REPUBLIC OF SUDAN

FIRE MANAGEMENT STRATEGY FRAMEWORK

FINAL REPORT 2021

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Acronyms

AFIS	Advanced Fire Information System
AVHRR	Advanced Very High-Resolution Radiometer
CBFiM	Community Based Fire Management
EC	European Commission
ESA	European Space Agency
EFFIS	European Forest Fire Information System
DNP	Dinder National Park
DNBR	Differenced Normalized Burn Ratio
FAO	Food and Agriculture Organization
FIRMS	Fire Information for Resource Management System
FNC	Forest National Corporation
GCOS	Global Climate Observing System
GHG	Greenhouse Gas
GoS	Government of the Republic of Sudan
IFMF	Institutional Fire Management Framework
IPCC	Intergovernmental Panel On Climate Change
LIADR	Light Detection and Ranging
MERIS	Medium Resolution Imaging Spectrometer
MANR	Ministry of Agriculture and Forestry
MSI	Multi Spectral Instrument
MODIS	Moderate Resolution Imaging Spectroradiometer
MRV	Measurement, Reporting, and Verification System for REDD+
NFI	National Forest Inventory
NDVI	Normalized Difference Vegetation Index
NBR	Normalized Burn Ratio
NOAA	National Oceanographic and Atmospheric Administration
NFMSC	National Fire Management Steering Committee
NIR	Near Infrared
SWIR	Short Wave Infrared
REDD+	Reducing Emissions from Deforestation and Forest Degradation
UNFCCC)	UN Framework Convention on Climate Change
UN –SPIDER	The United Nation for Space-based Information for Disaster Management and Emergency Response
VIIRS	Visible Infrared Imaging Radiometer
QGIS	Quantum Geographical Information System

Executive Summary

Wildfires play a central role at the national and international levels, by potentially acting harmfully on all REDD+ activities. They not only compromise carbon permanence in the country, but also affect human and animal health, livelihoods, air pollution, desertification and biodiversity. The Food and Agriculture Organization of the United Nations in the Republic of the Sudan (RoS) (FAO-SD) and the Forest National Corporation (FNC) at the Ministry of Agriculture and Natural Resources with support of the federal Government, assisted in the design and implementation of a Measurement, Reporting and Verification system (MRV) for REDD+ program in the RoS. As part of that project, the objective of the current report is to analyze and assess the actual wildfire status as well as to develop and structure a framework and outline for a fire management strategy based on the actual situation of fire in Sudan.

The development of the strategy framework and outline aimed to offer guidance and information about the positive and negative social, cultural, environmental and economic impacts of natural and non-natural wildfires, as well as to support decision makers in achieving sustainable fire management in the country. In order to setup the framework and outline of a fire management strategy, updated information needed to be collected and analyzed via both spatial and non-spatial means.

Spatial and temporal data were collected to investigate and analyze the causes, drivers and impacts of fires, as well as the historical perspective of the fire regime, such as seasonality, fire frequencies and spatial scale and distribution within the country. The methodology adopted by this report depended heavily on multistage data collection, the integration of updated information from agencies, institutions and consultations with direct and indirect stakeholders that have been involved in fire management in RoS. Under this context, online individual consultations, key informant interviews and physical focus group discussions were adopted in order to identify the roles and responsibilities of fire management within different levels in Sudan. Remotely sensed and spatial data were collected and analyzed to detect and map areas of high risk within RoS states. Moreover, field observations with the aid of GIS were taken to analyze environmental and socioeconomic impacts of fires with more emphasis on human and climate factors that influence fire ignition. Additionally, the analysis of the significant contribution of forest fire to GHG emission through remote-sensed estimation of burnt areas and calculation on one of the areas within RoS States was adopted.

A desk analysis was applied to review the existing fire management activities and plans in order to propose guidelines and tools for preparation of a fire management strategy suitable for Sudan. Moreover, policies, acts and legislation of fire management within the context of forests and other natural resources were reviewed and assessed to indicate the gaps, overlaps and coverage within these frameworks. The results of analysis indicated the fire map zones, fire frequencies, regime, seasonality, causes and their impacts. Furthermore, fire map zones were developed based on the total burned area per state and their fire frequencies during the period of 2001-2019.

Based on the analysis and discussion, the study came out with a set of outlines and frameworks for the development of wildfire management strategy options, which could further be applied down into different-level implementation action plans. These plans are expected to deal with the underlying causes, drivers, impacts and the available management opportunities at national and local levels. The outlines of each strategy option were developed and discussed within the context of the proposed institutional fire management framework. The proposed strategy options were formulated to setup the institutional fire management, fire management options, inventory, prioritization and mapping of fire areas, fire prevention, suppression and mitigation, training and education, and fire monitoring, evaluation and reporting system. The report identified the most important gaps, challenges and opportunities for implementation of these strategy options in short, medium and long-term phases.

After the validation workshop, some remarks and recommendations were suggested by the participants, and considered by this report. Among them are the following, more involvement of native administrations and women sector, within the proposed institutional fire management framework, addition of high-resolution remotely sensed data to provide a logical framework and to support the calculation of forest fire emissions in order to improve the GHG inventories on a seasonal basis, enhancement of detection and mapping of the accurate forest burnt areas within the country, assessing wildfire risk to quantify the existing and potential wildfire intensity, severity and effect on livelihood, and finally re-allocating the fire focal points as part of the institutional fire framework at FNC instead of the Ministry of Agriculture's suggestion for the state authorities to provide more funds for the implementation of the fire management plans in their domains.

ملخص تنفيذي

تلعب حرائق الغابات دوراً رئيساً على المستويين الوطني والدولي، وذلك من خلال الأثر السالب لها علي جميع أنشطة برنامج خفض الإنبعاثات للغازات الدفيئة المعروف بالرد بلس بجمهورية السودان. فهي تعيق تخزين الكربون، وأيضا تؤثر على صحة الإنسان والحيوان وسبل كسب العيش وتلوث الهواء والتصحر والتنوع البيولوجي. قامت منظمة الأغذية والزراعة التابعة للأمم المتحدة في البلاد وبمساعدة االهيئة القومية للغابات بوزارة الزراعة والموارد الطبيعية وبدعم من الحكومة الفيدرالية، بتصميم وتنفيذ نظم القياس والإبلاغ والإعتماد (MRV) لبرنامج الرد بلس كجزء من هذا المشروع. وعليه فإن الهدف الأساسي من هذا التقرير هو تحليل وتقييم حالة الحرائق البرية (التى تعرف ايضا بحرائق الغابات والمراعى) الآنية والسابقة لتطوير هيكل إطاري ومخطط استراتيجي لإدارة الحرائق في البلاد.

يهدف تطوير الهيكل الإطاري والمخطط الإستراتيجي إلى تقديم إرشادات ومعلومات حول التأثيرات الاجتماعية والثقافية والبيئية والاقتصادية (الإيجابية والسلبية) لحرائق الغابات الطبيعية وغير الطبيعية بالإضافة إلى دعم متخذي القرارات لتحقيق الإدارة المستدامة للحرائق بالبلاد. ومن أجل تحقيق ذلك تم إعداد إطار العمل المنهجي والخطوط العريضة لاستراتيجية إدارة الحرائق، من خلال جمع المعلومات المحدثة وتحليلها عبر الوسائل المكانية وغير المكانية.

أستخدم التقرير المناهج الوصفية والتحليلية والتاريخية لجمع البيانات المكانية والزمانية وتحليل أسباب ودوافع وتأثيرات الحرائق من حيث موسميتها وتواترها ومقياسها المكاني وتوزيعها داخل القطر. اعتمدت المنهجية بشكل أساسي على جمع العينات المتعددة المراحل، ودمج المعلومات المحدثة من الوكالات والمؤسسات والمشاورات مع أصحاب المصلحة المباشرين وغير المباشرين عبر الإتصالات الإسفيرية ومقابلات المخبرين الرئيسيين وجلسات النقاش الجماعي المباشرة من أجل تحديد أدوار ومسؤوليات إدارة الحرائق ضمن المستويات المختلفة بالبلاد. تم جمع بيانات الاستشعار عن بعد والبيانات المكانية وتحليلها لاكتشاف أهم مناطق الحرائق ومن ثم رسم خرائط للمناطق ذات المخاطر العالية داخل الولايات المختلفة بالسودان. علاوة على ذلك، تم أخذ الملاحظات الحقلية بمساعدة نظم المعلومات الجغرافية لتحليل الآثار البيئية والاجتماعية والاقتصادية للحرائق مع التركيز على العوامل البشرية والمناخية التي تؤثر على اشتعال الحرائق. كذلك، تم اعتماد تحليل المساهمة الكبيرة لحرائق الغابات في انبعاثات الغازات الدفيئة من خلال تقدير المساحات المحروقة التي تم الحصول عليها عبر صور الأقمار الصناعية وحساب عامل لإنبعاثات لهذه الحرائق بالسودان.

صاحب كل ذلك، تحليل مكتبي لمراجعة أنشطة وخطط إدارة الحرائق الحالية من أجل اقتراح مبادئ توجيهية وأدوات لإعداد استراتيجية إدارة الحرائق المناسبة بالبلاد. بالإضافة لذلك، تمت مراجعة وتقييم أعمال وسياسات وتشريعات إدارة حرائق الغابات والموارد الطبيعية الأخرى لتحديد الفجوات والتداخلات وكيفية معالجة وتغطية هذه الفجوات ضمن الهيكل الأطاري المقترح والخطط الإستراتيجية المعدة لذلك. أشارت نتائج التحليل إلى أكثر المناطق المتأثرة وذلك من خلال تخريط الحرائق؛ وتحديد مداها وتواتورها وموسميتها والأسباب المؤدية لها. بناء علي ذلك ، تم حساب إجمالي المساحة المحروقة لكل ولاية وتواتر حرائقها خلال الفترة من 2001-2019.

بناءً على التحليل والمناقشة ، خرجت الدراسة بمجموعة من الخطوط والأطر العريضة لتطوير خيارات استراتيجية لإدارة حرائق الغابات، والتي يمكن تطبيقها بشكل أكبر في خطط عمل تنفيذية على مستويات مختلفة. من المتوقع أن تتعامل هذه الخطط مع الأسباب الكامنة والدوافع والتأثيرات وفرص الإدارة المتاحة للحرائق على المستويين المحلي والقومي. كذلك تم تطوير الخطوط العريضة لكل خيار إستراتيجي ومناقشتها في سياق إطار إدارة الحرائق المؤسسي المقترح. وتمت صياغة خيارات الاستراتيجية المقترحة لإعداد إدارة الحرائق المؤسسية؛ وتشمل: جرد وتحديد الأولويات والمسئوليات للمتعامين بالموارد الطبيعية والغابات، التخريط المستمر لمناطق الحرائق؛ منع الحرائق وقمعها والتخفيف من حدتها؛ التدريب والتعليم؛ وتفعيل نظم مراقبة وتقييم الحرائق والإبلاغ عنها. حدد التقرير أهم الثغرات والتحديات والفرص لتنفيذ هذه الخيارات الاستراتيجية في المراحل القصيرة والمتوسطة والطويلة الأجل.

بعد ورشة الإعتماد لهذا التقرير، اقترح المشاركون فيها بعض الملاحظات والتوصيات ، والتي تم أخذها في الأعتبار ومن بينها ما يلي: زيادة مشاركة الإدارات الأهلية والقطاع النسوي في الإطار المؤسسي المقترح لإدارة الحرائق، إضافة بيانات الإستشعار عن بعد عالية الدقة لتوفير أطار منطقي لدعم حساب انبعاثات حرائق الغابات من أجل تحسين قوائم جرد الغازات الدفيئة على أساس موسمي، وتعزيز كشف ورسم خرائط دقيقة لتحديد المناطق المتأثرة بالحرائق داخل الغابات. هذا بالإضافة الي تقييم مخاطر حرائق الغابات وتحديد شدتها الحالية والمحتملة، وتأثيرها على سبل كسب العيش. كما أوصت الورشة بوضع نقاط اتصال الحرائق كجزء من الإطار المؤسسي المقترح لتكون بالهيئة القومية للغابات بدلا وضعها بوزارة الزراعة والموارد الطبيعية وأقترح علي سلطات الولايات أن توفر المزيد من الدعم المالي لتنفيذ خطط إدارة الحرائق في ولاياتها.

Introduction

Forests and woodland ecosystems are considered as an important key for the social, economic and environmental sustainability and development of the RoS. The Sudan forests and woodlands are diverse and spread over a number of ecological zones under the influence of rainfall, soil and topography. Their vital environmental roles, socioeconomic services and products have significant importance in supporting the livelihoods of rural populations and the national economy. Forests and woodlands are showing decreasing trends due to many factors contributing to deforestation and forest degradation (NFI 2020). Major social and economic changes in land use have affected the wildland/rural interface and resulted in increased amounts of biomass and a higher exposure to human-induced fire. Forest fires or wildfires can play a crucial role at the national and international level, by acting very negatively in all REDD+ activities - reducing emissions from deforestation, forest degradation, sustainable management of forests, conservation and enhancement of forest carbon stocks. Forest wildfires not only compromise carbon permanence in the country, but can also negatively affect human health, livelihoods, air pollution, desertification and loss of biodiversity.

Global warming and climate change are affecting the globe and will most likely exacerbate the current risks of forest fires. Particularly in RoS, where the large northern part of the country is mostly desert and semi desert with average annual temperatures around 30° C and average annual rainfall about 150 mm/year. The central part of the country is semi-desert to savannah with average annual temperatures that are around 27° C, and rainfall averaging to about 200 mm/year. Rainfall, which supports the great majority of agricultural activities, is erratic and varies significantly from the northern to southern ranges of the country. Consequently, the length and severity of the fire season, the extreme conditions in many areas and the extension of areas of risk sees the probability large fires will increase. Moreover, as well as changes in climate, the land use changes and human activities in the forest are expected to increase and can significantly affect wildfire risk and consequently increase the burned areas in the Sudan. Therefore, high international and national concerns were developed and integrated by FAO and FNC RoS, assistant in the design and implementation of a Measurement, Reporting and Verification system (MRV) for REDD+. Development of the RoS Fire Management Strategy is to help and facilitate understanding the risks and consequences of fires into the broader goals of the Sudan.

The Sudan fire management strategy must establish broad and national-level direction as a foundation for implementation of actions across the country. The strategy is informed by regional and national analyses, including in-depth risk-based analysis that delves into the specifics of national challenges, underlying causes, and the available management opportunities, fire danger rating, as well as monitoring and prevention. The outline strategy scope is to offer guidance and information about positive and negative social, cultural, environmental and economic impacts of natural and planned fires in forests, woodlands, rangelands, grasslands, and agricultural, rural and urban landscapes. The other aspect of the strategy guides fire managers to answers regarding monitoring, early warning, prevention, preparedness (international, national, subnational and community levels), safe and effective fire initial attack, and post fire landscape restoration.

Historical Perspective of Fire in RoS

Bayumi (1989) discussed the history of fire regimes in Sudan. He stated that the dry season starts two to three weeks after the rainy months i.e. November to April/May. During the dry season, associated with low humidity, high fuel loads and the presence of moving grazers, there was a heavy increase in grasses that led to wildfire hazards. Recently, the seasonality of fire begins at th end of August and ends on the thirty first of July the next year; it also follows the period between two successive rainy seasons. This suggests that the regime of fire in RoS is longer and influenced negatively by climate change. Annually wildfires are common and spread rapidly due to northeast winds and flat terrain. This is the case in central, western and southern Sudan. In colonial times and up to the end of the 1960s the Native Administration, under the supervision of the Range and Pasture Department and in close collaboration with the Forestry Department, maintained a firebreak network extending north-south over North Kordofan and North Darfur to protect grazing lands and gum gardens.

Due to limited awareness of the effects and impacts of wildland fires in RoS, inadequate actions are engaged to prevent and suppress fires. Stauber (1995) briefly described the situation in the country as follows: *"Responsibility for fire suppression has been clearly assigned to the Forests National Corporation (FNC) for Forest Reserves. Fires set by farmers or nomads are unchallenged in most of the natural rangelands of Sudan."* Usually four-meter-wide lines are cleared and spaced parallel to each other and separated by an 80 m wide area that is burnt just before the end of the rains. This pattern is repeated systematically over the semi-arid lands. Early warning, detection and monitoring systems are not available. Previously as stated, Bayumi reported there were no volunteer fire fighters available, but people and communities are obliged by the forest law to report and help fight wildfires.

Most fire information in RoS is still fragmented and scattered with very limited research and studies about the risk and impact of fire. Additionally, the early fire incidents in natural protected areas in Sudan could inform the history of fire in forestry. An understanding of fire history, natural and human caused, is important in fire management as it documents the frequency, distribution and severity of past events. It also provides insight into the effects of fire prevention, detection and mitigation within forested areas. During the last decade, much work has been carried out in forest fire detection, assessment, risk management and other related studies, considering the environmental degradation and direct consequences in climatic change locally and globally. Assessment of Forest Fire Management was carried out in Jebel Marra, which is one of the richest ecosystems in RoS, both in biodiversity and high scenic value. Natural forests and plantations are embedded in a high fire-prone environment in Jebel Marra (Elgamri, Gaiballa, and Goldammer, 2005).

Detection and Monitoring of Forest Fires during 2010 - 2014 using Remote Sensing was applied to forest fire in Dinder National Park (DNP), RoS, which is considered one of the richest biodiversity spots in the country (Mohamed, Elnour Hassbelkreem, 2015). Moreover, the effects of forest fire on natural resources within RoS regions were discussed via a few studies (Kammal, et,al. 2017,& Mai, et,al . 2014). However, the growing number of larger, damaging wildfire events indicates that contemporary fire management needs to account for the disturbance regimes and ecosystem types that define fire prone landscapes. This new context calls for more effective science-based forest fire management and risk-informed decision-making.

Legal, Institutional and Policy Framework of Fire Management

Fire management actions should be based on a clear and sound legal, institutional and policy framework. This framework provides the basis and structure for strategy options, considering plans and implementation actions. The legal framework for fire management encompasses broad multisector resource management plans, with clear-cut roles and responsibilities (Table 1). In order to ensure that Sudan's natural resources, forest, grassland, wildlife resources, water sources and land are not affected by wildfire, there is a need for a fire management policy besides just an institutional framework. Sector policies should either contain statements and directives addressing the problem of wildfire or refer to policies that do so. Some policies such as the forest, beekeeping, wildlife and rangeland policies contain statements for fire management.

However, most ministries do not effectively address the practices of fire management or ratify these policies at the implementation level. The forest policy of (1986) emphasizes the protection of forests against fire. The forest law (1989) prohibits trespassing of people and their animals into the reserved forests and prohibits the carrying of ignited material into the forests, making fires for cooking or other purposes in or near forests, and obliges people to help extinguish forest fires. Based on a field survey, responders stated policies for fire, indicating most of these laws are not well implemented. The Forests and Renewable Natural Resources Act (2002) offers a framework for the management and protection of forests and renewable natural resources surrounding pasture and range as well as the framework governing the managerial system of the forestry sector. The Act calls for the establishment of "National Forests and Renewable Resources Corporation," to intensify afforestation activities, encourage the establishment of forests and range lands and render technical advice to both the private and public sector in that regard, and to promote production of different types of gums and non-wood forest products and fodder, encourage community participation and facilitate trans-boundary grazing. All these activities act as prerequisite for an appropriate fire management strategy because they involve large participation of local communities.

The purpose of the Wildlife Conservation and National Parks Act (1986) is to conserve wild animals and protect national parks and game areas, encourage the wise use of wildlife resources and their development. The Act is still not fully enforced to address the protection of natural resources against fire risks.

The Environment Protection Act (2001) consists of 27 articles encompassed within 5 chapters: introduction provisions, the High Council for Environment and Natural Resources (HCENR), general policies and guidance for environmental protection, offences and penalties, and general provisions. The Act is intended to harmonize the different sectoral environmental laws, sets environmental standards, call for the protection of biodiversity and combating pollution, and requires environmental impact assessment to be carried prior to implementing any development project. Despite the fact that the environmental protection measures constitute the core of this Act, the fire management issues are not explicitly indicated.

The Rangelands and Forages Resource Development (Rationalization) Act 2015, clearly indicates statements and strategies for the protection of rangeland against fire incidents. Under this context, some management and prevention measures were suggested for protection and mitigation of rangelands. Despite that, this act is still not fully ratified to protect the rangelands and other natural resources.

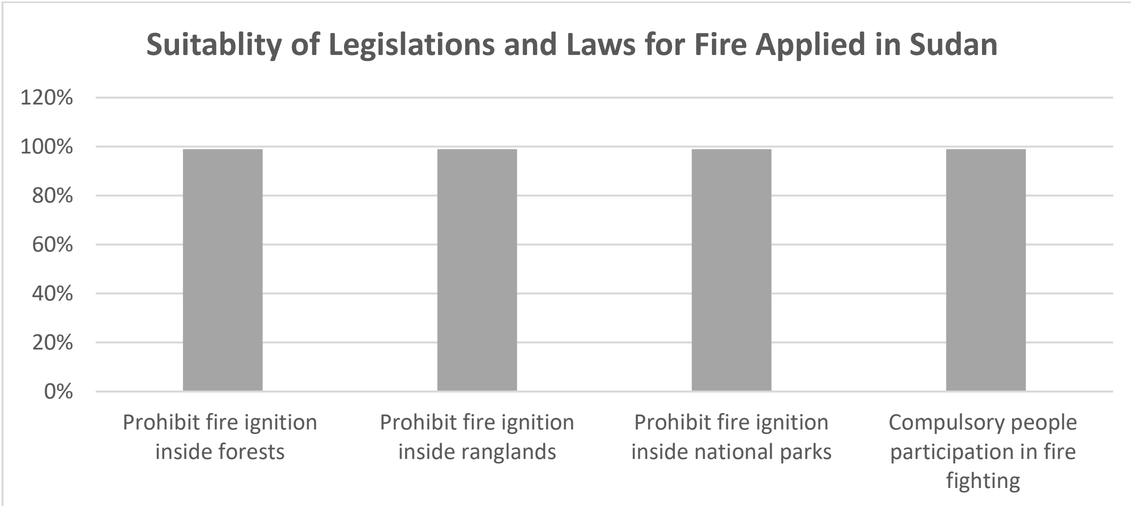

Figure 1: Legislation and laws adopted for fire in RoS (Field survey, 2019)

Although there were some laws applied, fire is still not significantly covered by existing policies and acts, and many related sectors neither commit resources nor programs for fire management. Many local governments have no laws or policies to address the fire problem, thus, limiting their capacity to protect natural resources. The formulation and implementation of by-laws have been plagued with a number of problems, among them that the by law formulation process is slow and inefficient. It is worth mentioning, that most of the laws are either not fully ratified or contradicted by the conflict of interest between the different natural resource sectors or between the state and federal levels. There is need to put in place a fire management policy and as a result establish a clear legal and institutional framework for fire management. Reduction of fires will definitely conserve the natural resources of the country and will improve the growth of many tree species. These plans elaborate the management, protection and restoration of land and resources. Based on this the strategy options outlined for fire management must include the following:

- Review of existing policies and legislation to eliminate the conflict of interest, overlaps and contradictions between policy and legal frameworks.
- Setup a clear and comprehensive policy, legal and institutional framework to cover all gaps with regard to fire management activities.
- Arrangement of appropriate and detailed input for every aspect of fire management, including fire use, prevention, detection, initial attack, large-fire suppression and restoration.
- Analysis of the actions that increase or decrease the risk and hazards affecting fire behavior, fire damage or benefit, as well as impacts on the safety of firefighters, fire managers and the public.
- Consider types of ecosystems, potential fire effects, fire regimes, and social, economic and environmental values.
- Define agencies, organizations, administrative units and stakeholder responsibilities, roles and duties for fire management.

Key Actors, Roles and Responsibilities and Guiding Principles

Based on consultations the agencies, sectors, institutions and stakeholders were mapped, and their roles as well as responsibilities in fire management are set down and discussed in Table 1.

