and health of trees depending on the characteristics of the forest, such as the type of habitat of fauna and flora, soil depth and type. Young plants such as seedlings and saplings are particularly susceptible whereas large trees with a more developed rooting system and greater stores of nutrients and carbon tend to be less sensitive to drought, though they are affected by more severe conditions.

Sanderson *et al.* (2012) observe that climate change impacts on forests are ambiguous as a result of uncertainties in global climate model projections on rainfall and atmospheric circulation. They relate their observation with predictions of the impact of climate change on forests, based on the outputs of general circulation models (GCMs). GCM predictions on average indicate that increased precipitation is associated with atmospheric warming. However, the pattern of changes in precipitation is irregular and difficult to forecast.

Other empirical studies have employed Dynamic Global Vegetation Models (DGVMs) to explain climate change and its impact on forests. The technique simulates competition between different vegetation types and to project how forested areas may change in response to a warming climate. Reu *et al.* (2011) have examined the relationship between climate change and plant physiological processes to ascertain the processes behind shifts in vegetation types and cover. They found that with warming climatic conditions, species concentration decreases in the tropics but increases in mid-latitudes.

Salazar *et al.* (2007) examined the effect of climate change on the Amazon forest using a single DGVM and meteorological data from 15 different climate models under low and high emissions. From the models, despite the large range of projected precipitation changes over the Amazon forest, they found that elevated temperatures are enough to cause the loss of forest and its conversion to savannah, even with high rainfall. However, because of the use only one DGVM in their study, there are concerns of efficiency, consistency and reliability as several DGVMs provide different responses. In a related study, Huntingford *et al.* (2008) argued that some attrition Amazonian rain forest would occur during the 21st century attributable to climate change. They observed further that the extent of attrition is dependent also on the projected changes in rainfall and temperature. However, the authors underscored the fact that the reduction in the forest will be worse than most projections owing to lag in response to climate change.

Sedjo and Sohngen (1998) evaluated potential sources of forest damage from climate change and the socio-economic consequences. They found a positive relationship between climate change and forests in general and timber harvests. This implies that previous research findings of severe consequences have exaggerated the risk. They also claim the effects of climate change on ecological values associated with forests are a source of concern, especially if climate change is relatively gradual and its adaptation is enhanced.

From the above reviewed studies, we posit that to the best of our knowledge no study has so far provided robust empirical evidence with the associated drivers of forest depletion in the GAR of Ghana. We contribute to the literature by filling this gap.

3. Methodology

3.1 Field procedures

This study was conducted in the GAR of Ghana specifically in Ga North Municipal (Gua Kuo Scared forest, Pokuase), Okaikwei North Municipal (Achimota Protected forest) and Shai Osudoku Municipal (Shai Hills Protected forest). These selected Municipals house the three selected forests used for the study. Household-level data were obtained from respondents within the selected Municipals in the GAR. Generally, the region has a total number of 766,955 households. A stratified random sampling technique was used in selecting the respondents. First, each municipal was divided into their respective strata (communities). Housing units within each stratum were listed, after which households within the housing units were randomly selected. A total number of 733 households were randomly selected and used as the sample size for the study. This comprises 248 (33.83%) from Okaikwei North Municipal, 243 (33.15%) from Ga West Municipal and 242 (33.02%) from Shai Osudoku Municipal.

The team of researchers comprised two investigators, 12 fieldworkers and three field coordinators. Each Municipal had four fieldworkers and supervised by a coordinator. The work of the coordinators was jointly supervised by the two investigators. The field team was taken through series of training sessions. First, the coordinators were trained on their core responsibilities vis-a-vis managing fieldworkers and familiarizing themselves with the tools for the data collection. Second, the fieldworkers were trained. A standard questionnaire that follows the format of the Ghana Statistical Service for national surveys was designed and used as the main research instrument. The fieldwork started with a pilot survey which was done in a day. Queries, comments and questions came up for discussion and subsequent revision of the questionnaire.

The final questionnaire was further perused by the investigators and other experts. The questionnaire was administered using the face-to-face interview approach. Overall, this yielded a total response rate of approximately 98%. This consists of 99% for Okaikwei North Municipal area and 97% each for Ga West Municipal and Shai Osudoku Municipal areas. In the event where the listed household was not available or declined interest in the survey, the next available household was interviewed. Thus, no single household was interviewed under compulsion. Households who participated in the survey were included in a randomized GH¢5 mobile phone credit draw as a way of incentivizing respondents.

The questionnaire was structured into sections. For brevity in presentation, we summarize it to include demographic data, forest and environment related data and contingent valuation questions. In obtaining the variable of interest, respondents were given the Likert scale options from very low (1) to very high (5). They were asked to

> Rank the extent to which *institutional failure* has contributed to the depletion of forest resources in your community?
>
> Rank the extent to which *climate change* has contributed to the depletion of forest resources in your community?
>
> Rank the extent to which *human behaviour* has contributed to the depletion of forest resources in your community?

