

Research Article

Forest Management Regimes and Drivers of Forest Cover Loss in Forest Reserves in the High Forest Zone of Ghana

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Forest cover loss, particularly those arising from deforestation and forest degradation, is largely driven by human activities and has attracted global attention over the decades. Globally, countries have adopted strategies to manage and conserve forests in response to these human disturbances. Ghana's strategy to ensure sustainable management of the forest and its estate was to zone the forest into management regimes based on the resource availability and the object of managing those particular areas. Whilst forest degradation and its drivers and actors have been widely reported in Ghana, it is not known how forest management regimes influence these issues. Focusing on four forest reserves in the high forest zone of Ghana, this paper used interviews of key forest stakeholders, analysis of Forestry Commission field reports, and field verification to demonstrate the effect of forest management regimes on drivers of forest degradation. A combination of many proximate and underlying factors was observed to drive degradation in a synergetic way. The main drivers which were identified and their corresponding actors varied and manifested differently across management regimes. The strive by forest landowners to earn revenue from the protected forest, perceived unfair payment of ground rents for protected areas by Timber Utilization Contract holders, poor forest management practices on the part of forestry personnel, nondeterrent penalties, poor forest monitoring, the granting of compartment re-entry permits to harvest residual yield, overdependence on few species, weak enforcement of forest regulations, and perceived corruption on the part of forestry officials were the major underlying factors that impact on how the drivers manifested in various regimes. Our study reveals that the primary forest stakeholders of the country are the main actors of forest degradation and have developed various means convenient for specific regimes that enable them to benefit from the forest at the expense of conservation.

1. Introduction

Forest cover loss, particularly those arising from deforestation and forest degradation, is largely driven by human activities and has attracted global attention over the decades. Apart from contributing to biodiversity loss, forest loss drives global climate change [1] as removal or degradation of forest is one of the major sources of greenhouse gas (GHG) emissions. In the Brazilian Amazon forest, for example, degradation is responsible for about 20% of total emissions [2]. Unfortunately, forest loss through deforestation and degradation is increasing globally, with the annual rate of forest degradation in Africa, for instance, being almost 50% of the annual rate of forest loss [3]. In Ghana, the net annual

loss of forest cover is estimated at 2% with forest degradation generally acknowledged as more prevalent as compared to deforestation. This trend of forest loss poses a significant threat to the livelihoods of forest fringe communities as well as ecosystem services and functionality that support the agrarian economy in countries such as Ghana [4].

Globally, countries have adopted strategies to manage and conserve forests in response to these human disturbances. Parties to the United Nations Framework Convention on Climate Change (UNFCCC) have developed a mechanism for reducing emissions from deforestation and forest degradation through the enhancement of forest carbon stocks, sustainable forest management, and conservation of forests (REDD+) in developing non-Annex I

countries [5]. The issue of identifying drivers and activities causing forest carbon change on the national level for REDD+ monitoring and implementation has received increasing attention in the REDD+ debate in addition to the discussion on policy incentives and modalities for measurements, reporting and verification (MRV) [5, 6]. The UNFCCC negotiations [5, 7] have encouraged developing countries to identify land use, land use change, and forestry activities, with particular emphasis on those that are linked to the drivers of deforestation and forest degradation, and to assess their potential contribution to the mitigation of climate change. It is therefore important to understand not only how much forests are changing but also how to define proper policies that are of relevance at the forest reserve management level and at the national strategic planning level [8, 9].

Ghana's strategy to ensure sustainable management of the forest and its estate was to zone the forest into management regimes (protection, production or selection, and conversion working circles) based on the resource availability and the object of managing those particular areas. The protection working circles, which are for maintaining the environment, are normally under hill sanctuaries, swamps, shelterbelts, and fire protection areas. These areas, according to [10], occupied 352,500 ha, of which 69% is inaccessible for logging, 16% is degraded, and 15% is well stocked and accessible. The convalescence areas, which currently cover 122,000 ha, are those areas with reduced stocking through overexploitation, fire, and poor management, but are considered capable of rehabilitation within one felling cycle (40 years). The production working circles cover an area of 762,600 ha [10] and are areas rich in timber and to be logged in a sustainable manner using selective or reduced impact logging practices. The conversion areas account for 127,200 ha (8%). They are areas that require planting, and the areas that were not inventoried occupied 270,000 ha (17%). For effective management of Ghana's flora and fauna, areas of biodiversity hotspots have been further earmarked as Globally Significant Biodiversity Areas (GSBAs). Notwithstanding these categorizations, a forest reserve can have all these working circles in it. A working circle is a forest area that is under a single system of forest management.

Although these regimes have different strategies and principles of management geared towards ensuring sustainable forest and wildlife management, yet in Ghana, loss of forest continues at an alarming rate of 2% per annum [11]. Since deforestation and forest degradation are driven by human interactions and are closely linked to the forest management regimes, to get a better understanding of how these occur, it is better to look at them from the regime perspective in order to provide more insight at the management regime level on how various drivers manifest across regimes to impact on forest cover loss. In Ghana's case, for example, forests are spread throughout various ecological zones and are managed by people with varying competencies, intents, and interest, so their level of exercising professional discretion may vary from one manager to another, and these are likely to affect their professional judgment which may have the consequences of influencing forest cover loss. Also, information from elsewhere indicates

that forest protection in priority areas, such as biodiversity hotspots, high elevations, steep slopes, and far from roads and cities, is considered better managed and likely to impact positively on forest cover loss [12, 13]. In addition, the way drivers of forest cover loss manifest in different regimes may be different likewise the underlying causes influencing these drivers. This calls for more robust, cross-ecological studies that examine the relationships between management regimes and conservation outcomes [14–16].

Unfortunately, forest reserve management regime level information on drivers and activities causing deforestation and forest degradation is limited. For international mechanisms such as REDD+ to be effective, there is the need to understand developments in various forest management regimes across various ecological zones so as to tailor appropriate strategies in addressing them. Also, it is imperative to understand how forest management regimes (protection, production, GSBA, etc.) influence the kind of drivers or how these drivers differ within various management regimes. The current paper therefore aims to demonstrate how different forest management regimes bring different perspectives to the meaning of forest cover loss and its drivers of change. It is anticipated that the findings of this study will help policy makers to design and implement policies, program, and projects that are tailored at addressing the challenges of deforestation and forest degradation to ensure sustainable forest management (SFM) and environmental sustainability.

2. Materials and Methods

2.1. Study Areas. The study was conducted in four forest reserves located within four ecological zones in Ghana, namely, Fure River (Wet Evergreen) (WE), Bia North Tributaries (Moist Semideciduous Northwest) (MSNW), and Tano-Offin (Upland Evergreen) (UE). The Forest Services Division (FSD) manages these three reserves, whilst Bia South Tributaries (Moist Evergreen) (ME), a wildlife protected reserve, is managed by the Wildlife Division (WD) of the Forestry Commission. The study area is presented in Figure 1 with the detailed areas shown in Table 1.

The study forest reserves (FRs) were demarcated and put under gazette between 1936 and 1940 and have since been managed as part of the forest and wildlife reserve network of the country. These FRs were selected because they possess multiple regimes thus making comparisons at the regime level simple by avoiding the need to take account of differences in biophysical factors between regimes being compared.