Key actors	Roles	Responsibilities	Guiding Principles
National Council for Civil Defense and Emergency Preparedness	Enabling states and supporting the experience of the federal government by delegating powers to the president of the council	Completed the legislation regulating civil protection work in Sudan	Laws: - Civil Defense Law - Requirements for protection and safety in public facilities - Pollution control and environmental protection measures - Volunteerism

Key actors	Roles	Responsibilities	Guiding Principles
Higher Council for Environment and Natural Resources (HCNR)	Formulation of laws and legislation that leads natural resource, prevention, monitoring within the legislative framework for the council	1- General coordination among stakeholders 2- Enhancement of the roles of different stockholders 3- Partially raising funds for different fire management activities 4- Follow the implementation of law and legislation	- Environment Protection law - Environmental Impact Assessment (AIE) - Supervision of all federal environmental projects - It has direct responsibility for preventing environment damage and loss, hence fire as one of the most destructive causes of environmental degradation
Ministries of Agriculture, Natural Resources, Energy, Ministry of Animal Resources, Wildlife, Health and Infrastructure and Transportation and Ministry of Civil Defense,	1-Setting policy, legislation of natural resource protection 2- Setting of management planning and strategies for natural resource management using appropriate tools and techniques 3- Setting plans and strategies to ensure	1- Empowering all stakeholders to achieve the strategy plans including goals and activities within fire management strategy frame work 2- Adopting best practices in prevention and monitoring fire risk 3- Coordinates with NGOS and developmental and environmental projects working on	It has a direct responsibility regarding all mentioned sectors. Aided with law and executive power at federal and state level.

	sustainable natural resources management and development 4- Setting polices for restoration base on land use maps in the areas under fire risk and threats	natural resources at local state and federal levels and encourage natural resources institutions 4- Provision of funds needed for implementing the fire management plans in their states.	
FNC	1- Setting federal frames and legislation of forest management 2- Restoration and deforestation plans 3- Setting and plan the fire lines within federal and state forests as part of national steering committees	1- Adopt the policies regarding all management activities for natural resources 2- Adopt all activities in relation to management, prevention, suppression and mitigation of forest fire in federal, state, and local levels	- Direct involvement in all forest laws. - Considered as the main implanting body for all forest management, utilization and protection. - Concerned with mitigation and restoration activities - Has federal and state existence

Key actors	Roles	Responsibilities	Guiding Principles
State and Locality administrations units	Administrating and monitoring	Implement the best practices in relation to natural resources management as well as firefighting at state and local levels	- Direct involvement at the state level - Aided with some state laws and regulation in accordance with the federal level
Local communities	1- Protection of the forest from fire causes by local and adjacent communities 2- prevention of forest boundaries from firing	1-Utilize the forest resources based on the recommended practices by state FNC level 2-Assist FNC in fire prevention and suppression 3- women participation in fire prevention and suppression	- Community participation in decision making and protection - Direct involvement in extension program and some implementation programs
Honey collectors, Fuelwood and charcoal	Conserve the forest resources from the fire accidental causes	Follow best practices in producing their	- Rationalization of activities

producers and traders		charcoal and fuelwood Follow the management plan of FNC at state level	
Meteorological and Weather Unit	Monitoring , mapping and forecasting all weather and climate information (rainfall amount and distribution, wind speed, temperature and humidity) which have direct relation to natural resources management and natural disasters risk reduction	Providing data and information in relation to natural resources management and natural disasters risk reduction	- Data base - Dissemination data, monitoring and evaluation
Oil and Mining	Disturbing ecosystems	Follow national resources land use maps	- Rationalization of activities
Large scale mechanized farming	Disturbing ecosystems	1-Follow roles, policies of agriculture farming 2- Natural resource land use maps	- Rehabilitation of forest sectors including shelterbelts and wind breaks in accordance with the restoration law

Key actors	Roles	Responsibilities	Guiding Principles
Remote Sensing Authority	capacity development through education, training and workshops- awareness programs	1- Coordinate the efforts and activities related to space technology making use of local and foreign expertise 2- Conduct a scientific research in the application of space technologies 3- Provide training in space technology applications	Data base - Dissemination data monitoring and follow up of projects in fire and other disaster management
Unit of Disaster	Motoring and mapping of natural disasters	Adopting best practices and advanced technologies for natural disaster management as well as fire risk reduction	- Data base - Dissemination data - Monitoring and evaluation - Follow up of projects in fire and other disaster management

Academics	1- Increasing awareness and training to raise capacity of local and adjacent communities, to adopt the best practice that led prevention and conservation of natural resources 2- Provide information (Fire line width, length and direction ...etc.) and research out puts which help in best management of natural resources to FNC and decision makers at national, state	Adopting research and advanced methods for fire assessment and fire risks	- Data base - Increasing fire technologies based and sciences

Table 1: Key actors, Roles, Responsibilities and Guiding Principles setup

Analysis of Current Wildfire Situation in RoS

Wildfire risk is determined by a combination of many factors, including vegetation (fuel), weather, climate, forest management practices and other socioeconomic parameters. Management actions and deployment of resources to reduce risk of fires must be planned based on where and how fires occur. Hence, precise fire mapping and statistics describing how wildfires are changing in time and space are essential for assessing the role of driving factors such as land use, human activities and climate. In addition to their ecological impact, wildfire events have socioeconomic impacts in terms of both loss of human life and economic damage. Adoption of integrated fire management plans cannot be prepared and the ecological effects of the fire on fauna and flora could not be identified without good knowledge of the fire regime. This calls for more effective science-based forest fire management and risk-informed decision-making, which account for the socioeconomic, climate and environmental roots of wildfires.

The information about the fire regime, including the extent, seasonality, frequency, intensity and spatial distribution of fires, is much needed. Thus, this report developed and structured an integrated analysis approach to assess the current situation of wildfire and developed a framework or outline for a fire management strategy in Sudan. The results of analysis and interpretation processes provides some statistical and descriptive information of wildfire frequencies, hot spots, seasonality, extent, causes as well as the ecological, socio-economic and environmental impacts.

Methodological Approach

This report is based on a multistage approach of data collection and analysis. Both spatially and temporally, data were collected for analysis and visual interpretation. Remotely, spatially, environment and socioeconomic data as well as desk review analyses were collected, applied and discussed through all analysis stages. Integration of spatial analysis and field survey data were analyzed, over-laid and mapped to detect and assess the fire risk within the States of RoS. Field observation and interviews were adopted for analyzing the environmental and socioeconomic impacts of fires with emphasis on human causes and other climate factors that influence the fire ignitions. Desk review analysis was applied to review the existing fire management activities and plans in order to propose guidelines and tools for preparation of a fire management strategy to be suitable for RoS. Additionally, a review and analysis of the policies, acts and institutional arrangement of fire management were discussed within the context of forest and other natural resource polices. The methodological aspects and staged approach are summarized in Fig 2.

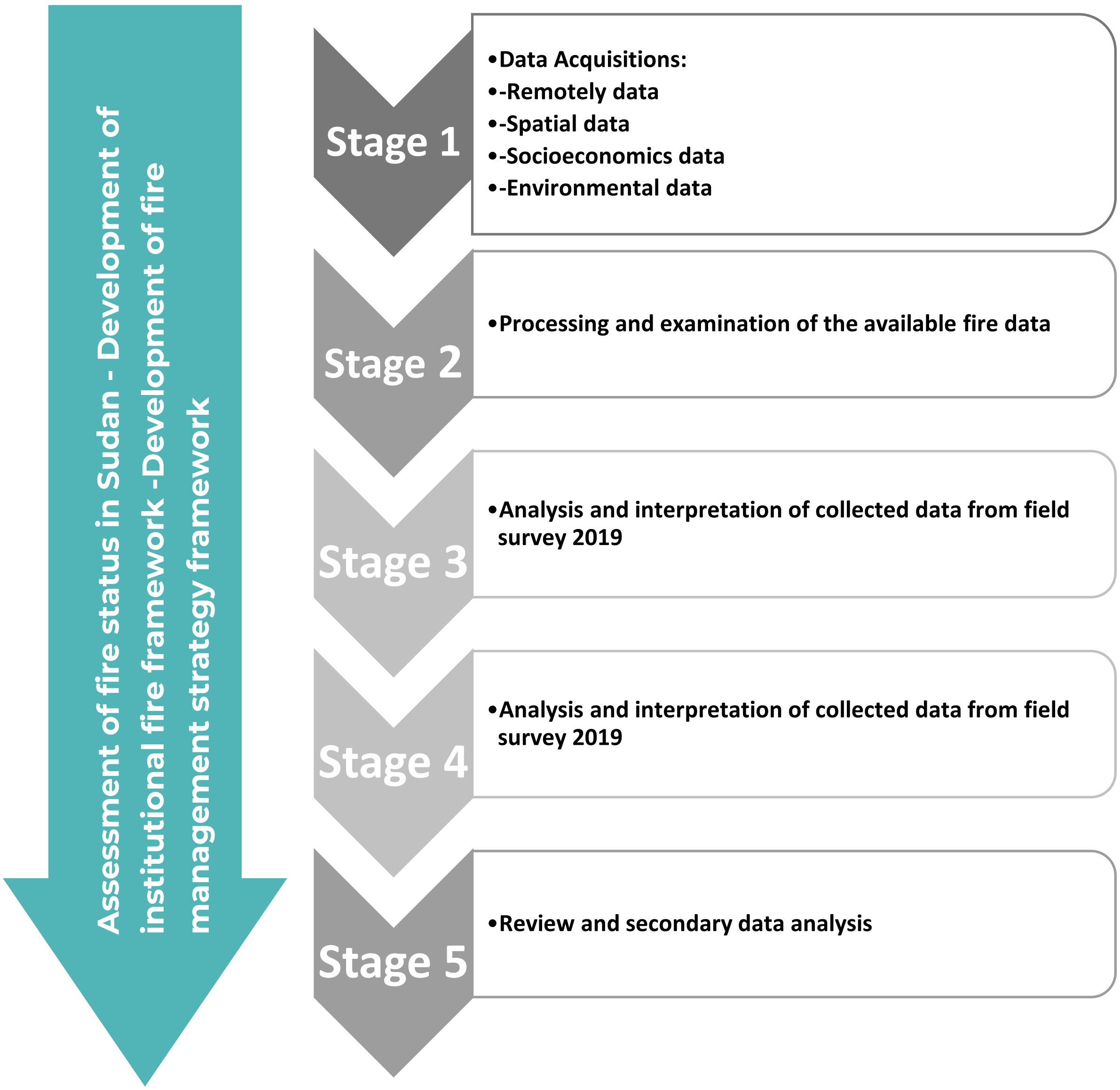

Figure 2: Adopted Methodological Framework

Satellites Remote Data and GIS Techniques for wildfire Management

Satellite, remotely sensed data and GIS techniques could provide an integrated technique of detecting, classifying and mapping the impacts of the diverse spatial and temporal patterns of fire for an ecosystem or landscape. The investigation and analysis of wildfire in Sudan were applied using MODIS (Moderate Resolution Imaging Spectroradiometer - MODIS 64A1 and Sentinel-2 Satellite Images) data downloaded free of charge from ba1 ftp server of University of Maryland(ftp://ba1.geog.umd.edu) and (Copernicus Open Access Hub: https://scihub.copernicus.eu/dhus/#/home,), to map and report the burned area and hotspots for fire season 2001 – 2020 in RoS. The frequencies and total burned area were reported and mapped from 2001 to 2019. Fire Information for Resource Management System (FIRMS) provide active fire hotspots data generated from MODIS and VIIRS (https://firms.modaps.eosdis.nasa.gov/download).

The results showed that the fire season each year starts in the period October to January and it follows the period of the rainy season. According to the trend of fire frequency and occurrence, fires occurred each year, covered large-scale of the country and may be attributed to frequent fire incidents. Ultimately, there may be increasing of total burned area in RoS and hence the increase of GHG release in the atmospheric.

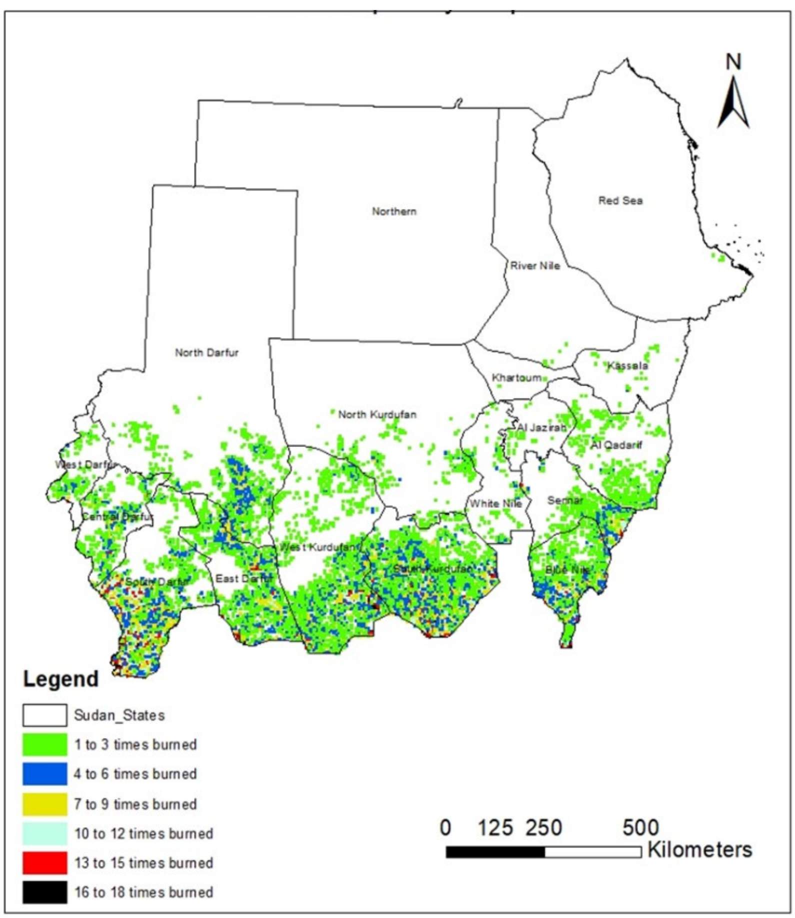

Figure 3: Fire frequency map of Sudan (MODIS data analysis for period of 2001- 2019)

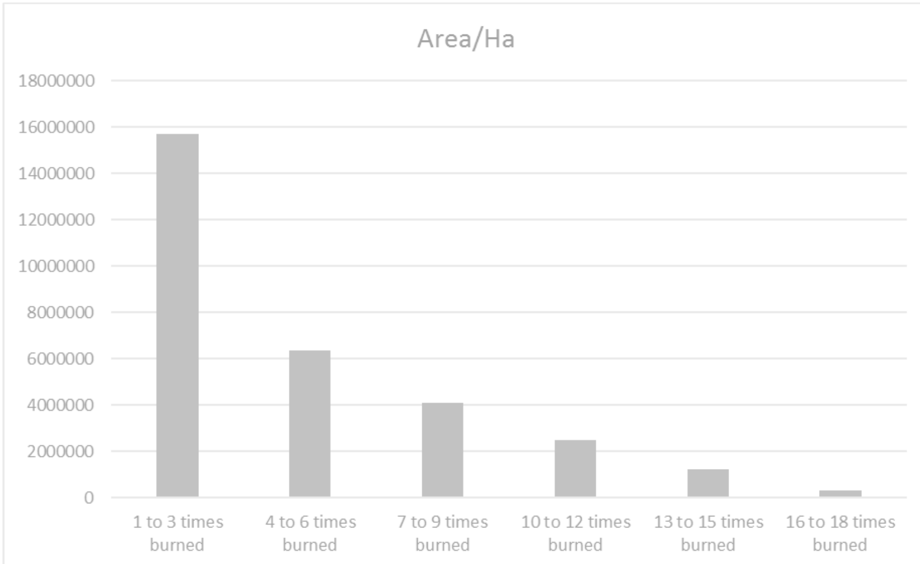

Figure 4: Frequency of Burned areas in RoS during the fire seasons (2001- 2019)

Additionally, the maps of fire hotspots during 2002-2019 were set out in Annex 1. Based on these maps the following observations could be made:

1. Most fire hotspots were detected within the southern and western part of the country indicated by Darfur, Kordofan, Sinnar, Gazira and Blue Nile States
2. Very few fire hotspots were detected within the Northern part of the country indicated by River Nile State
3. The rate of fire hotspots increased during the period 2001-2019
4. A notable increase in burned areas occurs during the period from October to January every year coupled with the increment of the fire hotspots in the country

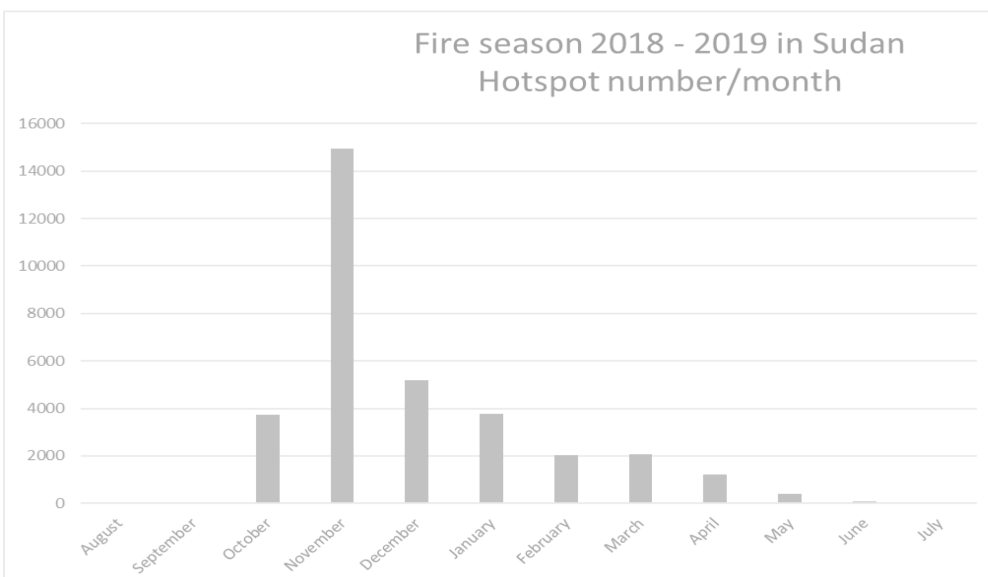

Figure 5: Total burned areas (ha) during the fire season in RoS during 2018- 2019

Further information concerning wildfires within the Sudan's States, which are facing annual fire incidence, were analyzed by using in-depth spatial analysis and GIS tools (Fig 6). The results showed that Sinnar State has lower percentages compared to other States. These results support the respondents argument, that most of the land in Sinnar State was converted from forest and range to agricultural land and consequently fire incidence is reduced, and it could be also because natural resources in Sinnar State occupy almost one third of the total area of the state and most of these natural resources (reserved forest Dinder National Park) are under protection and a management regime of fire exclusion and suppression. Whereas the lack of forest and plantation management coupled with the lack of silvicultural practices in other regions, such as Darfur, create circumstances that are favorable to the propagation of fires (Field Survey, 2019). It is useful to consider a vegetation map of Sudan: Distribution & extent of plant cover (fuel or combustible material).

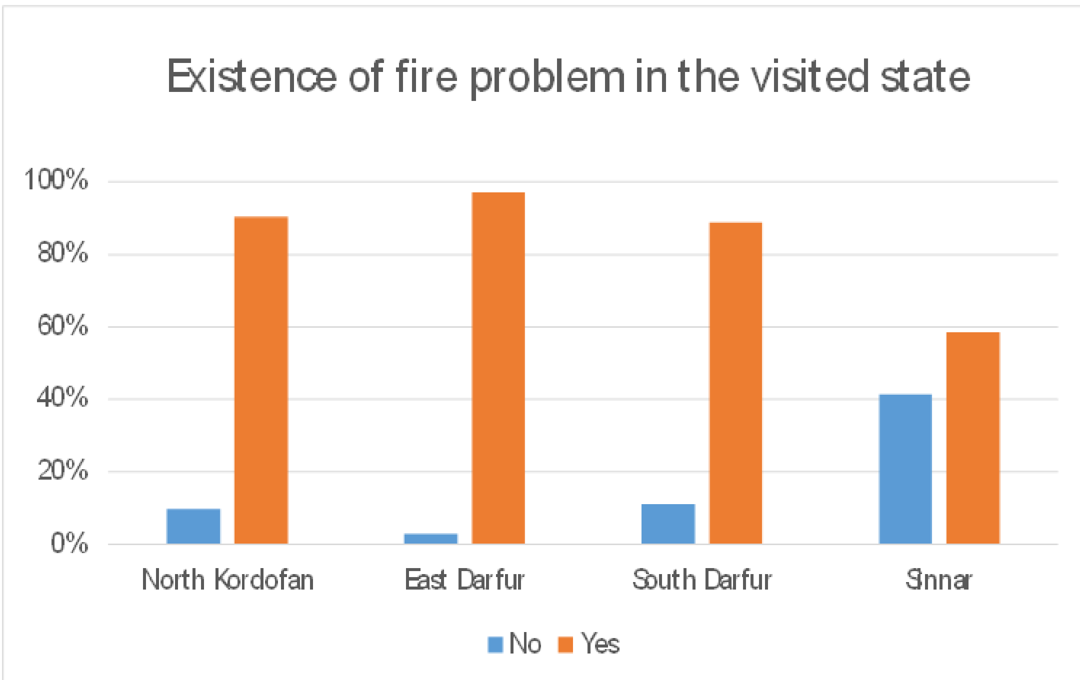

FIGURE 6: EXISTENCE OF WILDFIRE INCIDENCE WITHIN RoS AFFECTED STATES

An in-depth spatial analysis was applied to extract the burned areas and their percentages within the States. It is well recognized that fire was spread over all States but the more effected states are South Kordofan, South Darfur, Sinnar, and East Darfur. Most of theses States are under pressure of rain fed agricultural practices, nomadic tribes and military intervention that can be reflected in the vegetation cover. Remote and field data covering a broad spectrum of environmental, socioeconomic, and fire-related statistics during (2001- 2019) were assembled to support the development of in-depth spatial and temporal analysis for fire at national and local levels. These data were summarized and consolidated to the state level to provide a comparable unit of analysis across each State.

The analysis come out with very detailed information concering burned areas and fire incidence in each state and accordingly fires can be classified into four zones based on the percentage of burned areas and fire trend in each state (Annex 1 & 2: Figures, 28-38).

Analayis and Mapping of Burned Areas Within Sudan states During 2001-2019

As presented above, the most affected areas are located in the southern part in the country, which could be attributed to the following reasons;

1. These are the most forested woodland in the country, which face the intensive land use activities (traditional rain fed agriculture, range activities)
2. Huge livestock population
3. Nomadic pastoralists and their movement in search for water and pasture
4. Lack of sufficient livestock corridors
5. Civil war
6. Frequent conflicts over resources between pastoralist and farmers
7. Inadequate forest management plans due to the inaccessibility of these remote areas

The calculation of total burned areas in Sudan was presented in Figure 7. The results explain and further support the above discussion concerning the affected areas within the country.

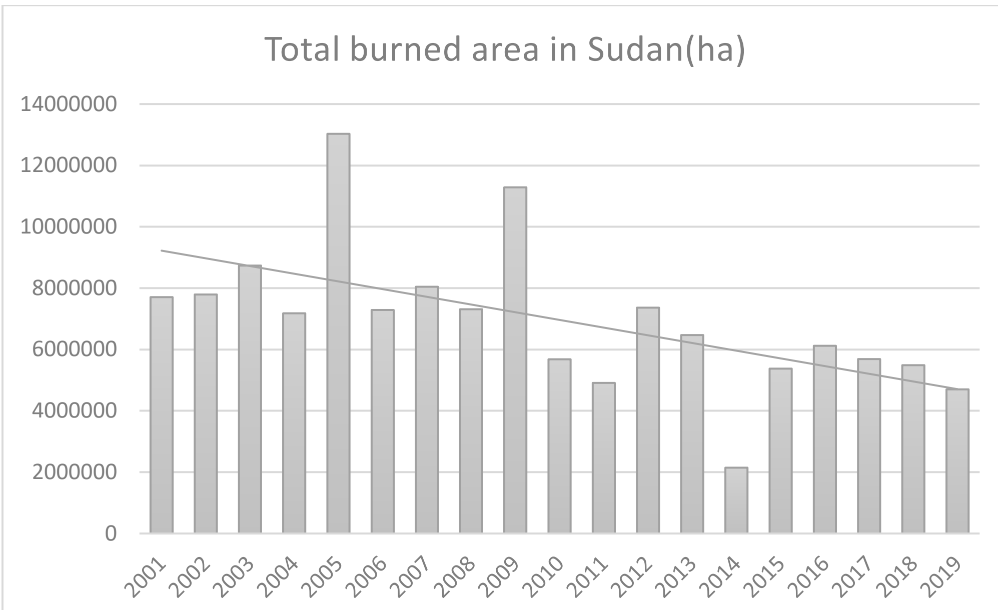

FIGURE 7: TOTAL BURNED AREA IN ROS (HA) DURING 2001-2019

As shown in Figure 7, the fire incident showed very high-burned areas in season 2005 and 2009. This may be due to the amount of grasses in these areas and lack of prevention activities for fire lines clearing and preparation. From the group discussion, it was indicated that during this season in East and South Darfur, South Kordofan and Blue Nile states, had a high rainfall precipitation during that season and increased grasses as well as grazing activities. More detail analysis was applied to calculate the amount of burned areas within the land cover classes obtain by NFI, 2020. Figure 8 showed the percentage of burned total area of forestland and other woodland. It indicated that the most affected land cover classes were also concentrated within the fire season 2025 and 2009. This result supports the above, and puts more emphasis on fire management plans within contexts of climate factors and vegetation cover.

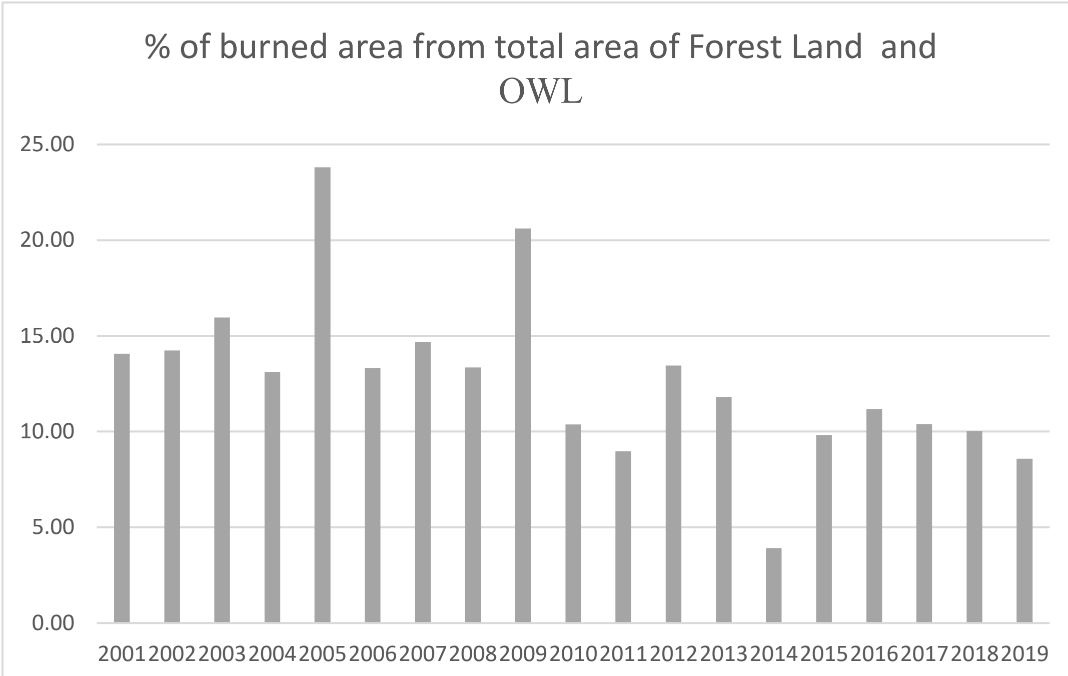

Figure 8: Percentage of burned area from total Forest Land and Other woodland area (ha)

Based on this analysis the fire occurrence and severity vary each year within the states, with a decreasing trend. Wildfire is subject to different factors, which vary with the type and condition of the vegetation cover, weather, hot, dry and windy conditions, which affect fire occurrence and behavior, within the states. The risk of fire can change quickly from day to day and week to week. Also, the number of fires and their impact is highly variable from year to year. This unbalanced manner of fire trends makes setting up a systematic, routine approach to fire management and the control of wildfires a very difficult and complex task. Thus, the development of annual and periodic monitoring, evaluation and reporting systems is badly needed.

