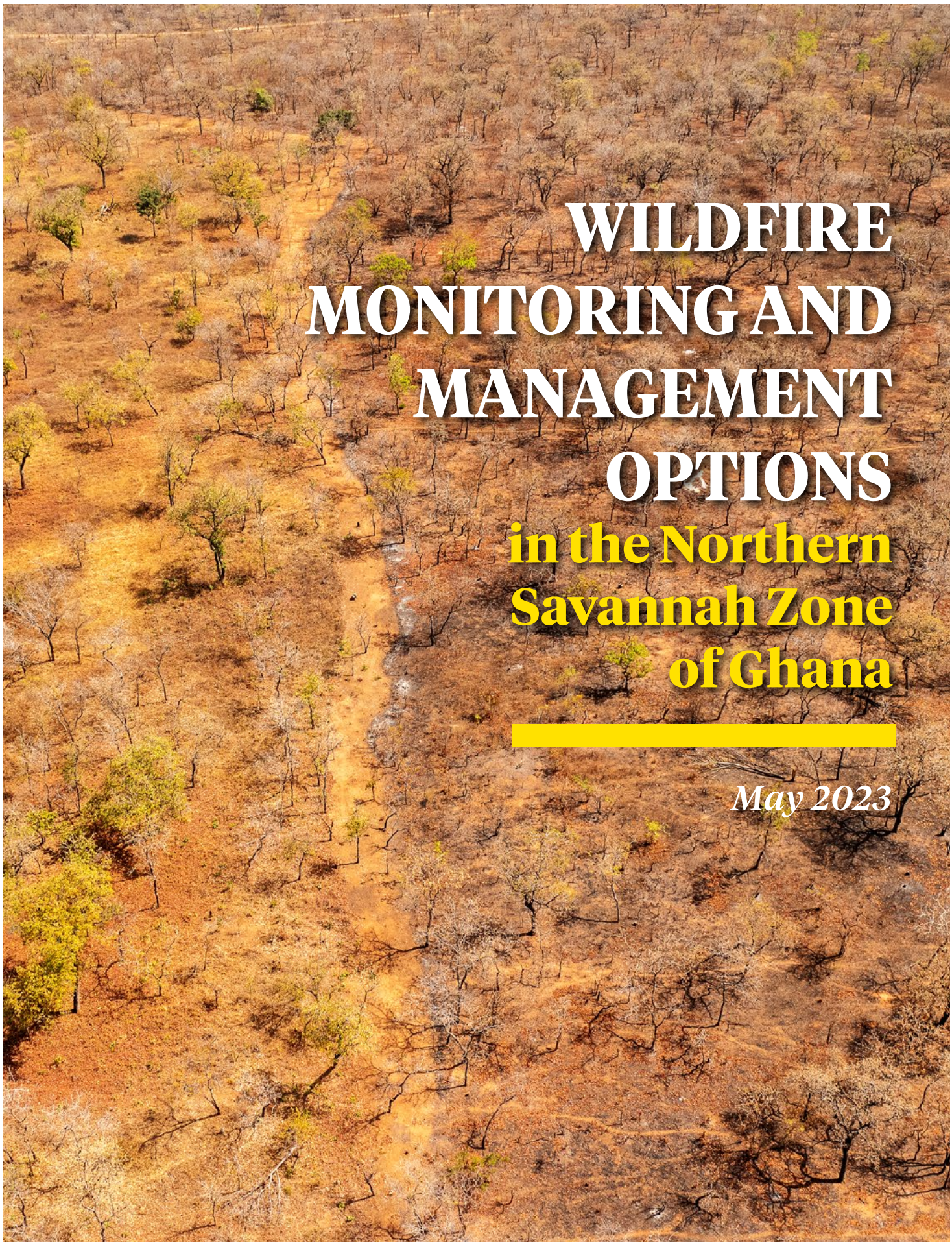

WILDFIRE MONITORING AND MANAGEMENT OPTIONS

in the Northern Savannah Zone of Ghana

May 2023

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Wildfire monitoring and management options in the Northern Savannah Zone of Ghana

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Environment, Natural Resources, and the Blue Economy Global Practice

Abstract

In common with savannah landscapes across Africa, anthropogenic fires have been an important driver of change in Ghana's Northern Savannah Zone (from wooded savannah to a landscape in which grassland appears to be more prevalent. This has significant consequences for ecosystem services. The wildfire situation in NSZ is not well controlled.

This report summarises the findings of an investigation into wildfires and their prevention, monitoring and management in Ghana's Northern Savannah Zone, based on a field assessment, relevant literature, and comparative international experiences. Three Ghanaian examples of community-based fire management approaches are documented. Practical suggestions are made for a remote sensing monitoring system for the region and other improvements in fire prevention and management. Issues requiring further investigation are also highlighted.

Acknowledgements

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Executive Summary

Overview

In common with savannah landscapes across Africa, anthropogenic fires have been an important driver of change in Ghana's Northern Savannah Zone (NSZ) from wooded savannah to a landscape in which grassland appears to be more prevalent. This has significant consequences for ecosystem services.

Grasses grow prolifically in the NSZ in the wet season and provide abundant fuel in the long dry season, which has daily maximum temperatures well above 30°C, resulting in a very high fire risk between December and April. Communities burn firebreaks to protect villages and food stores, and they use fire to flush out game, create fresh shoots for livestock grazing and clear vegetation to open up farms. As human activity increases, so do the sources of ignition and the consequent wildfires.

Wildfires in the NSZ are not well controlled. The Forestry Commission (FC) of Ghana is responsible for fire management within protected areas. Fires elsewhere either burn themselves out or are suppressed by volunteers, but only if community assets are threatened. The Ghana National Fire Service (GNFS) is legally required to respond to all fires, but for a variety of reasons cannot do so in rural areas. There is no other formal system of fire management in the NSZ. The only consistent fire monitoring is conducted within the FC's estate but is incomplete. More extensive and reliable data on fires in the NSZ is essential for proper planning and resourcing.

Lessons from Ghana and elsewhere

Effective fire management requires strong local leadership and delegation of authority from District Assemblies to local leaders and community champions. Rather than seeking to prevent fire altogether, the emphasis should be using fire as a tool to manage vegetation but avoiding uncontrolled wildfires.

Many of the innovations in fire management in fire-prone regions around the world are not suitable for the NSZ due to their high cost relative to the value of the assets being protected. These include full-time fire watches, real-time video monitoring and aerial surveillance. Using a fire danger index is also of questionable value because the dry season weather conditions in the NSZ generate a very high level of fire danger almost continuously. But satellite remote sensing is an affordable and technically appropriate means of improving the identification and monitoring of fires.

High priority recommendations

1. Mandate a single government institution to take responsibility for all issues relating to fire in the NSZ. The obvious institutional choice is the FC, whose role could initially be limited to improving the monitoring of fires in the region, while it is properly resourced to take on fire prevention and management responsibilities across the rural landscape.

2. Ensure that fire management interventions have strong champions in the community who represent, or work closely with, both the District Assembly and local traditional authorities.

3. Establish a satellite-based remote monitoring system for fire in the NSZ to generate a reliable baseline for the whole region and regularly updated fire frequency maps for specific areas.

4. Quantify the value of carbon credits that could be generated by changing from late dry season to early dry season burning and explore how to share the benefits of such a change.

5. Organise an annual conference for knowledge-sharing and exchange of experiences on fire monitoring and management for development organisations working in the NSZ.

Short-Term Recommendations

- Identify a small number of sites (suggest no more than 5), which preferably have some experience with co-operative decision-making, to pilot the changes proposed for devolved fire management decision-making based on the Yameriga experience or Form Ltd models.

- Advocate for the Minerals Commission to include a license requirement that requires artisanal miners to surround their operations with an adequate fire break.

Medium-Term Recommendations

- Validate the RMSC's Feb 2022 land cover map with ground-truthing. Consult savannah ecologists to define the boundary between grassy savannah and grassland, to establish whether the 63% of the landscape designated as grasslands are indeed grasslands.

  If these areas are shown to be grassy savannah, then an annual fire regime will cause no further damage but will also not promote the rapid recovery of the tree component of the vegetation. The only viable route to recovery of a less-grassy savannah at the scale required is the exclusion of fire for a considerable time period. This is extraordinarily difficult to achieve at the scale contemplated here but is perhaps achievable at small scale at various locations.

- Establish a reasonable estimate for the proportion of Late Dry Season fires in the NSZ, to determine whether the pursuit of carbon credits by effecting a change from Late Dry Season to Early Dry Season fire regimes has potential for generating a revenue stream from carbon credits and might, therefore, be worth pursuing.

- Support the development of a fire alert database using EORIC's Advanced Virtual Fire Information System. Fire alerts with time signature should be sent to appropriate forestry district offices. Require each forestry district office to add the following details to the database:

  (i) fire event already known or unknown (i.e., was the office already aware of the fire before the alert or not); and

  (ii) response chosen between:

  - allowed to burn/no action taken; or
  - responded to by FC and/or GNFS; or
  - responded to by volunteers without FC/GNFS assistance.

- Support field evaluations of the IGNIS drone ignition seeding system for fuel reduction burning.
- Strengthen and improve the community volunteer firefighting system by providing more refresher training; adequate basic tools; appropriate PPE; and allowances for firefighters.
- Support a project to promote cultural change amongst management in Government agencies regarding fire in savannah ecosystems. Fire as a necessary management tool is accepted by the FC, but elsewhere in government, fire appears to be seen as a 'menace' and only 'destructive'.
- Following the ground-truthed satellite image analysis proposed above, support a research programme to establish the proportion of the NSZ classified as grasslands that can feasibly be returned to functional savannah. For example, whether there are patches within the landscape classified as 'grassland', of the order of hundreds of hectares at least, where a fire exclusion policy for 3-5 years can be implemented.
- Increase the effort to improve upon the existing educational campaign aimed at preventing accidental ignitions throughout the dry season in rural communities
- Establish pilot sites to achieve community adoption of the seven guiding principles for IFM, as the outcome of a consultative process about the principles, their adaptation and application.

Long-Term Recommendations

- Measure every intervention planned and funded from external sources against the requirement that it sustain itself financially after the funded programme comes to an end.
- Accept that changing fire monitoring and management in the NSZ is a long-term project and an incremental process.

Contents

List of Acronyms

DCFO	Deputy Chief Fire Officer
EDS	Early Dry Season
EORIC	Earth Observation Research & Innovation Centre
FC	Forestry Commission
FDI	Fire Danger Index
GIS	Geographic Information System
GIZ	*Deutsche Gesellschaft für Internationale Zusammenarbeit*
GLRSSMP	Ghana Landscape Restoration and Small-Scale Mining Project
GMet	Ghana Meteorological Agency
GNFS	Ghana National Fire Service
HFZ	High Forest Zone
ICFM	Integrated Community Fire Management
IFM	Integrated Fire Management
LDS	Late Dry Season
MDS	Mid Dry Season
MoFA	Ministry of Food and Agriculture
NGO	Non-Governmental Organization
NSZ	Northern Savannah Zone
RMSC	Resource Management Support Centre
SA	South Africa
WB	World Bank

01

Introduction

1.1 Ghana's Northern Savannah Zone

The Northern Savannah Zone (NSZ) of Ghana comprises 41% of the country's land area,[1] extending northwards from the Black Volta River to the frontier with Burkina Faso (Figure 1). The dominant natural vegetation type is savannah, largely Guinea savannah, with a small area of Sudan savannah in the extreme northeast (SAL Consult, 2010) and gallery forests along some water courses.