The entire fieldwork and data processing for this project took place over a three-month period (April–June 2019). Data entry and cleaning were undertaken by a research assistant under the supervision of the investigators. All other works were undertaken by the investigators of this project.

3.2 Model specification

Given that the responses provided by respondents to the questions took ranked/ordered values from 1, 2, 3, . . . *J*, an ideal model to use is the ordered probit model. In line with Daykin and Moffatt (2002) and Amoah and Dorm-Adzobu (2013), we present the theoretical model followed by the empirical estimation model. First, let us assume that y_i^* is a latent variable for the respondent *i*, and it depends linearly on an independent variable (x_i). Thus,

$$y_i^* = x_i'\beta + u_i \quad i = 1, \ \ldots, \ n$$
$$u_i \sim N(0, \ 1)$$

β represents a vector of parameters to be estimated, and u also represents the error term, which is assumed to be normally distributed with a zero mean and constant variance. Given that y^* is latent, we specify an observed y as follows:

$$\begin{aligned} &y = 1 \text{ if } -\infty < y^* < T_1 \\ &y = 2 \text{ if } T_1 < y^* < T_2 \\ &y = 3 \text{ if } T_2 < y^* < T_3 \\ &\vdots \\ &y = J \text{ if } T_{J-1} < y^* < \infty \end{aligned}$$

where (T_J) represents the threshold parameters and $j = 1, \ldots, J-1$. Next, we specify the log-likelihood function with $P_i(y)$ as the probability that the response of the *i*th person is observable. We present this probability as follows:

$$P_i(y) = P\left(T_{y-1} < y_i^* < T_y\right) = \Phi\left(T_y - x_i'\beta\right) - \Phi\left(T_{y-1} - x_i'\beta\right)$$

From the model, the standard normal cumulative distribution function is symmetric, and it is represented as $\Phi(.)$. With a given sample (*n*), the log-likelihood function is shown as follows:

$$\text{Log}\, L = \sum_{i=1}^{n} \ln[P_i(y_i)] = \sum_{i=1}^{n} \ln\left[\Phi\left(T_{y_i} - x_i'\beta\right) - \Phi\left(T_{y_i} - x_i'\beta\right)\right]$$

In line with the theoretical model presented, we specify the functional form for estimation purposes. Here,

$$\text{FD} = \beta_0 + \beta_1 \text{HB} + \beta_2 \text{IR} + \beta_3 \text{CC} + \beta_4 Z + u$$

where FD measures the extent of forest depletion, HB is human behaviour which measures the extent to which human's indiscriminate actions hurt the forest resources, IR is institutional role or failure which measures the power of state institutions in preventing or allowing forest depletion, CC is climate change which shows the extent to which extreme changes in the average temperature affect forest depletion and Z is a vector of control variables mainly socio-economic variables and community specific dummies. A priori, one would expect indiscriminate human behaviour, weak institutions or institutional failure and rising levels of climate change to increase the extent of forest depletion.

Using a five-point Likert scale ranging from a minimum of 1 (very low) to a maximum of 5 (very high), the descriptive statistics presented in Table 1 shows the extent to which the three forest areas have been depleted. By implication, the view of the respondent regarding the extent to which the forest reserves have been depleted gives the option to use an ordered

Table 1.
Descriptive statistics

Statistics	Forest depletion	Human behaviour/ factor	Climate change factor	Institutional failure factor	Education	Age	Gender	International knowledge	Local knowledge
	Description of variables used								
	Extent of forest depletion	Extent of human factor causing depletion	Extent of climate change causing depletion	Extent of institutional failure causing depletion	Education of the respondent (dummy)	Age of the respondent	Gender of the respondent	Knowledge of international environmental issue	Knowledge of local environmental issue
How variables were measured	Rank on the scale of 1–5	Rank on the scale of 1–5	Rank on the scale of 1–5	Rank on the scale of 1–5	Dummy 1–educated, 0 –uneducated	Years reported by the respondent	Dummy 1–male, 0–female	Subjective knowledge 1–yes, 0–no	Subjective knowledge 1–yes, 0–no
Mean	3.21	3.60	3.52	3.25	0.93	35.25	0.54	0.72	0.52
Median	3.00	4.00	4.00	3.00	1.00	32.00	1.00	1.00	1.00
SD	1.11	1.10	1.15	1.21	0.26	12.55	0.50	0.45	0.50
Skewness	−0.28	−0.55	−0.51	−0.32	−3.26	0.96	−0.16	−1.00	−0.08
Kurtosis	2.37	2.62	2.53	2.15	11.65	3.47	1.03	2.01	1.01
Min	1.00	1.00	1.00	1.00	0.00	18.00	0.00	0.00	0.00
Max	5.00	5.00	5.00	5.00	1.00	81.00	1.00	1.00	1.00
N	*732.00*	*732.00*	*730.00*	*732.00*	*733.00*	*732.00*	*733.00*	*733.00*	*733.00*

probit model that accounts for the ordinal characteristics of the dependent variable. The mean suggests that, yes, the forest has been depleted but the extent of depletion is marginally above *moderate*. Given that the mean and the median are approximately the same, with skewness near zero and kurtosis near three, it is obvious that the distribution is near normal. This ordered variable is used as the dependent variable in the model specified for estimation.