Fire Zone Maps of Sudan

Based on the above spatial analysis and trends of wildfire distribution as well as the total burned area in each state and the frequencies of fire, RoS was classified into four fire zones as shown in figures 9 and 10.

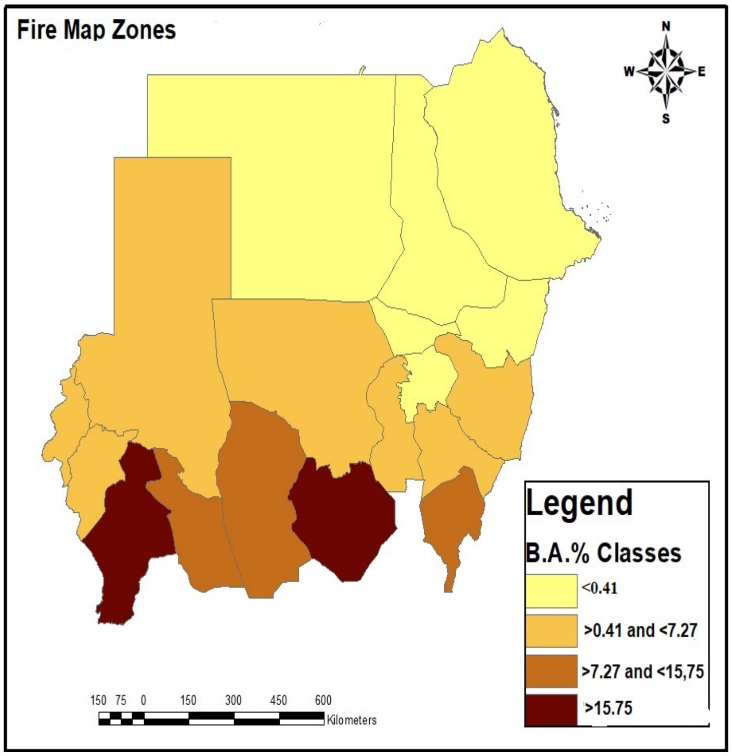

Figure 9: Fire Zones range in Sudan (remote sensing data analysis 2001-2019)

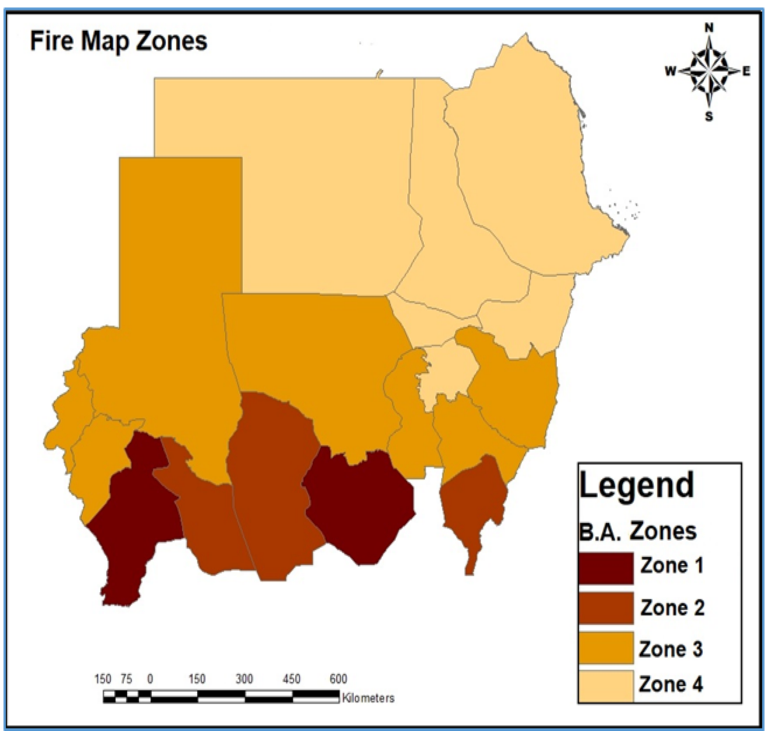

Figure 10: Fire map Zones – RoS

Based on the above fire map, the description of fire zones are as follows:

- **Zone 1**: represented by South Darfur and South Kordofan, indicates the Very Highly Risky Fire Zone area with regard to fire incidence. The complexity of the natural resource utilization in the area is mainly due to the huge population of livestock and frequent conflicts that arise between native tribes of farmers and livestock herders. The two states represent the most vulnerable areas that urgently need a fire management strategy in the short term, as well some future strategies for the mitigation of fire incidence in the long run.
- **Zone 2:** represented by East Darfur, South Kordofan and Blue Nile states, designates the second Highly Risky area with regard to fire incidence. The nature of these areas is to some extent similar to Zone 1, with rich forestlands, range and biodiversity. Accordingly, this zone should also be given high priority and urgency for fire management strategies in the short and long terms.
- **Zone 3**: represented by North Kordofan, Central Darfur, North Darfur, West Darfur, White Nile, Sinnar and Gadarif; is the largest zone with Moderately Risky fire incidence. Despite that this zone should receive high priority for any future fire management strategies because it comprises the main production areas of food (sorghum and millet) and cash crops (gum Arabic, sesame and groundnuts) within the traditional rain fed and mechanized farming system, i.e. a vital source livelihood and food security within the gum belt area of central Sudan.
- **Zone 4:** represented the most vulnerable areas and Slight Risk with regard to fire. It comprises Khartoum, Gazira, Red Sea, Kassala, River Nile, and Northern states. This zone should also be address by long-term strategies of fire management.

Causes of Wildfires in RoS

Fire is a natural and essential ecological process in most of world's forests and rangelands. In Sudan, fire has undesirable social and economic impacts, threatening human health, safety and property. Assessment of the potential benefits and risks of wildland fire is a complex task for land, natural resource and fire managers. In addition, it is a task vital to public safety and the sustainable management of forests and rangelands in RoS. Natural fires are caused by lightning but most of the fires in Sudan, which are recorded by survey data, are "human induced causes", mainly ignited for a purpose, making it complex to estimate their social, economic, cultural and ecological impact. Human-caused fire ignitions in RoS are more likely to dominate and increase according to the survey records, as climate change may increase fire season length and severity. Communities living around forests and rangelands use fire as a tool in land management and sometimes the fire burns out of control, causing unintentional wildfires. Perennial grassland fires are common in many areas around forests because, each year during the dry season, communities set grasslands on fire to keep them open and to facilitate the growth of new grass for livestock, this is especially common practice before the rain begins. Farmers use fire to prepare their farmlands, to break up impenetrable bushlands, control weeds, pests, and parasites and to keep wildlife away from homes. Bushland and forest fires are also common because some community members use fire to make charcoal, harvest wild honey, and hunt and roast game meat in protected areas. Wildlife poachers also ignite wildfires and there can be inter-community conflicts over water, pasture grounds between the locals and the pastoralists has also been a source of fire ignitions in RoS, and fire starting in these ways are likely to increase. During years of extreme drought, migrant pastoralists usually come to graze and set fire to the old grass to facilitate the growth of new grass, and then move away in search of good pasture grounds. This practice has been causing large fires and conflicts, due to the loss of grazing grounds for the locals and communities who depend on the grasslands for grazing their livestock. Additionally, the intensified cultivation of exotic fire-prone tree species can be a contributing factor. (Fig 11)

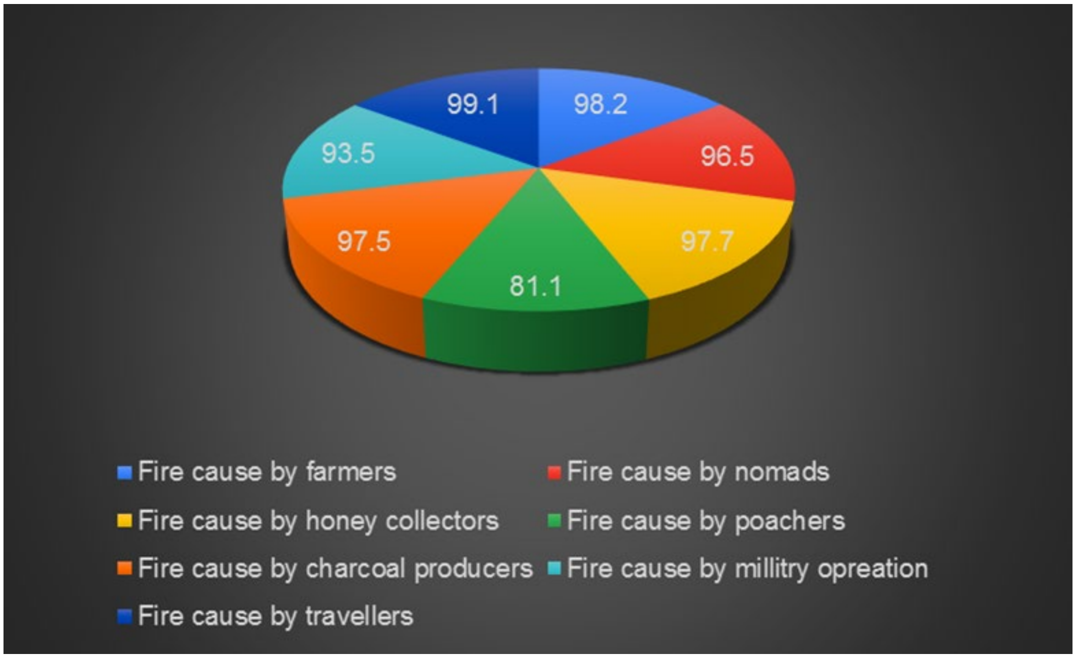

Figure 11: Distribution (percentage) of wildfires causes in Sudan

Fire used by farmers as a management tool is one of most significant factors that has led to increased fires in most states. The following is an example of these practices:

- Cleaning the agriculture land and reducing the seed bank to grow crops
- Early burning to grow watermelon as well as other crops and these practices are well recognized in North Kordofan State
- Create a buffer zone around their land
- Burning crop residues to prevent pastoralist from grazing

Nomads triggered fire to remove grass accumulated from previous seasons that occupies the available growing space, which hinders the growth of the palatable new lush grass. Usually, the Nomads burn the area as they are leaving to other places, in order to find better conditions when they return to the same area in the next season. The vast majority of forest fires were caused by human activities, and some of these activities are preventable. Therefore, adoption of risk reduction for human ignition as a management approach could be very applicable in most fire zones in RoS.

Impacts of Wildfires

“Fire is a good servant but a bad master,” this saying holds true for wildfires. Limited and controlled fires have been very useful and essential for healthy forest growth. However, uncontrolled forest fire may engulf and destroy healthy thick forest cover within no time that serves an important function in maintaining the health of certain ecosystems. Forest fires extensively affect vegetation cover, density, structure, composition, diversity, and productivity. The results of the field survey analysis indicated both negative and positive impacts of wildfire in

Sudan. According to the field survey 2019, most of positive impacts of fire are represented in figure 12 below:

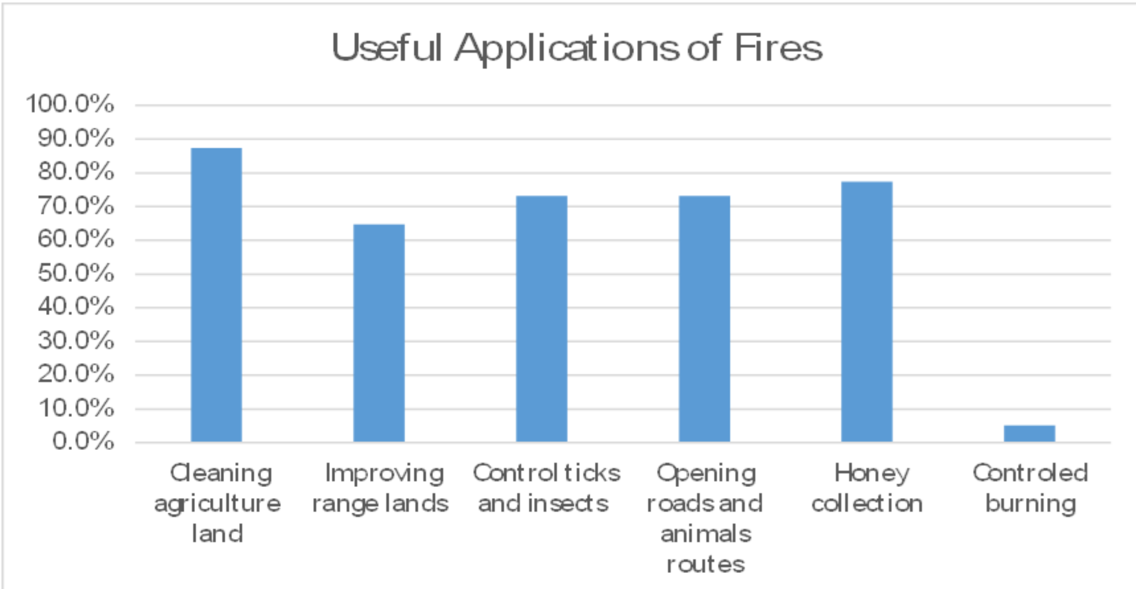

Figure 12: The positive impact of fires in RoS (Field survey analysis, 2019)

However, the impacts of wildland fires are not always positive. Additional information obtained via community group discussions revealed that fire could also cause the following negative impacts:

- Create firewood crisis because fires consume all of the fallen dead branches that are usually used by the local communities as firewood.
- Fire sometimes burns agricultural crops.
- Fires often damage or destroy whole villages with huts that are built from grass and wooden materials. Damage to the forest and destruction of wild fruits and traditional herbs and medicines, kills some of their domestic animals specially the newly born ones.
- Fires kill some of the wildlife in their area.

Ecological Impacts of Fires

In the group discussion, the participants also mentioned the following negative ecological impacts:

- Soil erosion due to burning of the grasses, debris and humus.
- Soil degradation, mentioned by respondents because the removal of the surface layer of grass, debris and leaves by fire will cause soil erosion. Contrary in the areas where there is no danger of soil erosion, the farmers prefer burning the surface remains because the ashes produced by fire will improve the soil fertility e. g. North Kordofan where there is less amount of rainfall and the sandy soil absorb most of the water and little water runoff takes place.
- Changing species composition of the forest toward the fire-resistant species, for example *Ziziphus spina christi* and *Acacia seyal*.

- Disturbance of wildlife habitats.

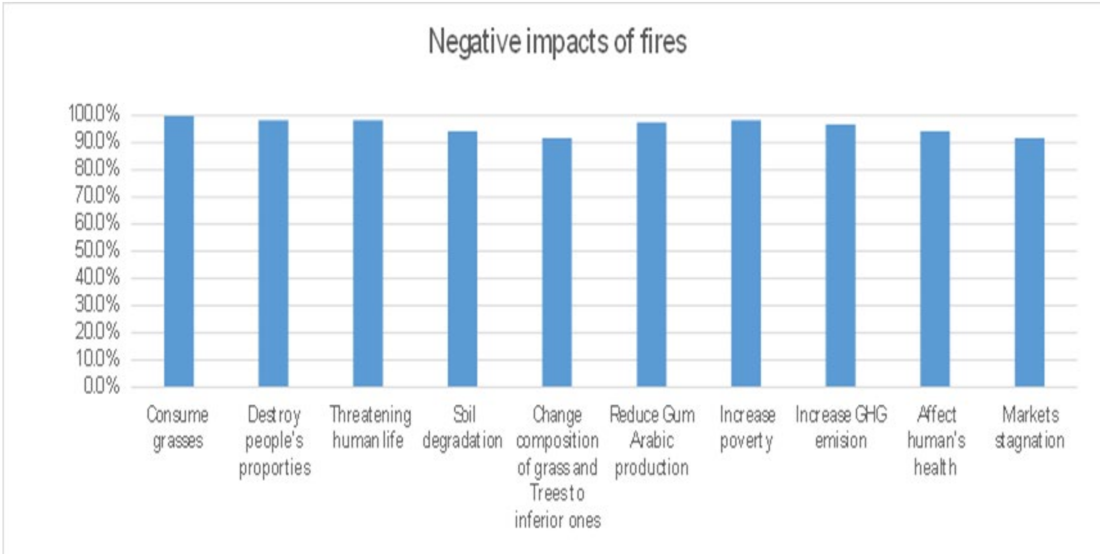

Figure 13: The negative impact of fires

Fire Types and Land Use

This new wildfire context globally is showing trends at least in part defined by extreme fire behavior, characterized by rapid-fire spread, intense burning and long-range fire spotting and unpredictable shifts. In addition to their serious ecological impact, extreme wildfire events have an extraordinary socioeconomic impact in terms of both loss of human life and economic damage. A useful and long accepted classification of fires is based on the availability of fuel described in and other matter on top soil that involved in combustion. Fire classification is useful for development of prevention or enforcement measures in the integrated forest fire management plan, as well as to design a plan for prevention, it is important to know the origin of fire. On the other hand, by describing the affected layer of the fuel, behavior and intensity of fire and wildfire can be classified into three types (Fig 14):

1. **Ground Fires:** A ground fire consumes the organic material beneath the surface litter. In many cases, a mantle of organic material accumulates on top of the mineral soil and a fire spreading in and consuming such material traveling entirely underground is a ground fire. Ground fires (sometimes called underground or subsurface fires) occur in deep accumulations of humus, peat and similar dead vegetation that become dry enough to burn. These fires move very slowly, but can become difficult to fully put out, or suppress, and typically follow a surface fire. They are also hard to detect, more destructive, and difficult to control. Ground Fires are rare in RoS.
2. **Surface Fire**: A surface fire is a fire that burns surface litter, other loose debris and small vegetation. It is the most common type and may be a mild, low – energy fire in sparse grass, or may be a very hot, fast moving fire. These are the easiest fires to put out and cause the least damage to the forest. Surface Fires are the most common in RoS.
3. **Crown fires** burn trees up their entire length to the top. These are the most intense and dangerous wildland fires. This type of fire is more spread in humid regions and it is not often experienced in Sudan.

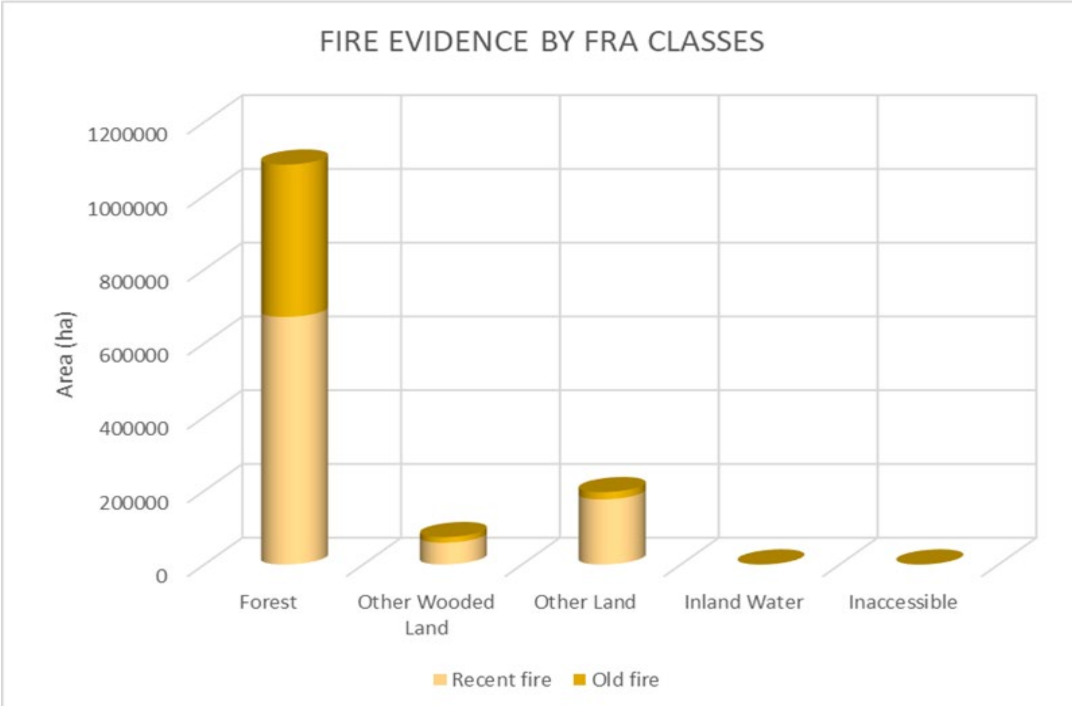

Figure 14: Fire evidence within the national land Use classes (NFI, 2020)

The above Figure suggests that fires are increasingly a cause of forest degradation in the country. Integrating forest fire reduction into REDD+ presents many challenges including in terms of monitoring and prediction of spatio-temporal patterns of forest fires across the country.

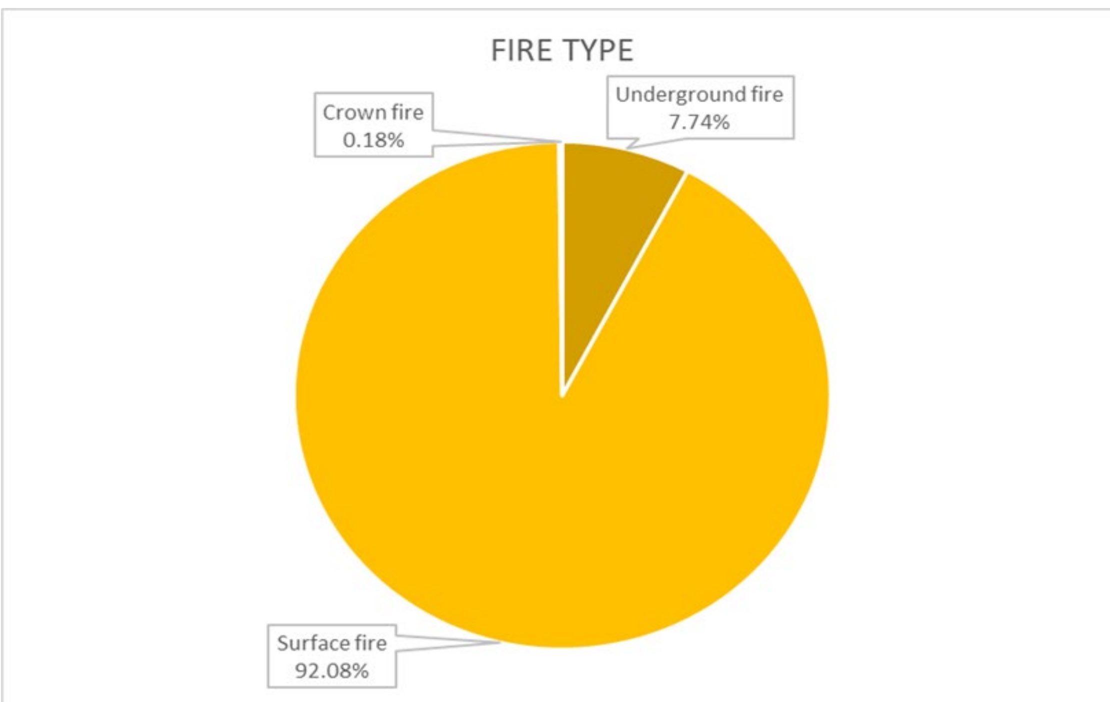

Figure 15: Distribution of fire type (NFI- 2020)

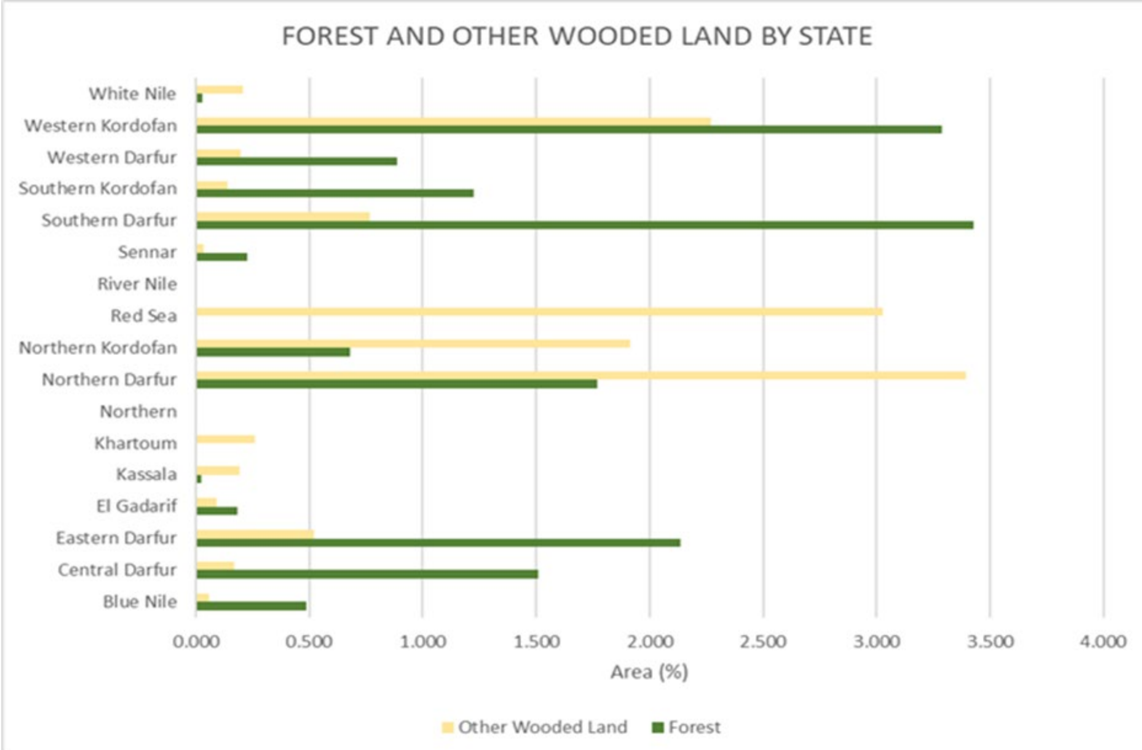

Figure 16: Forest and other wooded land by State (NFI, 2020)

Based on the NFI report, most of fire risk is surface and some underground fires, which are very hard and difficult to detect and prevent. Their zones map shows it is clear that fire incidents were very severe in woodland and grass rangeland. This assessment is supported by the FNI survey 2019, forest and woodland classes, which are concentrated within the most at-risk fire states (Fig 16). Therefore, the management of such types of fire is important and depends on understanding their behavior, spread, seasonality and vegetation types.