2.2. Data Collection

2.2.1. Determination of How Drivers Manifest in Different Management Regimes in the Forest Reserves. To determine how drivers of land/forest cover change manifest in various management regimes (protection, GSBA, and production), a desk study was conducted at the Regional and District Forestry Offices to review from their archives essential working documents spanning a 10-year period from 2009 to 2019 after consent, and official permit had been obtained from the Forestry Commission. Official documents such as

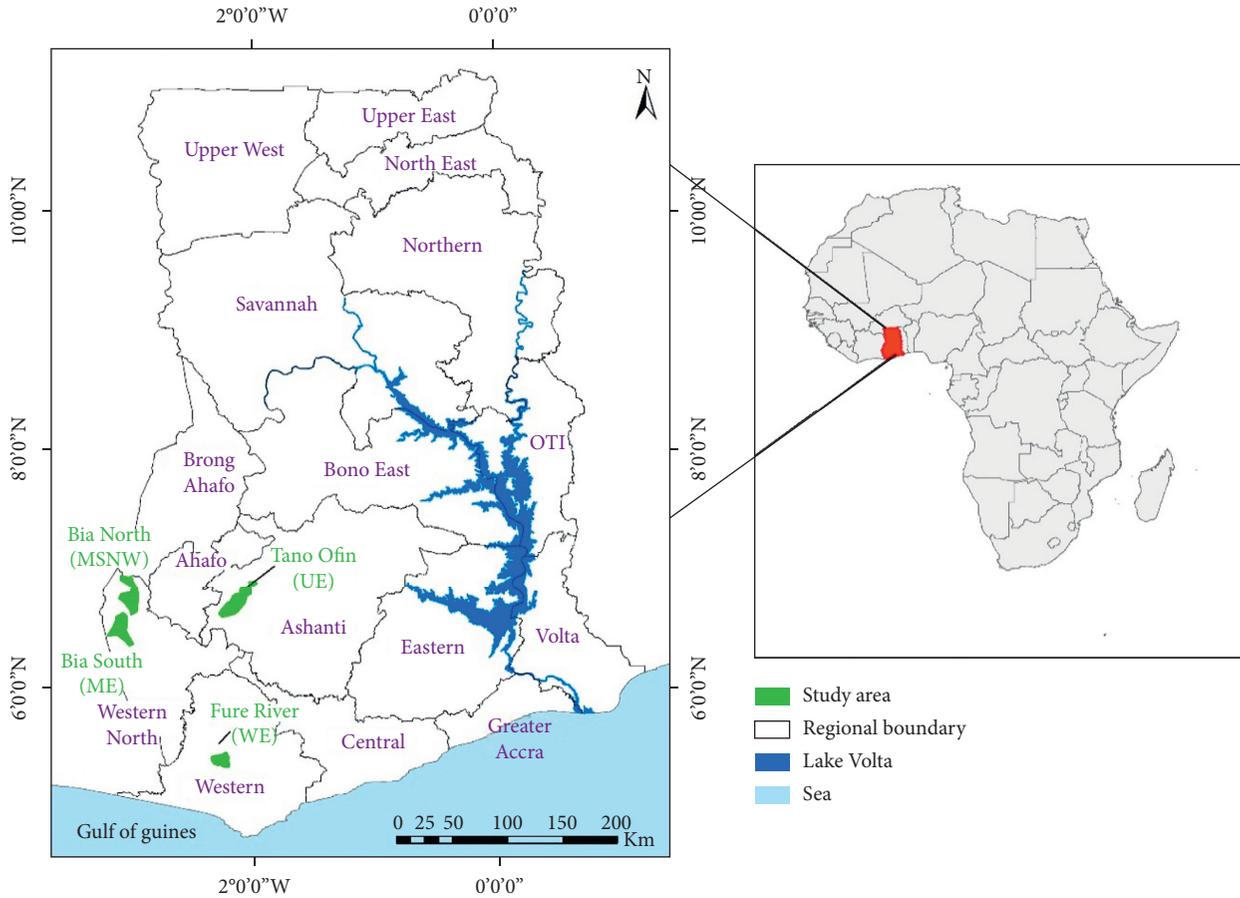


FIGURE 1: Map of study area. The selected reserves are coloured green.

TABLE 1: Study areas and their management regimes.

| Forest reserve | Area (km ²) | Ecological zone | Management regimes | Management responsibility |
|----------------|-------------------------|-----------------|------------------------------|---------------------------|
| Fure River | 158.23 | WE | Protection, production, GSBA | FSD |
| Bia North | 356.2 | MSNW | Protection, production | FSD |
| Tano-Offin | 413.92 | UE | Protection, production, GSBA | FSD |
| Bia South | 306 | ME | Protection | WD |

Ecological zones as identified by Hall and Swaine [17].

reserve management plans, offence reports, quarterly and monthly report files, permit files, harvesting reports, and any other report of interest were reviewed to show historical antecedent (frequency of occurrence of the drivers and extent of coverage) of the areas under study. Additionally, existing literature and academic write-ups were reviewed to obtain a broader understanding on the dynamics of the drivers of forest degradation. Field verification was also undertaken in all the study areas to observe the physical evidence of occurrence of these drivers in the forest.

To understand the drivers of change and how they manifest in various regimes, views from experts and forest fringe communities were solicited through interviews and focus group discussions.

Respondents were drawn from Ghana Timber Millers Organization (GTMO), Ghana Timber Association (GTA), Timber Utilization Contract (TUC) holders, chainsaw

operators, Forestry Commission and their subsidiary divisions, Forest Services Division (FSD), Resource Management Support Centre (RMSC), and Wildlife Division (WD). Details of the respondents are presented in Table 2. The study focused on the most important actors in the entire forest supply chain who are into either management or harvesting and milling of trees. It also covered members of forest fringe communities some of whom had admitted farms in the reserves. Overall, 100 respondents spread across the study areas were interviewed. The number was chosen because the issues that were interrogated were very technical and sensitive and therefore required a sizeable number that could be well managed to guard against the possibility of the results being adulterated by people who could provide data without understanding and appreciating the issues involved.

In addition, one focus group discussion involving forest fringe communities was held for each of the four forest

TABLE 2: Category of respondents and the roles their institutions play in forest management and utilization.

| Stakeholder group | No. of respondents | Institutional roles |
|---|--------------------|--|
| Ghana Timber Millers Organization | 5 | This is a trade organization subscribed by timber processing companies in Ghana. They strive to improve on the standard of timber products for both local and export markets. |
| Ghana Timber Association | 5 | Private entity that coordinates all activities of loggers in Ghana and helps the government to promulgate laws affecting logging in Ghana. |
| Timber Utilization Contract (TUC) holders | 10 | Companies granted timber harvesting rights by the government of Ghana following competitive bidding. |
| Forest Services Division (FSD) | 15 | Public sector agency which is a division under the Forestry Commission (FC) mandated to protect, develop, and manage forests in Ghana. |
| Wildlife Division | 10 | Public sector agency which is a division under the Forestry Commission (FC) mandated for the protection and conservation of wildlife resources within protected areas in Ghana. |
| Resource Management Support Centre | 5 | This is a technical wing of the Forestry Commission (FC) responsible for the exploration, development, facilitation, institutionalization, implementation, and monitoring of effective and affordable forest and wildlife management systems in Ghana. |
| Traditional authorities | 5 | They are the custodians of lands and the main opinion leaders in communities where forest reserves are located. |
| Community members | 25 | They involve residents of the forest fringe communities. Active members involved in community participation in forest management activities were interviewed. |
| Chainsaw millers | 20 | They are private individuals who use fuel-powered chainsaw machines for harvesting timber species and converting the logs in situ into lumber. |

reserves studied. This group of people was selected from the community opinion leaders, admitted farm owners, chainsaw operators, migrant settlers/farmers, and community youth members who have been providing services as carriers and loaders of chainsaw lumber. This stratification was designed in order to reflect various roles played by these actors and to solicit their opinion on all shades of issues.