1.2 Study objectives

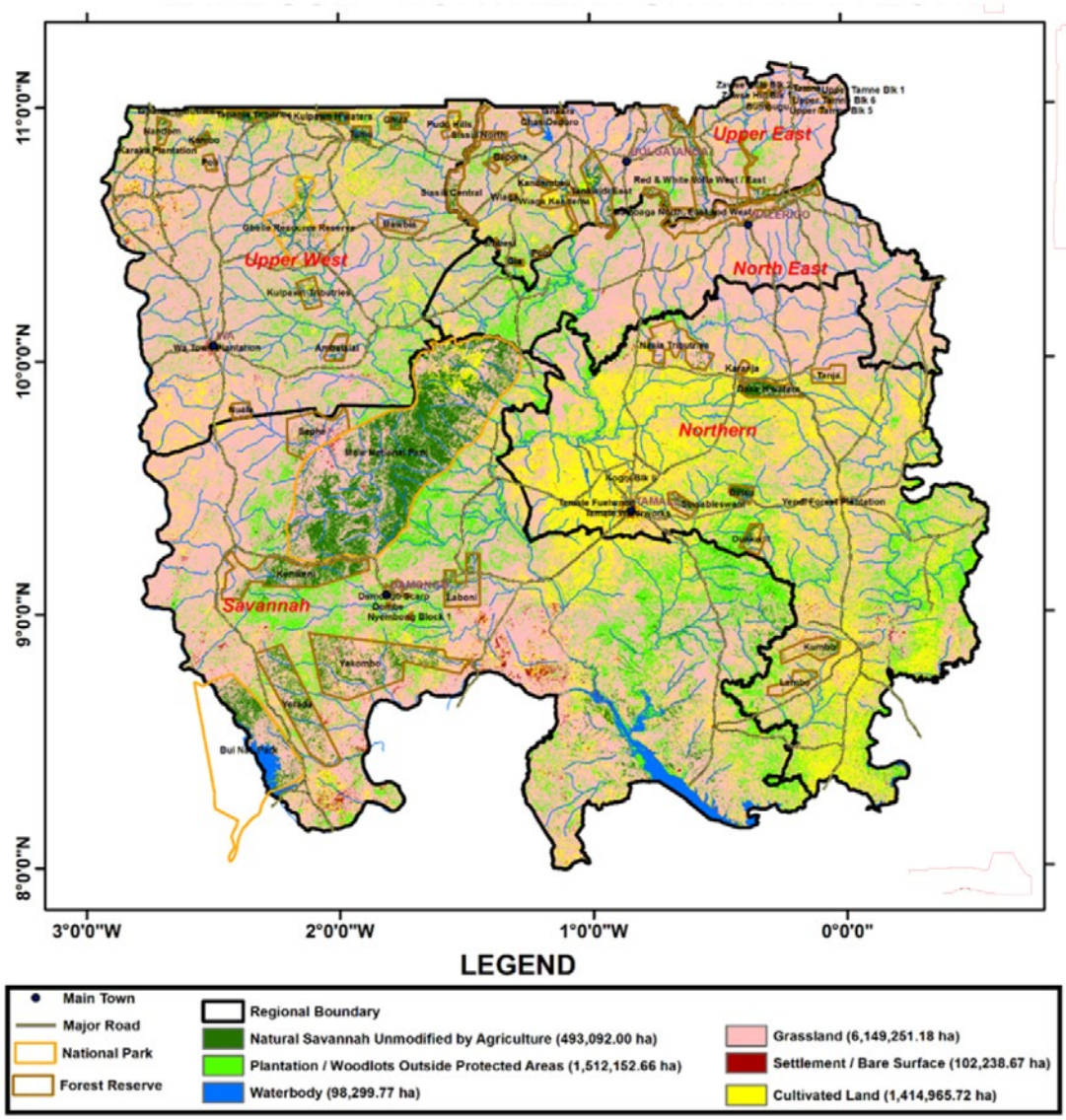
Recognising that fire can be a serious threat to vegetation in savannah landscapes, a rapid assessment of wildfires in the NSZ was commissioned under the World Bank-supported Ghana Landscape Restoration and Small-Scale Mining Project (GLRSSMP). The assessment set out to collate relevant knowledge on fire monitoring and management in the NSZ, investigate promising examples of fire management efforts and promote better understanding of the dynamics of periodic fires in the savannah ecosystem. Options were explored for better monitoring and management of fires in the NSZ, and issues requiring more in-depth investigation were identified.

The target audience for this report is primarily the GLRSSMP team in the World Bank and the Government of Ghana. Natural resource managers of all types, particularly in the Forestry Commission (FC), the Ministry of Lands and Natural Resources and the Ministry of Food and Agriculture (MoFA), should also find the report of value; as should all those engaged in community development initiatives in the NSZ, whether NGOs, government agencies or community members themselves.

It is hoped that the report will focus the attention of natural resource managers on the range of opportunities available for fire prevention and fire management; promote a more balanced view of fire and its role in the savannah than exists currently amongst many government officials; encourage transfer of knowledge from the excellent examples of community-based fire management already present in Ghana; and result in the establishment of a remote sensing solution to significantly improve fire monitoring across the NSZ.

1 The administrative Regions in the NSZ are Savanna (35,862 km²), Northern (25,448 km²), North East (9,072 km²), Upper West (18,476 km²) and Upper East (8,842 km²), totalling 97,700 km2 out of Ghana's land area of 238,535 km².

Figure 1. Land cover in Ghana's Northern Savannah Zone



Source: GIS Section, Resource Management Support Centre (RMSC), Forestry Commission

1.3 Notes on methodology

This report was developed using published and unpublished written material, interviews with a range of actors living in the NSZ or working on aspects of resource management in the region, and the findings of a 10-day field visit in January 2022. It draws on a sample of views, opinions and perspectives, supplemented by the lead author's observations and personal experiences from Brazil, Chile, France, the USA and South Africa. It does not purport to be a complete review of the literature or an exhaustive assessment of possible actions and further research questions, and was not intended to be a rigorous, statistically valid survey.

There is a dearth of reliable information on wildfires in Ghana's NSZ. The only moderately reliable statistics come from the FC's annual fire reports, but these are incomplete and relate mainly to gazetted Forest Reserves. Since the Ghana National Fire Service (GNFS)

does not attend to the overwhelming majority of fires across the rural landscape, its legal mandate notwithstanding, GNFS data on fire across the NSZ did not prove to be useful.

Observers are inclined to assume that their roadside observations give a reasonable indication of the state of the whole, but travelling by road means that the vast majority of the NSZ remains unseen. Interviewee statements such as “the whole place burns every year” are invariably based on a limited observer perspective. Remote sensing is the only reliable and practical means of establishing the facts regarding the area burned annually and other wildfire characteristics. The setting up of a region-wide remote sensing system for monitoring wildfires is therefore one of the study’s prioritised recommendations.

02

Wildfires in the NSZ

2.1 Fires and the African Savannah

Africa has two extensive belts of sub-humid savannah woodlands. North of the equator is the Guinea-Sudan savannah and south of the equator is the wide belt of Miombo woodlands,[2] stretching virtually coast to coast, from Angola to Mozambique and covering much of Tanzania. As the ecological dynamics of these systems are essentially the same, findings on savannah system dynamics are valid across geographies.

The indigenous populations of African savannah areas have used fire as an ecological management tool for centuries (Archibald *et al.*, 2011; Fairhead & Leach, 1995). In general, these people respect (rather than fear) fire and continue to use it as they have always done. Early dry season (EDS) burning to remove moribund grasses and encourage resprouting of palatable shoots for livestock is common practice. This creates a patchwork of burn scars that will resprout at different times. The users of fire do not generally concern themselves with extinguishing fire unless it threatens something of value. Savannah fires typically extinguish themselves when they run out of fuel, often when they burn up to roads or fire breaks in wind conditions that do not allow the fire to jump across.

The ecosystem services provided by the savannah depend on the balance between grasses and trees shifting back and forth like a pendulum, but essentially being maintained. Products like firewood, fruits, nuts and plants with medicinal uses, as well as services reliant on stable carbon stocking and reliable hydrological services, are best delivered by the system remaining in balance, with more trees than grasses in some places and in others the reverse.

Fire, at intervals of approximately three to five years - and more frequently in many cases - is an essential part of maintaining the balance in the savannah between trees and grasses (Louppe *et al.*, 1995; Bond, 2008; Laris *et al.*, 2017; N'Dri *et al.*, 2022). When fires are too frequent or occur consistently in the late dry season (LDS), saplings from germinating tree seeds or resprouting roots do not survive long enough to become fire-tolerant. The ecosystem evolves towards a pure grassland quite rapidly when the interval between fires

2 Miombo woodland is characterized by the dominant presence of *Brachystegia* and *Julbernardia* tree species.

is too short over a long period of time, such as when there are two burns in the same season for several years successively or when LDS burns occurring for several successive seasons. More grass implies greater quantities of fine fuels, so the intensity of the fires, when they occur, increases.

In contrast, long-term experiments in the West African savannah have confirmed that the exclusion of fire eventually results in a closed canopy forest (Prof. William Bond, pers. comm.). An interval of at least three years between fires is a suitable target for maintaining trees. The trees progressively shade out the light-dependent grasses. Sustained overgrazing has the same effect as the exclusion of fire, by eliminating the competition from grasses as well as removing a significant fuel source for fires in the future (Skarpe, 1991).

So fires at an appropriate interval - say three years or less - keep trees in check, by removing saplings and preventing a swing in the direction of a closed canopy forest. The interval between fires should be shorter in moist savannahs, such as the Guinea savannah of the NSZ. The high annual rainfall in these areas, which averaged 1,150 mm between 1960 and 2015 (Incoom *et al.*, 2020), results in prolific fuel loads that require annual burning. Some recruiting tree seedlings and coppice shoots will be destroyed by EDS burning in these systems, but this is not harmful to tree succession because these fires are heterogeneous enough for there to be cooler and unburned patches where enough trees survive or emerge to maintain the tree/grass balance (Louppe *et al.*, 1995; N'dri *et al.*, 2018; Laris *et al.*, 2017; Laris & Wardell, 2006). The optimal interval between fires may be longer than three years in the NSZ's limited area of drier Sudan savannah.

The science indicates that annual EDS burning should be conducted universally. There is no reason to treat the grasslands differently from more heavily wooded areas. When fuel production in the wet season is less prolific, there may be a case for extending the fire interval. So following a particularly poor wet season when the grass sward has not grown vigorously, annual burning may be skipped for that year. The need can be determined on an annual basis.

What should be avoided is the exclusion of fire for extended periods, unless there is a specific aim of restoring the tree stock. Complete exclusion of fire is in any case extremely difficult to achieve, except in relatively small areas such as the gallery forests found along water courses. These areas will not burn at all, barring a period of severe and extended drought, so usually require no protection against fire.