Next, we investigate the properties of the perceived causal factors of the depletion. The key driver intensities of depletion pointed out by the respondents included human behaviour, institutional failure and climate change. The mean value for human behaviour and climate change of approximately 4.00 indicates that depletion of the forest caused by human behaviour and climate change is *high*. In addition, the mean value of 3.25 for institutional failure shows that the extent of depletion caused by institutional failure is marginally above *moderate*. That is, respondents believe that on the average all three factors drive depletion of the forest resources in Ghana. However, human behaviour and climate change drive the depletion more than institutional failure.

Additional socio-economic controls were included in the model. These include education, age, gender and international and local knowledge. For education, 93% were educated whiles 7% were uneducated (no formal education). The minimum age of respondents was 18 years whiles the maximum age was 81 years. The average age of respondents was about 35 years. The age ranges show the diversity in the age of respondents used for the study. Averagely, 54% of respondents were males while 46% were females. This reflects a near balance in the distribution of the gender of respondents. In Ghana, for household level data, household heads are usually male dominated. Given the recent increase in the level of formal education in Ghana, it was observed that 72% have knowledge about the environment while only 52% had knowledge of local environmental laws. Local laws on environmental issues are less talked about in the media as compared to global environmental issues.

4. Results

4.1 Descriptive analysis of results

The respondents were asked to indicate the extent to which the three selected forests in the GAR have been depleted. From Figure 1 and Table 1, respectively, majority, constituting approximately 44% of the respondents indicated that the depletion is *high*. About 30% and 26% indicated that the depletion is *moderate* and *low,* respectively. These categories show

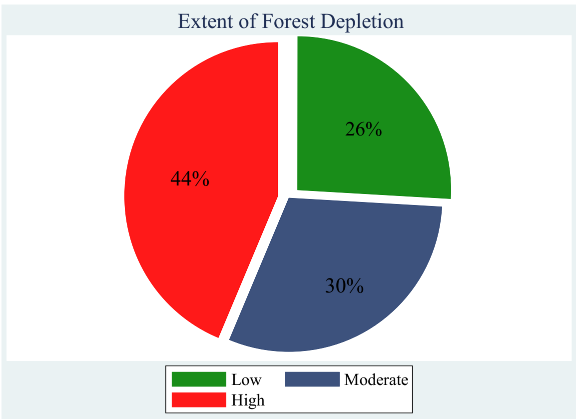

Figure 1. The extent of forest depletion in the GAR

that there is evidence of depletion. We further investigated the extent of depletion by the type of forest and present the results in Figure 2.

According to the respondents, the depletion of the Gua Kuo forest is four percentage points higher than Achimota forest and 11 percentage points higher than the Shai Hills forest. In effect, the Gua Kuo forest has experienced more depletion than the other two forests under study. In contrast, the Shai Hills forest is believed to have experienced less depletion as compared to the other two forest areas. The remote sensing evidence of the depletion is presented in Figures 3–5 to support the findings.

The geographic information system (GIS) provides remote sensing evidence showing the degree of loss in green vegetation (closed and open canopy) and growing incidence of human activities shown as built-up/bare areas for all forest locations from 1990 to 2015 (see Figures 6–8).

Using the most recent available data on herb/grass cover loss and built-up/bare areas spanning the period from 1990 to 2015, we graphically show that, generally, there is a positive trend regarding the depletion of the three protected forest areas in the GAR, Ghana. Thus, the extent of depletion of the protected forests keeps rising. This presents a worrying situation that needs an immediate response by the Forestry Commission of Ghana (see Table 2).

Next, we evaluate respondents' views on key driver intensities of forest depletion in the GAR. The first driver intensity we consider is human behaviour. Here, we asked respondents the extent to which human behaviour has contributed to depletion of forest reserves in the study area. The survey results show that 17% of the depletion caused by human behaviour were below moderate whilst 59% were above moderate. This indicates that majority of respondents believe human behaviour is considered either high or very high in contributing to the depletion of the forest resources in the GAR. Again, we asked respondents the extent to which climate change has contributed to depletion of forest reserves in the study area. Similarly, 55% of the responses were above moderate whilst 18% were below moderate. This implies that majority of the respondents believe that climate change is also a key contributing factor to the forest depletion. Lastly, respondents were asked the extent to which institutional