2.3. Data Analysis. In analysing admitted farm extension, percentage deviation from the originally allocated farm was determined, whilst a paired *t*-test was also performed to determine whether farm extensions were significant to cause changes in forest cover. Mauchly's test was used to test if the assumption of sphericity had not been violated [18]. Data collected from the desk study were summarized and presented as statements. Using Microsoft Excel, administered questionnaires were analysed through calculations of percentages. The qualitative data from the key informant interviews and the focus group discussions were analysed using content analysis [19], involving convergence, or agreement of respondents on issues and concerns on how the drivers of forest cover change manifested in various management regimes of the forest reserves.

3. Results

For the presentation of results, the regimes are grouped as (1) GSBAs and other protection regimes and (2) production regime. Generally, the proximate causes of forest degradation the study observed were illegal logging, illegal farming, wildfires, and illegal mining. These drivers of forest cover change manifested variously in different management regimes and were triggered by a variety of underlying factors. Figures 2 and 3 present a summarized account of the

underlying drivers and their manifestation in various management regimes.

The study observed that the highest number of underlying drivers of forest degradation was recorded for illegal logging with the least recorded for illegal farming. It was also revealed that some of these underlying drivers were unique to certain management regimes, while others were similar across regimes (Figure 2). For instance, lack of revenue (timber royalties) to stool landowners, low presence of Forestry Commission staff in protected areas, and perceived unfair payment of ground rent for protected areas by TUC holders were underlying drivers of illegal logging that were unique to the GSBAs and protection regimes. The grant of compartment re-entry permits to harvest residual yield and weak enforcement of forest regulations by Forestry Commission staff were unique drivers of illegal logging that were observed in the production management regime (Figure 2).

Similarly, though these proximate drivers of forest degradation appear similar across regimes, some of them also manifested differently as shown in Figure 3.

The findings from the study revealed that illegal logging and illegal mining were the most intriguing proximate drivers of forest degradation as they manifested differently in different regimes with various actors playing several roles to induce forest degradation. How each proximate driver manifested in a specific regime is detailed in the following.

3.1. Illegal Logging as a Driver of Forest Cover Change. Illegal logging is unauthorized removal or harvesting of trees in contravention of current forest laws. From the data, it was evident that illegal logging has several actors and manifests itself in diverse ways in different regimes considered.



FIGURE 2: Underlying drivers of forest degradation in various management regimes.

3.1.1. *Illegal Logging in GSBAs and Other Protection Management Regimes and Its Main Actors.* We found that illegal logging was spread throughout the GSBAs and protection management regimes and manifested in four main ways with each having specific actors.

The first form of illegal logging commonly found was in situ chainsaw milling. This is where chainsaw operators move into the forest either with or without the support of landowners and community members to fell and mill timber. This was common as 68 cases of this type of logging were reported at the GSBA in the Tano-Offin FR at the forest district office between 2010 and 2014. The second occurred where TUC holders and other timber contractors with felling permits working in timber production compartments stray into adjoining GSBAs to illegally fell trees, with or without the connivance of other actors such as landowners and FSD staff. This trespassing according to respondents and confirmed by official records on file is attributed to unclear delineation of the forest compartments and internal regime

boundaries. Within the monitoring period, 13 cases of trespassing were reported in the GSBAs and 18 within the protected areas that share common boundary with production compartments.

The third form of illegal logging which was corroborated by 85% of respondents from the expert group occurred when permits were issued to loggers/TUC holders to evacuate abandoned logs by chainsaw millers who, after felling trees and due to fear of being arrested, abandoned them in the forest. Taking advantage of their entry into the forest, the permit-holding loggers then remove standing trees contrary to stipulations of the permit. In one of the study areas, illegal logging in a protected area was allegedly started by unknown chainsaw operators who felled 11 trees. The district manager recommended for the trees to be evacuated on permits to avoid their economic wastage, but a company permitted to carry out the evacuation stayed in the protection zone for more than 3 months while evacuating the 11 trees, and the permit was renewed thrice as a result of alleged breakdown

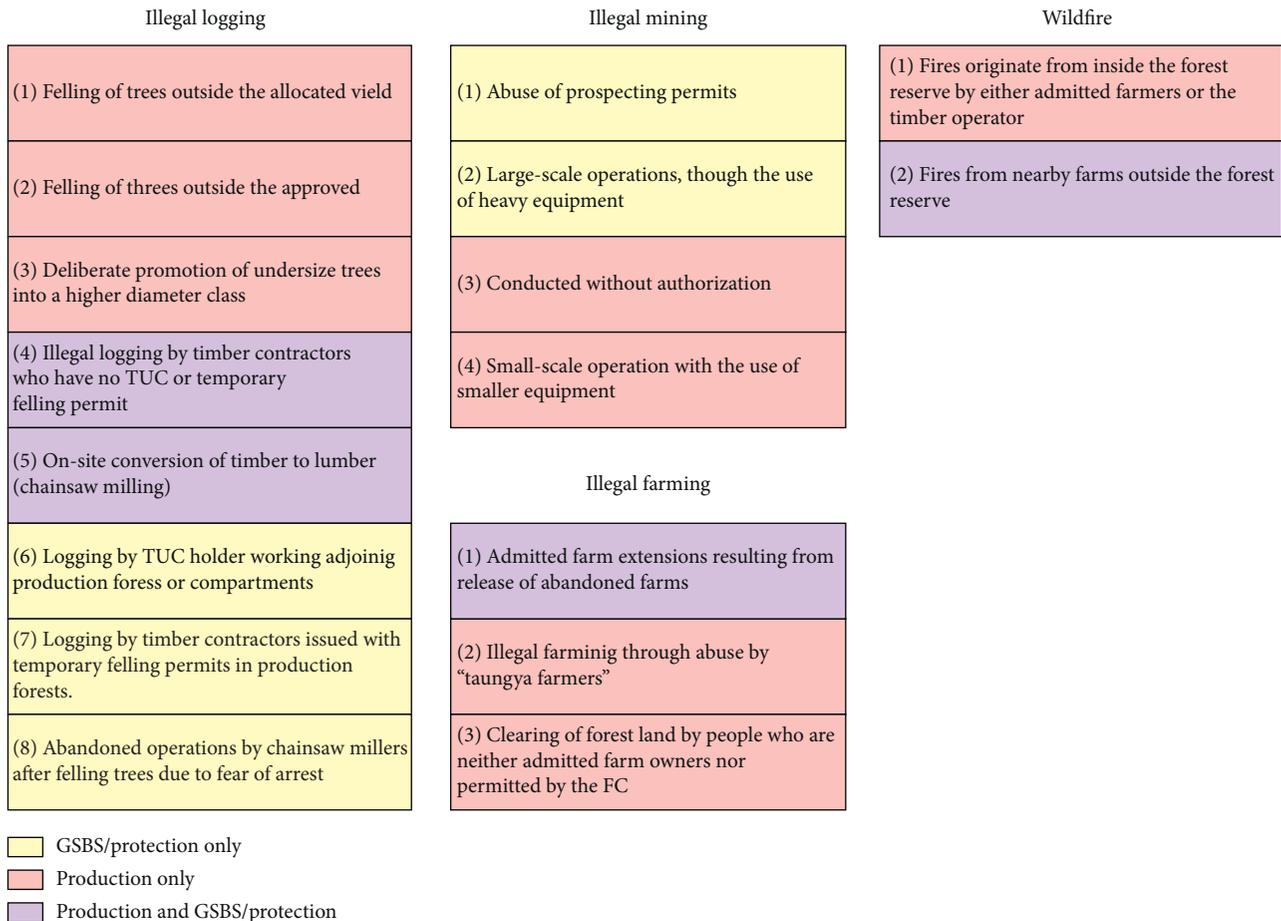


FIGURE 3: Manifestation of drivers in various management regimes.