2.2 The impact of tree felling

Fire is not the only process at work in the savannah landscape. Deliberate tree felling can also change the balance between trees and grasses. With sufficient felling, the use of fire to maintain the tree/grass balance is unnecessary. Nevertheless, fire will always be needed to promote early wet season grazing. Fire is also the germination trigger for the seeds of certain plants and a stimulus for fruiting in others. There is no practical means to achieve these effects other than by using fire, preferably by controlled burning rather than wildfires.

Tree-felling in the NSZ may be occurring at an unsustainable rate. This will eventually produce an open grassland with very few trees. However, the grassland that results from

unsustainable tree-felling will not deliver the same ecosystem services as the natural savannah. The loss of these services is of concern to the people living in the region, due to the growing scarcity of wood for domestic cooking and for charcoal production, and the disappearance of certain tree-based medicinal resources and fruits and nuts that provide supplementary food sources or additions to household incomes. Shea trees, previously protected for their cultural and economic value, are now often felled for charcoal.

An initial assumption in this study that charcoal production was a major source of ignition for wildfires proved to be misguided. The team visited many charcoal production sites looking for evidence of smouldering material that could ignite new fires. There was none to be found. On the contrary, partially burned wood is carefully collected and set aside to be included in the next kiln load.

2.3 Land cover dynamics in the NSZ

The area under each land cover type in the NSZ is summarised in Table 1. With 63% of the NSZ already classified as grassland, there appears to be permanent conversion of savannah to open grassland underway, although concrete evidence - such as a vegetation map from 30 years ago for comparison - is apparently unavailable. This profound change will have a serious impact on ecosystem services (Leh *et al.*, 2013; Luvuno *et al.*, 2022; Van Jaarsveld *et al.*, 2005), particularly on hydrology and on the nutritional and medicinal safety net that the savannah provides for the communities living within it.

Table 1. Land cover in the NSZ

Category	Area (ha)	% of land area of NSZ
Natural savannah (unmodified by agriculture)	493,092	5.0
Plantations/woodlots & gallery forest outside Forest Reserves	1,512,153	15.5
Water	98,300	1.0
Grassland	6,149,251	62.9
Settlement/bare surface	102,239	1.0
Cultivated land	1,414,966	14.5
Total area	**9,770,000**	**100.0**
Including:		
National Parks	715,224	7.3
Forest Reserves	665,271	6.8
	1,380,495	**14.1**

Source: GIS Section, RMSC, Forestry Commission

Note: The description 'Plantations/woodlots' is used for areas of woody vegetation outside protected areas, but as this is known to also indicate gallery forest along water courses, the definition has been expanded.

If the NSZ was predominantly natural savannah in the past, with a balance between grasses and trees, the question arises whether it has been irretrievably damaged to the point where no amount of fire exclusion will cause a swing back toward a more treed landscape. It seems unlikely that true savannah will ever recover in many of these areas, although there may be locations where its return is still a possibility. Enrichment planting and reseeding are options on a very limited scale. The slowness of the recovery at Goziir after 35 years of fire exclusion (see 5.1.2 below) should sound a cautionary note.

The land cover classification in Table 1 was produced from satellite data and raises potential interpretative errors[3] that require follow-up by ground-truthing. The most important is the true extent of the 'grassland'. Is this grassland in the ecological sense?[4] Or could it be misclassified farms with crop residues in the fields? Prof. William Bond, a renowned fire ecologist and African savannah specialist from the University of Cape Town, having closely examined Google Earth images and the associated photo galleries, thinks that there may be no grasslands at all in the NSZ, only grassy savannah (pers. comm.). However, the view that these 'grasslands' exist was articulated with conviction by senior FC staff (M. Yakubu, Feb 2022, pers. comm.). The actual state of the apparent grasslands will have a profound impact on the conclusions that can be drawn and the recommendations made. It is essential that this finding is subjected to reliable field verification.

2.4 Savannah fragmentation

In common with Africa's other savannahs, the NSZ of Ghana is undergoing fragmentation resulting from the expansion of subsistence and commercial agriculture, small-scale mining and human settlement. A more fragmented land use mosaic limits the amount of grass available as a contiguous fuel source, although there is always some fine fuel available that allows fire to spread. In the history of the region, natural sources of ignition may have been present. If these ignition sources are still present, they are not experienced or observed. Informants[5] were unanimous that all fires today are caused by human activities.[6] As the number of anthropogenic ignition events increases, so does the number of fires; but the average size of the burn scar (the area burned in each fire) decreases.

3 The image classifies only 5% of the NSZ as natural savannah, unmodified by agriculture, mostly inside protected areas. Additional areas of natural savannah that are subject to annual burning may not be correctly identified due to small differences in spectral signature. 'Plantations/woodlots' cover 15.5% of the NSZ, but in reality these areas include extensive natural gallery forests. Smallholder farms are notoriously difficult to map accurately using remote sensing and are often significantly underestimated. Grassland (at 62.9%) is by far the most extensive land cover category, but is likely to include areas of fallow agricultural land that are covered with grasses or crop residues, as well as some open savannah.

4 Grassland is defined as "ecosystems characterized by a relatively high cover of grasses and other graminoid vegetation in an open, often rolling, landscape with little or no cover of trees and shrubs" (Blair *et al.*, 2014).

5 During interactions with many individuals in the NSZ (including FC staff at senior level and district managers, staff of Mole National Park, officials of the Dept of Agriculture, the manager at Form Ltd, community leaders and members, and research workers) everyone held the view, without exception, that fires in the NSZ were always caused by human activities. They were adamant that there are no natural causes of ignition.

6 During the infrequent thunderstorms of the dry season, Ghana Meteorological Agency staff have observed lightning strikes that have sometimes brought down trees. These are rare events. If lightning happens to strike a patch of dry grasses, it will almost certainly start a fire.

Working in the southern African Miombo woodlands, Archibald *et al.* (2010) found that:

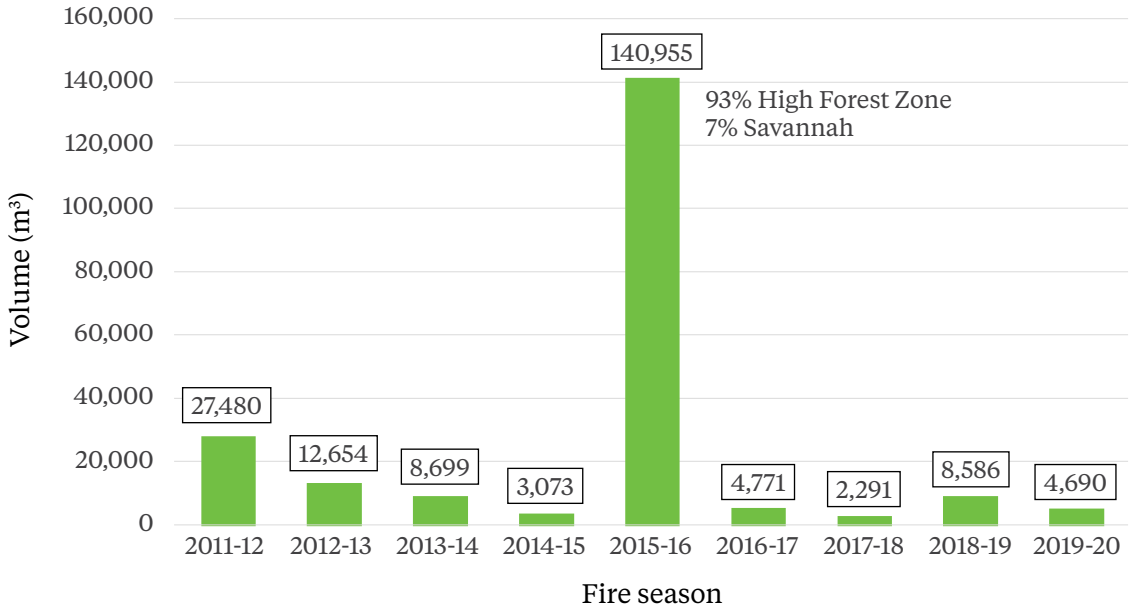
> … fire characteristics change across a gradient of intensity of human impact (which is assumed to increase from protected areas, uncultivated but grazed land, cultivated land and settlements). Although the annual mean burned area fraction, maximum fire size, fire repeat frequency and cumulative fire-affected area all decrease as human impact increases, the effect on the seasonality of fire, the number of individual fires and the frequency of fire in the places that do burn is much less obvious. This implies that the ignition regimes in these different areas are quite similar, and that it is **fire spread and fuel continuity** (*author's emphasis*) that are most affected by intensifying human use of the landscape.

This is borne out in all African savannahs, including the NSZ: as human activity causes additional fragmentation of the land-use mosaic and more natural savannah is converted to other uses, there will probably be more fires, but the average area burned in each fire should diminish.

2.5 Fire records in the NSZ

Figure 2 below shows the cumulative area burned in Ghana each fire season[7] from 2011/2012 to 2019/2020, according to the FC's fire reports. The FC records fires only on the estate it manages (i.e., Forest Reserves and other protected areas), so fires in 'off-reserve' areas are generally not included, except where they threaten a protected area. The data combine the savannah and the high forest zone (HFZ) to its south.

Figure 2. **Cumulative area burned each fire season in Ghana, 2011/12–2019/20**



Source: FC fire report, 2020–2021.

7 The fire season is the period from approximately mid-October to late April or mid-May when the NSZ is subjected to high temperatures and very little rain. These conditions cause the grasses to cure and become a highly inflammable source of fine fuel.

The number of fires and the total area burned was considerably greater in the savannah than in the HFZ for all years except 2015/2016. In that season, there was one very large fire covering more than 100,000 ha in Ashanti Region. The sum of the area burned for the remaining eight fire seasons was 120,751 ha. Assuming that the entire burned area in these years was located in the NSZ, then the average recorded area burned per year in the Forest Reserves and 'off-reserve' areas in the savannah was 15,094 ha, or 2.3% of the Forest Reserve area. This is undoubtedly a significant under-recording, but the actual percentage of the NSZ that burns each year is unknowable because neither fire frequency nor area burned is recorded in most of the NSZ.

Anecdotal evidence (based on perceptions and continual reinforcement by additional anecdotes) suggests that the entire NSZ burns annually. *"Fire is a major problem. It sweeps through annually ... the strategies [to prevent this] are not working"* (Joseph Osiakwan, Ag. Technical Director - Forestry, MoLNR, pers. comm.). This common assertion should be treated with caution, given the lack of a baseline against which to make reliable evaluations. Although in Mole National Park, officers confirmed that virtually the entire Park burns every year, except for some habitats that are less fire-prone, such as gallery forests along water courses.

While annual fires are certainly a problem in the NSZ, the perceived extent of the problem is influenced by observational bias. Fire recordings are generally made from roads. Unless the burned area is properly monitored and measured annually, it is impossible to establish the true extent of the fire problem, much less to quantify it.