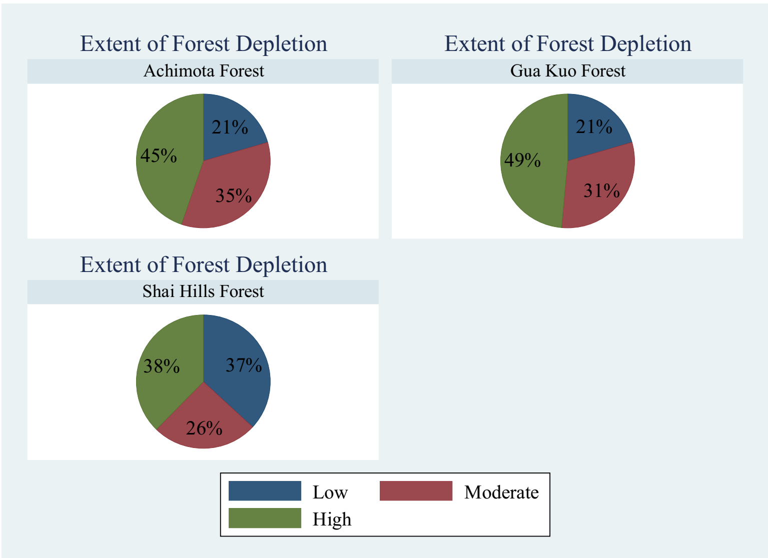

Figure 2.
The extent of forest depletion by forest

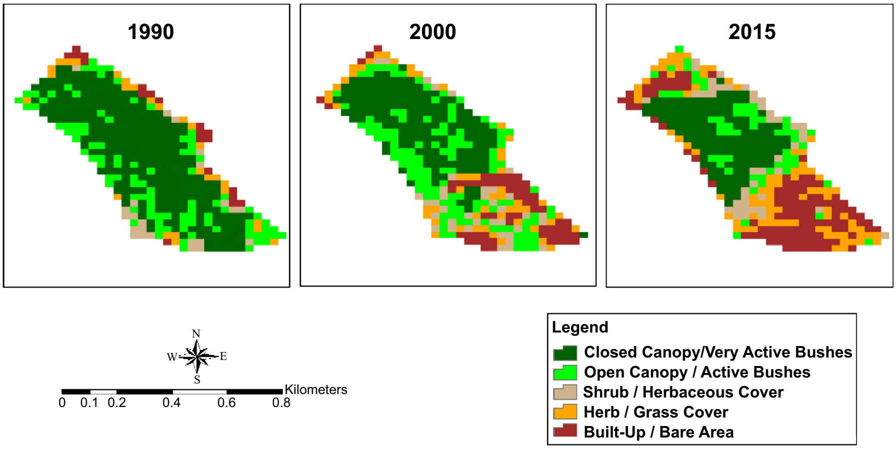

Figure 3.
Trend of depletion at the Gua Kuo forest

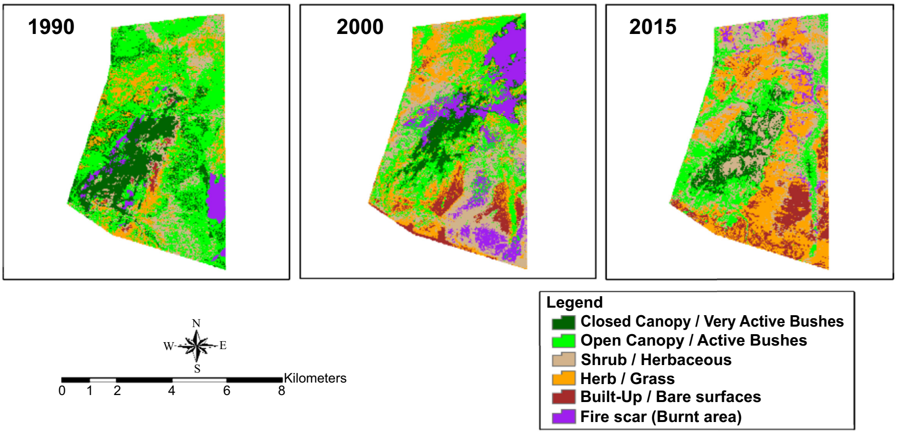

Figure 4.
Trend of depletion at the Shai hills forest

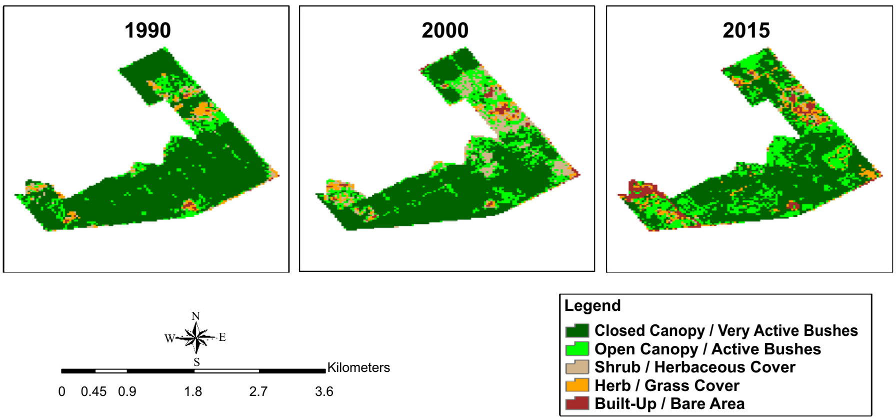

Figure 5.
Trend of depletion at the Achimota forest

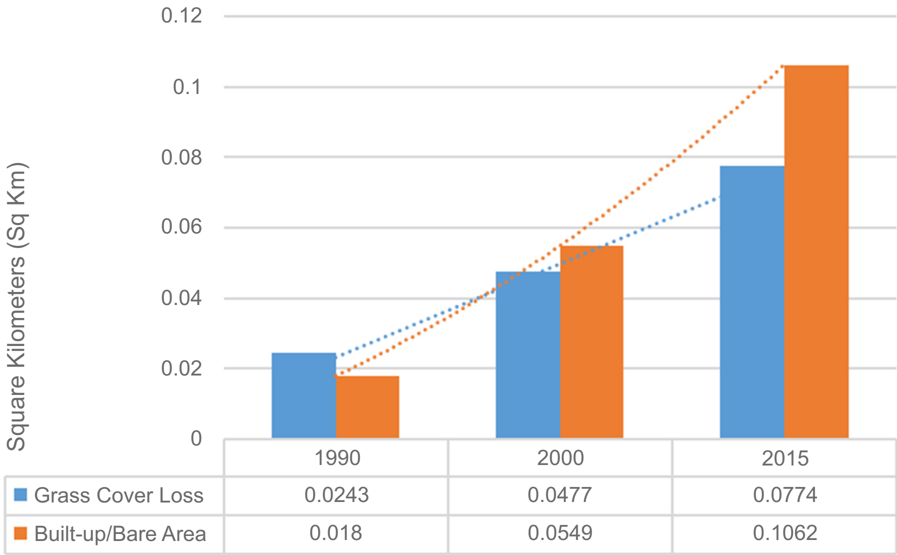

Figure 6.
Trend of the depletion of Gua Kuo Sacred forest

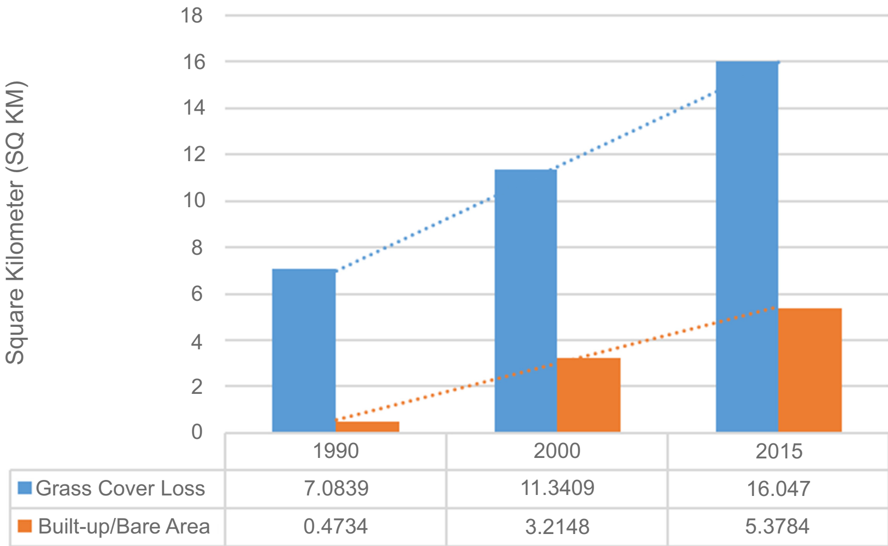

Figure 7.
Trend of the depletion of Shai Hill forest

failure has contributed to depletion of forest reserves in the study area. In line with the earlier findings, 48% of the responses were above moderate whilst as high as 28% were below moderate. In our evidence, respondents believe that the mandated institutions responsible for protecting the forest have not lived up to expectation, and that their failure has contributed to the depletion of the forest.

By way of comparison, it is obvious that human behaviour intensity drives the depletion of the forest more than institutional failure and climate change. This is followed by climate change then institutional failure. Statistically, respondents are of the view that human behaviour intensity drives forest depletion by four and 11 percentage points more than climate change and institutional failure, respectively. Climate change intensity is seven percentage points more than institutional failure regarding forest depletion in the GAR (see Table 2).