Biodiversity and Wildfires

The consequences of fires on vegetation, animals and soil are enormous. It causes change on vegetation cover, defoliation and reduction in both tree height and diameter growth. Fire can affect the number and growth of trees, bushes and grasses. Fire may reduce both plant and animal population over time and to an extent contributes to irreparable loss of biodiversity. According to the field survey analysis there are many tree, bush and grass species, which disappeared and reduced when fire frequency increased in the period 2001 to 2019 (Figs 17, 18 & 19).

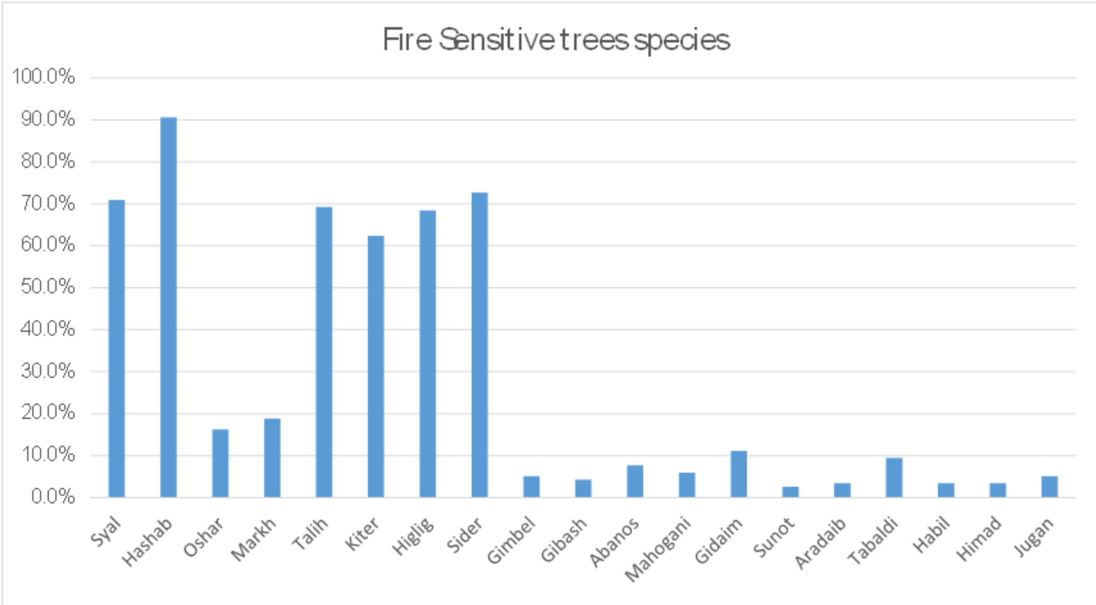

Figure 17: Reduction of trees, bushes and grasses species when fire frequency increases.

As indicated, Talih (*Acacia seyal var.seyal*) and Hashab (*Acacia senegal*) are the Gum Arabic producing trees which play a great role in Sudan's economy. They are fire sensitive species and are ones that are more valuable. Therefore, there was the negative impacts due to the disappearance of these species.

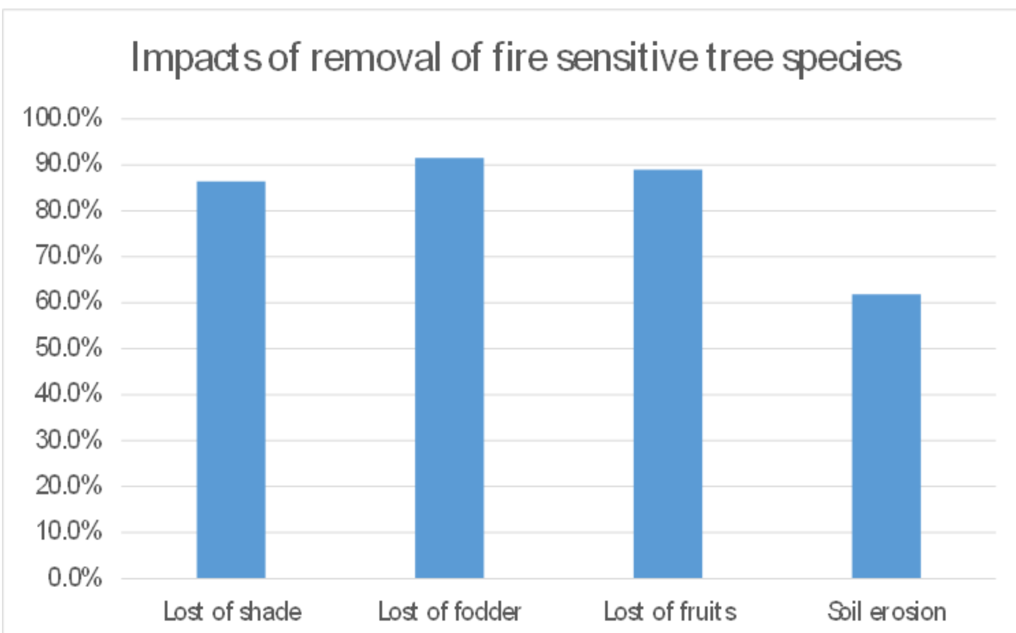

Figure 18: Impact of removal of fire sensitive tree species

At the same time, there were disturbances in some grasses, which can influence grazing practice and biodiversity (figure 18). Of the respondents, 92.7 percent mentioned loss of fodder as a negative impact due to the disappearance of these grass species. The fire-resistant species *Calatropis procera* and *Leptadenia pyrotechnica* are the most unpalatable and provide only a limited amount of shade. Moreover, the fire-resistant grasses *Aristida adscensionis* (Gaw) and *Sesamum alatum* (Simeima) are the most unpalatable and of less nutritional value.

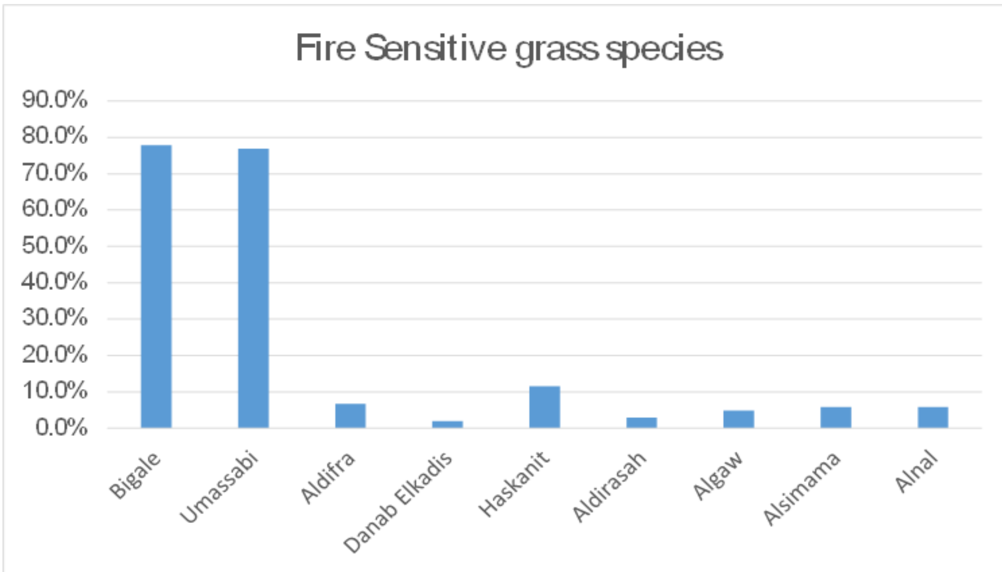

Figure 19: Fire sensitive grass species

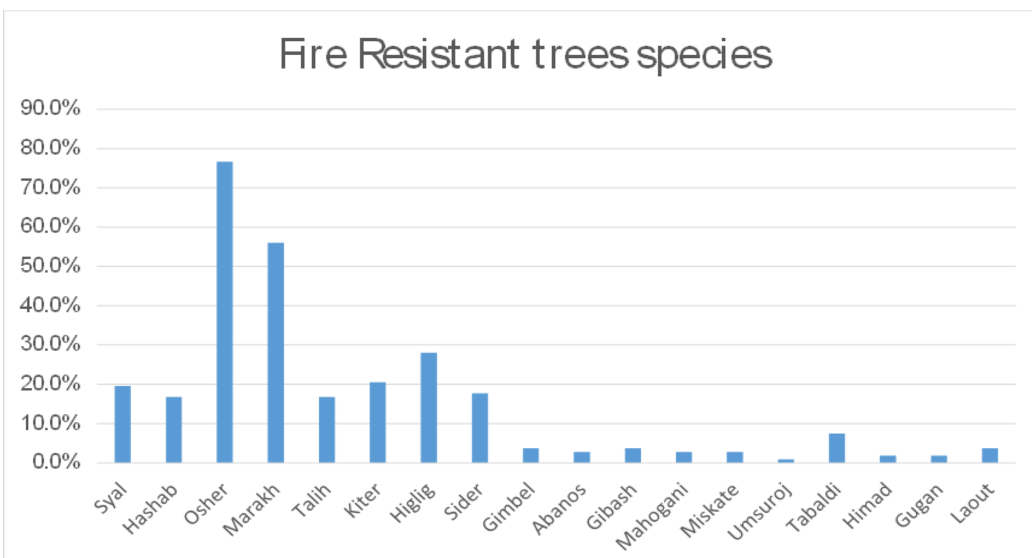

Figure 20: Fire resistant tree species

Impacts of Wildfire Carbon Emission on the Atmosphere

Based on the GCOS (Global Climate Observing System) document "Systematic Observation Requirements for Satellite-based products for Climate", and ESA Climate Initiative, the emissions of greenhouse gases (GHGs) and aerosols from fires are important climate forcing factors, contributing on average between 25-35% of total CO2 emissions to the atmosphere, as well as CO, methane and aerosols. Thus, calculation of GHG released by fires represents a very important task. In order to calculate adequate Carbon emissions from forest fire, it is essential to have an accurate estimation of extent, location, and type of forest cover affected. As more accurate post-event delineation of wildfire extents, and as much as smaller areas affected by wildfires can be determined and assessed. In order to be able to predict the existence of forest fires, it is necessary to incorporate indicators of very heterogeneous types of indicators, which sometimes fall out of the field of earth observation studies; indicators related to economy, social, human activities and historical statistics. The main magnitude used as an indicator is the vegetation index, above all, the NDVI (Normalized Difference Vegetation Index). The estimation of the fire risk, although not in real time, was obtained through analyses by the satellites belonging to NOAA (National Oceanographic and Atmospheric Administration) series, by means of AVHRR (Advanced Very High-Resolution Radiometer) sensor.

The conceptual framework of how to calculate the carbon emission of fire was well presented and discussed by using MODIS64A1 and Sentinel 2 data. The data of MODIS burned area product, for each fire season, was downloaded free of charge from ba1 ftp server of University of Marry land (ftp://ba1.geog.umd.edu) and fire hotspots downloaded from web site of Fire Information for Resources Management System (FIRMS) generated from MODIS and VIIRS (https://firms.modaps.eosdis.nasa.gov/download) on a monthly basis. QGIS software and a spatial analysis tool is used for calculating, processing, and extracting burned area data. The monthly-burned data summed up to produce the burned area for the entire fire season, which was then clipped by the shape file of the external boundary of RoS, as well as by the shape file of each state separately. Then maps were produced, and the area burned calculated in each state for each season. Fire frequency maps were generated by summing up all fire seasons maps and density slices obtained for each fire frequency category.

Rapid and accurate mapping of forest fire burnt areas is an essential initiative to support forest fire management activities plans, mitigation measurement, restoration of forest cover and GHG gas emissions estimation. Consequently, FAO is supporting countries, such as Sudan, in improving their national inventories as well as strengthening capacities to detect and accurately report burned areas and related GHG emissions.

Mapping the forest burnt areas remains a challenge to be addressed by application of remote satellites technologies. Beside improving the detection of and response times to such fires, there is also a need to improve post-event delineation, assessment and monitoring of the affected areas. Such post-event analysis can then feed back into strategies and policies for wildfire prevention, prediction, mitigation and response. Currently there is a wide range of satellite-based products from low (1 km) to high (10 m) spatial resolution that makes it possible to accurately map the burnt areas from regional to local levels. However, the increase in spatial resolution also has a decrease in temporal resolution, which results in small-burnt areas, products. Systems for detecting wildfires and monitoring the risk of wildfire development, such as EFFIS (European

Forest Fire Information System) and AFIS (Advanced Fire Information System), provide excellent up-to-date information on wildfires. However, the detection of such fires by these systems is prone to low accuracy in terms of the exact location and extent of wildfire events and burnt areas, and lack of identifying the occurrence of smaller wildfires.

Forest Burned area detection is still challenging in a variety of ways. The diversity of methodologies, depend on the availability of multiple sensors data, and advance methods that produce the accurate detection of burned areas. Under this context, most fire studies used a wide spectrum of remote data to monitor active fires and burnt areas at the local and global scales. Sensors like Advanced Very High-Resolution Radiometer (AVHRR), Moderate Resolution Imaging Spectroradiometer (MODIS) and Medium Resolution Imaging Spectrometer (MERIS) with spatial resolutions between 300m and 1 km are useful for regional and global fire studies (Mouillot, ; Schultz, ; Yue ; Cadule, & Chuvieco, 2014). These sensors have a daily revisit cycle that is useful to capture active fire signatures or burn areas; however, the relatively coarse spatial resolution causes underestimations in the case of small-burnt area extent (Alonso, Chuvieco, 2015). Comparisons between different burnt area products from these sensors is generally highly recommended and needed. Detection of active fires serves as part of the validation process for burnt areas (i.e., is the burnt area associated with previous observations of active fire). Detection of active fires provides an indicator of seasonal, regional and inter annual variability in fire frequency and shifts in geographic location and timing of fire events. To estimate the burned area, data of medium spatial resolution are widely used. Taking advantage of 2015 Sentinel-2 data, which have a higher spatial resolution and shorter revisit period (every 2-3 days), support for more comprehensive analysis of the causes, consequences and extent of wildfires is possible.

Coarse spatial resolution satellite data also presents challenges in terms of assigning the correct vegetation class to the burnt area, which is important either for estimating emissions or for evaluating the ecological disturbance of fires (Eva & Lambin, 2007). The Guidelines for National Greenhouse Gas Inventories, developed by the Intergovernmental Panel on Climate Change (IPCC, 2006) allow countries to estimate and report data at various tiers of complexity, from simpler (Tier 1) to more complex (Tiers 2 and 3) approaches. Based on the investigation and analysis of wildfire by using MODIS64A1, the frequencies and total burned area were reported and mapped from 2001 to 2020. However, the burnt areas within forest cover areas are still misplaced and need more elaborated analysis. Using the high-resolution satellites such as sentinel 1, 2 and LIDAR data are recommended.

Therefore, the current task was based on analysis of the significant contribution of forest fire to GHG emission through remote-sensed estimation of burnt areas and model of calculation on one of the hotspots within RoS States. In addition, it followed IPCC guidelines in the calculation of the GHG and updated methodologies for estimation of GHG from burnt forest areas. The study was based on comparison between burnt areas from low-resolution image MODIS to a high one, Sentinel 2, within selected fire hotspots in RoS. It comprised the processing and analysis of both MODIS and Sentinel 2 images and compared the burnt areas to calculate the fire emission following the IPCC guideline for GHG gas emission. The simplest Tier 1 approach consists of the multiplication of burned area by default, static parameters describing the biomass available for combustion per hectare, and by GHG emission factors, differentiated by broad geographical, climatic or vegetation characteristics. Tier 2 approaches use the same method, but employ country specific, rather than default parameters. Tier 3 approaches allow for the use of more complex models to derive the necessary parameters, including simulation of biophysical variables at fine temporal and geospatial scales. IPCC Guidelines provide three methodological tiers varying in complexity to be chosen based on national circumstances.

Tier 1: –Simple first order approach–spatially coarse default data based on globally available data –large uncertainties –methods involving several simplifying assumptions–default values of the parameters from the IPCC guidelines.

Tier 2: A more accurate approach–country or region-specific values for the general defaults – more disaggregated activity data –relatively smaller uncertainties.

Tier 3: –Higher order methods–detailed modeling and/or inventory measurement systems – data at a greater resolution –lower uncertainties than the previous two methods.

Methodology:

Dinder Park in Sinner State was selected as pilot study area for detecting forest burnt areas and thus used to calculate the fire emission from biomass burning using a Tier 1 approach (Figure 21). Sentinel 2 mission provide two satellites Sentinel 2A and Sentinel 2B, as part of the joint program of EC (European Commission) and ESA (European Space Agency) and it has wide-swath, high spatial resolution (10m, 20m and 60 m) and multi spectral instrument (MSI), with 13 spectral bands (Sentinel website). The temporal resolution of a combination of Sentinel 2A and 2B is 5 days at the equator and the datasets are useful for a wide range of applications, especially in forestry and agriculture. The Sentinel 2A data over the study area were downloaded from the Copernicus Open Access Hub. Moderate Resolution Imaging Spectroradiometer (MODIS64 A1-collection 6) Active fire hotspot data (MCD14) during the entire fire episode were downloaded from the Fire Information for Resource Management System (FIRMS) website. The MCD14 data are actively burning locations at the time of satellite overpass and it is in a point shape of file format with a spatial resolution of 1 km. SUOMI NPP Visible Infrared Imaging Radiometer Suite (VIIRS) product (VNP14IMGTDL_NRT) has been providing information on the fire occurrence across the world on a daily scale with a spatial resolution of 375 m and these data can be downloaded from the FIRMS website. Both the MODIS and VIIRS data during the fire event were overlaid on the burn severity map for verification.

Forest burned area (BA) estimates based on satellite observations have provided critical insights into patterns and trends of fire occurrence. Fires are identified by comparing a BA product generated from Sentinel-2 MSI (Multispectral Instrument) images (20-m spatial resolution) with a widely used global BA product based on Moderate Resolution Imaging Spectroradiometer (MODIS64 A1) images (500 m) focusing on RoS.

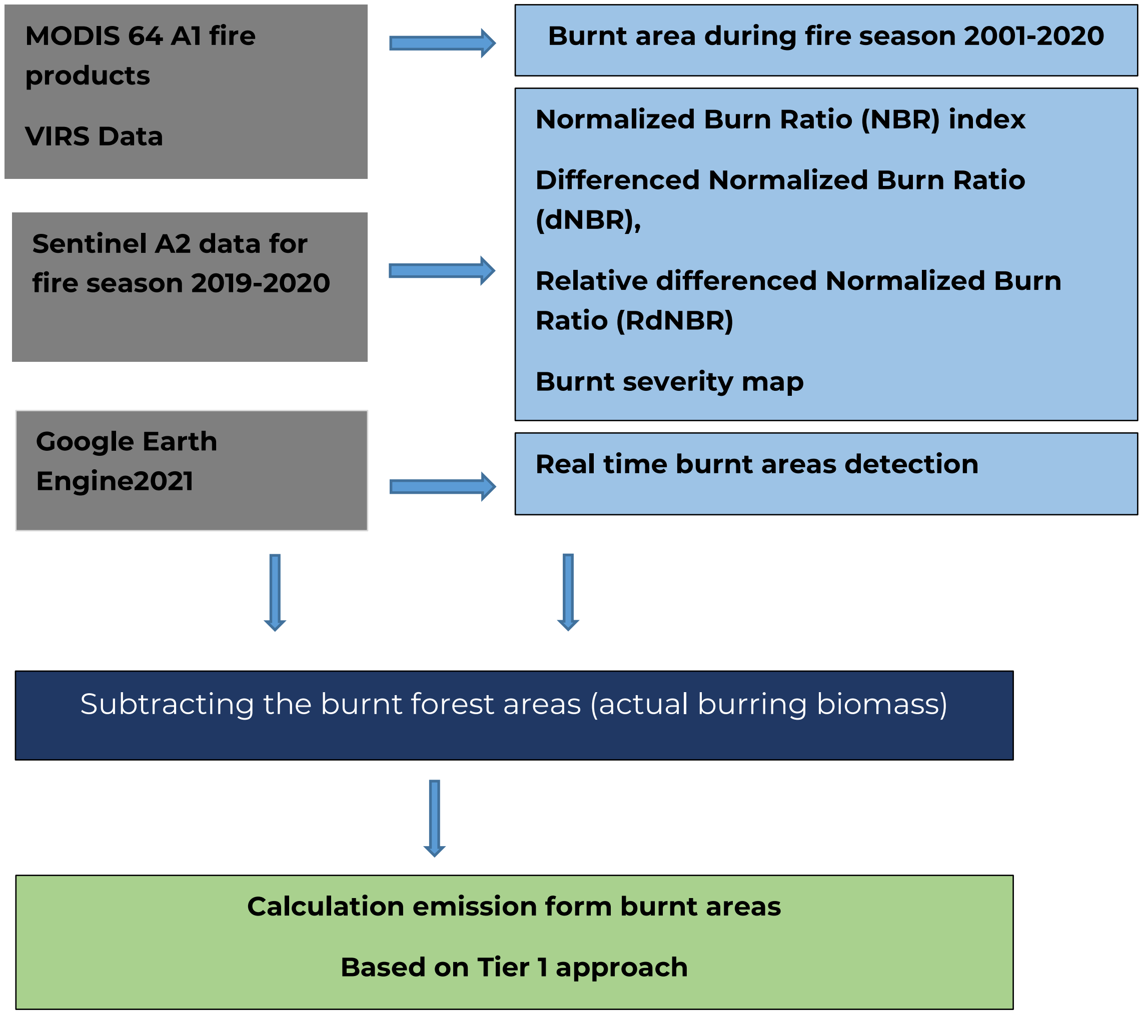

Figure 21: METHODOLOGY FOR FOREST BURNT AREAS EMISSION

The Tier 1 methodology was applied, with the emissions from biomass burning being calculated using the following equation (Equation 2.27 from IPCC 2006 Guidelines):

$L_{fire} = A \times M_B \times C_f \times G_{ef} \times 10^{-6}$ (Eq .1)

Where:

L_{fire} = amount of greenhouse gas emissions from fire, tonnes of each GHG e.g., CH_4, N_2O, etc.

A = area burned, ha

M_B = mass of fuel available for combustion, tonnes ha^{-1}. This includes biomass, ground litter and dead wood. When Tier 1 methods are used then litter and dead wood pools are assumed zero, except where there is a land-use change.

C_f = combustion factor, dimensionless (default values in Table 2.6, IPCC 2006)

G_{ef} = emission factor, g kg^{-1} dry matter burnt (default values in Table 2.5, IPCC 2006).

To fill the formula variables, the Biomass Consumption and Combustion Factor were calculated from the four land covers (shrub lands, savanna woodland (early and lately burned, savanna grassland (early and lately burned) and agricultural land) within the fire zones.

Normalized Burn Ratio (NBR) index is one of the most actively used indexes in fire observation studies conducted with remote sensing. The Normalized Burn Ratio (NBR index), near infrared (NIR) and short-wave infrared bands (SWIR) values are applied by proportioning their differences and totals (Roy et al. 2006). The NBR index is expressed in values between -1 and +1. Since the reduction in vegetation will occur in the process after the fire, near infrared band reflection is greatly reduced. Healthy vegetation generally gives high values, while empty terrain or recently burned areas give low index values. Differenced Normalized Burn Ratio (dNBR), determines the scar of burned regions using difference of NBR calculated from pre and post event images. Since the gray values in the NBR index before fire are larger than the gray values in the burned areas after the fire, it can be understood that the fire has occurred in areas with positive gray values in the dNBR index, while the fire does not affect the areas with negative values. Relative differenced Normalized Burn Ratio (RdNBR) uses NBR calculated from pre-fire satellite images, as well as dNBR from pre- and post-fire images, to measure spectral variation (Miller and Thode 2007). Another NBR based alternative index is called Relativized Burn Ratio (RBR) that is the ratio of dNBR to NBR calculated from pre-fire image (Parks et al. 2014).

$$NBR = (Band\ 8 - Band\ 12)/(Band\ 8 + Band\ 12) \quad \text{(Eq. 2)}$$

$$dNBR = NBRpre\ fire - NBRpost\ fire \quad \text{(Eq. 3)}$$

Based on above equations, Tier 1 approach, IPCC guidelines for CO2 and other gas emissions the calculation was applied to estimate the amount of CO2 and other gas emissions in the different fire zones in RoS.

Forest Burned Area Derived from MOD64A1 and Calculation of Carbon Dioxide Emission within RoS States

Burned Area

The forest burned area mapping is essential for the forest and land manager to plan for mitigation measures and restoration activities after the fire season. Rapid and more accurate burnt areas mapping is a very important task for fire risk assessment. Forest burned area (BA) estimates based on satellite observations have provided critical insights into patterns and trends of fire occurrence. Accurate forest burnt area mapping is still very challenging by using low-resolution satellite data and might need more enhancing in RoS. The emission of forest burnt areas could negatively contribute to climate change along with other GHG produced by biomass burning, and more emphasis may be adopted for GHG mitigation strategies in the fire high-risk zones if assessed as necessary. The analysis of MODIS 64A1 data through the fire seasons in country showed that most of the forest burned areas were in the fire zone 1 & 2. The results expressed and indicated the forest burnt areas and Co2 emission during 2001-2020 within target states of RoS (Annex 12). Moreover, the results showed the most forest burn areas were in Blue

Nile, South Kordofan and South Darfur. (Figure 22&Table 2). The interpretation and comparison between these results it is obvious that these areas were still insignificant compared to the total burnt areas in country. This might be attributed to high incidences of fire outbreak in dense grass area rather than forestland. The potential for future increases in carbon storage in these areas are limited by fire and its controls on the recovery of forest cover in fire-prone areas.