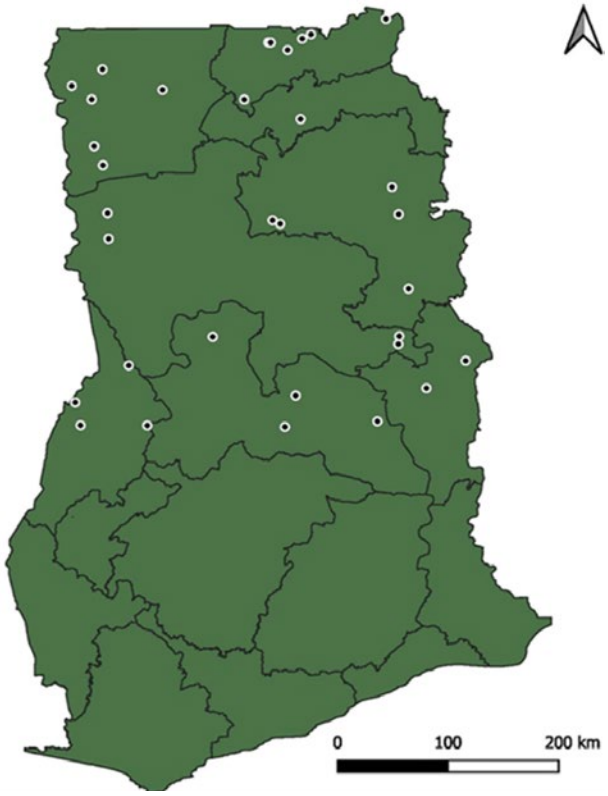
03

Weather as a driver of wildfires in the NSZ

The high prevalence of wildfires in the NSZ results from a combination of conducive weather conditions, high loads of fine fuels (grasses), particularly in the late dry season, and human activities. In this section we consider the role of the weather.

The dry season in the NSZ lasts eight months, from early October to late May. Information on weather conditions can be used to predict the likelihood of fire occurring within this season. The Ghana Meteorological Agency (GMet) has a network of 24 automatic and six manual weather stations in the NSZ, and a further 10 automatic stations just south of the NSZ (see Figure 3).

Figure 3. Weather stations in northern Ghana



Weather data was compiled for the 2020/21 dry season for five of the stations in the NSZ (see Figure 4 and Table 2). Anecdotally, this was considered a normal season of moderate intensity, with the Harmattan very little in evidence (J. Portuphy, Director, GMet, pers. comm.).

Figure 4. Weather stations supplying fire weather data for this study

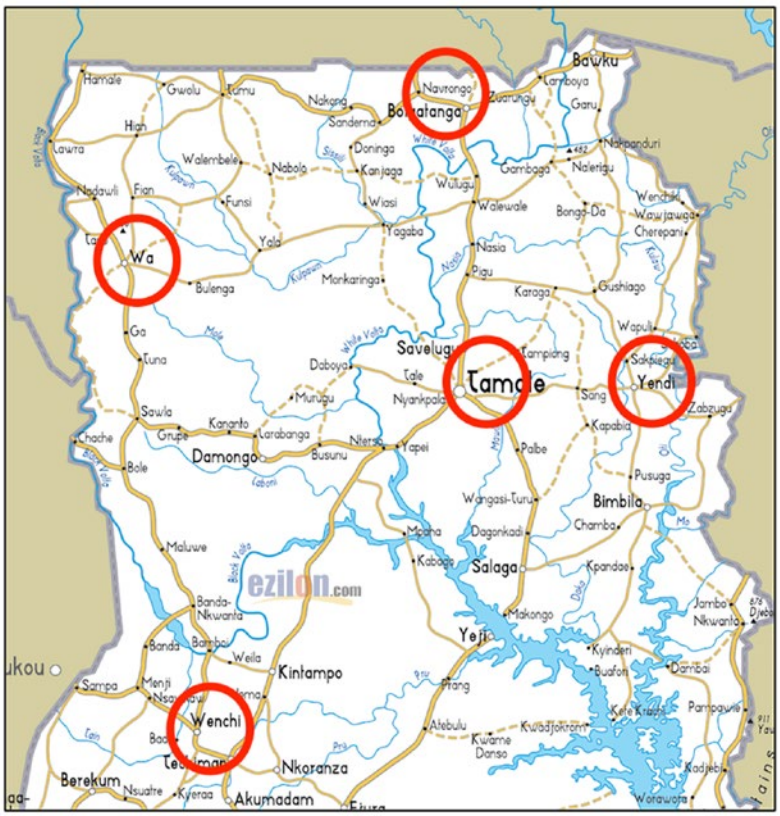


Table 2. Weather parameters for dry season 1 Nov 2020 – 30 Apr 2021, for selected weather stations

	Weather station and altitude				
	Tamale 151 m	**Yendi 207 m**	**Wa 305 m**	**Navrongo 198 m**	**Wenchi* 304 m**
Average daily maximum temp, °C	38.7	37.6	37.2	39.4	33.9
Highest max. temperature, °C	43.2	42.0	42.0	49.5	37.4
Average daily min. relative humidity (RH) at 15:00	26.6	32.2	26.7	25.3	48.5
Lowest min. RH	7.0	14.0	14.0	12.0	16.0
No. of days with recorded wind	181	177	178	181	181
24 hr ave. windspeed, km/hr	3.8	1.9	6.6	2.9	3.0
Max. windspeed, km/hr	9.3	8.1	14.6	9.0	9.4
No. of days with wind >5 km/hr	24	4	130	6	6
No. of days with wind >7.5 km/hr	1	3	51	1	4
No. of days with rain	4	9	8	1	30
Max. rainfall event (mm)	29.6	51.6	43.1	14.4	37.8
Total rainfall (mm)	66.5	103.1	146.4	14.4	282.1

* Wenchi is south of the Black Volta River, so technically outside the NSZ, but was included to allow a north-south gradient to be examined.

The most striking feature of the weather data is the low average wind speed. Taken at face value, wind does not therefore seem to be a serious issue for the spread of fires in the NSZ. But the windspeed data represents the 24-hour average of anemometer readings taken every five minutes at ground level. Short periods of gusting are lost through this averaging; and winds above ground level are not captured at all.

A wind gust is a localised phenomenon lasting a few seconds up to a few minutes, which can cause a fire to flare briefly, but this may only for the duration of the gust. Predicting the effect of gusting on fire spread is therefore difficult.

In this data set it is also difficult to detect the Harmattan, which is a warm, dry, dust-laden wind that blows consistently from the north-east for at least three months with speeds of 9-19 km/hr. It deposits dust along its track, reducing visibility at ground level to 300-700 m and making smoke very difficult to detect. But the Harmattan blows well above ground level at approximately 1,000 m (J. Portuphy, pers. comm.) so its occurrence is not detectable from the weather station records.

The Harmattan does not directly impact fire behaviour. But in combination with high temperatures, it has a desiccating effect on the environment, especially the dead grasses, driving relative humidity below 30% and sometimes as low as 10%. This makes the region a tinder box for most of the dry season. It has been estimated that the land area prone to wildfire annually is over 90% in the dry Northern Savannah Zones (National Wildfire Management Policy, 2006). While "prone" does not mean that 90% of the area actually burns every year, the slightest ignition source will start a fire and it will spread quite rapidly under these conditions.

There is a strong north-south gradient in the pattern of dry season rainfall in Ghana. This is relevant for fire because rain causes relative humidity to rise temporarily, which moderates the fire risk, even when temperatures remain high. But considering all fire risk factors together, rainfall is only one contributing variable, and rainfall differences cause only minimal variation in the fire risk between locations in the NSZ.

Topography can also affect the weather and fire behaviour in some areas, but this is not thought to be a major factor in the NSZ. The landscape forms an extensive basin, with Tamale roughly at its centre and approximately its lowest point, from where the land rises in all directions by 50-100 m. Elevation change of this magnitude does not markedly impact the weather parameters. It may be responsible in a small way for the greater rainfall at Wa, but altitude will not be the main determinant. The much higher rainfall recorded at Wenchi is also likely to be the result of factors other than elevation, as it gets wetter generally as one moves southwards in Ghana.

Fires can only burn when all three elements of the 'fire triangle' are present (see image). In the NSZ, the average maximum daily temperature in the dry season is very high at around 38.5°C ± 1.5°C. As the season changes from wet to dry in September/October, the grasses cure until they provide fine fuel in abundance. The three elements of the fire triangle are therefore all present. But they will not produce any spontaneous fires. A fire requires an ignition source, and human activities provide sources of ignition in abundance.

After the weather conditions, it is human behaviour that is the second key driver of wildfire in the NSZ. The indigenous communities of the region, like all peoples of the African savannahs, have used fire for centuries to produce early wet season grazing and to flush out animals for hunting. In most cases, these fires are left to burn themselves out. Such entrenched behaviours are not easily changed.

04

Current fire management systems in the NSZ

4.1 Fire prevention and protection

Local communities in the savannah have a good understanding of how to manage vegetation using fire. They have been burning for early wet season grazing for centuries. They also burn to remove fuel adjacent to areas that need protection, such as villages. Staff of the GNFS and FC engage in awareness-raising efforts at the start of the dry season to highlight the dangers of careless ignition and the resulting fires.

Where valuable assets require protection, 5 metre-wide belts are cleared down to the mineral soil or burned. Where the heavier elements of the grass sward have not yet cured fully, the EDS burning of these belts clears the finest of the dry fuel. But it does not burn the heavier elements, which results in a belt that could still burn under the right conditions in the late dry season.

The FC cuts firebreaks on the perimeter and internally within the protected areas under its jurisdiction, such as Mole National Park. Where the terrain allows and the necessary equipment is available, the perimeter belts are graded and serve as access roads. In more difficult terrain, these boundary belts and internal firebreaks may be hoed or burned. They also provide a safe place from which to start a back-burn to combat an approaching fire.

With average wind speeds in the NSZ during the dry season generally less than 7.5 km/hr (and mostly less than 5 km/hr), firebreaks of these kinds can be quite effective. However, winds may gust at higher speeds for short periods, causing fires to cross breaks if there is suitable fuel on the other side. So while firebreaks around villages are deemed to be successful in some places, in others (such as Mole National Park), neither external firebreaks nor prescribed burning seem to prevent the entire park, certain sensitive habitats excepted, from burning every year, according to the Park Manager.

Deliberate burns for grazing, hunting or protection of a village add to the mosaic of land covers during the dry season. Again, fires will jump fuel-free burn scars if there is sufficient wind velocity and adequate fuel on the downwind side of the burned area.

There has been some effort to create green belts for fire prevention by strip cultivation of crops, in which the weeding out of competing grasses can dramatically reduce the fuel load. The opportunities for such belts are limited to places within reasonable walking distance of villages. An alternative that requires less tending is green belts of fast-growing trees such

as *Senna siamea* or teak (*Tectona grandis*), which are already planted quite widely, or neem (*Azadirachta indica*), which produces medicinal and oil products, in addition to firewood. Growth rates appear to be extremely slow, however. At one site visited, no canopy closure was observed after three years, and FC staff estimated that it would not occur before six years. Until the canopy starts to close and shade out grasses, these belts are ineffective as firebreaks.

The overall effectiveness of fire prevention measures in the NSZ cannot be assessed without a reliable baseline, which does not currently exist.