4.2 Regression analysis of results

To commence with the interpretation of the ordered regression results, we first undertook some relevant diagnostic tests. The Wald chi squared test for all the estimated models show that at least one of the coefficients of the predictors is non-zero. This implies that the models are correctly specified. Again, to control for heteroscedasticity, all models (see Table 3) are estimated with robust standard errors. From the mean variance inflation factor values, we

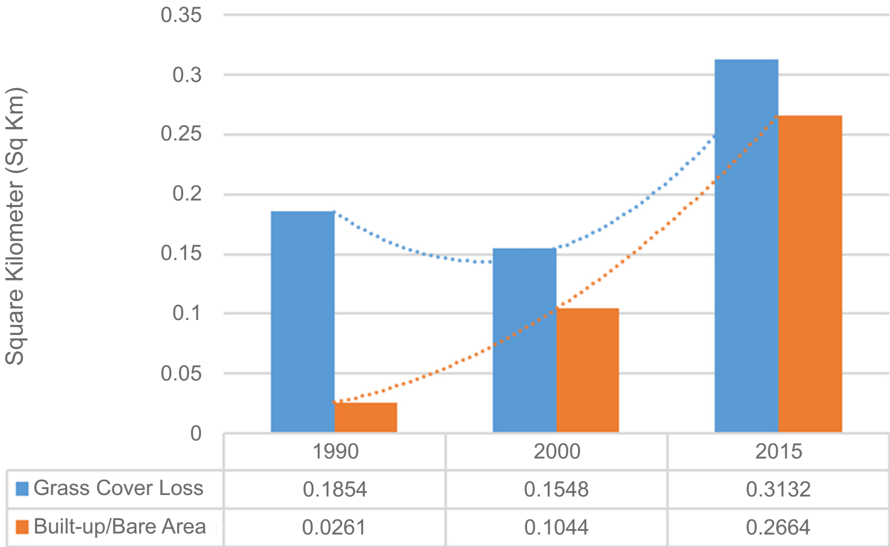

Figure 8.
Trend of the depletion of Achimota forest

Categories*	Human Behaviour (%)		Climate Change (%)		Institutional Failure (%)		Overall Intensity (%)	
Very Low	5	17	7	18	10	28	8	26
Low	12		11		18		18	
Moderate	24		27		24		30	
High	37	59	33	55	33	48	33	44
Very High	22		22		15		11	
Total	**100**		**100**		**100**		**100**	

Note(s): *Category A = Very Low and Low, Category B = Moderate, Category C = Very High and High
Source(s): Fieldwork, 2019

Table 2.
Extent of forest depletion by driver intensity

Variables	Human	Institution	Climate change	Pooled
Human behaviour				
Low	0.4428 (0.312)			0.1418 (0.334)
Moderate	0.9495*** (0.309)			0.4567 (0.339)
High	1.6707*** (0.318)			0.8871** (0.351)
Very high	1.8327*** (0.328)			0.8565** (0.347)
Institutional role				
Low		0.2454 (0.219)		0.1511 (0.223)
Moderate		0.7850*** (0.219)		0.5191** (0.229)
High		1.3960*** (0.231)		0.9875*** (0.243)
Very high		1.8748*** (0.259)		1.2892*** (0.276)
Role of climate change				
Low			0.2428 (0.238)	0.4745* (0.267)
Moderate			0.9108*** (0.234)	0.7155*** (0.255)
High			1.0520*** (0.234)	0.6263** (0.264)
Very high			1.6240*** (0.242)	1.2045*** (0.269)
Socio-economic factors				
Education	0.0125 (0.137)	0.1763 (0.131)	0.1193 (0.148)	0.0513 (0.138)
Age	0.0080** (0.003)	0.0055* (0.003)	0.0034 (0.003)	0.0056* (0.003)
Gender (Male)	−0.1425* (0.082)	−0.1327 (0.081)	−0.1243 (0.082)	−0.1575* (0.084)
International knowledge	0.1364 (0.093)	0.0094 (0.095)	0.2506*** (0.095)	0.0795 (0.094)
Local knowledge	−0.0085 (0.084)	0.0646 (0.084)	0.0885 (0.082)	0.0037 (0.086)
Community dummies	Yes	Yes	Yes	Yes
Constant cut1–cut4	Yes	Yes	Yes	Yes
Wald $\chi^2(30)$	4325.98***	3991.32***	4129.75***	4058.46***
Pseudo R^2	0.1128	0.1294	0.0956	0.1755
Mean VIF	2.57	1.68	2.08	3.68
Observations	729	729	727	727

Note(s): Dep variable: extent of forest depletion, robust standard errors in parentheses and ***p < 0.01, **p < 0.05 and *p < 0.1

Table 3.
Ordered probit regression model

have no evidence of multicollinearity among the explanatory variables. Community specific dummies are included in all estimated models to account for unobserved heterogeneity amongst the communities within the study areas (see Tables 3 and 4). We focus the interpretation on the marginal effects (see Table 4) as it shows the relative changes in probabilities of the dependent variable to a unit change in the independent variables.