of machinery. The consequences of this action were that more trees were illegally felled and reported as new ones being discovered because according to the contractor, they had been concealed under the forest canopy and he could not see them on previous occasions. The area got opened up as access roads were created and other illegal activities, especially chainsaw milling, expanded. The fourth type of illegal logging the study found in these regimes was carried out by loggers who had neither TUCs nor entry permits but they simply dashed into the reserves in a hit-and-run fashion to steal trees with or without the connivance of landowners. This was common in the Tano-Offin FR where 14 of such incidences were recorded at the district.

From the interviews and review of official documents, it was observed that about 60% of the offences reported were triggered by chainsaw operators, whilst TUC holders and timber contractors were often cited for hiding behind the chainsaw operators in perpetuating this act of illegalities. About 70% of respondents from the expert group agreed that landowners and FC staff collaborate and aid the other actors to illegally log in these regimes.

Though illegal logging in this management regime is on the decline according to FC respondents, it was found that economically rare and highly sought-after species were normally those felled from the regime.

Lack of revenue flow from GSBA and other protected areas to landowners, which the study observed as a major underlying cause, according to respondents from the FC, compels landowners to aid illegal operators by selling trees to them. This was also confirmed during the focus group discussion, and this is how a respondent who buys from landowners expressed it: *“Due to this revenue disparity between production forests and GSBA plus other protected areas, these communities especially their chiefs feel disgruntled. Consequently, chiefs and sometimes opinion leaders illegally sell trees to us (chainsaw operators, TUC holders working in adjoining compartments of production forests as well as timber contractors who have neither TUCs nor felling permits)”*.

On the issue of ground rent, TUC holders interviewed complained about how they are being made to pay for entire forest reserves (with both production and protection regimes) when they are entitled to harvest only from production compartments. Some of these TUC holders who pay ground rent for protected areas fell trees illegally to defray their cost. Four of such cases were reported in 2017 at the Bia North FR, and 80% of TUC holders interviewed confirmed the practice. The offence reports indicated that when such trees are felled, the TUC holder or contractor without TUCs may either report the incident to the Forest Services Division

(FSD) as stolen and abandoned logs by an unknown agent or move logs without reporting to the FSD. Where a report is made, FSD then sells logs to the TUC holder by issuing a permit to regularize the acquisition of the logs. However, 80% of TUC holders interviewed indicated that these temporary permits are often abused by felling additional trees other than the approved ones, mostly with the connivance of FC officials. As stated before, 70% of respondents from the traditional authorities and the fringe communities claimed that TUC holders or timber contractors sometimes fell trees with the connivance of FC officials. About 80% of TUC holders interviewed indicated that being aware of the risk associated with logging in a forest reserve, they mostly connive with FSD officials by paying monies to them, whilst they in turn aid them to comfortably work in the forest and also allow them to use other company's property mark to help them secure transportation documents to cover the products. This assertion of connivance was confirmed by 45% of respondents from the FC. This explains the identification of corruption as a driver of illegal logging in this regime.

It was also found that poor forest monitoring was responsible for the perceived high level of illegalities. In confirming this, a mix of respondents revealed that some contractors monitor officials of the FSD to know their movement so as to outwit them. They stated that illegal loggers normally operate at night, on holidays, and during the weekends when officers may not be on duty. They said because of the high risk associated with such activities, they usually operate in accessible areas such as road side where they can avoid long skidding distances in what they term as "fell and take." It was also alleged that FSD staff usually give less priority to GSBA and protection forest monitoring compared to production forests. On the issue of sanctions, the penalties meted out to illegal loggers were cited to be too low to deter offenders from committing further forest crimes. In cases where offences are detected by FC staff, the loggers'/TUC holders are sanctioned to pay penalties equivalent to ten times the stumpage fee of the stolen tree. However, respondents from the FC indicated that these penalties are not deterrent enough since the stumpage fees on which the penalties are calculated are too small, and in some instances, offenders hide behind politicians to avoid being penalized.

3.1.2. Illegal Logging in the Production Management Regime and Its Main Actors. Logging in this regime is allowed on a sustainable basis using the selective logging practices. TUC holders and timber contractors are given permission to fell prescribed amount of trees based on the approved yield. Nevertheless, illegal logging does occur in this regime, and our analysis indicated that it does manifest itself in five distinct ways.

The first form, which we called outside yield felling, was observed to occur when TUC holders/lease-holding timber contractors operating under a prescribed yield in an approved compartment fell trees other than those allocated to them with or without the connivance of FSD officials. About

65% of offence reports reviewed revealed that one way in which this occurs is the swapping of allocated low-value species with unallocated high-value species or allocated low-quality trees with unallocated high-quality ones of the same species. These actors do so by scraping off the original stock numbers and replacing them with numbers of the preferred trees. Similarly, stock numbers approved in the yield for felling the lesser-known species are exchanged and used to remove other species which are considered more valuable. For example, in the offence report for Tano-Offin and Bia North FRs, the offenders swapped yield numbers for *Chrysophyllum albidum* (akasa) with *Aningeria robusta* (asanfina). Concession holders without any reference to the yield can also fell trees. In this case, the contractor fells an unapproved tree and conceals his action by burying the stump of the felled tree. Highly valuable species such as *Milicia excelsa* (odum) and *Tieghemela heckelii* (makore) were cited as those that are stolen by contractors in this fashion.

Other forms of harvesting outside the yield were cases where trees along the main access road to the harvested compartments were deliberately felled with the pretext that they posed threat during road construction and also trespassing into adjoining production compartments to fell trees. In the latter case, TUC holders repeat the stock numbers from their operating compartments and, with the connivance of officials, secure transportation documents to convey the logs. Loggers involved in this illegality through an interview disclosed that they normally indulge in this act of swapping and other forms of felling more trees outside the approved yield in order to fulfill their contract volumes that the approved yield allocation in most cases cannot satisfy and to reduce logging cost.

The second form of illegal logging is when TUC holders hide behind chainsaw operators and contract them to fell trees in compartments that are not yet due for harvesting knowing very well that, as concession holders, they will be given the first option of evacuating such logs. When such trees are felled, TUC holders report the incident to the FSD as stolen but abandoned logs by the unknown agent. The FSD then grants the TUC holder a permit to regularize the acquisition of such logs.

The third form of illegal logging is when undersize trees are promoted into higher girth classes and allowed for felling. These occurred when undersized trees are deliberately assigned higher diameters by stock survey teams (FC staff) and included in the yield for felling. For instance, in the Bia North FR, stock/tree number 656 which was a mahogany was measured as 94 cm, but in the stock book, it had been indicated as 110 cm; it was noted that the felling diameter limit for mahogany was 110 cm, so if the actual diameter of 94 cm had been indicated, it would not have qualified to be included in the approved yield. This deliberate act, which was synonymous with the heavily demanded tree species, increases the number of trees to be felled from a compartment. Respondents from TUC holders and loggers admitted that, in some cases, this had to be done to qualify a poorly stocked area for harvesting and, in other instances, to help increase the number of desirable trees that are to be included in the approved yield for felling.