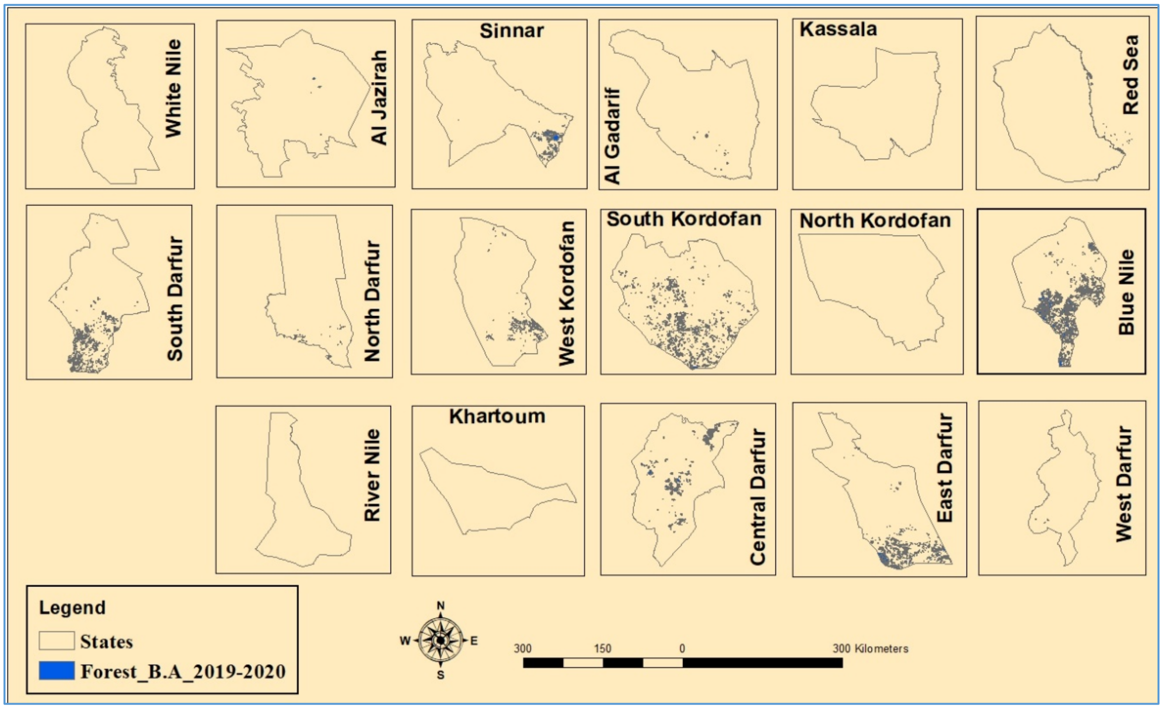

Figure 22: SPATIAL DISTRIBUTION OF BURN AREA FROM FOREST BURNING BY STATE DETECTED BY MOD64A1, 2019-2020.

Table 2: Forest burned area derived from MOD64A1 and Co2 emission (Gg), 2019-2020

State	Forest_BA(ha)	Co2(Gg)	State	Forest_BA(ha)	Co2(Gg)
Blue Nile	314791.30	1477.39	Red Sea	237.66	1.12
East Darfur	149070.46	699.62	River Nile	0.00	0.00
Gadarif	3224.17	15.13	Sinnar	51568.16	242.02
Gazira	1019.45	4.78	South Darfur	151507.55	711.06
Kassala	533.07	2.50	South Kordofan	161073.86	755.96
Khartoum	0.00	0.00	White Nile	0.00	0.00
North Darfur	12957.81	60.81	West Darfur	721.14	3.38
North Kordofan	63.07	0.30	West Kordofan	96093.06	450.99
Northern	0.00	0.00	Central Darfur	64862.35	304.41

Fire Impact

For enhancing of forest fire management, it is necessary to analyze the impact of fire on the ecosystem. Information about the disturbance on forest cover from fire incidence is an essential element to support fire management activities such as strategic planning, mitigation measures and monitoring restoration of vegetation in forest areas. Burn severity can be defined as the degree of change in the vegetation and soil constituents due to fire (Miller and Thode, 2007). Thus, the study applied more investigation and analysis for detection and map burnt areas by using Sentinel-2 Satellite Images for DNR site area in RoS. The NBR and dNBR values as well as burnt severity were calculated during the fire season of DNR site area. The resultant dNBR map was produced to categorize the fire severity levels based on United States Geological Survey (USGS) proposed severity levels (un-spider.org) and is shown in Table 3. The Burn severity map was generated by reclassifying the dNBR map based on Un-Spider severity level (Figure 24). Burnt areas show higher reflectance and healthy vegetation is shown to be lower in SWIR region. Therefore, the higher NBR value indicates healthy vegetation and lower value for burned areas.

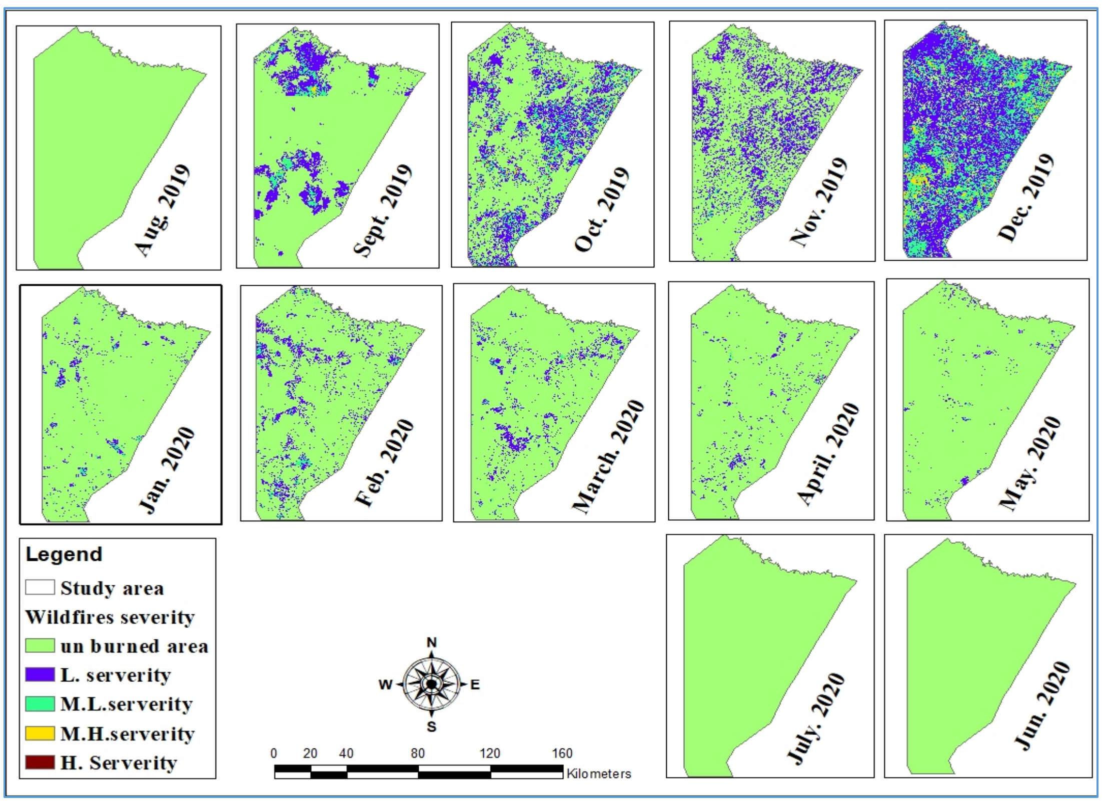

Figure 23: SPATIAL DISTRIBUTION OF BURN SEVERITY IN DNP DETECTED BY SENTINEL_2, 2019-2020

In discussion of wildfire disturbance in forest cover, it is important to distinguish between fire intensity and burn severity. Fire intensity refers to the heat energy released during a wildfire event. Fire severity refers to the effects of wildfire intensity on plant communities. In forests, fire severity is measured in terms of tree mortality, canopy loss, or bole and crown scorch. Mapping the burn severity is very a important task since it is relevant to forest cover more than shrub lands, where perhaps most all aboveground biomass is killed in crown fires. Mapping of fire severity might be more useful to build more information about the actual damage on forest areas and calculation of Carbon emission, based on damage of forest burnt areas (Table 3 & 4). Depending on the spatial and temporal resolution of Sentinel 2, detection of fire severity on forest will influence the climate and CO2 emission within GHG inventories in RoS.

Table 3 : Burned area derived from Sentinel_2 and Co2 emission (Gg), 2019-2020

Total BA (ha)			
Year	**Months**	**Area(ha)**	**Co2(Gg)**
2019	Aug	0	0.00
2019	Sept	134374.8	630.65
2019	Oct	279969.7	1313.96
2019	Nov	217525.3	1020.90
2019	Dec	699046.5	3280.79
2020	Jan	37722.88	177.04
2020	Feb	98004.32	459.96
2020	Mar	64328.72	301.91
2020	Apr	29179.6	136.95
2020	May	16908.56	79.36
2020	Jun	0	0.00
2020	Jul	0	0.00
Total		1577060	7401.51

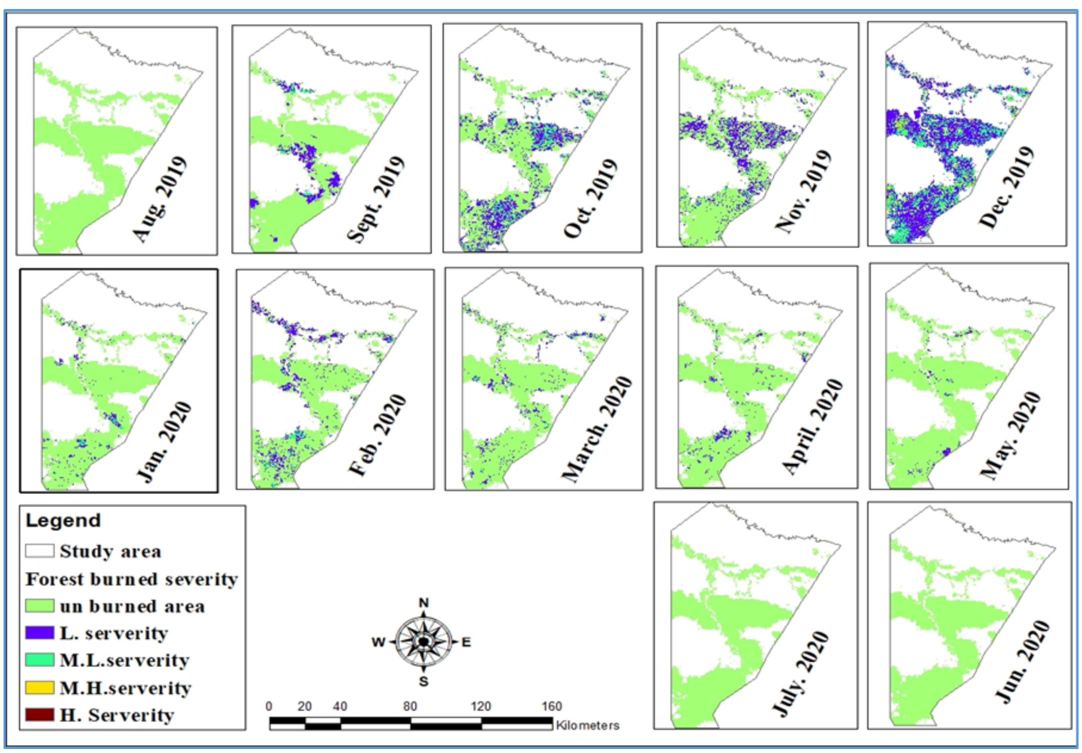

Figure 24: Spatial Distribution of forest burn area in DNP and severity level detected by Sentinel_2, 2019-2020

Table 4 : Forest burned area derived from Sentinel_2 and Co2 emission (Gg), 2019-2020

Total BA (ha)			
Year	**Months**	**Area(ha)**	**Co2(Gg)**
2019	August	0	0.00
2019	Sept	33776.44	158.52
2019	Oct	102255.2	479.91
2019	Nov	75038.96	352.18
2019	Dec	261236.3	1226.04
2020	Jan	16814.52	78.91
2020	Feb	50306.64	236.10
2020	March	25737.2	120.79
2020	April	16859.92	79.13
2020	May	8186.48	38.42
2020	June	0	0.00
2020	July	0	0.00
Total		590211.6	2770.00

Comparing between MODIS64A1 and sentinel 2 products, the result showed that the capability of high-resolution data in detecting the small burnt areas as well as forest areas. (Figure 25 & Table 5). It is clear that the burnt areas were increased by using sentinel 2.

Combustion Factor	
Type	MB
All shrub lands	0.72
All savanna woodland(early and lately burned)	1.14
All savanna grassland(early and lately burned)	1.51
All agricultural residence	0.825
Total	4.195
Mean	0.6992

Table 5 : Comparison between Sentinel_2 and MOD64A1 in total burned area (ha)

Year	Month	Burned area(ha)_Sentinel_2	Burned area (ha) from MOD64A1
2019	Aug.	0	0.00
2019	Sept.	134374.76	108.10
2019	Oct.	279969.72	49790.31
2019	Nov.	217525.34	148458.60
2019	Dec.	699046.5	50620.60
2020	Jan.	37722.88	8250.78
2020	Feb.	98004.32	17249.14
2020	March	64328.72	30780.80
2020	April	29179.6	1698.91
2020	May	16908.56	2346.10
2020	June	0	0.00
2020	July	0	0.00

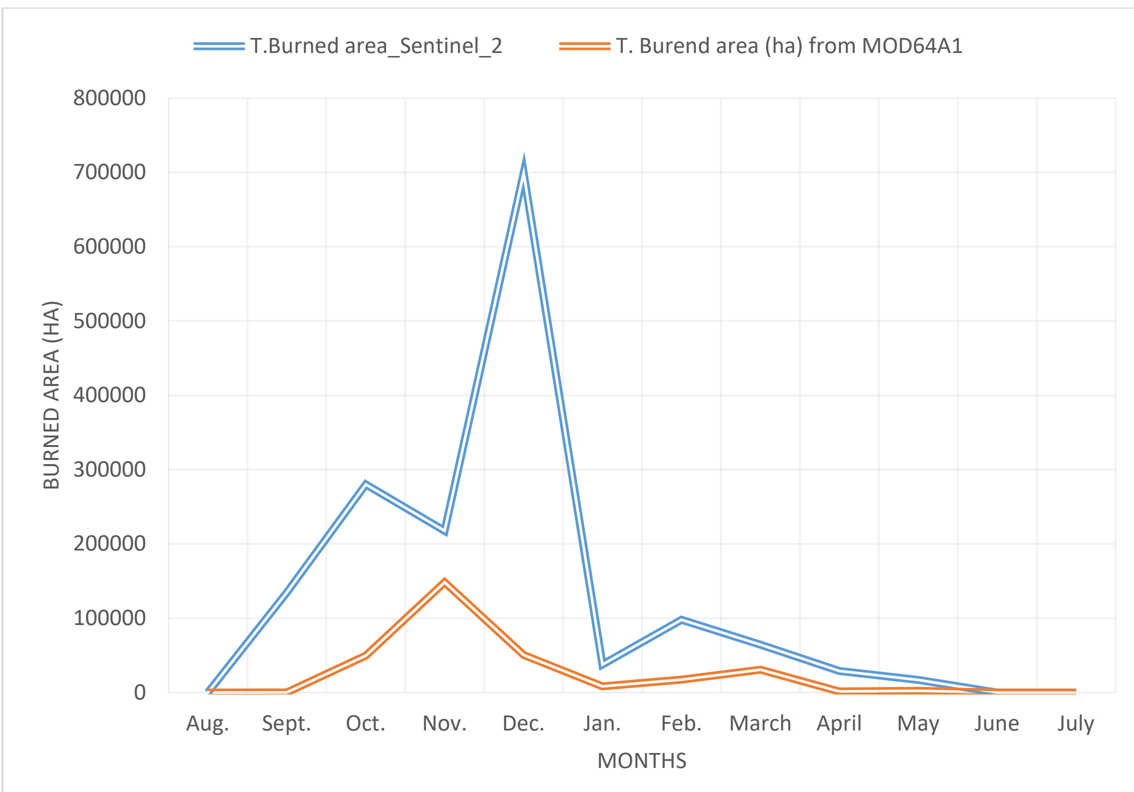

Figure 25: Comparison between Sentinel_2 and MOD64A1 in total burned area (ha)

Current Fire Management Activities

Information obtained via community group discussions revealed that fire management plans in Sudan were not formulated. There are some activities undertaken each year to control fire such as cleaning fire lines, patrolling and backfiring. Stauber (1995) and Byoumi (1999) confirmed that fires burning in RoS are a challenge because there is no application of actual fire management plans. Most management activities are based on fire prevention, fire detection and initial attack, cleaning of fire lines, fire suppression and participation of local people in firefighting. According to the survey data, cleaning fire lines recorded a higher value (97%) followed by awareness raising, early warning, fire detection, communication systems, fire bridges, transportation, availability of fire extinguishing equipment and burn area recovery (Table 5).

Activities			Percent
Cleaning firelines	Is cleaning of firelines one of the activities carried out for fire management	118	97.5%
Awareness raising	Is awareness raising one of the activities carried out for fire management	103	85.1%
Early warning	Is early warning about areas of fire hazard one of the activities carried out for fire management	83	68.6%
Fire detection	Is early detection of wildfires via patrolling or towers whatching one of the activities carried out for fire management	73	60.3%
Communication system	Is communication system for reporting wildfires, one of the activities carried out for fire management	83	68.6%
Fire brigades	Is existance of fire brigades and their training, one of the activities carried out for fire management	68	56.2%
Transportation	Is means of transportation for fire fighters, one of the activities carried out for fire management	73	60.3%
Availablity of fire extinguishing equipment	Is fire extinguishing equipment's availability, one of the activities carried out for fire management	70	57.9%
Burned area recovery	Is burned area recovery, one of the activities carried out for fire management	75	62.0%

Figure 26: CURRENT FIRE MANAGEMENT ACTIVITIES APPLIED IN SUDAN BASED ON THE FIELD SURVEY

According to field survey 97% of respondents agreed about prevention management, which takes account of cleaning of firebreaks. Cleaning of fire lines is a difficult operation and a very expensive one as responders mentioned. Most of existing management activities rank fire prevention more highly than suppression. This may be attributed to the absence of a fire management plan and the lack of financial resources for suppression processes. The work on fire lines cleaning sometimes ends late after fire season starts. However, sometimes the delay is due to financial problem. As Bayumi stated, fire management needs cannot be detailed due to the complexity of the different environmental conditions and the need for different management techniques. "*The very large size of the country, the various local factors and weather conditions, the trend toward repeated severe droughts and desertification, the increase in population and domestic animals, the displacement of rural people to cities, the expansion of unplanned rain-fed cultivation, the poverty of the people and the lack of knowledge of decision makers regarding forest conservation are all major problems and impediments. RoS needs extension capability to teach people how to protect their lands.*

Research is needed to find safer methods to prepare land for agriculture or forest plantations. Above all, trained personnel and supporting equipment are needed for transport, detecting and fighting forest fires."

This indicates an urgent need for fire management plans and integrated community-based approaches as well as human led management.

Fire Management Strategy Options (Directions)

An understanding of fire history, frequency, distribution, and severity and human causes, as well as an appropriate policy framework, is important in fire management strategies. An understanding of fire history and regime has been formed and provides an initial database that can guide management strategy options and preparation of guidelines. Moreover, the legal and institutional framework for existing fire management was discussed along with the forest and natural resource policies. Based on the analysis results and consultation process, the proposed fire management strategy was described and outlined in order to explain how the Sudan can focus on future efforts to reduce the severe effects of wildfire on areas of high risk. Multiple opportunities are available to meet wildland fire challenges. Adopting any option involves spatial and temporal compromises. Reducing long-term risk of fire requires prioritization of identifying the fire management direction for the purposes of protecting, maintaining and restoring burned areas. The Strategy outlines management principles, goals, objectives and a fire management program must be designed to minimize the hazard and risk of uncontrolled natural, and human caused fires in affected areas. Management options allow policy and decision-makers to understand where each option is more likely to reduce risk. The current strategy recognizes that fire management requirements and potential impacts differ across the fire zones depending on resource and land management direction, types of forest and severity of fires. These strategy options are not prescriptive in deciding which options to apply locally or regionally. The fire management strategy should be directed more to prevention and mitigation than to suppression process. However, the specific management objectives for each fire zone must be taken into account and, as a result, the operational standards and actions may vary.

Strategy Option 1: Setup of Institutional Framework for Wildfire Management

As set out in Table 1, some sectors and ministries have some direct and indirect involvement in fire management, however, it is noted the role of government with regard to fire management in RoS is often non-exist or insufficient. All reviewed policies, acts, plans and strategies are observed to be fragmented and dealing with protection of natural resources, without any institutional framework devoted specifically to fire management. Accordingly, some reasons were stated to argue the inappropriate handling of fire management issues in the country:

(A) Absence of a clear statements pertinent to fire management within the forest policies and legislations
(B) Lack of integration with regards to fire management aspects within and between sectors
(C) Low capacity of local institutions towards handling and managing fire risks
(D) Insufficient technical, logistical and financial resources to deal with fire management.
(E) Lack of periodic monitoring and evaluation of wildfire risks

Based on that, many arguments are supporting the establishment of an integrated institutional fire management framework at national and local levels with specific roles and responsibilities. **The Institutional Fire Management Framework (IFMF)** is proposed to comprise the following entities with specific roles and responsibilities as depicted in Fig (27). IFMF framework emphasizes the governmental body represented by the Ministry of Agriculture and forestry that could be more concentrated in FNC as focal point. The National Fire Management Steering Committee (NFMSC) engages governments, stakeholders, local communities and the public on the need to update the direction for wildland fire management across the different states. NFMSC encompasses representatives from all actors, agencies, stakeholders and institutions that have direct involvement in wildfire management at the federal level. The NFMSC is required for the broad range of interventions, involvement of several parties and the needs for coordinated decisions. The government will take the lead in the implementation; however, it will not shoulder this responsibility alone. Major stakeholders, namely the private sector and the farmer's union will be represented in the Steering Committee. The NFMSC will address challenges by continuing to maintain a fire management program that is mobile, flexible and able to expand when necessary, to respond to areas of fire hazard and fire activity to ensure coordination at the operational side, the Steering Committee should be at the Undersecretaries level and should meet quarterly to review the progress. A focal point institute should be designated to act as the secretariat for the Steering Committee.

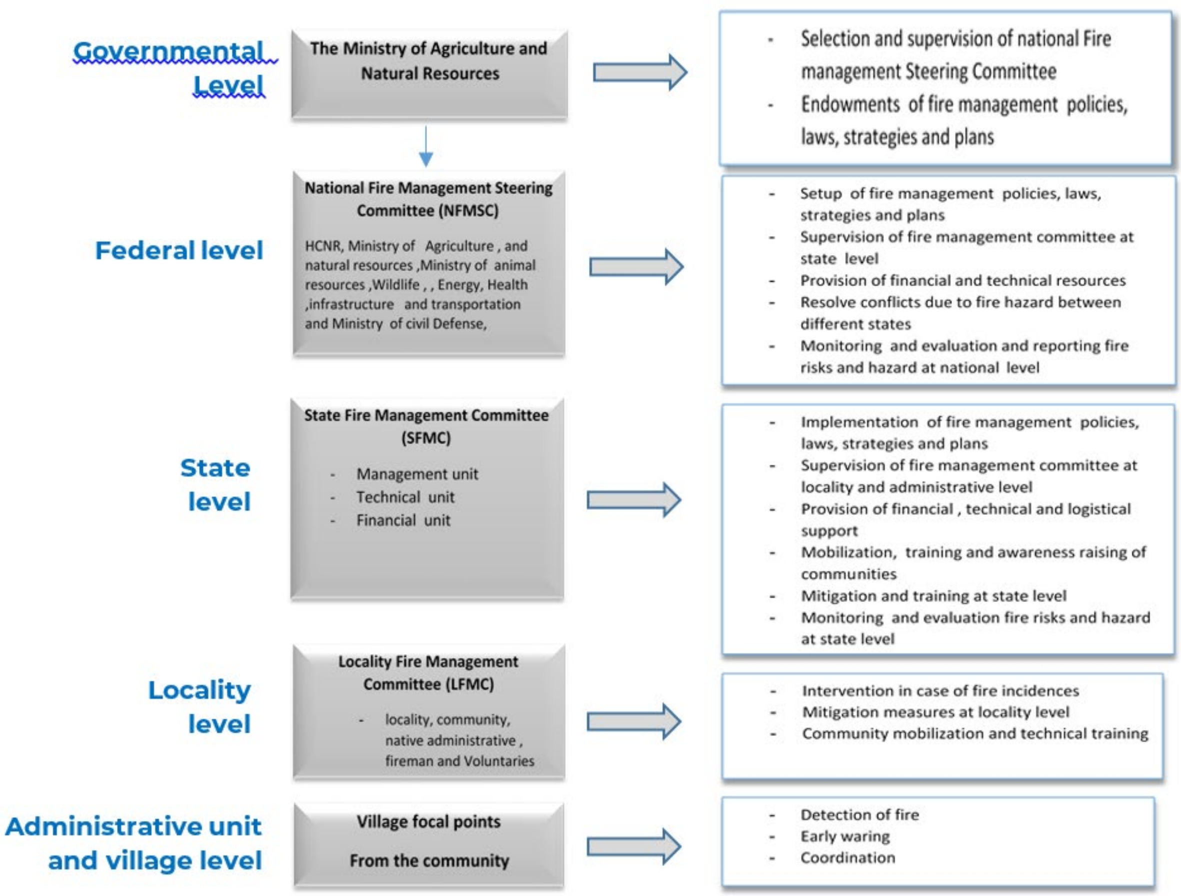

Figure 27: Proposed Institutional Fire Management Framework (IFMF) DiagramStrategy

Option 2: Fire Monitoring, Evaluation and Reporting System

Wildfires have increased in both frequency and severity, in most of the forest and woodland areas in RoS. Detection, monitoring and controlling of these fires are vital to human health, environmental protection, and natural resources management in Sudan. As discussed previously, the monitoring system of fire in RoS is still fragmented and not well established. Most monitoring processed within the fire sectors and other natural resources institutions is based mainly on remotely sensed data and little ground-based measurement. The ground-based measurement still faces challenges since the fire incident occurs in remote areas and often accidently. Therefore, the development of strong **Fire Monitoring, Evaluating and Reporting System (FMERS)** will support the understanding and improvement of wildfire strategy options at national and local levels. The FMERS Framework could be implemented at the national level and includes all activities undertaken in line with the plans to measure, review and improve the natural resource management strategies. The role of monitoring, evaluation and reporting in wildfire management will allow land managers to quantify and qualify the collected fire information and support success of their wildfire management actions and strategies for achieving objectives. As well, as enabling greater understanding of the effects of wildfire risk and then, improve their management plans and actions over time. The system will consider management activities across the Preparedness, Prevention, Fuel Management (including planned burning), and response and recovery processes within fire zones in Sudan.