For specificity, we consider the key individual factors driving the extent of depletion with their respective socio-economic characteristics in models 1–3. These are human behaviour, institutional failure and climate change. The results for all three models have exhibited the a priori positive signs, and they are highly statistically significant for all categories except *low*. In a broader sense, for human behaviour, respondents who indicated *moderate, high* and *very high* are more likely to attribute the extent of depletion to human behaviour as compared to those who indicated *very low and* even *low*. Indeed, relative to respondents who indicated that human behaviour is *very low* in influencing the depletion of forest reserves, it can be observed that if the respondent indicated perceived depletion to be *moderate*, the extent of depletion associated with human behaviour will increase by approximately 16%. If the respondent indicated perceived depletion to be *high*, the extent of depletion associated with human behaviour will increase by approximately 29%. If the respondent indicated perceived

Variables	Model 1 (margins)	Model 2 (margins)	Model 3 (margins)	Pooled (margins)
Human behaviour				
Low	0.0773 (0.0549)			0.1235 (0.2588)
Moderate	0.1657*** (0.0551)			0.3922 (0.2667)
High	0.2915*** (0.0575)			0.7954*** (0.2732)
Very high	0.3198*** (0.0583)			0.7893*** (0.2669)
Institutional role				
Low		0.0403 (0.0358)		0.0421 (0.1819)
Moderate		0.1288*** (0.0352)		0.3489* (0.1843)
High		0.2290*** (0.0369)		0.7736*** (0.1915)
Very high		0.3076*** (0.0401)		0.9744*** (0.2098)
Role of climate change				
Low			0.0442 (0.0433)	0.4795 (0.2112)
Moderate			0.1659*** (0.0429)	0.5841*** (0.2038)
High			0.1917*** (0.0431)	0.5166*** (0.2107)
Very high			0.2959*** (0.0431)	0.9893*** (0.2156)
Socio-economic factors				
Education	0.0022 (0.0239)	0.0289 (0.0214)	0.0217 (0.0269)	0.0377 (0.1105)
Age	0.0014** (0.0006)	0.0009* (0.0005)	0.0006 (0.0006)	0.0048** (0.0025)
Gender (Male)	−0.0249* (0.0144)	−0.0218* (0.0133)	−0.0226 (0.0149)	−0.1613** (0.0672)
International knowledge	0.0238 (0.0162)	0.0015 (0.0157)	0.0456*** (0.0176)	0.0598 (0.0760)
Local knowledge	−0.0015 (0.0146)	0.0106 (0.0138)	0.0161 (0.0152)	0.02042 (0.0682)
Community dummies	Yes	Yes	Yes	Yes
Observations	729	729	727	727

Note(s): Dep variable: extent of forest depletion, robust standard errors in parentheses and ***$p < 0.01$, **$p < 0.05$ and *$p < 0.1$

Table 4. Marginal effects

depletion to be *very high*, the extent of depletion associated with human behaviour will increase by approximately 32%. This reflects an increasing order effect. That is, the higher the human behaviour is perceived to lie on the rank, the more they are found hurt the forest resources.

For institutional failure, respondents who indicated *very low and even low* are less likely to attribute the extent of depletion to institutional failure as compared to those who indicated *moderate, high* and *very high.* Thus, relative to respondents who indicated that institutional failure is *very low* in influencing the depletion of forest reserves, it can be observed that if the respondent indicated perceived depletion to be *moderate*, the extent of depletion associated with institutional failure will increase by approximately 13%. If the respondent indicated perceived depletion to be *high*, the extent of depletion associated with institutional failure will increase by approximately 23%. If the respondent indicated perceived depletion to be *very high*, the extent of depletion associated with institutional failure will increase by approximately 31%. This reflects an increasing order effect. That is, the higher the institutional failure is perceived to lie on the rank, the more they are found to hurt the forest resources.

In the case of climate change, respondents who indicated *moderate, high and very high* are more likely to attribute the extent of depletion to climate change relative to respondents who indicated *very low and even low.* Thus, by way of comparison, respondents who indicated that climate change is *very low* in influencing the depletion of forest reserves, it can be observed that if the respondent indicated perceived depletion to be *moderate*, the extent of depletion associated with climate change will increase by approximately 17%. If the respondent indicated perceived depletion to be *high*, the extent of depletion associated with climate change will increase by approximately 19%. If the respondent indicated perceived depletion to be *very high*, the extent of depletion associated with climate change will increase by approximately 30%. This reflects an increasing order effect. That is, the higher the climate change is perceived to lie on the rank, the more they are found to hurt the forest resources.

Given that models 1–3 may suffer from missing variable bias, we considered a pooled ordered probit model that has all three driver intensities in addition to relevant socio-economic control variables and community fixed effects. The Mcfadden pseudo R results suggest that it is the best model as compared to the other estimated models. Again, for interpretation, we suggest that the estimates should be interpreted as association or correlation instead of causal impact. In the case of human behaviour, the pooled model had the right signs for all categories. However, *low* and *moderate* were found to be statistically insignificant, unlike model 1 where only *low* was found to be insignificant. Implying that, all else held constant, the extent of forest depletion associated with human behaviour rises if respondents indicated that perceived depletion were *high* and *very high* relative to *very low or even low.* The evidence of an increasing order effect is observed until the respondent indicated *very high*, then a decreasing order effect is realized, albeit marginally (one percentage point).