The fourth form of illegal logging, which was not common, was logging by timber contractors who had neither TUCs nor temporary felling permit. In this regime, it is highly risky for such contractors to operate since most TUC holders have concession guards who collaborate with FSD officials to clamp down on illegalities by outsiders. Notwithstanding, some connived with concession guards and officials of the FSD to perpetuate such crime as indicated by landowners and fringe community members. Though TUC holders corroborated this assertion, respondents from the FC disagreed but rather cited community members and concession guards to be behind this form of illegalities.

The last form of illegal logging is the on-site conversion of timber into lumber using the chainsaw machine. This either involved chainsaw operators of small timber companies who are normally employed from forest fringe communities or chainsaw operating gangs whose main preoccupation is illegal chainsaw milling in and outside forest reserves. Those operators engaged from the fringe communities, having previously worked in the forest, know where the quality trees are located and have become conversant with the amount of laxity in forest law enforcement by the forestry officers. They therefore return to saw the leftover trees knowing very well when they can easily operate without the offence being detected. This was identified with areas where TUC holders sublet the timber operations to smaller companies to log on their behalf. In the second form of illegal chainsaw milling, operators carry out their activities with or without the connivance of other forest actors. Chainsaw operators interviewed revealed that because of the many actors involved in this regime, it makes it highly risky to operate without detection, so in most cases, they pay off the major actors (concession guards, forestry officials, and opinion leaders) before they enter into the forest. One chainsaw operator revealed that “*whilst some chiefs sell the trees to us, others rather request for lumber with the pretext of using it for community projects before allowing us into the forest.*” According to FC officials, accessibility, created as a result of timber harvesting, triggers the influx of chainsaw activities since it offers easy transportation of lumber from the forests into the local timber markets.

We observed that illegal logging in this regime was driven by some underlying factors such as those described in the following:

- (1) The granting of compartment re-entry permits to harvest residual yield: the FC logging manual requires a compartment to be closed 3 years after being opened for harvesting, and when such compartment is closed, returning into it within the current contract is not permitted. The rationale, as explained by experts, is to ensure that natural regeneration is not tampered with from further disturbances that may result from re-entering to extract residual yield. This notwithstanding, our data suggest that compartments which had been closed from harvesting and on the verge of recovery after going through a dormancy period of 4–7 years had been issued with entry permits from the Forestry Commission to remove

yield balance from previous operations. Summary of the reasons from the document reviewed includes the inability of the TUC holder to exhaust their allocated yield and unavailability of market for the species at the time of previous harvest. Unfortunately, due to poor record keeping and the passage of time, there are inaccuracies in the yield balance. In addition, permit holders find it difficult to find the trees in the allocated yield balance; therefore, they harvest different trees in substitution and use the stock numbers from the yield to aid them in evacuating the illegally felled trees. This observation was corroborated by 75% of respondents from the TUC holders and FSD field officers.

- (2) Overdependence on few species: overdependence of few species was cited as a reason (driver) for illegal logging. Respondents from the FC complained that it is always difficult to get timber companies to harvest the lesser-known species when they are included in the prescribed yield. The industry still relies on the few traditional species for exports; hence, it indulges in various forms of illicit harvesting to compensate for shortfalls in its export targets for the traditional species.

Other underlying factors mentioned included weak enforcement of forest regulations, poor monitoring of forest operations, and corruption on the part of FC officials.

3.2. Illegal Farming as a Driver of Forest Cover Change. Illegal farming is the conversion of forest land into a farmland or agricultural land without authorization from a competent forest authority. This driver also was found to manifest in different forms in the regimes.

3.2.1. Illegal Farming in GSBA and Other Protection Regimes and Its Main Actors. Two forms of illegal farming manifested in GSBA and protection regimes. The first was through admitted farm extensions. It was observed that some chiefs and family heads, who are the original owners of admitted farms, either sell their farms to migrant settlers or enter into a benefit-sharing arrangement with them to work on the farms. Farmers take advantage of the not properly pillared and check-surveyed admitted farms to extend the sizes of their farms. Check surveys conducted in 11 admitted farms randomly selected from three reserves, for example, showed a mean extension of 7 ± 3.25 ha per farm with current area significantly higher than the original size (Table 3).

The second form of illegal farming observed in this regime was clearing of forest land by people who are neither admitted farm owners nor have been permitted to do so by the Forestry Commission. Respondents claimed that the GSBA created cover part of their forestland previously used for farming. They are therefore compelled to enter and illegally farm in protest to take back their land, especially since the FSD has failed to provide them with extra farmlands. Poor supervision from staff of the FC was observed as the

TABLE 3: Comparative analysis of check survey of some selected farms ($n = 11$) in three forest reserves.

| | Original area (Ha) | Current area (Ha) |
|----------------|--------------------|-------------------|
| Mean | 6.633636364 | 13.98636364 |
| Df | 10 | |
| <i>t</i> -stat | -2.260734809 | |
| <i>p</i> | 0.047309419 | |

main underlying cause to these extensions. It became evident during the study that because protected areas do not have major activities, supervisory efforts are more concentrated in the productive parts of the reserve resulting in farm extensions in probably all the GSBA and protected areas.

3.2.2. Illegal Farming in the Production Regimes and Its Main Actors. Four different forms of illegal farming were observed in this regime. The first was through admitted farm extensions as observed in the protection regime. However, for this regime, most of them originated as a result of the release of abandoned admitted farms to farmers. Farmers who were fortunate to have their ancestral admitted farmlands released to them regrettably abused this right by extending the boundaries of the admitted farms in the false belief that their unlawful conduct would not be detected. Some farmers interviewed also revealed that they sold their released admitted farms to migrant farmers, who in a bid to reap higher benefits from their investments extended their farms.

The second form of illegal farming was through abuse by “taungya farmers.” It was detected that some taungya farmers used by the FC to reforest degraded forest lands overstayed after the program and cleared portions of the forest for farming. When questioned why they betrayed the trust the Commission had in them by indulging in this illegal act, one taungya headman who doubles as a subchief sums it this way: “*all these years we were made to believe by the FC that forest reserves cannot be cleared for any purpose, and so if they have allocated portions to us to farm and it's possible, why do we have to wait for them again when in fact we own the forest?*”

The third form of illegal farming was through the allocation of forest lands to private plantation developers for reforestation. Some of the private developers adopted the taungya approach for reforestation where farmers were invited to plant their agricultural crops together with the trees. Because the farmers only reward was their food produce, they concentrated on the agricultural crops and mostly abandoned the tree-planting component. Therefore, after harvesting their produce, they were chased out of the land by the developers, and many of them ended up in the adjoining part of the reserve which was not allocated for reforestation to farm. The last form of illegal farming observed in this regime was through encroachment by farmers who had sold their off-reserve farmlands to illegal miners. After they had lost their lands to mining, but probably had not made enough money to migrate to other livelihood pursuits, the farmers turned to the forest reserve for farming.