The FMER system should be communicated with stakeholders, staff and partner agencies at national and local levels. This will be necessary for more effectively and transparently reporting on wildfire management outcomes to government entities and the community. This option will support the reduction of ecological and economical damage by offering appropriate and reliable information on spatial and temporal distribution of fire as well as size and intensity.

The principles of FMERS will support the improvement of wildfire management via the public responsibility, integration of learning and knowledge, integrated management, collaboration and communication amongst all members of the community with shared responsibilities and constructive partnerships to have better manage of wildfire.

The FMERS framework will support all activities and plans at national level for fire management actions, reducing fire risk, increasing fire response and implemented the fire recovery. The outcomes will be within the 3 phase's short, medium and long term as proposed in Figure 28.

Strategy Option 3: Community Based Fire Management

Given the complexity of fire management and policies, which was discussed previously, there is an urgent need for an integrated approach that includes fire prevention, early warning, monitoring and assessment, fire preparedness, fire suppression, as well as restoration of burned areas. Local communities in Sudan, continue to use fire in an unsafe and ineffective manner to improve livelihoods and protect their land. These communities are not quite familiar with fire and its uses for traditional livelihood activities such as clearing vegetation for agriculture, improving pastures for grazing, hunting and managing non-timber forest products (NTFPs). These communities may continue to use fire to manage their resources, therefore, they need to have information in how they can use fire effectively, safely and sustainably. Community Based Fire Management (CBFiM) can be considered a suitable approach for fire management options.

CBFIM is an approach to fire management in which local communities are actively engaged in the development, and in some instances the implementation, of fire management strategies designed to prevent, control or utilize fires in ways that will improve their livelihood, health and security. The success of this approach varies depending upon a number of factors, including the existence of: supporting policy and legislation, land tenure, and institutional and community capacity.

Activities	**Outputs**	**Short-term outcomes**	**Medium term outcomes**	**Long-term outcomes**
- Preparedness - Inventory - Prioritization and mapping of fire areas; - Fire prevention, - Suppression - Response - Mitigation process within the four fire zones in RoS.	- Controlling, enforcement and awareness strategies - Prepared and capable staff and resources - Risk analysis systems - Partnership arrangements - Identified risks and Recovery plans	- Reduced incidence of fire caused by human ignition - Risk analysis informs capability and resource allocation - Fire suppressed and managed to reduce risk - mitigated damage caused by fire	- Enhanced partnership with other fire and emergency management agencies - Supporting the communities by re-establishing safety from fire	- Improved wildfire prevention, - Preparedness, response and recovery - Improved the understanding of fires role by different stakeholders and communities

Figure 28 : FMERS OUTPUTS IN THE THREE PHASES

This fire management option is based on the strategy to include local communities in the proper application of land-use fires (managed beneficial fires for controlling weeds, reducing the impact of pests and diseases, generating income from Non-timber forest products, creating forage and hunting, etc.) The rationale for CBFiM was identified as the following:

- Traditional or indigenous knowledge for local people can help in informing and undertaking fire management, and be planned, conducted and controlled by them.
- Most fire management activities involve a range of local actors that need some traditional practice and technical capacity.
- Volunteers from the community can play a very important role and conduct fire management on behalf of the community across affected areas. This may be limited to a role in which the community is informed of management decisions and designated roles and responsibilities by the government.
- Participation of local communities can reduce wildland fires and their impact. For this reason, most fire management approaches include activities with local communities to assist in fire prevention, monitoring and control. These include awareness raising campaigns, capacity building and equipping of community fire brigades. However, involvement and participation of local people faces challenges attribute to the following reasons:

- There are no extension services to local people to be aware of the negative impacts of the fire to their environment.

- There is no incentive to encourage the local people to participate in firefighting.
- The shortage of drinking water and food during firefighting, which may take several days in some cases.
- The problem of insecurity discourages the local people to participate in firefighting, especially at night.
- Lack of training and tools necessary to perform the job of firefighting safely and easily.

Strategy Option 4: Human–Caused Ignitions Management

Firstly, because wildfires in RoS are primarily human in origin, the prevention of future fires is a task that must involve the people. Fires will continue to destroy large areas of forests and grasslands unless there is a radical change in the way of life for the forest adjacent communities. Accordingly, the most justifiable recommendations must focus on improving the livelihood for those people who interact directly with the land, which means giving attention to the interests of farmers, pastoralists and grassroots communities to benefit from the land on which they live.

Secondly, based on the fire regimes discussed previously, it is noted fires are strongly affected by the biophysical influences of vegetation, climate, and natural ignitions, but the human influence and its effect on fire regimes is also recognized. The human-driven regime reflects the primary influence of human-caused ignitions and the influence of suppression activities. Investigations of the differences between human and natural causes are clearly important to the concept of designing management options to affect ignitions. The adoption of programs that target the prevention of human-caused ignitions have the potential to affect wildfire occurrence and extent across the county.

There is a need to support fire prevention educational efforts as well as to develop adequate and enforceable state and local ordinances related to wildfire prevention. Such programs are most effective when they focus on the underlying causes of these human-caused ignitions in each state, and tailor the prevention programs to specific causal factors and community dynamics. This strategy option, based on identifying the priorities, includes emphasizing programs and activities, designed to meet identified local needs, which seek to prevent human-caused ignitions within the fire zones in Sudan.

Strategy Option 5: Training and Education

The numbers and extent of wildfires, together with the increased concern about fire safety and costs, requires better strategies and tactics for fire management activities. There is a strong need for professional development in firefighting and the promotion of safe practices for firefighters in order to face extreme wildfire events in Sudan. In fact, current staff do not possess the required experience and skills in wildfire management. Successful professional development in firefighting depends on the integration of training and education, which are aligned with the principles of integrated fire management. A formal fire-training program and a supporting manual should be developed for the States fire units and this manual should outline the basic fire management training requirements, the safety requirements, and the equipment operation. Safety is a key issue for all involved in fire management. Currently there is lack of research or selection of appropriate firefighting protective equipment, and for promotion of safety concerns for current and potential vulnerable areas. Awareness campaigns on fire safety, optimization of operations — such as firefighters' equipment and the use of forest roads for evacuation and for safe firefighting are required and needed in all part of the fire safety issue. Additionally, fire education programs should include the following:

- The cause and impact of the wildfire (positive and negative impacts)
- Fire as a management tool, control of accidental and wildfires
- Protection of vegetation against the spread of wildfires and accidental fires
- Firebreaks and fuel breaks including information about location and direction of firebreaks, construction of firebreak grids, time to construct the firebreaks, how to clear the firebreak of vegetation (mechanically and practically)
- Information about burning time and practice.

The education and training on advancing our understanding of people's perception and knowledge of fire management activities and plans are a prerequisite for their successful implementation of this strategy option.

Strategy Option 6: Fire Prevention, Suppression and Mitigation

Fire prevention is one of the most effective counter measures for management of impacts of wildfire in a country. Preventing fires and mitigating losses (taking steps that can reduce losses when a fire occurs) is a very efficient option for community-based management of fire risk. In terms of fire prevention, the objective becomes prevention of large or uncontrollable fires rather than simply a reduction in the total number of fires. As wildfires have increased both in frequency, seasonality, extent and regime, fire prevention strategies should include control of both fire risks and fire hazards. Two principles are involved- risk reduction and mitigation.

Fire risk reduction via developing a training program to increase the level of staff awareness in the area of fire prevention. Staff awareness is one of the most critical factors in the reduction of unwanted fire ignitions within natural areas. According to the survey records, there was no extension program held in order to reduce or eliminate fire incidence through educating the people and raising their awareness about wildfire prevention. Fire prevention measures include public education and regulation of high-risk activities, particularly during times of high fire danger. Because of the threat that fires represent, operational systems have been developed for use in fire management that includes fire danger prediction, fire detection and fire control.

The mitigation option should be developed with more reliable plans for ecosystem and vegetation management goals for areas disturbed by fire. Especially, a focus on fire incidences spread over rich diversity areas in RoS as well as most of gum Arabic belt that is considered an important economic resource. In order to ensure ecosystem protection in such areas, the rehabilitation and mitigation strategies should be based on a comprehensive rehabilitation plan that outlines mitigation strategies to limit the effects of a large fire on ecosystem structure and function. Rehabilitation planning should be consistent with the ecosystem-based approach to vegetation management. It may focus on:

1. Control of woody plants,
2. Management of grassland
3. Control of fire hazard by removal of fuel that might endanger neighboring sensitive ecosystems

4. Maintaining, constructing firebreaks regularly, and annually immediately after rain season
5. Considering alternatives such as using chemical herbicides for the clearance of the firebreaks and control the weeds and grass growing
6. Construction of fire detection means such as lookout towers for fire detection including in the natural rangeland where fires can be caused naturally.
7. Short-term re-vegetation plantation
8. Long-term reforestation

The objective of any mitigation action efforts should be focused on minimizing the effects of fire on fire zonation areas and meeting the long-term objectives of the strategy. This strategy must be consistent with an ecosystem. The early detection of forest fires should be a key component of the overall fire management efforts. Currently, alerts by the public and communities accomplish fire detection. Fire information is then forwarded to the unit for suppression. Because detection of forest fires relies heavily on public awareness and response, it is important to facilitate fire awareness through improved signage and education programs. Fire reporting information should be posted at strategic locations allowing visitors to respond quickly and report the fires to the fire unit. Timely and accurate detection requires the integration of fire behavior and forest knowledge at strategy and planned levels. Rapid wildfire detection is therefore fundamental to coordinating and performing a quicker and stronger initial attack. Any organized detection program should utilize local communities and volunteers for high hazard areas or for areas with a history of fires. Effective detection is heavily dependent on good communication. All departments within the fire unit must be made aware of the protocols and procedures for reporting fires.

Fire suppression options face big challenges and include fire preparedness and pre-suppression planning, initial attack and fire suppression. The fire units should engage in specialized training in the suppression of natural area fires and to acquire appropriate firefighting equipment in order to effectively suppress a natural area fire and minimize ecological damage. Currently, it appears there no responsibility assumed for fire suppression activities in most affected areas. This option could be the long-term implementation phase within all fire zones, and consider the other factors of fire causes in each zone.

Strategy Option 7: Inventory, Prioritization and Mapping of Fire Zones

Large and damaging wildfires are occurring in many different regions in RoS and the various agencies and communities are generally not prepared to cope with these new challenges. A fire history database such as cause, location, time of year, vegetation types and area burned should be developed and maintained and then updated and reviewed annually. Application of satellite images will support this strongly. Remote sensing and space technologies will offer a valuable, free data source in different phases of fire management both before (prevention) and after the fire (damage assessment). The temporal, spectral and spatial characteristics of these instruments provide a wide range of sensing capabilities in detection, monitoring and mapping the fire. Therefore, the purpose of this option should examine several satellites sensors, which will offer more detailed information and possible inputs to fire risk modeling, fuel mapping, active fire detection, burned area estimates, burn severity assessments and monitoring vegetation recovery.

Moreover, development of an inventory program to identify areas of high hazard is needed to build zonation fire maps. The zonation fire maps in this report were developed based on the amount of burned area, frequency and trend of fire in each State in Sudan during 2001 to 2019. Identification of these areas and annual inventory activities will support and maintain fire management plans. Management options were mapped in an attempt to show the prioritization maps that reflect how multiple management options can be implement in the same location for similar purposes.

This supports fire management issues that are outstanding or unique to a particular zone in order to meet fire reduction and prevention options. Based upon a relative comparison of the zonation area, the areas for detailed as well as high level risk and hazard assessment were prioritized based upon the identified dominant land use, history of fire incidence, identified ecological, environmental, and social, economic factors, relative availability of water sources and assessment fire risk and hazard.

Strategy Implementation

This option should show how management priorities and actions to prevent and reduce the fire risk within the fire zones in RoS are addressed. It is proposed to be divided into three implementation phases of fire management actions.

1. The short-term phase of the implementation focuses on a number of immediate actions that can be taken to prevent and reduce the fire risk in highly risky areas. It includes the enhancing fire safety education and awareness, raising local communities participation, improving data collection, conducting a gap analysis, developing a risk-based approach, strengthening fire detection, enhancing restoration of disturbance areas, adopted fire preparedness among high-risk fire zones.
2. The medium-term phase will continue with many activities from the short-term, while setting the database for future action to address the policies and gaps of fire management. Medium-term activities include conducting an analysis of fire management options using information available from the community-based and human caused management. Using this analysis to consider ways to enhance fire prevention, suppression training and education, integrating fire management into community activities, collecting and analyzing spatial data for fire risk assessment and creating an action plans for removing the overlap and closing gaps between different sectors in fire management.
3. The long-term phase centers on implementing actions to rehabilitate and mitigate high-risk zones in Sudan. It includes fire management plans as well as evaluating progress under the strategy and planning for future action.

Concluding Remarks and Way Forward

- The methodology adopted by this study depended heavily on multistage data collection, the integration of updated information from agencies, institutions and consultations with direct and indirect stakeholders that have been involved in fire management in RoS.

- To fulfill the stated terms of reference, the study was made of the causes, drivers and impact of fire risks. It provides a detailed investigation dealing with fire regime, seasonality, frequencies, scale and distribution within the country.
- The results indicated that the wildfires in Sudan are primarily human in origin, and the prevention of future fires is a difficult task. Fires will continue to affect large areas of forests and grasslands unless there is a radical change in the way the forest adjacent communities and other direct stakeholders consider appropriate fire management activities, including fire prevention, detection, suppression and mitigation.
- Based on the spatial analysis and trends of wildfire distribution, the total burned area, frequencies of fire, the country has been classified into four fire zones showing the most vulnerable areas with regard to wildfire risks.
- The study identified and highlighted the roles and responsibilities of the direct and indirect stakeholders pertinent to fire management, such as local communities, federal and state administrations, main agencies, organizations, academicians and other related entities.
- Forest burned area (BA) estimates based on multi-temporal satellite observations have provided critical insights into patterns and trends of fire occurrence in term of fire severity and Differenced Normalized Burn Ratio.
- Calculation of carbon emission due to wildfire incidents showed a significant rate, which influences climate change and affects the sound resource-base for forests and rangelands.
- The findings indicated overlaps, contradictions, conflicts of interest and deficiency in the existing policy and legislation frameworks regarding fire management at national and state levels.
- The study developed eight strategy options aimed to offer guidance and information to achieve sustainable wildfire management in RoS. These options were formulated to set up an effective institutional fire management, inventory, prioritization and mapping of fire areas, fire prevention, suppression and mitigation, training and education, and fire monitoring, evaluation and reporting system.
- The strategy options could further trickle down into different-level implementation action plans. These plans are expected to deal with the underlying causes, drivers, impacts and the available management opportunities at national and local levels.
- For the rational and gradual implementation of the action plans, it is recommended to develop minimum one model State Forest Fire Management Plan to serve as an example for subsequent State plans and National plan. Plans are to be organized into a series of program components, which can be considered for development assistance by international donors and financiers.
- To be successful, a strategy must be guided by a foundation of common values or guiding principles, a mutual understanding of the issues and alternatives, and a collective commitment to work toward a shared vision that can be reached through achievable recommendations.
- Guiding Principles Focus on Action-Oriented Solutions. Achieving these solutions will require an integrated, collaborative effort from a broad and diverse group of stakeholders at federal, State, and Local governments, NGOs, Private sector and local community.

Remarks suggested by the validation workshop

The following remarks were suggested by the validation workshop and considered by this report:

- Involvement of native administration with specific role and responsibilities was suggested to take part with fire management framework.
- Additional high-resolution remotely sensed data was suggested to provide logical framework and support the calculation of forest fire emission in order to improve the GHG inventories. Under this context the results were modified to analysis and map the fire on seasonal bases.
- Enhancement of detecting and mapping the accurate forest burnt areas within the Ros states was applied by using comparative analysis between MODIS64 products and Sentinel 2 data.
- More involvement of women in fire management framework was also suggested to mitigate the gender disparity and in favor of women participation.
- Assessing wildfire risk was also suggested during the validation workshop to quantify the existing and potential wildfire intensity, severity and effect on livelihood.
- Some arguments that evolved during the validation workshop stressed and called for replacing the fire focal points within the proposed institutional fire framework at FNC instead of ministry of Agriculture.
- Concerning the role and responsibilities within of the institutional framework, some views suggested that the states authorities should be committed to provide more funding need for implementing the fire management plans in their states.

Glossary and Terminologies

Beneficial Fire: Fire burning in forest, grass and shrub that contributes to the proper ecological function of the ecosystem, contributes to resource management objectives or protects public safety (e.g., by reducing hazardous forest conditions).

Biodiversity: The variety of life on Earth, which is the variability among living organisms from all sources, including, among other things, terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are a part. This includes diversity within species, between species and of ecosystems.

Ecological Role of Fire: Fire plays an important role in the ecology of the forest regions of Ontario. A natural force sustains the cycle of growth, death and regrowth. Ecosystems and fire are linked in an irregular sequence of alternating fire disturbance and regrowth that repeatedly rejuvenates the ecosystem.

Fire Behavior: The manner in which fuels ignite, flames develop; fire spreads and fires go out. These involve the physics and chemistry of combustion, and the interactions among fire, fuel, terrain, and weather.

Fire Ecology: The study of the relationship between fire, the physical environment, and organisms.

Fire Management: The activities concerned with the protection of people, property, and forest values from wildland fire and the use of wildland fire for the attainment of forest management and land management goals and objectives, all conducted in a manner that considers environmental, social, and economic criteria.

Fire Prevention: Activities directed at reducing fire occurrence; includes public education, law enforcement, personal contact and reduction of fire hazards and risks.

Fire Science: The study and practice of analyzing, building and organizing knowledge related to wildland fire including fire ecology, fire behavior, and the application of advanced analytical methods to improve efficiency, aid decision making and manage risks in wildland fire management.

Firebreak is defined as "any natural or constructed discontinuity in a fueled fire, utilized to segregate, stop, and control the spread of fire or to provide a control line from which to suppress a fire."

Forest Fire: Any fire burning in forested areas, grass, or alpine/tundra vegetation – synonymous with wildland fire.

Fuels: Wildland vegetation materials that can burn. While usually referring to aboveground living and dead wildland surface vegetation, roots and organic soils such as peat are often included.

Hazard Reduction: A treatment of dead or dying forest fuels to diminish the chance of fire starting, and to lessen the potential rate of spread and resistance to control.

Preparedness: Condition or degree of being able and ready to cope with an anticipated fire situation.

Prescribed Burning: The deliberate, planned and knowledgeable application of fire by authorized personnel and in accordance with MNRF policy and guidelines to a specific land area to accomplish pre-determined forest management or other land use objectives.

Resource Management: The science-based management of public or private land, water, soil, plants and animals for ecological sustainability, economic viability and social benefits for current and future generations. It involves the scientific and technical understanding of biology, physiology and ecology and the life-supporting capacity of the natural environment.

Restricted Fire Zone: An area in which specified activities related to open burning are temporarily restricted by the MNRF by the authority of the Forest Fires Prevention Act to reduce risk of human-caused fire.

Suppression: All activities concerned with controlling and extinguishing a fire following its detection

Unwanted Fire: Any wildland fire that puts human life and property at unnecessary risk or is deemed by a management agency to cause unnecessary social and economic disruption.

Wildland Fire Manager: The person empowered by a wildland fire management agency to make decisions to manage, control and direct wildland fires and fire management resources.

Wildland fire: Any fire burning in forest, grass, or alpine/ tundra vegetation – synonymous with forest fire.

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Annexes

Annex 1: Fire Active Detections in Sudan (hotspots)