4.2 Fire detection

Fire detection in the NSZ relies mainly on the observations of the people who live and work in the region, including farmers, community members and forest guards on patrol. The usual time from fire detection to the arrival of an initial response team is claimed to be about an hour, but is often longer. Given the fire-conducive weather during the dry season, even on days when the wind is blowing at 5 km/hr or less, a fire would spread downwind quite rapidly unless it runs out of fuel. The spread on the flanks would be less fierce, and much slower still on the upwind side of the burned area.

More sophisticated solutions for fire detection do exist. These include:

(i) Fire watch towers of 30 m or taller, manned around the clock during the fire season;

(ii) A network of mast-mounted video cameras (e.g., rotating through 360° every 10 minutes with a range of 15-25 km);

(iii) Aircraft patrolling at approximately 2 km above ground level; and

(iv) Satellite remote sensing for near real-time detection at a frequency of perhaps 4 hours or less, depending on the chosen satellite.

The first three measures are widely used in fire-prone regions around the world, but only in association with high-value assets with a system of rapid response to any fire alert. These systems cannot be economically justified for fire detection in the NSZ. The plantation forestry company Form Ltd has developed a network of tower-mounted cameras for fire detection in its estates in Bono and Ashanti Regions, but they have a range of only around 6 km due to airborne dust from the Harmattan. Since the number of cameras required to cover a given area increases by the square of the radius of the range, complete coverage in such locations of restricted visibility becomes exceedingly expensive.

Of the four solutions listed, satellite detection is the lowest cost option, and is therefore one of the interventions recommended by this study for better fire monitoring and detection in the NSZ.

4.3 Initial attack or first responders

District Forest Officers are responsible for all the protected areas within a Forest District's geographical boundary. Each FC-managed protected area employs at least one guard and usually a larger number of staff headed by the reserve manager or park manager, possibly with an assistant and lower-level staff.

Where a fire breaks out inside a Forest Reserve or close by, alerts are usually raised by forest guards on patrol or others observing smoke. Other FC staff are usually first on the scene. In the most favourable circumstances, they could be equipped with a fire tender with 500-1,000 litres of water, a high-pressure pump and a 50 m hose reel. There is usually at least one serviceable vehicle available for moving people and equipment to the scene, in addition to motorcycles and bicycles. FC staff are well trained and usually have access to some personal protective equipment and hand tools. When more firefighters are required, it is common practice to send a vehicle to the nearest village to collect community volunteers.

But the FC has fewer than ten serviceable fire tenders for the entire country (Richard Ninnoni, RMSC, pers. comm.). Single tenders without an established refilling infrastructure are unlikely to be effective. These units are only useful if they can get to a fire quickly and refill and return within a short time, ideally less than 30 minutes. So it is purely fortuitous if these units prove useful for firefighting in the savannah. They are spread too thinly and lack the necessary water replenishment network.

FC staff also focus on protected areas and only respond to fires 'off-reserve' at places of interest to them, such as plantations or woodlots, or where a reserve is threatened by an oncoming fire. There is no capacity to respond to rural fires in general, most of which receive no attention from the FC.

The mandate for rural firefighting lies with the Rural Fire Division of the GNFS. But *"GNFS only responds to calls in reasonable proximity. If the drive time to the scene is assessed as being too long, the road conditions are too poor or there is no water infrastructure available close to the scene, then they do not respond. When they do, the typical response time is 20-25 minutes."* (Deputy Chief Fire Officer [DCFO] Owusu Adjei, Head of Rural Fires, GNFS, pers. comm.). Given these conditionalities, it is unlikely that GNFS responds to more than 5% (and probably less than 1%) of rural fires in the NSZ.

Therefore, while the GNFS has a legal obligation to respond to all fires, wherever they may occur, this obligation is not honoured in rural areas because it is constrained by the thin spread of its staff and facilities, the limited off-road capabilities of its fire tenders and a lack of rural water infrastructure for resupply. Its biggest contribution in rural areas is assisting the FC with annual training of community volunteers. Designating an agency to manage rural fires that has no ability to comply with its mandate is counterproductive. It has the effect of causing other agencies, which equally lack the means to respond, to point to the GNFS's mandate as a reason for their own lack of action to acquire the necessary capacity.

Its Rural Fire Division notwithstanding, the GNFS is essentially an urban fire service. A central tenet within the culture of every urban fire service is that it exists to suppress all fires as quickly as possible, saving lives and containing damage to property. Responding to the idea that fire is not always destructive, but in some circumstances can be a useful process or a force for good, DCFO Adjei responded: *"I beg to differ"*. It is very difficult to get an urban fire service to accept that there are fires that should be allowed to burn, and that fire is an

essential process in some ecosystems. Furthermore, to the urban firefighter, deliberately starting a fire in order to reduce the natural build-up of fuel is almost sacrilegious, yet this is an essential process for reducing fire danger in the savannah.

These issues are not unique to Ghana. It is a common error to look at an urban fire service that is on 24-hour standby and simply to extend their mandate to respond to rural fires as well. There is only one location within the author's experience where an urban fire service has been able to respond satisfactorily to rural fires. This is in the Mediterranean region of the south of France, where staff from all levels were seconded from the conservation services to the fire service and vice versa, for a period of not less than 12 months. After several years of this inter-agency exchange program, the culture within the fire service changed sufficiently for it to undertake rural firefighting effectively, also after being adequately equipped to do so.

Providing a fire service that can operate effectively across the vast expanse of the NSZ is an impossible undertaking. Rural people currently take a lead in fire protection and suppression because they know there is no institution capable of doing it for them. Using community fire volunteers is a more practical way to provide an initial response to wildfires across the NSZ's vast rural landscape, where the average distance between communities is roughly 5 km (Richard Ninnoni, RMSC, pers. comm.).

People in these communities have a good practical understanding of fire behaviour, which is probably one of the reasons that there have not been serious accidents or fatalities at fire scenes attended by community volunteers. But it is openly acknowledged that community volunteers tend to respond only when they have a direct interest at stake, for example when an advancing fire is threatening harvested crops still stored on their lands. And these firefighters have little to no personal protective equipment and very elementary or improvised tools. A further widespread deficiency is that they can only get to a fire on foot or by bicycle. There is no easy solution to these considerable practical and logistical challenges, but it is clear that community-based solutions hold out the best prospects for positive change.

4.4 Extended attack

There are occasions when the FC needs assistance and will send their pick-up to the nearest village to bring ten volunteers, if they can find that many people willing and able to participate. But instances in the NSZ where an extended attack is necessary because the first responders cannot contain the fire are rare. The fire may be contained around a farm that it is threatened, for example, but then it is abandoned to burn itself out.

When more than one party is responding to the same fire, there is an established command protocol. If the GNFS is present, they take command; failing which, if the FC is present, one of its senior staff takes the role of fire boss. Where more than one community is responding in the absence of either government agency, they are left to their own devices.

The main means of communication in fire response teams is usually a megaphone plus the mobile telephone network, which is patchy at best. Fire scenes can be noisy places. Adding to the general noise level by using megaphones to communicate is not a good idea. Besides, megaphones are only effective over relatively short distances and where more than

one team is engaged in suppressing a fire, they may be 1 km or more apart. If the mobile network is not reliable, messengers must be sent to convey communications person-to-person. Messengers may suffice for smaller fires but are not an adequate solution for fires greater than 50 ha and even some smaller fires, particularly if the wind speed increases above 10 km/hr. Where there is no means of reliable and immediate communication with all actors at a fire scene, the effectiveness of the fire boss is dramatically reduced and safety is compromised, with a higher risk of serious injury and loss of life.

Wildfires often cause burning or smouldering material (branches, clumps of grass and the like) to be thrown up into the air high enough to be caught by the wind and carried ahead of the fire front, often as far as several kilometres. This is known as a 'spotting' and can cause a new fire to start. The extent to which this happens depends on factors such as the fuel being burned, the intensity of the fire and the wind speed. Spotting events constitute a safety risk to firefighters. This is a further reason to support better communications at firefighting operations than those currently available.

The use of a counter-fire (also known as a back-burn) to stop an advancing fire is an unlikely eventuality, but one of which FC managers are aware. This technique is included in the training of community volunteers, but there are mixed reports regarding the depth of that training. If ever the decision is made to use a counter-fire, the safety of firefighters cannot be guaranteed, given the current poor communication systems.

Fires make their own wind, as hot air rising sucks in air from all sides, the more fiercely as the intensity of the fire increases. Fire also moves naturally upslope, with greater speed as the gradient increases. This is unlikely to be a widespread phenomenon, but may be an issue below the Gambaga escarpment in North East Region.

4.5 Fire monitoring

The current system of fire monitoring in the NSZ depends on the FC's District Managers filing fire reports on a standardised form providing details such as the cause, the area burned and the size of fire at the initial attack. Most fires go unreported because they are either outside the FC estate or because staff fail to maintain accurate records. With many more fires occurring beyond the boundaries of the FC's estate than within it, the current system undercounts both the number of fires and the area burned. However, this system provides the only fire statistics available in the NSZ. It could be used as a baseline, albeit an imperfect one, from which to make improvements.

05

Learning opportunities

5.1 Experiences in Ghana

The experiences of three fire-related initiatives in Ghana can provide useful lessons regarding the efficacy and suitability of different measures for better fire management in the NSZ.

5.1.1 Form Ltd: Co-operation and collaboration by different partners

Form Ltd is a plantation forestry company operating near Sunyani, Berekum and Akumadan. At Sunyani they have 12,000 ha is planted to teak. Fire was causing significant damage to these plantations, so the company installed a system of four rotating video cameras atop 30 m masts for the early detection of fires, that could cause damage to Form's plantations. Such fires originate outside of the plantation area from the rest of the forest reserve and/or communal areas[8].

Data from these cameras revealed that most fires were being started at around 13:00 or 17:00, timed with lunch breaks and the end of the working day. Form's own workers are extremely dedicated to protecting their plantations. The company realised that many of these fires were started by farmers or community members[9].

In order to control and reduce this damage, in 2017 the company embarked on an Integrated Community Fire Management (ICFM) project.[10] The initiative began with an extensive process of consultation that engaged the District Assembly, the chief and the communities within the area. The process resulted in the parties agreeing that the problem was not fire *per se*, but wildfires burning out of control. A common agreed objective was therefore to reduce wildfire events to the extent possible, but not to stop fires altogether.

The company trained a network of community fire volunteers on all aspects of fire prevention and now pays them an allowance of GH¢ 120(about US$ 10) per month (May, 2023) which is intended to assist them with the fire protection of their own properties[11]. A bylaw from the District Assembly previously made it illegal to undertake any burning operations between December 15 and the onset of the rainy season, usually during May. But farmers needing to clear land in preparation for planting were not ready to cease burning by this date. The District Assembly agreed to lift the burning restriction and to delegate

8 W. Fourie, GM, Form Ltd.

9 *ibid.*

10 See www.formghana.com/integrated-community-fire-management

11 W. Fourie, GM, Form Ltd.

the authority to approve burning operations to the chief, on a case-by-case basis. The chief now asks community fire volunteers to inspect the firebreaks that farmers create around their land. If they are deemed satisfactory, he gives permission for a controlled fire on the condition that the fire weather[12] is not too dangerous and there will be volunteers present with beaters. The company keeps track of the fire weather and advises the chief in a timely manner when it is too dangerous for burning operations.