The main actors identified in illegal farming in this regime were staff of FC, farmers (taungya and nontaungya), and private plantation developers. Poor supervision as a result of inadequate staff (forest guards) to man various beats of the forest reserves and weak forest law enforcement underpin illegal farming in this regime. In addition, penalties meted out by the law courts to farmers who encroach on forest reserves are not deterrent enough. This rather served as a motivation to offenders than a deterrent to stop them.

3.3. Wildfire as a Driver of Forest Cover Change. Wildfires in this study refer to uncontrolled fires that sweep through forests. They are destructive and cause forest canopy loss.

3.3.1. Wildfire in GSBA and Other Protection Regimes and Its Main Actors. In GSBA and protection regimes, fires originated from both inside and outside the reserve. Those from outside the reserve occurred when fires from nearby farms find their way into the forest. However, those that originated from inside the reserve occurred when hunters burn portions of the degraded forest reserve with the aim of trapping wildlife. For instance, in Bia North, it was detected during the field visit and interviews that fires were set to trap wildlife that had found their way from the adjoining wildlife conservation area (Bia South) into the reserve. Because of high protection levels at the wildlife conservation areas, hunters see Bia North with limited protection as a haven for hunting since it is a corridor for wildlife. With the exception of the wet and moist evergreen forests, the rest of the reserves in the Upland Evergreen and Dry Semideciduous zones experience annual fire outbreak.

In this regime, only two major actors played various roles in the setting out of wildfires. They were hunters and farmers who farm along the reserves. Lack of collaboration among major stakeholders (staff of FC, farmers, and fringe communities) and inadequate community sensitization were identified as major underlying causes of wildfires. Farmers and community members interviewed bemoaned the level of collaboration between them and FC as respondents say they have not had any form of education on fire prevention and control mechanisms.

3.3.2. Wildfire in Production Regimes and Its Main Actors. In production regimes, almost all fires start from within the forest reserve with the exception of the annual fire outbreak in the Tano Offin FR, which begins from outside the forest reserve by farmers and cattle herders who deliberately burn the grasses to stimulate the growth of fresh grass for the cattle. The data gathered indicate that fires originating from the inside reserve were set by either admitted farmers or timber operators. Interviewees revealed that admitted farmers, especially those operating under the modified taungya system, due to fear of being ejected from the forest after canopy closure of their plots, deliberately set fire to the plots to kill the planted trees so that they can continue to farm on the plots. Also, during land preparation, fires from

admitted farms often get out of hand and spread to other parts of the reserve. Timber operators, on the contrary, allegedly, set fire to compartments not due for harvesting and later apply to salvage burnt and dying trees from the burnt compartment. This source of wildfire may not be widespread but was a suspected case in the Tano-Offin FR. In the Tano-Offin FR case, though yield marking was granted for the trees to be salvaged, there was no evidence on file to substantiate claims of arson.

The main underlying causes of these fires are poor forest monitoring, lack of control over forest users, and the absence of a fire management plan.

3.4. Illegal Mining as a Driver of Forest Cover Change. This involves mining activity in any form that is undertaken in a forest reserve without authorization from a competent forest authority.

3.4.1. Illegal Mining in GSBAs and Other Protection Regimes and Its Main Actors. Documents reviewed and field visits revealed that illegal mining in this regime occurred in recent times mainly due to abuse of prospecting permits that were granted to some mining companies. These prospecting permits were not supposed to result in serious forest disturbance (open the forest canopy or cause tree removal); however, as at the time of field verification, some had been converted into full-scale mining without approval from the FC (Figures 4 and 5). Respondents from the fringe communities reiterated that it was the introduction of the permit system that brought illegal mining into these two reserves. This establishes the fact that illegal mining operations began after the Forestry Commission had gone contrary to its own rules to issue a prospecting permit to two companies in both Fure River and Tano-Offin FRs. Until then, records of mining in Fure River and Tano-Offin Forest Reserves only existed in previous working plans dated as far back as 1928. Heavy-duty mining equipment was found being used in both reserves.

It is without doubt that poor management decisions by the Forestry Commission (FC) in granting prospecting permits in a protected area, which was also driven by political pressure, were the underlying causes to this illegal mining.

3.4.2. Illegal Mining in the Production Regimes and Its Main Actors. In this regime, small implements and tools were used for illegal mining (galamsey). We observed that the illegal operators work in groups with leaders who finance the operations. Usually, they are armed making it difficult for forest guards to confront them. The study revealed that even though these operators work without authorization because of the kind of implements being used by them, their level of destruction was not comparable to what was observed in the GSBAs.

In instances where the FC collaborates with the security agencies to effect arrests, the operators often get political support to escape prosecutions, and when they are prosecuted, the fines are not deterrent enough. For instance,

between August 17, 2017, and September 5, 2017, 11 people who were arrested from the Fure River FR and prosecuted at the law courts on charges of illegal mining were fined between 40 and 80 penalty units amounting to GHC 480–GHC 960, respectively (District 4th Quarterly reports, 2017). This was despite the fact that Forest Protection Amendment Act 624 of 2002, section 1 subsection 1(i), on which they were charged prescribes penalty units not exceeding 500 or to imprisonment not exceeding 2 years or to both.

Illegal mining in this regime was driven by inadequate protection measures put in place by both the mining lease holders and the FC. Whilst FC staff are not armed to fight the illegal miners who are well equipped with arms, the mine concession holders do not even have concession guards in place to complement the efforts of FC staff.

4. Discussion

The current study aimed at interrogating how different forest management regimes in the high forest zone of Ghana bring different perspectives to the meaning of forest cover loss and its drivers of change. Results indicated that the factors responsible for forest cover change manifested themselves differently within various management regimes and often had specific actors behind them. These drivers were observed to be multifaceted and intertwined similar to what was observed by [20].

4.1. Illegal Logging. The fight against illegal logging over the years is reported to be a topmost priority for Ghana [21]. Notwithstanding, this study observed illegal logging is widespread and manifests differently across regimes. This confirms earlier studies conducted by Birikorang et al. and Glastra [22, 23], but contrary to the argument that forest protection in conservation priority areas, such as biodiversity hotspots, is more effective and likely to impact positively on forest cover retention [3, 12].

One observation made in this study is that, in the GSBAs and protection regimes, offenders seem to engage many actors in perpetuating the illegalities than in the production regime. This was similar to what was reported by Boakye [24] in his analysis of what motivates chainsaw milling in Ghana. The observation could be attributed to the fact that because GSBAs and protection areas are excluded from logging, they are high-risk areas to illegal loggers; hence, they strategize to involve many actors as a means to reduce the risk of being apprehended. It was also evident that the manifestation of illegal logging in the GSBAs and other protection areas was not as complex as that of the production regime. This is probably because in the GSBAs, the actors will normally be in a hurry to orchestrate the illegal act to avoid detection since they do not have the right to operate in the forest in the first place. Where they have temporary rights, such as right to evacuate abandoned logs, their stay in the forest is for a short duration and may be closely monitored.

Manifestation of illegal logging in the production regimes appeared more complex possibly due to the fact that logging is permitted in these regimes. Most of the actors are



FIGURE 4: Remnant portions of the Fure River Forest Reserve GSBA adjoining the prospecting area.



FIGURE 5: Scene of the prospecting area in Fure River Forest Reserve GSBA turned into surface mining.