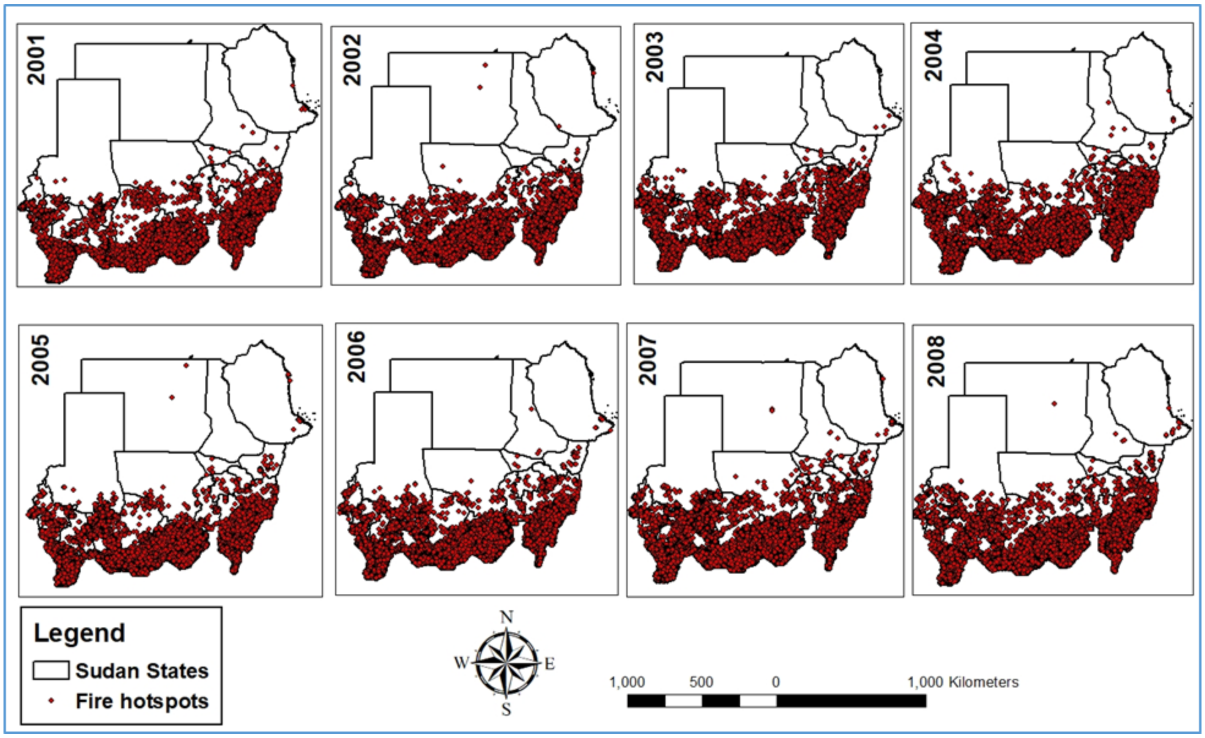


FIGURE 29 : SUDAN FIRE HOTSPOTS DURING 2001-2008

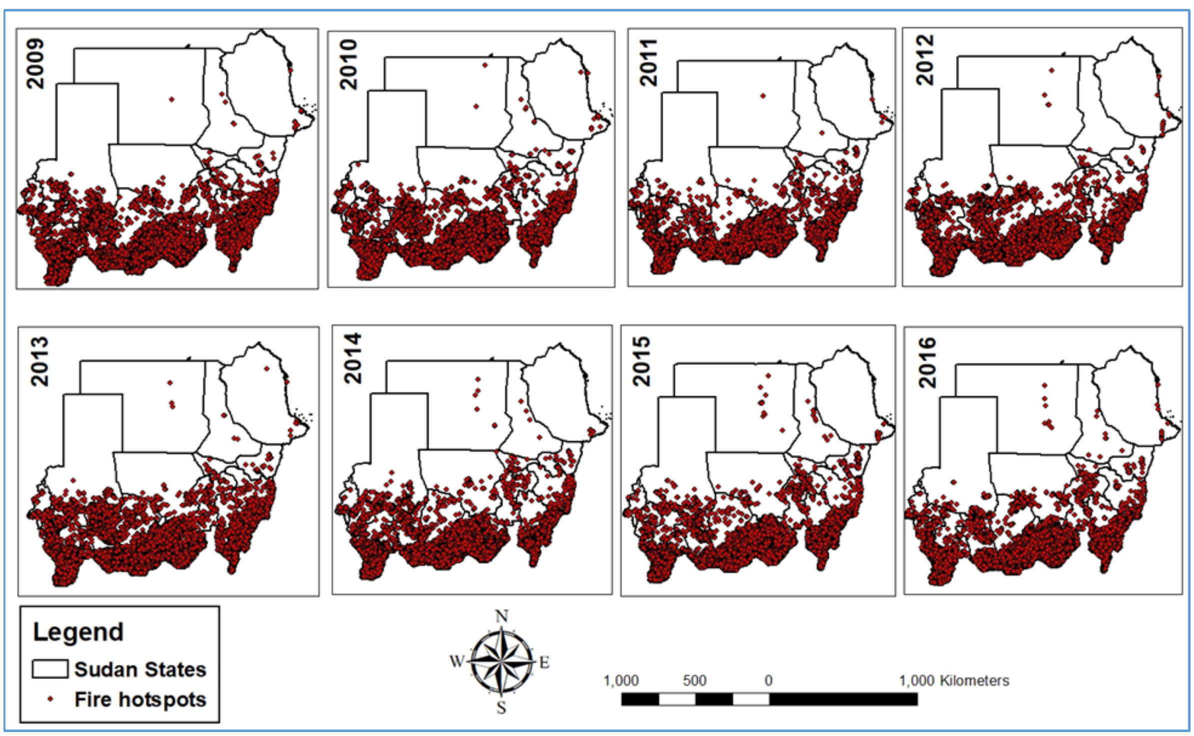


FIGURE 30: ROS FIRE HOTSPOTS DURING 2009-2016

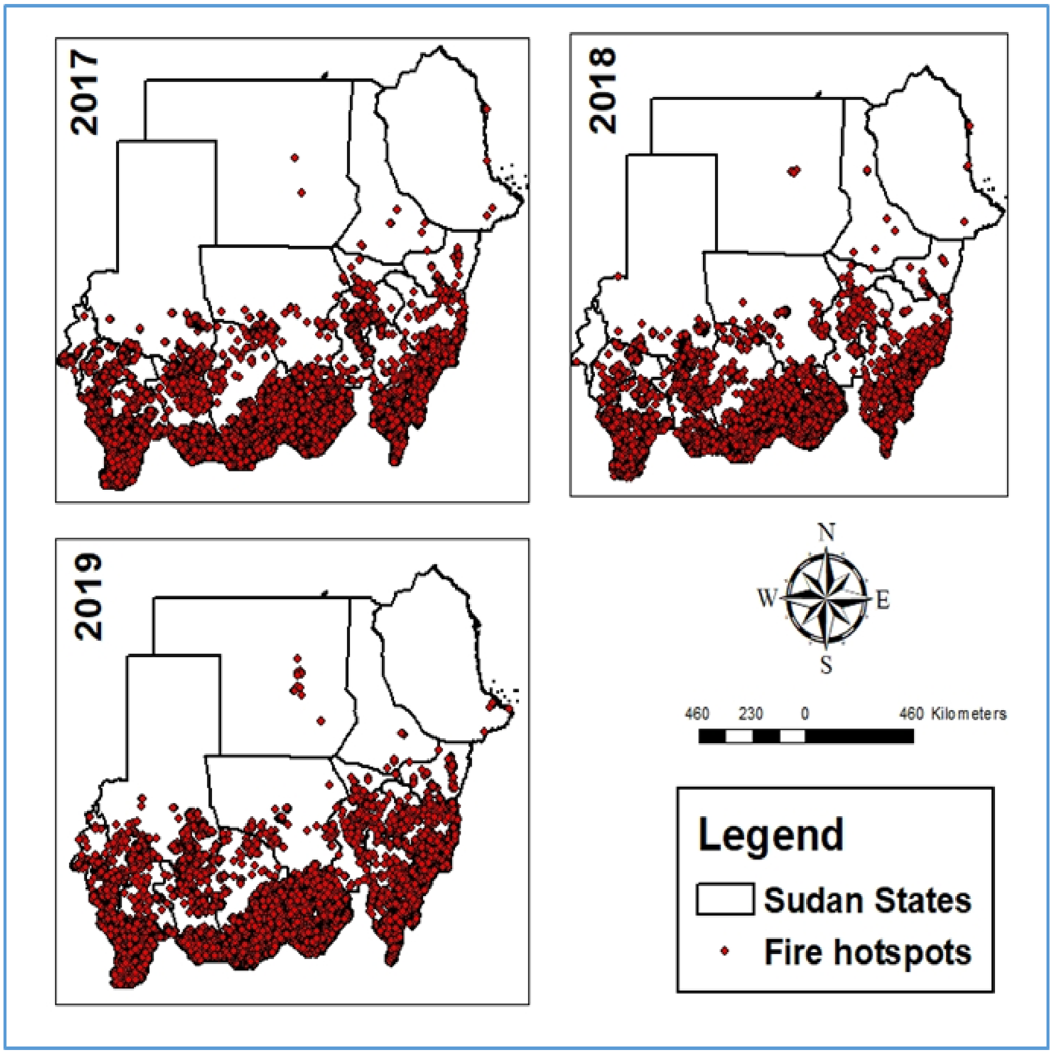


FIGURE 31: SUDAN FIRE HOTSPOTS DURING 2017-2019

Annex 2: Distribution of Burned Area by States 2001-2019

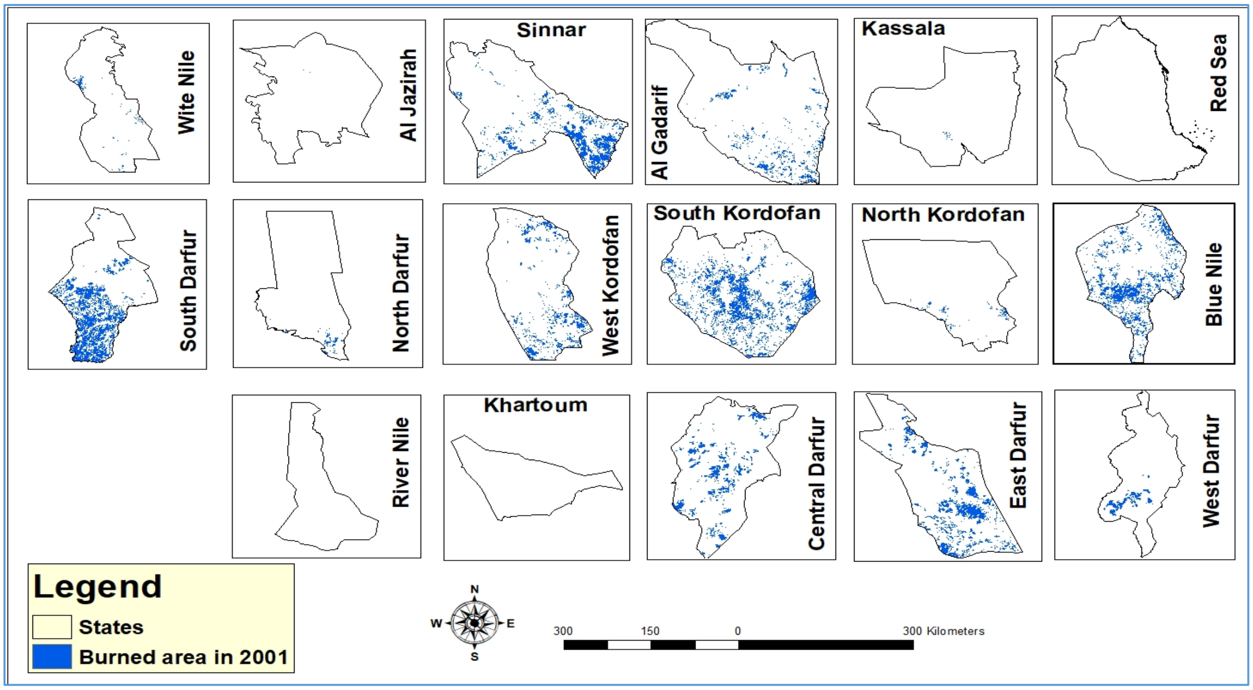


Figure 32: Distribution of burned area within RoS States in 2001

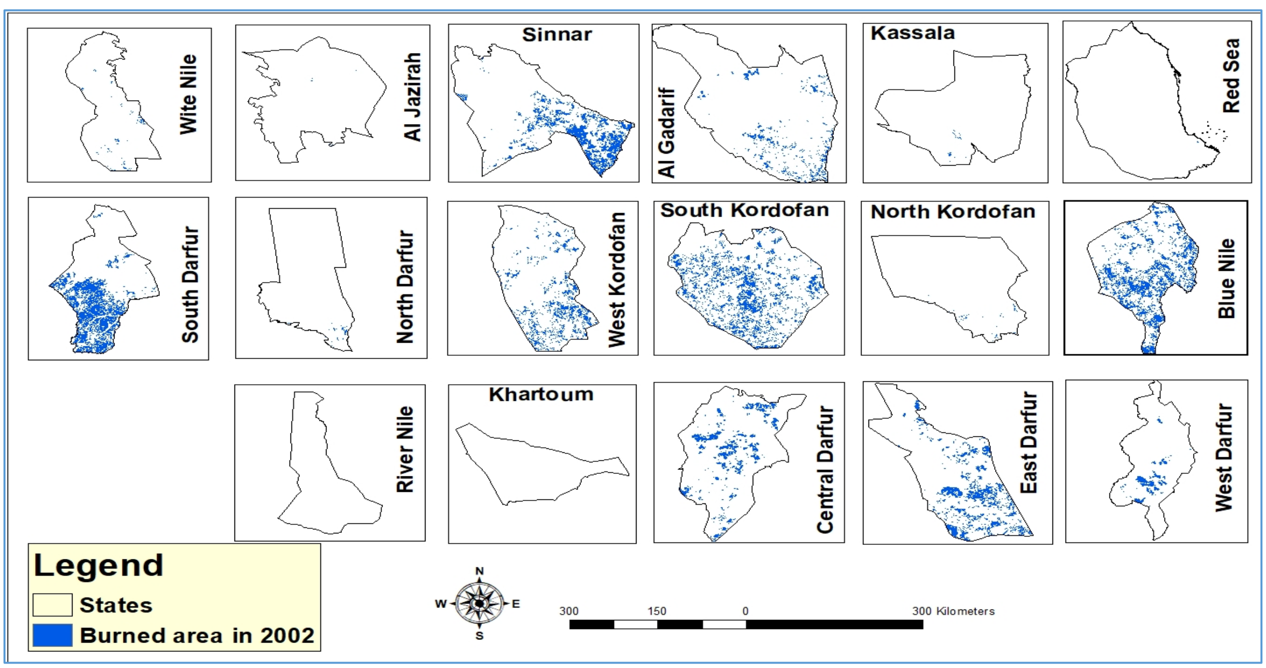


Figure 33 : Distribution of burned area within Sudan States in 2002

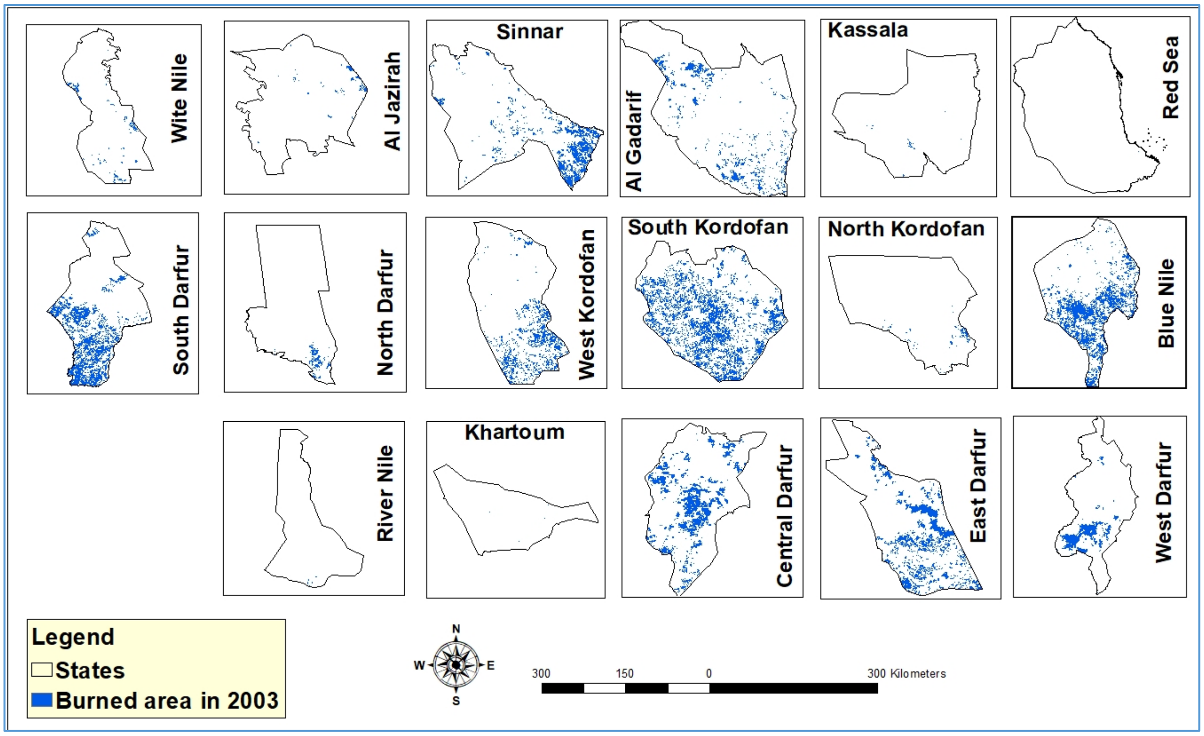


FIGURE 34: DISTRIBUTION OF BURNED AREA WITHIN ROS STATES IN 2003

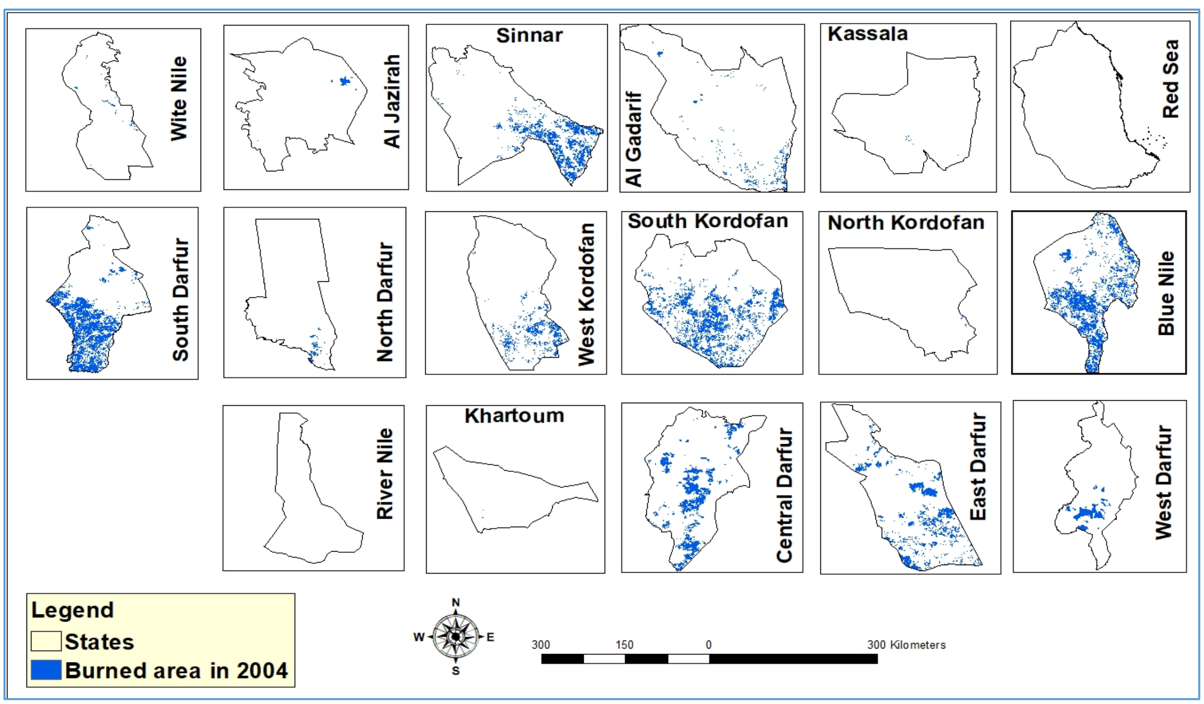


FIGURE 35: DISTRIBUTION OF BURNED AREA WITHIN SUDAN STATES IN 2004

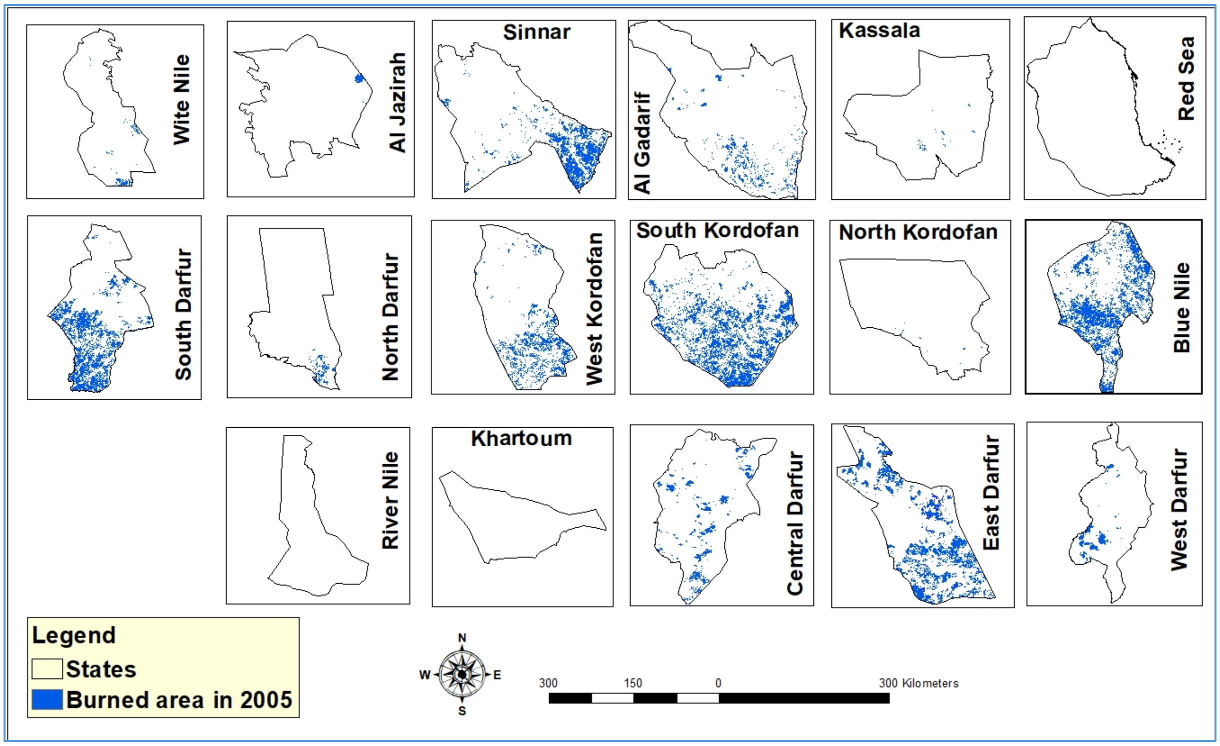


FIGURE 36 : DISTRIBUTION OF BURNED AREA WITHIN ROS STATES IN 2005

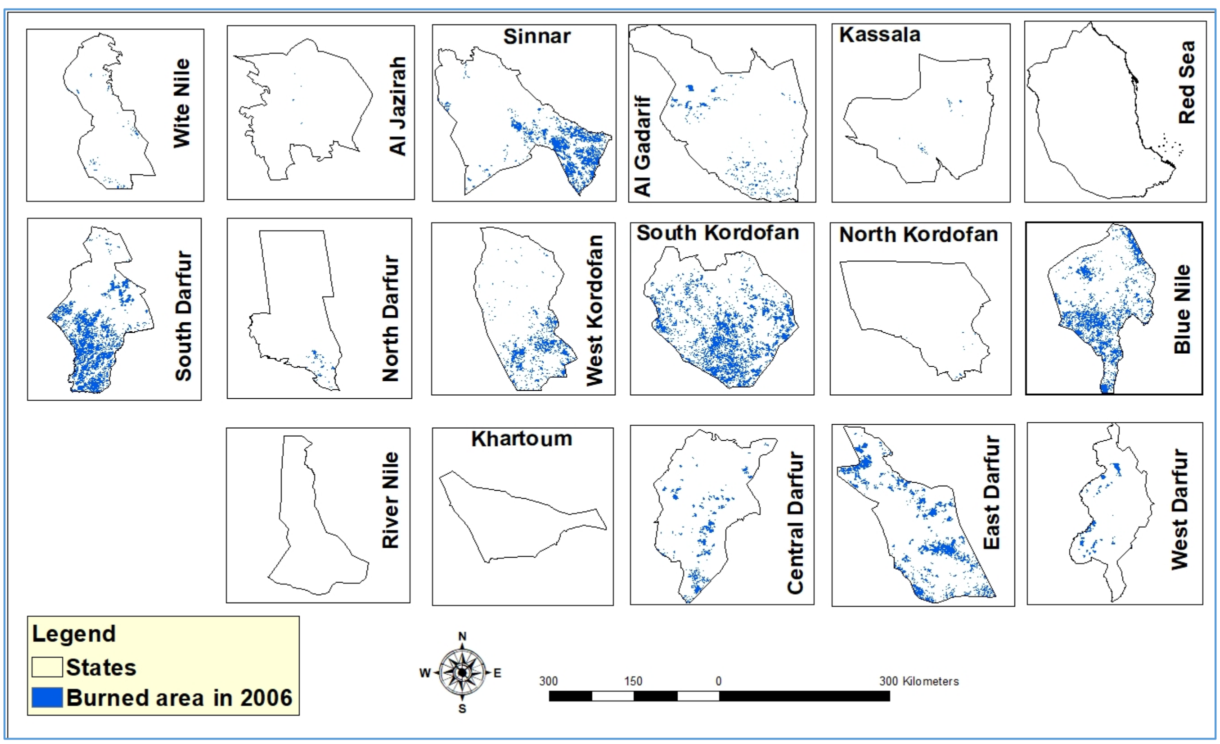


FIGURE 37: DISTRIBUTION OF BURNED AREA WITHIN THE SUDAN STATES IN 2006

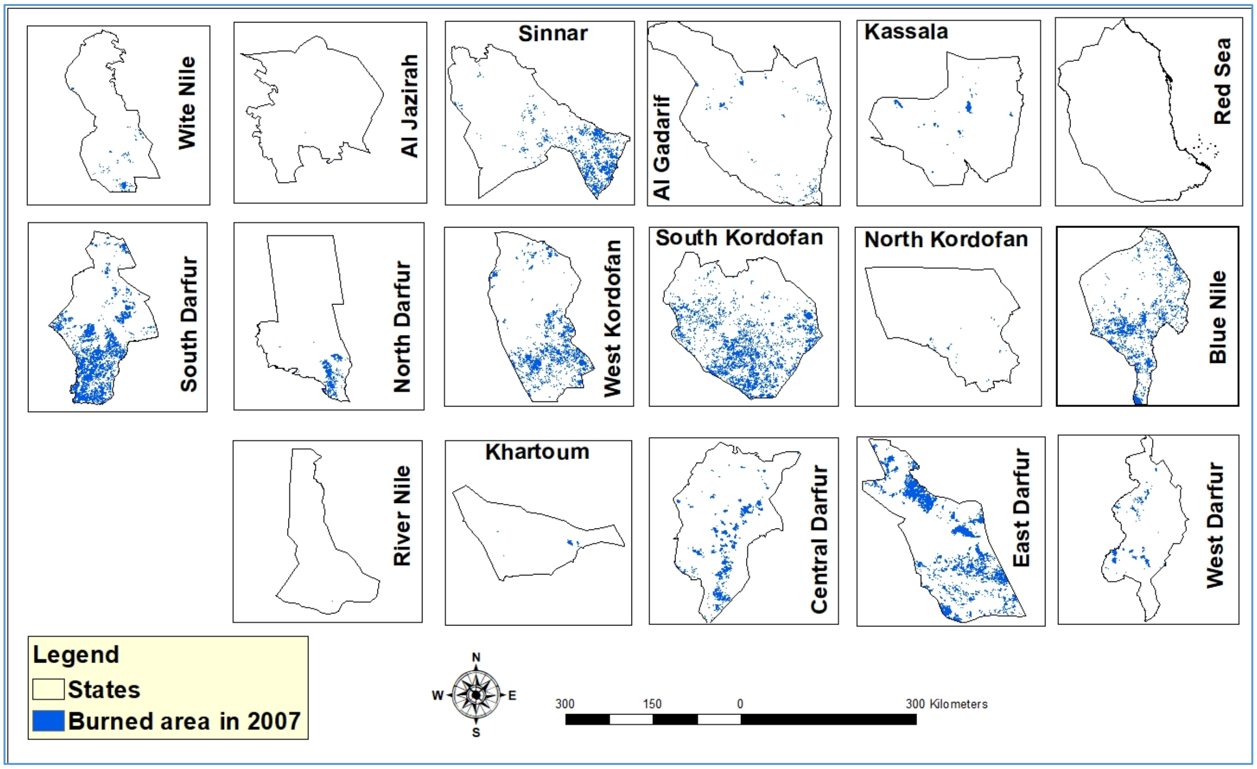