In the first dry season following the implementation of these agreements, Form Ltd recorded a 70% reduction in the number of wildfires within their area of concern (Table 3). This area of concern is defined as the Integrated Community Fire Management Area which is the communal land and/or forest reserve land, which is not allocated to Form Ltd. In the subsequent season, they recorded a further reduction of 23% from the baseline. The number of wildfires was expected to reduce even further in the 2022/23 fire season, which was ongoing at the time of writing. The reduction in the number of wildfires supports the company's view that there have been major behavioural changes in the surrounding communities as a direct result of its ICFM initiative.

Table 3. Wildfires recorded in Form Ltd and adjacent ICFM areas, 2017/18 and 2021/22 fire seasons

	Fire season	
	2017/18	2021/2022
No. of wildfires in entire area*	323	70
No. of wildfires in ICFM areas	213	23

Source: General Manager, Form Ltd. Published with the company's permission.

* 'Entire area' includes land managed by Form Ltd and also includes nearby community and forest reserve land where communities are active participants.

5.1.2 Goziir: Excluding fire in the savannah

At Goziir, a community in Nandom Municipality in the Upper West Region, the chief (with the co-operation of his sub-chiefs) stopped burning in the community in 1987. The current chief confirmed that there has been no management burning and very few wildfires since that time. In a community of approximately 20,000 people, a culture has been established that is completely intolerant of fire (Smith, 2020; interview with Chief Naa Simon Yiryel III, Jan 2022). It is deemed to be destructive without any benefits. Fighting fire has become a whole-community activity. Although devout Catholics, community members will interrupt Sunday mass to respond to a fire if necessary. Starting a fire or felling a tree without permission is punished with a significant fine.

An important motivating factor for this change was that regular fires had reduced the available grazing to such an extent that the community was forced to drive their cattle 5 km to the Black Volta River on the border with Burkina Faso to find pasture and water. They were then plagued by cattle theft to such an extent that finding sufficient cattle "to dowry their wives" had become a serious problem.

After 35 years, the tree canopy has closed in places, as predicted by the current understanding of the dynamics of savannahs from which fire is excluded for long periods

12 Fire weather refers to weather conditions that make successful ignition events more likely and which will promote the rapid spread of fires.

of time. Many of the gaps between the mature shea trees and other trees that predate the 1987 burning prohibition are closing, as a result of resprouting or germinating seedlings. But there are also many gaps where no recruitment of saplings has occurred. And there are virtually no saplings exceeding 4 m in height.

What is particularly striking is how slow the process of moving to closed canopy forest actually is. This may be the result of two factors: the harshness of a dry season of eight months' duration, and possibly the shallowness of the soils in places where there is a hard pan in the soil profile. Of the entire NSZ, 54% is underlain by a hard or iron-pan, an impervious layer approximately 50 cm below the surface (Dr Edward Yeboah, Ag. Director, Soil Research Institute, Kumasi, pers. comm.).

Part of the price of this managed change in the composition of the vegetation has been a reduction in natural grazing for livestock, but it is still sufficient when supplemented with crop residues. The changes have also had a direct impact on household income during the dry season. Collecting firewood for sale was a viable activity for women, but that is no longer the case because there is no dead wood available from trees killed or damaged by fire. The Centre for Indigenous Knowledge and Organisational Development mitigated this adverse consequence by supporting the establishment of food gardens for dry season vegetable crops, each equipped with a borehole and hand pump. This was complemented by a MoFA programme that taught community members to make compost from leaves, grass and cow dung to improve soil productivity.

The Goziir experience demonstrates the consequences of excluding fire from the natural savannah. At first sight it may appear desirable, but the outcomes are profound in terms of the changes in ecosystem services that the savannah provides.

5.1.3 Yameriga: Community Fire Volunteers

The Yameriga community in Talensi District, Upper East Region first designated fire volunteers in 1993, when 46 people were trained by the FC and GNFS. The group has since grown to 76 members and the NGO World Vision has supported additional training. The fact that the original group has grown and that they have replaced the original wellington boots supplied, from their own resources, are positive indications that the community sees real value in the service that the volunteers provide. They claim that the main benefit is far fewer fires and that their trees bear now fruit every year.[13]

This community successfully excluded or controlled wildfires in their area from 2009 to December 2021, a period of 12 years. A scar from a 2021 fire was clearly visible on one of the hillsides. Although there was no obviously compelling reason to suppress this fire halfway across a hillside, the community did so because they have developed a culture of intolerance to uncontrolled wildfires. They believed that a fire on the hillside would result in serious erosion.[14]

This success reflects a change in the community's culture from laissez-faire to intolerance of wildfire, which is reflected in three programmes of action:

(i) With the co-operation of the District Assembly and their chiefs, a fine of GH¢ 50 per incident was introduced for those responsible for fires that get out of control. Members of the community's Volunteer Fire Squad apprehend culprits and their

13 On the latter point there are contradictory accounts, though not in this particular community; for example, the claim that shea trees must be exposed to fire every year to produce an annual crop of nuts.

14 In fact a grass fire sweeping through an area removes the above-ground portion of the grasses, but the tufts and root systems generally survive and continue to bind the soil, so serious erosion was unlikely to occur after the 2021 hillside fire.

leader collects the fines, which are deposited in a bank account to support the squad's activities. In village communities, the culprits are known to everyone but can never be apprehended by the formal state authorities. Isolated rural communities, on the other hand, are characterised by family relationships and residents know and interact with each other. They are disinclined to appeal to outside parties, beyond their chief, to resolve any issues that may arise between them.

(ii) The community has a system of firebreaks 10–15 m wide that are prepared by removing all vegetation down to the mineral soil and burning this slashed material as soon as it is dry enough to do so.

(iii) Farmers also make firebreaks around their farms and only burn the slash with the fire volunteers in attendance. When these norms are not adhered to, farmers are fined (see Table 4).

Table 4. Money collected from fines in the Yameriga community

Period	2009-2010	2011-2017	2018-2019
Amount GH¢	150	300	400

Source: E Yeboah, Regional Manager, Upper East, FC.

5.1.4 Lessons to be drawn

These Ghanaian examples (and others from around the world) illustrate that changes designed to create a solution to a community 'problem' must be designed jointly with that community and be implemented with their support. Addressing the wildfire problem in the NSZ therefore means engaging the District Assemblies, traditional leaders and community members, including locals and nomadic Fulani herdsmen, artisanal miners and possibly others.

The associated lesson is that attempts to change entrenched behaviours regarding the use of fire in any way other than by agreement will not only fail, but will also turn the authorities responsible into the 'enemy'. The approach to reducing wildfire must be a co-operative one that focuses on the benefits of such co-operation in controlling or reducing the incidence of wildfires, both for the farmers and for other actors.

Some additional lessons from the Ghana experiences are as follows:

(i) **Delegation:** Legal restrictions on the use of fire promulgated at the District Assembly level can be delegated to the local chief. Indeed, they appear to work more effectively when administered locally and stand a better chance of avoiding the unintended consequence of driving restricted behaviour underground, rather than preventing it. An important power delegated to the chief at Form Ltd is the authority to create a closed fire season when burning operations are not permitted, and to determine any permitted exceptions.

(ii) **Leadership:** The communities at Goziir and Yameriga have demonstrated that fire can be successfully excluded for long periods from community lands, under the guidance of a passionate leader and champion. This can be a strong leadership figure in the community, who is not necessarily the chief. These communities have used different approaches to achieve similar results: the Goziir community

has developed a culture of intolerance to fire as a tool for managing vegetation; the Yameriga people use fire for a variety of purposes, but their community fire volunteers ensure that this is done safely and that the fire is properly extinguished once the purpose has been achieved.

(iii) **Incremental approaches:** Both examples have existed for a considerable time in a wider environment where wildfires are prevalent and left to burn themselves out. They show that an incremental approach can be successful, working with willing communities and aiming to bring about changes in behaviour regarding the use of fire, even when a community is surrounded by others that may initially be less willing to co-operate, and where wildfires are commonplace.

(iv) **Balancing benefits and risks:** The work involving Form Ltd demonstrates that fire as a management tool can live alongside the idea that wildfire is destructive and should be prevented where possible. The company's work on fire prevention provides a good illustration of adoption by neighbours, persuaded by the evidence before their eyes.

(v) **Cost-appropriate solutions:** Many of the innovations in fire management in fire-prone regions around the world are not appropriate for the NSZ. There are no commercial forestry operations in the NSZ, such as extensive timber plantations requiring protection from fire, that could justify such cost-intensive measures.

(vi) **The need for government leadership for large-scale strategies:** Fuel reduction burning (sometimes called controlled or prescribed burning) on a large scale to create barriers to the advance of wildfires has potential, but is very difficult to implement where no government agency takes responsibility for fire management, as is currently the case in the NSZ.

Other informative examples of fire management in savannah landscapes include the following (see bibliography for full references):

- From the Guinean savannah of West Africa: The early/late fire dichotomy: Time for a reassessment of Aubréville's savanna fire experiments (Laris *et al.*, 2017)
- From Zambia: The environmental impacts of charcoal production in tropical ecosystems of the world: A synthesis (Chidumayo & Gumbo, 2013)
- From Zimbabwe: Savanna burning and the assessment of long-term fire experiments with particular reference to Zimbabwe (Furley *et al.*, 2008)
- From Mozambique: How does fire intensity and frequency affect miombo woodland tree populations and biomass? (Ryan & Williams, 2011).
- From South Africa (Kruger National Park): Effects of fire on woody vegetation structure in African savanna (Smit *et al.*, 2010).

5.2 Experiences with Integrated Fire Management systems

Integrated Fire Management (IFM) is an approach to addressing the problems and issues posed by both damaging and beneficial fires within the context of the natural environments and socio-economic systems in which they occur, by evaluating and balancing the relative risks posed by fire with the beneficial or necessary ecological and economic roles that it may play in a given landscape (The Nature Conservancy, 2018). IFM facilitates cost-

effective approaches to both preventing damaging fires and maintaining desirable fire regimes. When fires do occur, it provides a framework for (1) evaluating whether the effects will be detrimental, beneficial or benign, (2) weighing relative benefits and risks, and (3) responding appropriately and effectively based on stated objectives for the area in question.

Successful systems for IFM around the world follow seven guiding principles (Knowles *et al.*, 2017):

(i) The principles for IFM at landscape level must be defined by local context and needs, through a bottom-up approach with extensive stakeholder engagement with relevant parties.

(ii) Formal integration of IFM across the landscape is essential to ensure that one part of the land use mosaic does not present a threat to other areas.

(iii) Fire should be actively used as a cost-effective tool to provide protection, early wet season grazing and reduction of fuel loads.

(iv) IFM should be informed by comprehensive monitoring and reporting (e.g., prescribed burning strategies need a sound understanding of the condition of the grass sward and the state of regeneration of trees).

(v) There should be an emphasis on local recruiting, training and equipment, as this delivers local benefits and promotes a sense of ownership of IFM at local level.