“insiders,” i.e., stakeholders who have legal entitlement to the forest in one way or the other; hence, they have a lot of room to manipulate the system. Stakeholders such as TUC or concession holders have up to at least three years within which to stay in a compartment. This period offers enough time to plan and execute illegal activities in a manner that allows them to cover their tracks. Also, within this same period, in most cases, the same FC officials supervise the actors, so there is the possibility of compromising professionalism due to familiarity. Some of the forms in which illegal logging takes such as deliberate promotion of undersize trees to qualify them for felling in the approved yield, scrapping off stock numbers, swapping trees, and burying stumps in attempt to fell more trees than the allocated yield have not been identified by other studies. This shows how sophisticated illegal logging has become and how far the actors are prepared to go in order to satisfy their resource needs. It also demonstrates high probability of multiple actor involvement and lends credence to the respondents’ claim of corruption and other unprofessional practices by FC officials connected with logging.

Concerning the underlying drivers of illegal logging, our observations point to issues which are similar in all regimes as well as those that appear specific to some regimes. For instance, issues of corruption, poor forest monitoring, and weak law enforcement ran across all regimes and have been widely reported by other studies [2, 24–26]. However, the lack of revenue flow to forest land owners and loss of felling rights to timber right holders were unique to GSBA and protected areas. Regarding forest revenue, landowners and TUC holders claimed they were not adequately consulted in the creation of GSBA and protection areas although the FC knew the decision to create these regimes would deprive landowners and TUC holders of revenue. Such situations according to [11] do create perverse incentives that drive forest degradation. Although the GSBA management plans show that stakeholder consultation was quite elaborate [3] and therefore the above stated claims may not be accurate, the fact that no compensation was paid for these areas and there is no revenue generation from the GSBA and protection areas make it a litigious case with very uncertain stakeholder collaboration outcome. In production forests,

the underlying drivers have their root in the desire of timber contractors to maintain their production levels in the face of dwindling raw material base and reliance on few traditional export species. These drivers underscore the need for Ghana to support its timber harvesting with robust silvicultural treatments to encourage forest regeneration and early replacement of harvested stock as suggested by various studies [27].

4.2. Illegal Farming. The study observed that illegal farming manifests itself differently across the regimes even though, in most cases, it originated from admitted farm extensions. The policy of allowing admitted farmers the right to continue farming in agricultural field enclaves in forest reserves was well intended; however, it has now become more problematic because these farmers continue to extend their farms to the detriment of the forest. This admitted farm extension phenomenon observed by this study tends to follow a historical antecedent because it confirms the work of Owubah et al. [28], who observed similar forest reserve encroachment in the Tano-Ehuro Forest Reserve in the Western Region of Ghana. RMSC [29] also revealed the widespread nature of the problem in the country.

The regime effect on illegal farming is revealed through the type of farmers involved in the encroachment and the point of entry for encroachment. Whilst in the GSBAs and protected areas, encroachers are farmers, most of whom had no farming rights in the forest and operate from healthy looking forests, in the production forests, encroachers were mainly previous modified taungya farmers and farmers of private developers who have taken over degraded forest areas which have been abandoned by private plantation developers. The upsurge of illegal farming in the production regime may be attributed to the poor monitoring on the part of FC officials. This observation is consistent with that of Watson [30] who reported that although the taungya system is considered as a low-cost mechanism by governments for forest plantation development, the influx of illegal farmers that is left in its wake to perpetuate illegal farming is expected to be more costly and devastating to forest estates. The involvement of modified taungya farmers in forest encroachment betrays the spirit of collaboration between the FC and forest fringe communities, but more importantly, the results suggest that collaboration could turn into a driver of deforestation if not managed well.

4.3. Wildfire Regimes. The study found that, with the exception of the Wet Evergreen forest type, wildfires drive forest degradation and deforestation, especially in the Moist Semideciduous zone. This is not surprising since the Wet Evergreen zone has the highest rainfall in Ghana, whilst high temperatures, occasional droughts, and the "invasion" of grass species characterize the Moist Semideciduous zone [17]. It was, however, interesting to note that the origin of wildfires was different among the management regimes, suggesting a link between forest use and fire incidences.

The main actors behind wildfires were hunters and farmers; thus, fire is linked to the pursuit of livelihood

activities in all the regimes, yet the perception of fire incidences was higher in the production regime. Technically, production forests are more prone to wildfires due to desiccation resulting from canopy opening and the rise in fuel load following logging [31]. This may partly explain the above claim. However, it can also be argued that the two regimes face different levels of fire threat. For instance, it was observed that a contractor deliberately sets fire to a forest in order to gain access to fire-damaged trees for salvage felling. Although it appears as an isolated case, the relatively large number of fire-damaged trees that are harvested through salvage permits gives cause to speculate that persistent wildfires in TUC areas may have incendiary motives and are probably triggered by the industry players for their economic interest.

4.4. Illegal Mining. Officially, mining is allowed to a certain extent (max. 2% of the forest reserve area) in production reserves but not in GSBAs and protected areas [32]. However, the results show that both officially sanctioned mining and illegal ones were quite common in production as well as GSBAs and protected areas. For now, it is not clear if management regimes impact differently on illegal mining; what is evident, nonetheless, is the fact that mining is now an important driver of forest cover loss in forest reserves, a situation that was probably unthinkable a few years ago. Similar impact of mining on forests was reported by Asner and Tupayachi [33] in Peru where gold mining has led to the degradation of Peruvian Amazon forest reserves and continues to pose a major threat to biodiversity, water quality, forest carbon stocks, and human health.

Illegal mining in at least one of the GSBAs was triggered by unprofessional judgment of officials of the FC in granting a prospecting permit that metamorphosed into surface mining. Though the Commission maintains that it did not grant mining permits to the companies, the granting of the prospecting permits was in itself inconsistent with the forest reserves' strategic management plan [34], and the claim that the decision was as a result of political interference creates uncertainty about the FC's ability to control mining in forest reserves. It is evident from the study that there are no signs that illegal mining is going to be stopped due to the influence of politicians and inadequate punishment meted to offenders. Already Ghana is reported to be among countries with the highest rate of deforestation in the world [35] with the deforestation rate of 2.19 percent per annum [10]. Mining in forest reserves if not remedied will jeopardize the already precarious state of forest degradation in the country.

5. Conclusions

The drivers of deforestation and forest degradation identified in this study were not always similar across various management regimes, likewise their manifestations and the actors behind them. The study confirms the assertion that drivers of deforestation and forest degradation can hardly be reduced to a single factor causation variable; rather, the interplay of several proximate as well as underlying factors

drives forest degradation in a synergetic way. Illegal logging and illegal mining appeared the most intriguing in terms of taking different shapes because they manifested uniquely in all the regimes studied. TUC holders, FC officials, farmers, community members, and some landowners were the major actors that orchestrated illegalities in all the regimes (GSBA, protection, and production). These actors performed different roles in different regimes in driving illegalities. The strive by forest landowners to earn revenue from forest areas excluded from timber harvesting, professional indiscretion of the management authority of the Forestry Commission aided by political interest in the issuance of timber harvesting and mineral prospecting permits, poor forest monitoring, and perceived corruption on the part of FC officials were the strongest underlying factors that exerted the strongest impact on how the drivers manifested in various forest management regimes. The study therefore identifies the primary forest stakeholders of the country as the main actors of forest degradation who have developed various means convenient for specific regimes that enable them to benefit from the forest at the expense of conservation.