Similarly, regarding institutional role, the pooled model had the right signs for all categories. However, only *low* was found to be statistically insignificant akin to model 2. This suggests that all else held constant, the extent of forest depletion associated with institutional failure rises if respondents indicated that perceived depletion were *high* and *very high* relative to *very low or even low.*

Consistent with the cases earlier analyzed, climate change had the expected signs for all categories. The only category that was found to be statistically insignificant was *low*. Holding all other factors constant, we have evidence that the extent of forest depletion associated with climate change rises if respondents indicated that perceived depletion were *high* and *very high* relative to *very low or even low.*

In effect, if human behaviour, institutional failure and climate change as causes of depletion were perceived to be *high* and *very high* relative to *very low or even low*, the extent of forest depletion rises.

The age of the respondent is used as a measure of experience with respect to observation of the environment over time. The age of the respondent is found to be positive and statistically significant for all models except model 3. Holding all else constant, an increase in age by one year is associated with an increase in the extent of forest depletion by less than 1% in all models. This implies that older respondents who have witnessed changes in the forest resources over the years have a higher probability of observing the extent of forest depletion perhaps as attributed to human behaviour, climate change and institutional failure. This is plausible on grounds that relative to the younger age groups, older respondents who have observed the climate changes, institutional negligence and indiscriminate behaviour of people towards the forest overtime are more inclined to report forest depletion margins based on their experience.

The environmental literature has observed disparities in gender attitude and behaviour towards the environment. In this study, gender is included to observe the possible behavioural difference and how it determines the extent of forest depletion. Gender of the respondent is found to be negative and statistically significant in all models except model 3. That is, all else being constant, male respondents are less likely to observe the extent of forest depletion as compared to female respondents. This is consistent with expectation because from the perspective of environmental literature, females or women generally report stronger environmental behaviours and attitudes than males or men (Amoah and Addoah, 2020).

Local and international knowledge of the respondent are included to ascertain whether respondents know the repercussions of forest depletion and the benefit of forest resources.

They were found to be ambiguous and statistically insignificant in all models except model 3. In effect, both variables may be considered superfluous but are used as relevant controls in the model. This evidence contradicts with the study of Amoah *et al.* (2018), which found local and international knowledge to be relevant in making environmentally friendly choice decisions.

5. Conclusion and policy recommendation

5.1 Conclusion

This research project seeks to reveal empirically the perceived impact of climate change, human and institutional activities on forest depletion in the GAR of Ghana. We employ a survey approach to collect primary data and provide evidence of urban forest depletion. Further, we use the GIS (remote sensing) to substantiate this evidence. An ordered probit econometric estimation technique is used to predict the key driver intensities of forest depletion. This study finds evidence that forest reserves in the GAR have experienced some degree of depletion. Human behaviour is found as the main driver intensity of forest depletion, followed by climate change and then institutional failure. In all cases of human, climate and institutional factors influencing forest depletion, there is an observed increasing order effect, which implies that the higher these factors are perceived to be in rank, the more they are found to hurt forest resources.

5.2 Key policy recommendations

Climatic and institutional factors affecting forests can be controlled when laws and regulations guiding behaviour are effective. When institutions succeed in shaping human behaviour towards pro-environmental actions, the resultant positive changes in intention will promote behaviour that seek to reduce greenhouse gas emissions into the atmosphere. As human activities become pro-environmental, forests are preserved and protected, which in turn enhances a stable natural climatic condition. The core mandate of ensuring pro-environmental behaviour to protect forests begins with institutions. Nonetheless, institutions are human. The Forestry Commission in Ghana, which is mandated to manage forest resources, needs support from local government agencies such as the metropolitan, municipal and district assemblies to foster synergy for advocacy, information dissemination and awareness creation among residents in various communities nationwide. As suggested by Blankenberg and Alhusen (2018) and Kollmuss and Agyemang (2002), regulators and civil societies must use advocacy and direct acts of experience such as community tree planting exercises, clean-ups and dialogue to influence behaviour. These methods must also be sensitive to address peculiar attitudes of age groups and gender. Older respondents who have witnessed changes in the forest resources over the years have a higher probability of protecting forests than the younger. Therefore, more advocacy and direct pro-environmental actions should be targeting the relatively younger among the population. Also, these interventions should focus more on shaping male actions since they are less likely to observe the extent of forest depletion as compared to female respondents.

In order to begin the process of advocacy and direct environmental actions, a seminar involving selected key stakeholders in government, Forestry Commission, local government authorities, civil societies and individuals was organized to share pertinent information on the findings from the field survey. We also in collaboration with the Forestry Commission and with the help of Green Club Volunteers embarked on a tree planting exercise around boundaries of the three forests reserves involved in the study. This is meant to demarcate and protect the forests in the long term.

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