(vi) IFM requires central co-ordination of relevant institutions to manage prescribed burning year-by-year, to co-ordinate education, awareness and training, to provide required equipment, and to lead the response to large fires.

(vii) Awareness and education are required so that all parties within the focus area are aware of potential changes in the fire management philosophy and their personal role in the process.

In operational terms, best practice in IFM has many common characteristics. For example, there is a heavy emphasis on early detection of fires and rapid initial attack by firefighters, supported by equipment that can deliver significant quantities of water, sometimes mixed with fire-retardant chemicals. A substantial investment is required to have crews correctly equipped and available on standby during the fire season. A network of elevated water storage tanks is required to refill truck-mounted tanks rapidly. Water is mainly used to reduce the temperature of the fire so that it can be fought by beaters. The critical issue is the time interval between each application. A 1,000 litre tender has minimal impact if the turnaround time for refilling is an hour or more, for example. Such systems in their entirety are generally unaffordable in the NSZ, but IFM offers a pathway to a system that can be implemented incrementally.

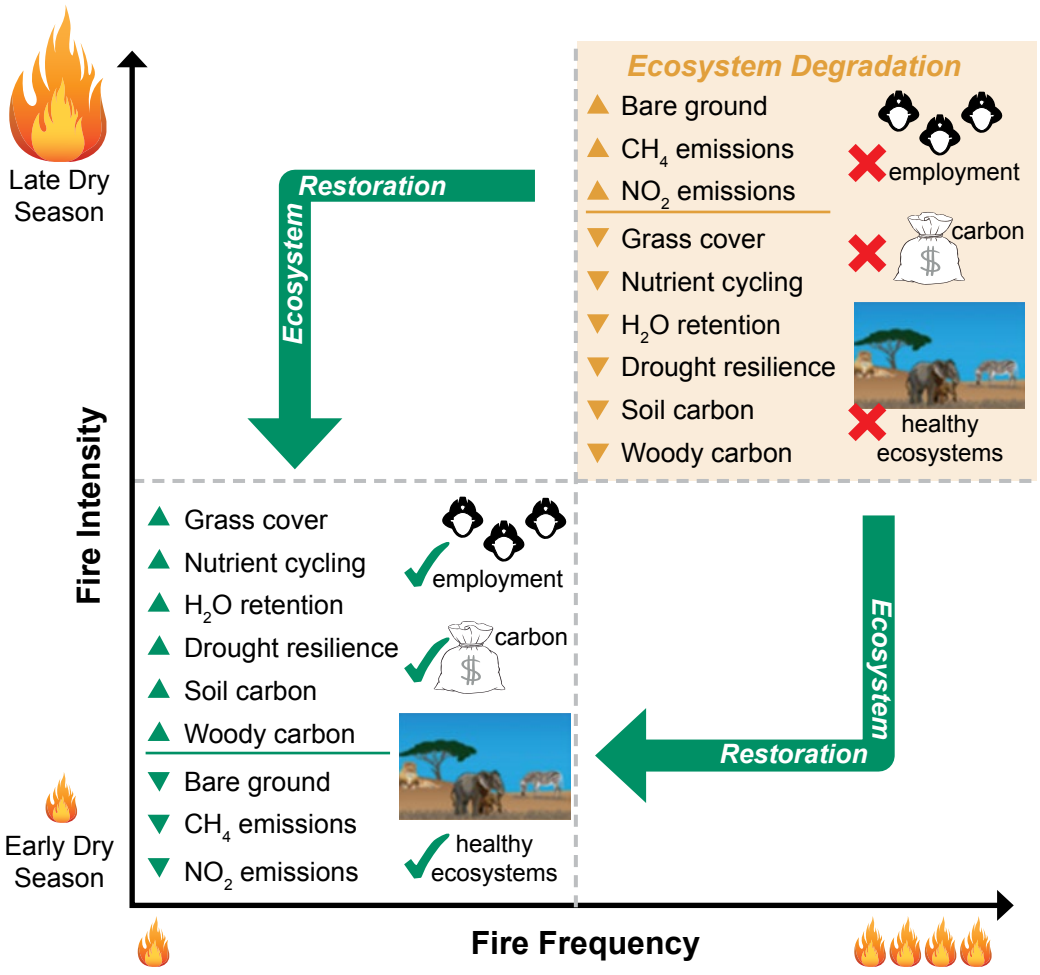
Fire tenders are currently allocated to some (but not all) Forest Districts in Ghana. They are not effective in the absence of the necessary water infrastructure. As a first step in a new IFM system, it would be sensible for all the fire tenders allocated to the NSZ to be concentrated in one place. Mole National Park is a good option. This would need to be conditional on the simultaneous establishment of the water-filling infrastructure necessary for the tenders to be effective firefighting tools. The next step at Mole could be to improve early detection of fires, which would boost the effectiveness of the fire tenders.

Greatly improved communications are also a high priority. Successful IFM systems use proprietary radio networks that work universally across the landscape. They are proprietary to avoid interference from non-fire-related traffic. This may require temporary radio repeater stations to be deployed, depending on the terrain. If an IFM project was to be initiated at Mole, then recent work at the Earth Observation Research and Innovation Centre (EORIC) at the University of Energy and Natural Resources in Sunyani, which relates to communicating fire information directly to farmers and other land users, may have direct application.

Another important lesson is that IFM cannot be successfully implemented without a reliable baseline against which progress can be measured. Remote sensing using satellite data is the only feasible way to monitor the fires and the areas burned for the entire NSZ.

The final lesson on IFM relates to the opportunities for new benefit streams in the NSZ. Recent work in the savannah of northern Australia (Tear et al., 2021) shows that moving grass burning from the LDS to the EDS can generate significant ecosystem and economic benefits (see Figure 5).

Figure 5. **Differences in ecosystem impacts between early vs. late dry season burning in the savannah**



Source: Tear et al., 2021.

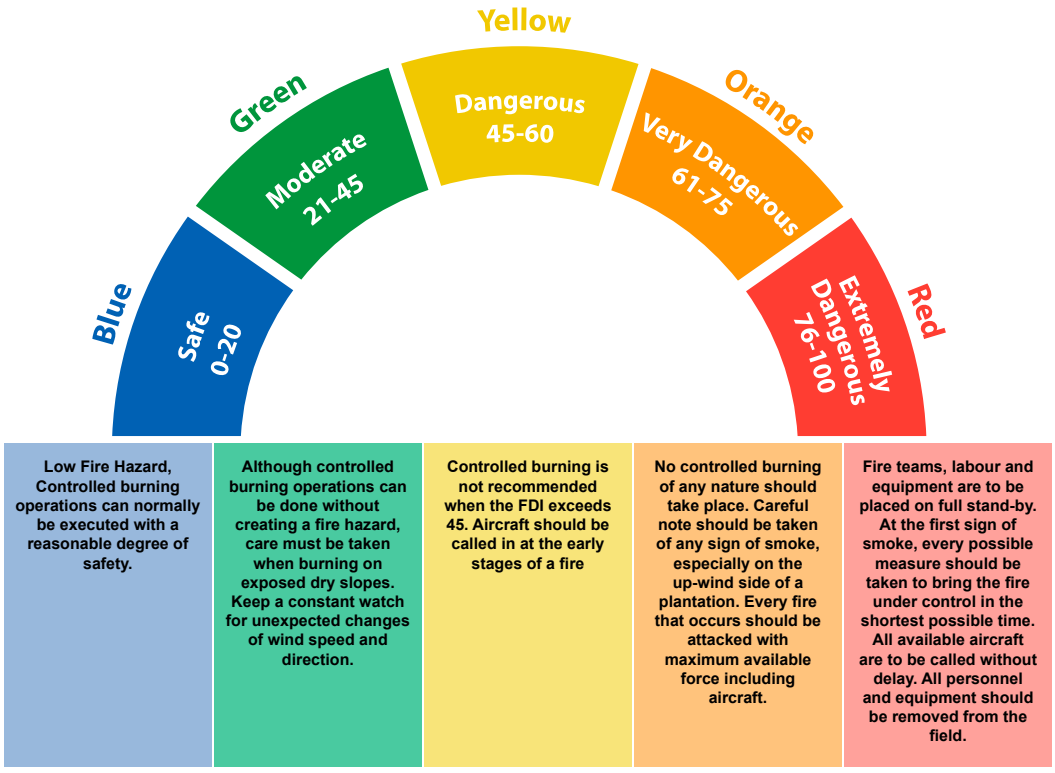
The study's authors present the case for savannah protected areas to raise funds from carbon credits, based on the difference between greenhouse gas emissions achieved by switching from EDS to LDS burning. This is an opportunity that can be grasped in any savannah ecosystem and could provide a powerful incentive for community co-operation in the NSZ. Once the necessary baseline has been established, the extent of the change achieved by the switch in burning practices can be monitored remotely using satellite imagery at a regular frequency.

5.3 The utility of a Fire Danger Index

The idea of predicting the degree of danger from wildfires in natural vegetation has a long history. In places such as Australia, Canada, California and South Africa, predicting fire danger has been routine since the 1970s.[15] While the various indices in use around the world have some differences, they all consider measurable weather parameters such as temperature, relative humidity, recent rainfall amount, time since last rainfall and wind speed.

South Africa's Fire Danger Index (FDI) ranges from zero to 100 and is divided into five colour-coded sections from Blue (Safe) to Red (Extremely Dangerous) (see Figure 6). The FDI gives a good practical indication of the danger of fires getting out of control under particular weather conditions. A forecast for the FDI at 10:00 and 14:00, on the basis of weather parameters observed at 07:00, allows management to prepare for what will come later in the day. This allows the moderation of activities that could cause ignition events and gives advance warning of the need for preparatory actions.

Figure 6. The South African Fire Danger Index



15 Department of Agriculture, Forestry & Fisheries (DAFF), South Africa (2013).

Analysis was carried out to give an initial indication of the usefulness of a FDI in the NSZ, using the South African Index as an example because it does not require laboratory work or the quantification of fuel loads, like some other indices.

Weather data from the five stations previously investigated (see Table 2) was analysed to establish its effect on the daily FDI using the formula for the South African Index.[16] The analysis showed the FDI to be in the Yellow or Orange zone for long spells during the 2020/21 dry season, punctuated by short periods of relief after the occasional rainfall events. Despite stable high temperatures and low relative humidity, there were no Red days due to the relatively light winds. In other parts of the world, Red days are characterised by sustained fairly strong winds, often strengthening as the maximum daily temperature is approached.

The index for the NSZ occasionally reached 75, the upper limit for Orange. Just a small increase in windspeed would have pushed it into the Red. At wind speeds exceeding 17 km/hr, 15 points are added to the FDI. So whenever the wind is gusting, a Yellow Index will convert to Orange, or an Orange index will convert to Red, for the duration of the gust. Gusts of more than 17 km/hr therefore briefly increase the fire danger, but to really have an impact there would need to be a gust at this speed or higher every minute over an extended period. Even then, the effect on fire danger would be lower than a sustained wind at the same speed.