Data Availability

All data used will be available on the corresponding author's research gate page and also will be made available when requested.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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References

- [1] P. H. Verburg, N. Crossman, E. C. Ellis et al., "Land system science and sustainable development of the earth system: a global land project perspective," *Anthropocene*, vol. 12, pp. 29–41, 2015.
- [2] G. P. Asner, D. E. Knapp, E. N. Broadbent, P. J. C. Oliveira, M. Keller, and J. N. Silva, "Selective logging in the Brazilian amazon," *Science*, vol. 310, 2005.
- [3] E. F. Lambin, H. J. Geist, and E. Lepers, "Dynamics of land-use and land-cover change in tropical regions," *Annual Review of Environment and Resources*, vol. 28, no. 1, pp. 205–241, 2003.
- [4] GRPS, "Ghana REDD+ strategy," 2016, <https://www.fcghana.org/userfiles/files/REDD+/GhanaREDD+Strategy.pdf>.
- [5] UNFCCC, "Outcome of the work of the ad hoc working group on long-term cooperative action under the convention—policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries: and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries," in *Proceedings of the United Nations Framework Convention on Climate Change Conference*, Durban, South Africa, 2010.
- [6] R. Bendorf, S. Federici, C. Forner et al., "Including land use, land-use change, and forestry in future climate change, agreements: thinking outside the box," *Environmental Science & Policy*, vol. 10, no. 4, pp. 283–294, 2007.
- [7] UNFCCC, "Report of the conference of the parties on its fifteenth session, held in Copenhagen from 7 to 19 December 2009," 2009, <https://unfccc.int/resource/docs/2009/cop15/eng/11a01.pdf>.
- [8] D. Boucher, P. Elias, K. Lininger, C. May-Tobin, S. Roquemore, and E. Saxon, "The root of the problem: what's driving tropical deforestation today?," 2011, <https://www.ucsusa.org/>.
- [9] B. F. T. Rudorff, M. Adami, D. A. Aguiar et al., "The soy moratorium in the amazon biome monitored by remote sensing images," *Remote Sensing*, vol. 3, no. 1, pp. 185–202, 2011.
- [10] "Ghana forest plantation strategy (GFPS): 2016–2040," 2016, <https://fcghana.org/userfiles/files/PlantationAnnualReport/ghanaforestplantationstrategy.pdf>.
- [11] E. Boon and A. Ahenkan, "Enhancing food security and poverty reduction in ghana through non-timber forest products farming: case study of Sefwi Wiawso district," 2008, <https://www.grin.com/document/86653>.
- [12] C. B. Schmitt, M. Denich, S. Demissew, I. Friis, and H. J. Boehmer, "Floristic diversity in fragmented Afro-montane rainforests: altitudinal variation and conservation importance," *Applied Vegetation Science*, vol. 13, pp. 291–304, 2010.
- [13] L. N. Joppa and A. Pfaff, "High and far: biases in the location of protected areas," *PLoS One*, vol. 4, no. 12, Article ID e8273, 2009.
- [14] J. F. Lund and T. Treue, "Are we getting there? Evidence of decentralized forest management from the Tanzanian Miombo woodlands," *World Development*, vol. 36, no. 12, pp. 2780–2800, 2008.
- [15] D. C. Miller, M. Minn, and B. Sinsin, "The importance of national political context to the impacts of international conservation aid: evidence from the national parks of Benin and Niger," *Environmental Research Letters*, vol. 10, no. 11, Article ID 115001, 2015.
- [16] G. D. Wright, K. P. Andersson, C. C. Gibson, and T. P. Evans, "Decentralization can help reduce deforestation when user groups engage with local government," *Proceedings of the National Academy of Sciences*, vol. 113, no. 52, pp. 14958–14963, 2016.
- [17] J. B. Hall and M. D. Swaine, *Distribution and Ecology of Vascular Plants in a Tropical Rain Forest*, Springer Netherlands, The Hague, Netherlands, 1981.
- [18] R. Ho, *Handbook of Univariate and Multivariate Data Analysis and Interpretation with SPSS*, Chapman & Hall/CRC, Boca Raton, FL, USA, 2006.
- [19] U. Flick, *An Introduction to Qualitative Research*, Sage, Thousand Oaks, CA, USA, 3rd edition, 2009.
- [20] A. Banana, M. Buyinza, E. Luoga, and P. Ongugo, "Emerging local economic and social dynamics shaping East African forest landscapes," *Forests and Society: Responding to Global Drivers of Change*, vol. 25, pp. 315–334, IUFRO (International Union of Forestry Research Organizations) Secretariat, Vienna, Austria, 2010.
- [21] MLFM, *The True Cost of Legal Timber*, MLFM, Accra, Ghana, 2005.

- [22] G. Birikorang, R. Okai, K. Asenso-Okyere, S. Afrane, and G. Robinson, *Ghana Wood Industry and Log Export Ban Study Ban*, Forestry Commission, Accra, Ghana, 2001.
- [23] R. Glastra, "Cut and run: illegal logging and timber trade in the tropics," *Friends of the Earth International*, IDRC, Ottawa, Canada, 1999.
- [24] J. Boakye, "Understanding motivations for violation of timber harvesting regulation: the case of chainsaw operators in Ghana," *Forest Policy and Economics*, vol. 87, pp. 85–92, 2017.
- [25] E. Marfo, "Chainsaw milling in Ghana context, drivers and impacts," 2010, https://www.fornis.net/sites/default/files/documents/chainsaw_milling_ghana_marfo.pdf.
- [26] E. Nutakor, E. Marfo, and P. O. Tutu, "Socio-political constraints to the enforcement of forest laws: a case study of chainsaw operations in Ghana," *Ghana Journal of Forestry*, vol. 27, 2011.
- [27] K. A. Adam, M. A. Pinard, and M. D. Swaine, "Nine decades of regulating timber harvest from forest reserves and the status of residual forests in Ghana," *International Forestry Review*, vol. 8, no. 3, pp. 280–296, 2006.
- [28] C. E. Owubah, N. T. Donkor, and R. D. Nsenkyire, "Forest reserve encroachment: the case of Tano-Ehuro forest reserve in Western Ghana," *The International Forestry Review*, vol. 2, pp. 105–111, 2000.
- [29] RMSC, *Inventory and Mapping of Planned on-going Activities in Atewa Forest and Its Immediate Environment*, Resources Management Support Centre, Forestry Commission, Kumasi, Ghana, 2016.
- [30] G. A. Watson, "Development of mixed tree and food crop systems in the humid tropics: a response to population pressure and de-forestation," *Experimental Agriculture*, vol. 19, no. 4, pp. 311–332, 1983.
- [31] M. D. Swaine, V. K. Agyeman, B. Kyere, T. K. Orgle, J. Thomson, and E. M. Veenendaal, "Ecology of forest trees in Ghana (76p)," *ODA Forestry Series No. 7*, Overseas Development Administration, London, UK, 1997.
- [32] Ministry of Lands, Forestry and Mines and Environment Science and Technology (MLFM & MEST), *Environmental Guidelines for Mining in Production Forest Reserves in Ghana (EGMPFRG)*, Ministry of Lands, Forestry and Mines and Environment Science and Technology, Accra, Ghana, 2001.
- [33] G. P. Asner and R. Tupayachi, "Accelerated losses of protected forests from gold mining in the Peruvian Amazon," *Environmental Research Letters*, vol. 12, Article ID 094004, 2017.
- [34] Forest Services Division (FSD), *Fure River Forest Reserve Management Plan (2011–2020)*, Forest Services Division, Accra, Ghana, 2011.
- [35] ITTO, *Status of Tropical Forest Management 2011*, International Tropical Timber Organization, Yokohama, Japan, 2011.