The South African FDI is a robust system that has been used beyond the borders of the region where it was developed. To be useful, however, an FDI must identify the relatively small number of days when exceptionally high levels of danger are present, thus justifying exceptional measures (such as cancelling all mechanised operations or placing standby firefighting resources at strategic locations).

If the weather parameters produce an index that shows most days to be consistently Dangerous or Very Dangerous, as they have done in this brief analysis using data from the NSZ, then that index is not useful in calibrating an appropriate response because exceptional measures can only be sustained by exception. This makes it difficult to transfer the South African FDI to the NSZ in a way that would be useful. In the South African Lowveld (a savannah region), there may be only ten days that are Red during a fire season of 150 days. However, in the dry season in the NSZ, the days of high danger are the norm. They are virtually continuous for many successive days. People do not respond well to the claim that a very dangerous state is the prevailing condition. It is therefore of doubtful value to introduce an FDI system in the NSZ, the main purpose of which is to identify, by exception, when the conditions are so extreme that runaway fires are virtually inevitable.

5.4 Priority behavioural measures

By far the largest cause of fires in FC's reports is the "unknown cause" category, almost certainly translating to human activity of some kind. Given this preeminent role of human activity, it is clear that the primary focus of efforts to improve fire prevention and management in the NSZ should be behaviour change among the people who live in the rural landscape. Local residents have a long history and understanding of the role of fire, but there are undoubtedly areas where behaviour can be improved to reduce the negative impacts of fire, and especially of uncontrolled wildfires.

16 The index is calculated using maximum temperature, relative humidity, wind speed and rainfall (DAFF South Africa, 2013).

The FC and GNFS already educate and sensitise communities about using fire appropriately, while preventing wildfires. This work should be re-examined to identify ways to make it more effective, especially with regular and repeated reinforcement of key messages throughout the dry season. The most important practices to promote are as follows:

- **Construction of firebreaks:** Many fires result from the slash and burn activities of farmers. These ignition events could be prevented by creating a firebreak on the perimeter of the farm and by only conducting burning in the presence of the community fire volunteers, so that wherever the fire jumps the break, it can be beaten out immediately. The Yameriga community and the communities around Form Ltd have adopted this practice.

- **Cultivation:** Fuel can be removed by cultivation. Fuel modification through appropriate agronomic practices merits further investigation. Green fire belts and agroforestry woodlots have some potential. While this approach does not guarantee protection against fire, it may significantly reduce the available grasses. It is the abundance of this fine fuel that causes intense fires. Green belts using food crops are only practical within short distances of where people are living, which greatly limits their potential. Green belts using fast-growing exotic tree species (such as *Senna siamea*) can provide effective fire belts after canopy closure. This may take around six years, but there are circumstances where it is worth persevering. "One of the most important requirements in land use practices is socio-economic compatibility. If the local population does not accept and support the form of land use, implementation and long-term sustainability might be hard to achieve" (Lemke, 2020).

- **Early burning at strategic locations:** A degree of control can be exercised over the quantity of fuel available at strategically important places. Communities understand this principle and generally burn the vegetation surrounding the village diligently, early in the dry season, to ensure that a wildfire cannot come close enough to set their thatched roofs alight.

- **Extinguishing fires after use:** Communities are less diligent about extinguishing fires once a firebreak of a safe width has been created between the fire and the assets they are trying to protect. But it is vital that once the fire's purpose has been accomplished, it is properly extinguished.

- **Controlled burning:** Fuel reduction can be carried out mechanically in a limited way, for example by hoeing a fire belt, or on a much wider scale by controlled or prescribed burning. This is undoubtedly the most cost-effective way to reduce fuel loads at scale, but is also the method that runs the greatest risk of getting out of control. The risk can be reduced by conducting controlled burning operations at night, when the temperature usually drops significantly. Ignition capsules aerially delivered by drone allow controlled burns to be managed more safely and to be completed more rapidly. Drones can also be used at night.

5.5 Options for increasing the value of natural resources in the NSZ

Any measures that add value to natural resources can enhance the prospects for a stronger conservation ethos and are therefore complementary to better fire management.

Established behaviour patterns amongst residents of the NSZ seem to indicate that some of the natural resources at their disposal are perceived to have no value, monetary or otherwise. Evidence comes from the widespread practice of slash and burn. Burning the slash from the opening of new land for farming is a convenient way of disposing of biomass that is perceived to be a nuisance by the farmer. But in addition to the fire hazard created by this practice, it is a missed opportunity. There is some nutrient release from burning the slash, but the beneficial effect on the crop is short-lived.

A better practice would be to carbonise the woody materials on-farm in a small mobile kiln and return the char to the soil. This 'biochar' improves soil pH and holds nutrients and moisture to be released slowly over time. It also provides a habitat for mycorrhiza, quite apart from the reduction in fire hazard that this change of practice would bring about (Dr Yeboah, Soil Research Institute, Kumasi, pers. comm.).

Finer materials (grass etc) cannot be carbonised easily as they tend to burn to ash. However, they are suitable for composting. There is apparently some resistance from farmers to the use of organic compost (Sylvester de Clerog Mensah, Regional Extension Officer, Northern Region, MoFA, pers. comm.). This could be because if the materials used are not fully decomposed before the compost is incorporated into the soil, their further decomposition draws nitrogen from the soils to the detriment of the crop.

The slash from farms could be purchased and moved to a central site where the woody elements could be carbonised efficiently, and the finer materials processed to produce quality-controlled compost. Both biochar and organic compost could be sold back to the farmers (Prof. Abdul Halim Abubakari, University of Development Studies, Tamale, pers. comm.). There is already at least one commercial compost producer in the north selling 50 kg rice bags filled with organic compost for GH¢ 40.

In the same vein as controlling slash and burn fires, could community fire volunteers provide a service to farmers by safely burning their slash for a fee?

Any ideas that can improve smallholder productivity and so contribute to the prosperity of the local economy deserve serious consideration, provided that the economics are attractive and the resistance of conservative farmers can be overcome. Additional ideas (from Prof. Abubakari) are:

(i) Promote minimum or zero tillage.

(ii) Plant *Icacina oliviformis* (false yam) to create green fire belts around villages. Although poisonous, its tuber is edible if properly treated and can be used as animal feed.

(iii) Encourage an end to the practice of directly adding fresh animal manure to the soil. This adds too much nitrogen, to the detriment of the crop. It is better to use all available manure in compost.

If a market can be created for dry grass, other than for thatching or basket weaving, then grass surrounding villages at the start of the dry season could be harvested and sold, rather than burned for no advantage other than the firebreak created. If dry grass has a value that allows communities to supplement their dry-season income, then attitudes to letting grass fires burn themselves out may change.

06

Recommendations

The recommendations arising from this analysis are intended to be practical and implementable, given the resource-constrained circumstances of the Forestry Services Division of the FC. They are targeted primarily at the World Bank and Government of Ghana partners in the GLRSSMP.

The following five recommendations are of high priority and should be initiated as soon as possible:

A. **Reconsider institutional mandates:** Mandate a single government institution to take responsibility for all issues relating to fire in the NSZ. The obvious institutional choice for this role is the FC, which implies accepting that the legal mandate of the GNFS for fire management in the rural NSZ is ineffective. The FC's role could initially be limited to monitoring fire in the region, while it is properly resourced to take on the broader role of fire prevention and management across the rural landscape.

B. **Work through champions:** Ensure that fire management interventions have strong champions in the community who represent, or work closely with, both the District Assembly and the local chief.

C. **Monitor via satellite:** Establish a satellite-based remote monitoring system for fire in the NSZ, as a joint initiative of RMSC and EORIC. This could generate a reliable baseline for the NSZ as a whole and for the smaller geographic units, as well fire frequency maps for specific areas.[17] Among its many benefits it would allow the effectiveness of various interventions to be monitored and measured over time.

D. **Quantify carbon credits:** Quantify the potential value of carbon credits generated by changing from a LDS to EDS burning regime, and explore how to share the benefits appropriately between the communities and the agencies driving the process. This will require external technical assistance, possibly from Australian experts, especially for estimating the current proportion of LDS fires.

E. **Pool knowledge:** Organise an annual conference for knowledge-sharing and exchange of experience on fire monitoring and management for development organisations working in the NSZ (including the World Bank, UNDP, GIZ and NGOs). There is much that is not shared and therefore does not benefit from the potential cross-pollination that could result.

17 See examples of such maps compiled by Form Ghana: www.formghana.com/integrated-community-fire-management

The following additional recommendations are of less-pressing priority:

Short Term Recommendations

- **Devolved fire management:** Identify up to five sites, preferably with experience with co-operative decision-making, to pilot devolved fire management based on the models from Yameriga and Form Ltd.

- **Mining regulation:** Advocate for the Minerals Commission to include a licensing condition requiring artisanal miners to surround their operations with an adequate firebreak.

Medium Term Recommendations

- **Land cover verification:** Validate the RMSC's Feb 2022 land cover map. This will require a combination of ground-truthing and consultation with savannah ecologists to define the boundary between grassland and grassy savannah.

- **Fire exclusion:** Following this land cover verification, establish the proportion of the NSZ classified as grasslands that can feasibly be returned to functional savannah. For example, are there patches of grassland covering several hundred hectares where a fire exclusion policy for 3-5 years can be implemented?

- **Community firefighting:** Strengthen the community volunteer firefighting system through:

  (i) more refresher training;

  (ii) provision of adequate basic tools;

  (iii) provision of appropriate PPE; and

  (iv) allowances for firefighters.

- **Cultural change:** Promote cultural change amongst management in Government agencies regarding fire in savannah ecosystems. Fire as a necessary management tool is accepted by the FC, but elsewhere in government, fire appears to be seen as a 'menace' and only 'destructive'.

- **Community education:** Improve upon the existing fire education campaign with targeted messaging around key practices (e.g., firebreaks, greenbelts, strategic early burning, extinguishing fires, controlled burning).

- **Piloting IFM:** Establish pilot sites to achieve community adoption of the seven guiding principles for IFM, as the outcome of a consultative process about the principles, their adaptation and application. This should include a trial VHF radio network, including mobile with repeater stations.

- **Fire tender consolidation:** Relocate all FC fire tenders allocated to the NSZ to one place, ideally Mole National Park. This must be conditional on the simultaneous establishment of the water-filling infrastructure necessary for the tenders to be effective firefighting tools.

- **Green belts:** Support the establishment of green fire belts wherever feasible.

- **FC fire records:** Require each Forestry District office to add the following details to the existing FC fire database:

  (i) fire event already known or unknown (i.e., was the office already aware of the fire before the alert or not); and

  (ii) response chosen between:
    - allowed to burn/no action taken; or
    - responded to by FC and/or GNFS; or
    - responded to by volunteers without FC/GNFS assistance.

- **Fire alert database:** Support the development of a fire alert database using EORIC's Advanced Virtual Fire Information System. Fire alerts with time signature should be sent to appropriate Forestry District offices.

- **Fire ignition by drone:** Conduct field evaluations of the IGNIS drone ignition seeding system for fuel reduction burning.

Long-term Recommendations

- Measure every intervention planned and funded from external sources against the requirement that it sustain itself financially after the funded programme comes to an end.

- Accept that changing fire monitoring and management in the NSZ is a long-term project and an incremental process.

07

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