FIGURE 38: DISTRIBUTION OF BURNED AREA WITHIN THE RoS STATES IN 2007

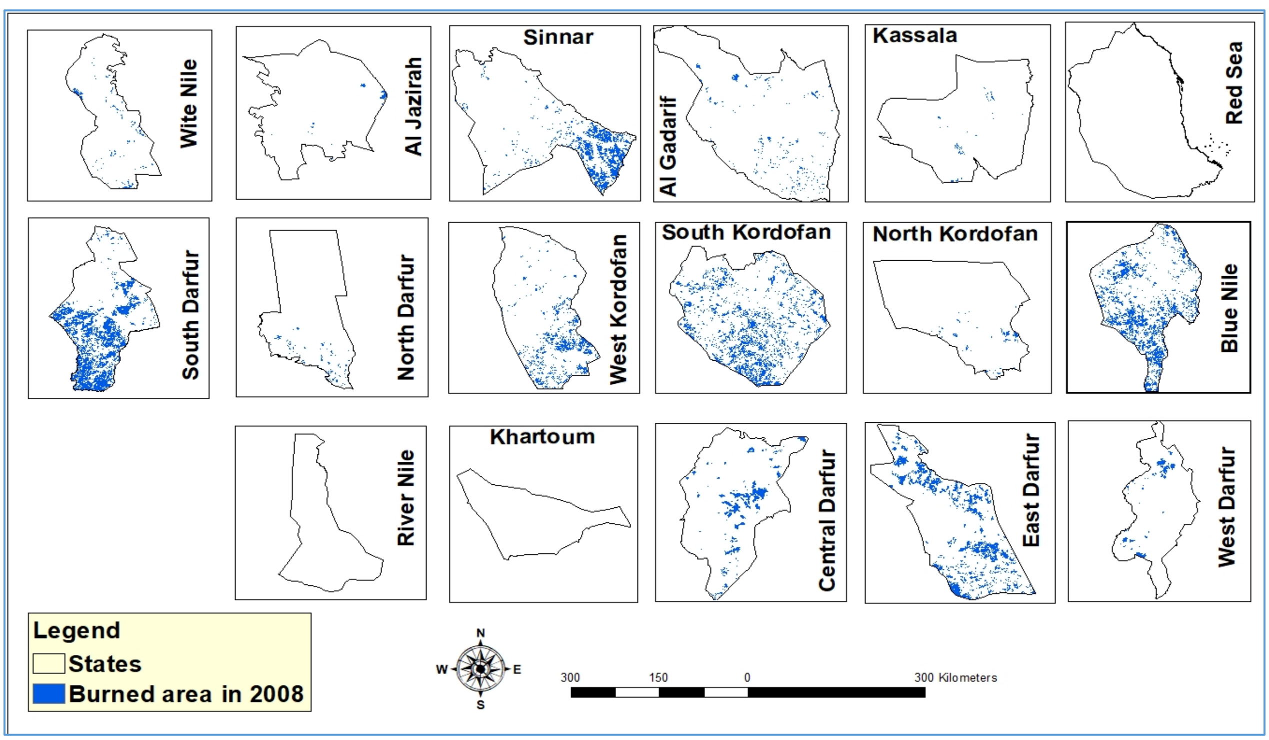


FIGURE 39 : DISTRIBUTION OF BURNED AREA WITHIN SUDAN STATES IN 2008

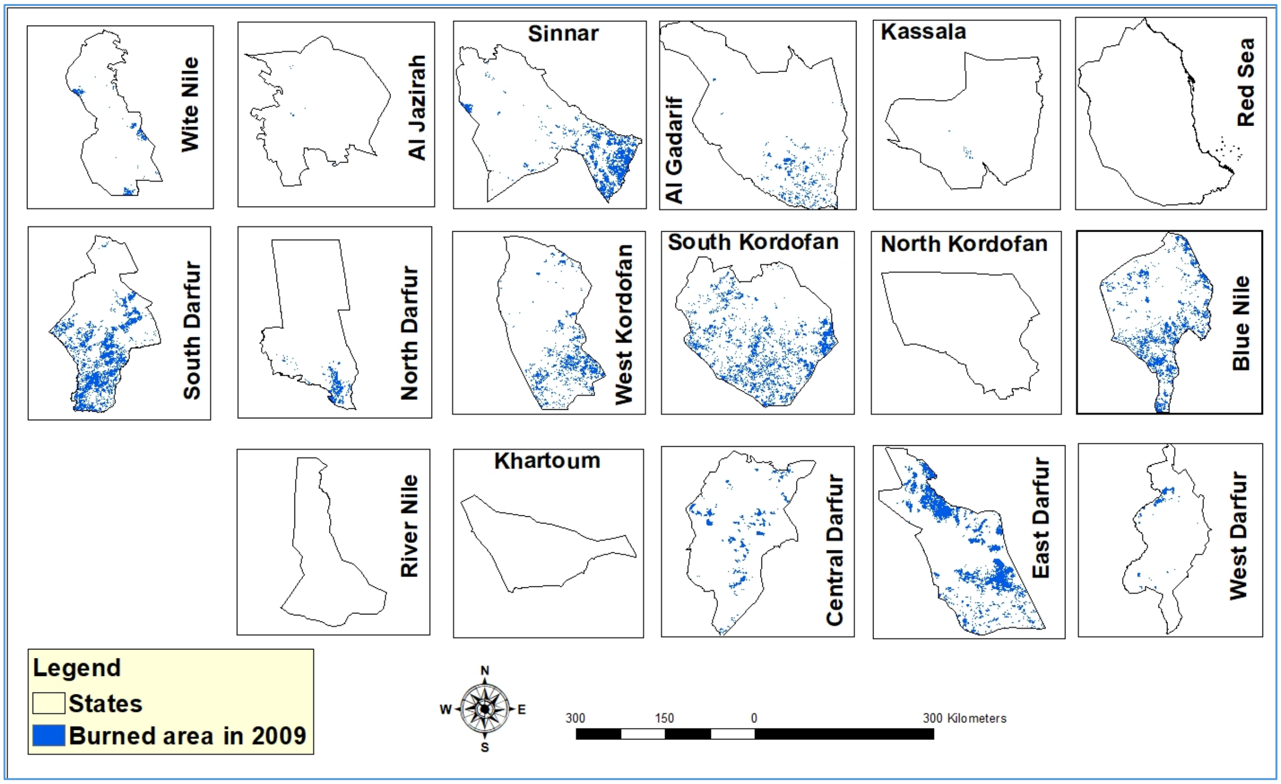


FIGURE 40: DISTRIBUTION OF BURNED AREA WITHIN ROS STATES IN 2009

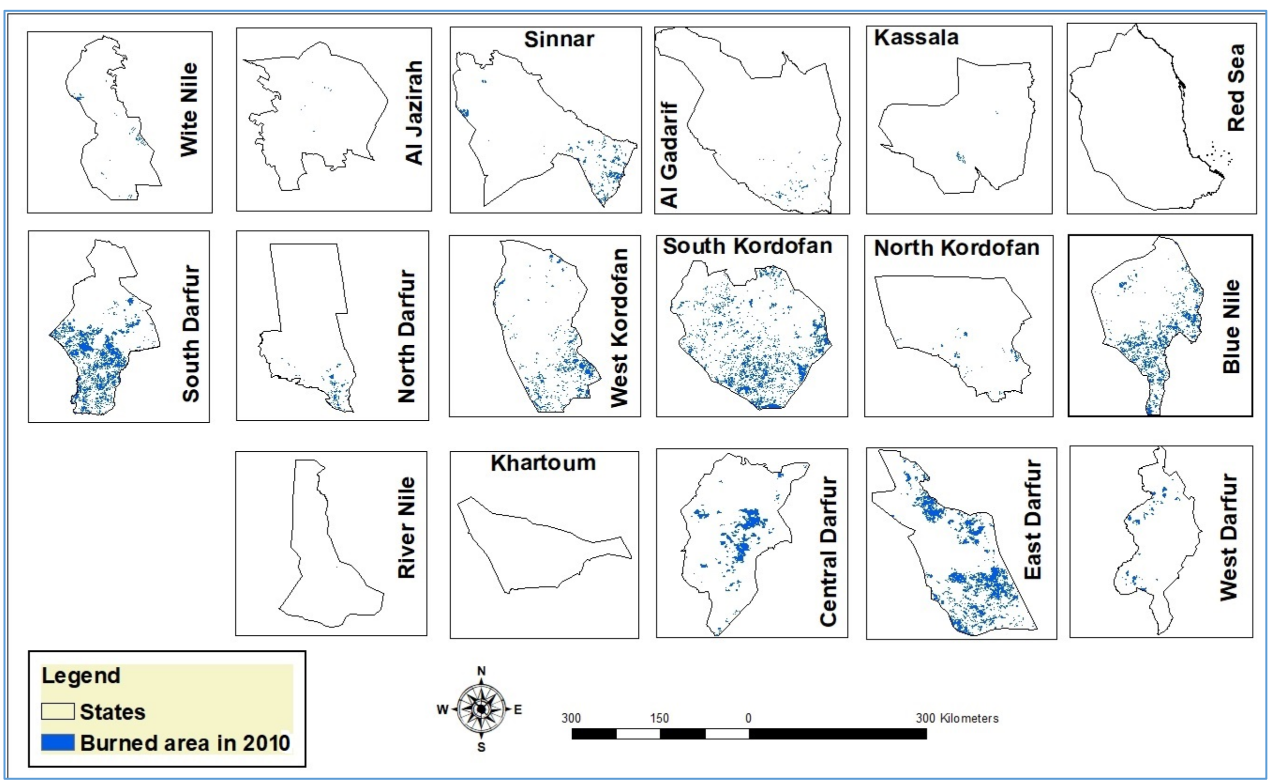


FIGURE 41: DISTRIBUTION OF BURNED AREA WITHIN SUDAN STATES IN 2010

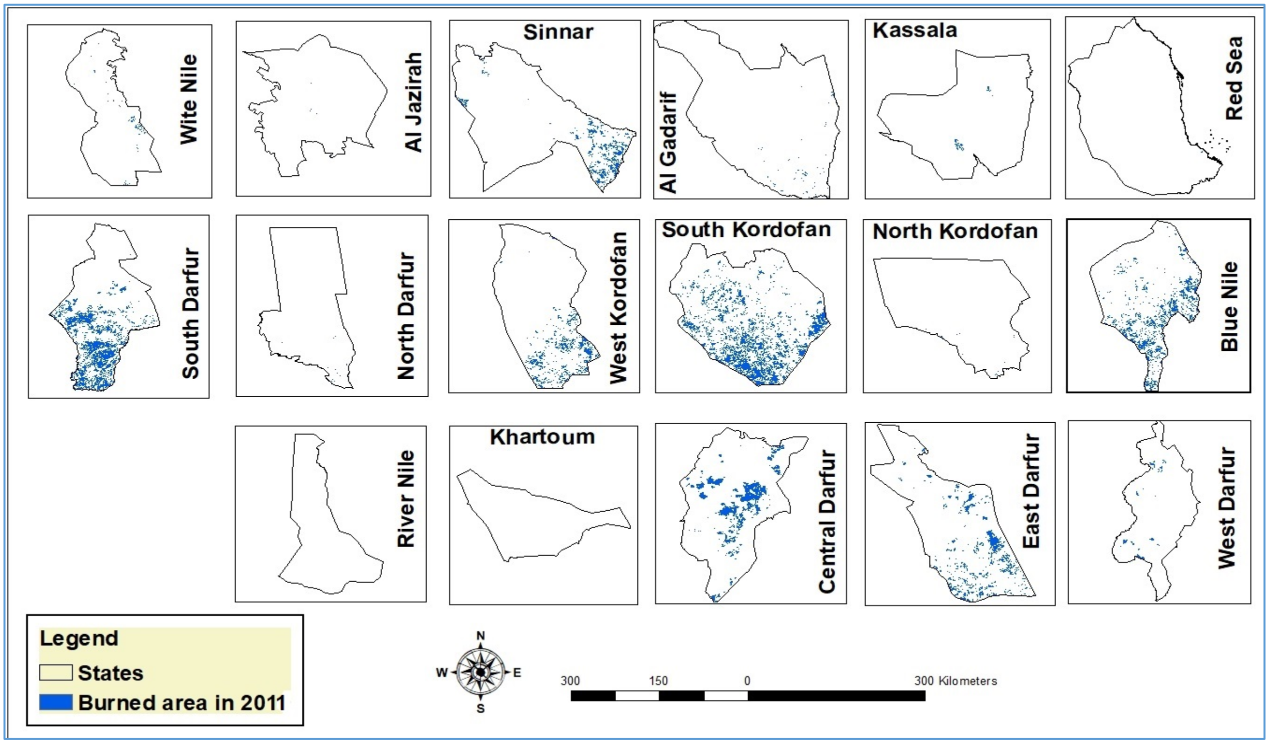


FIGURE 42: DISTRIBUTION OF BURNED AREA WITHIN RoS STATES IN 2011

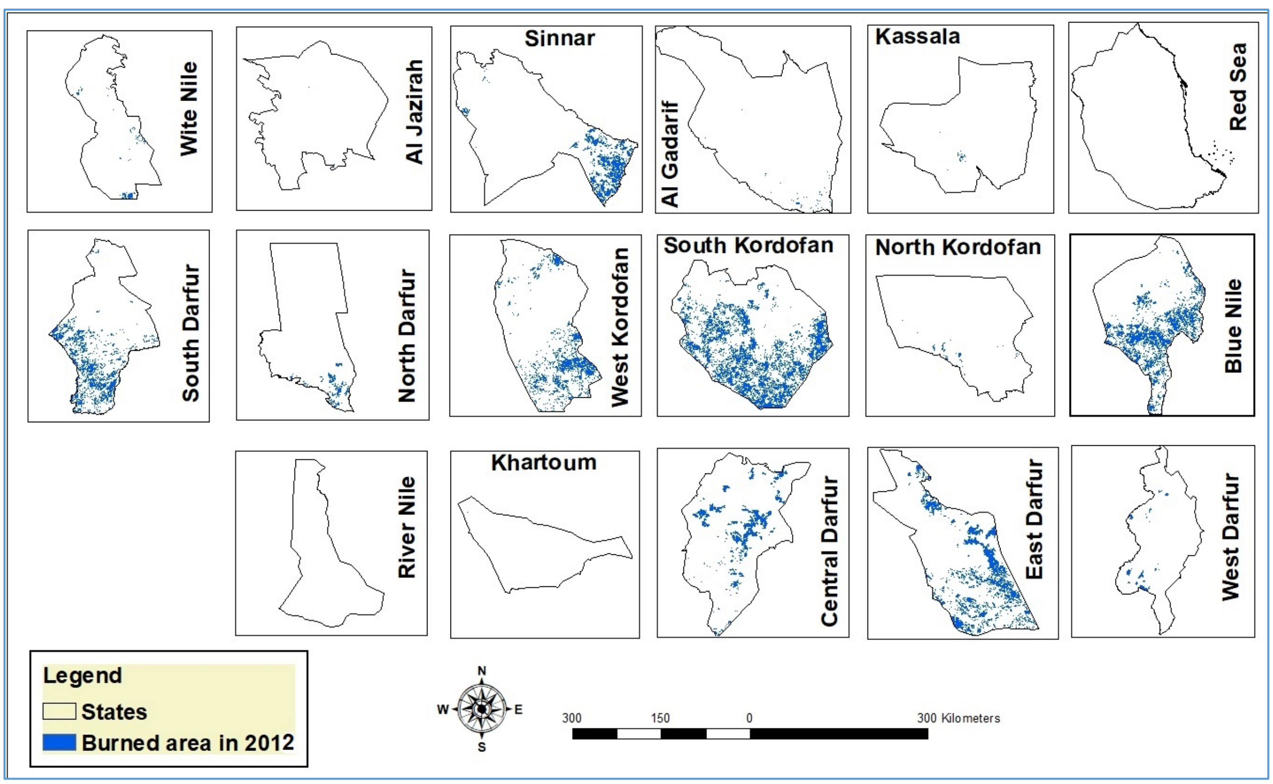


FIGURE 43: DISTRIBUTION OF BURNED AREA WITHIN SUDAN STATES IN 2012

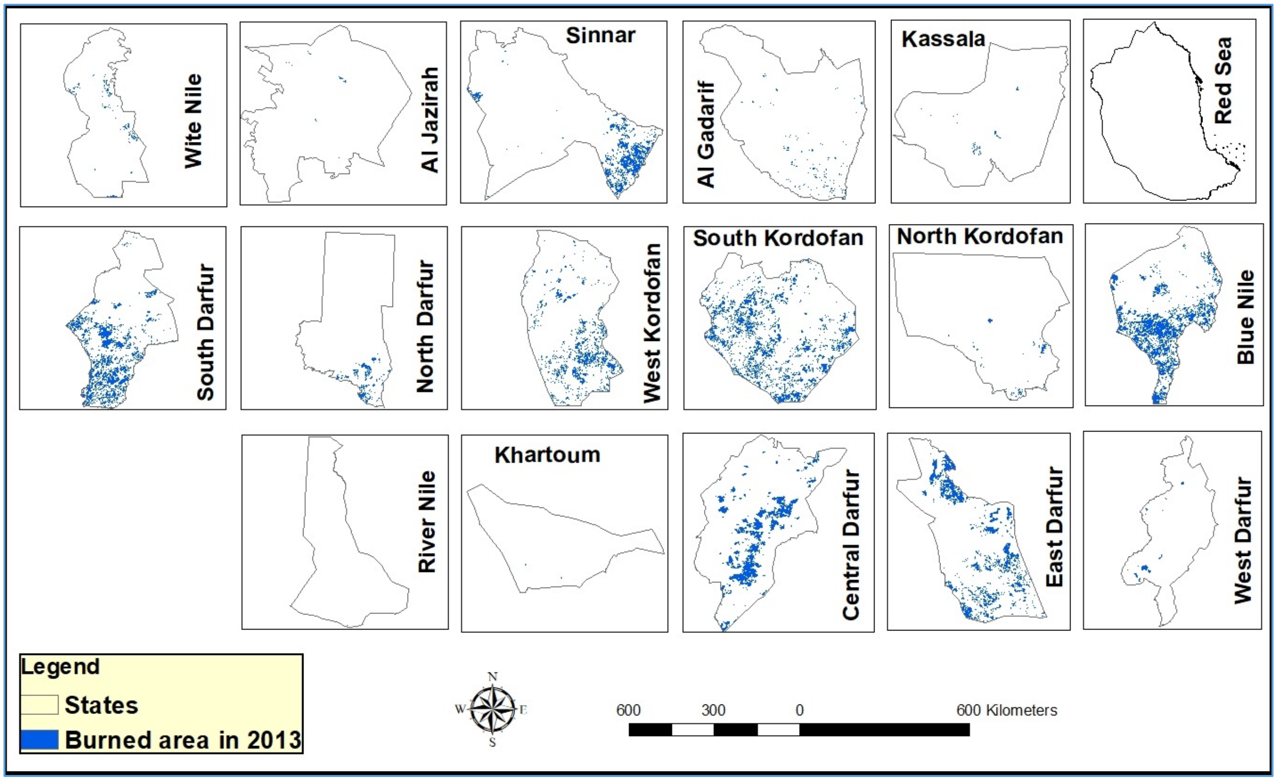


FIGURE 44: DISTRIBUTION OF BURNED AREA WITHIN ROS STATES IN 2013

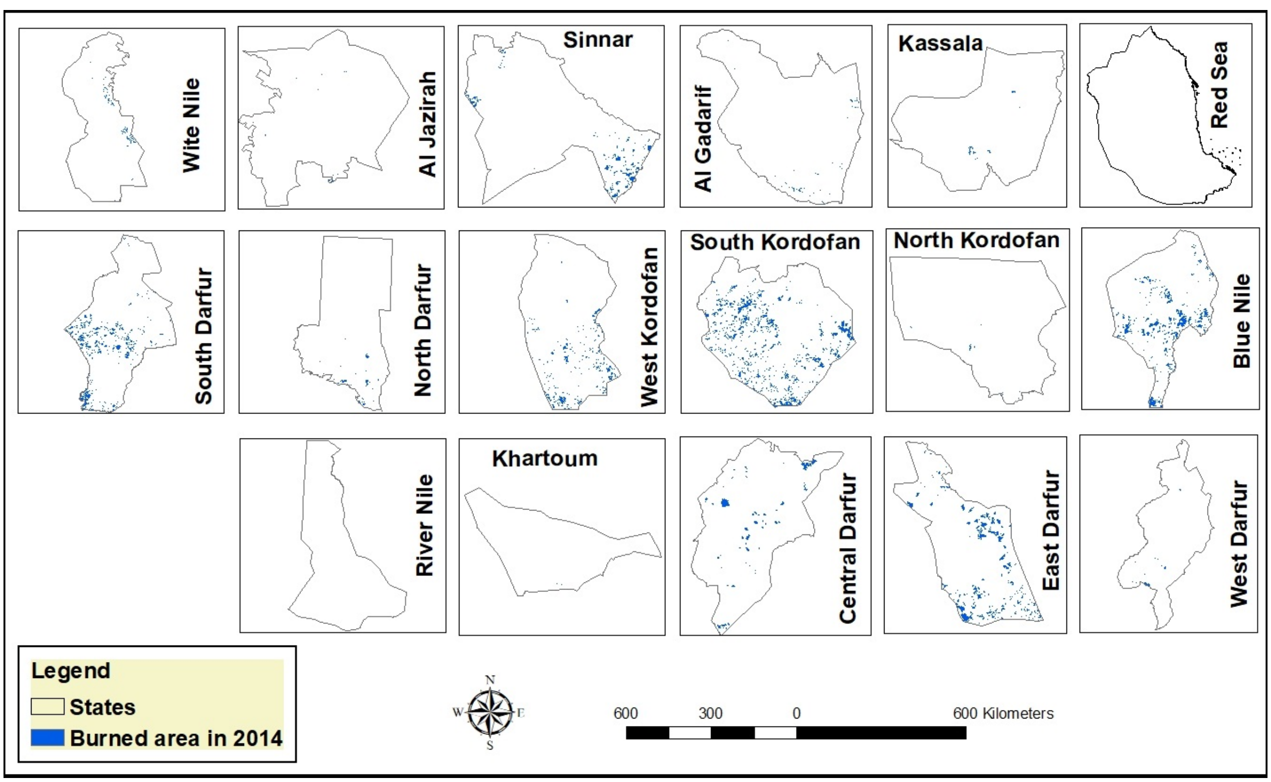


FIGURE 45: DISTRIBUTION OF BURNED AREA IN SUDAN STATES IN 2014

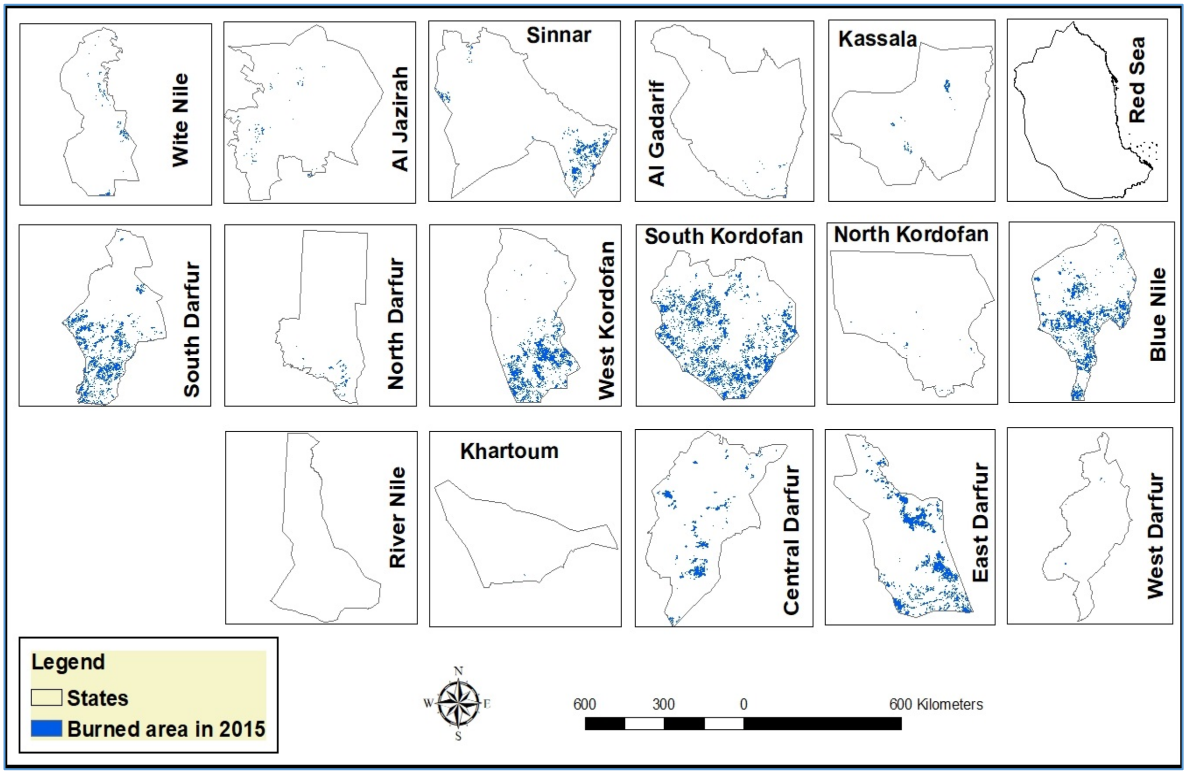


FIGURE 46: DISTRIBUTION OF BURNED AREA IN ROS STATES IN 2015

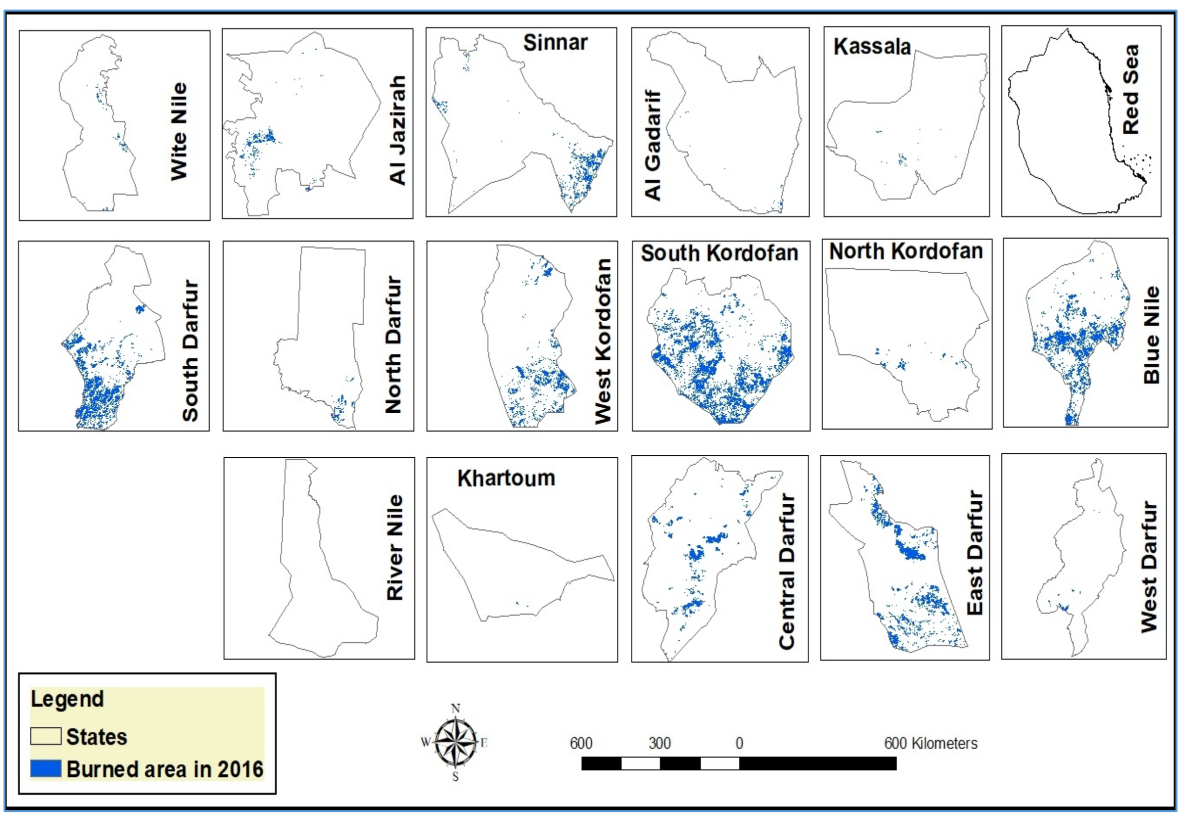


FIGURE 47: DISTRIBUTION OF BURNED AREA IN THE STATES IN 2016

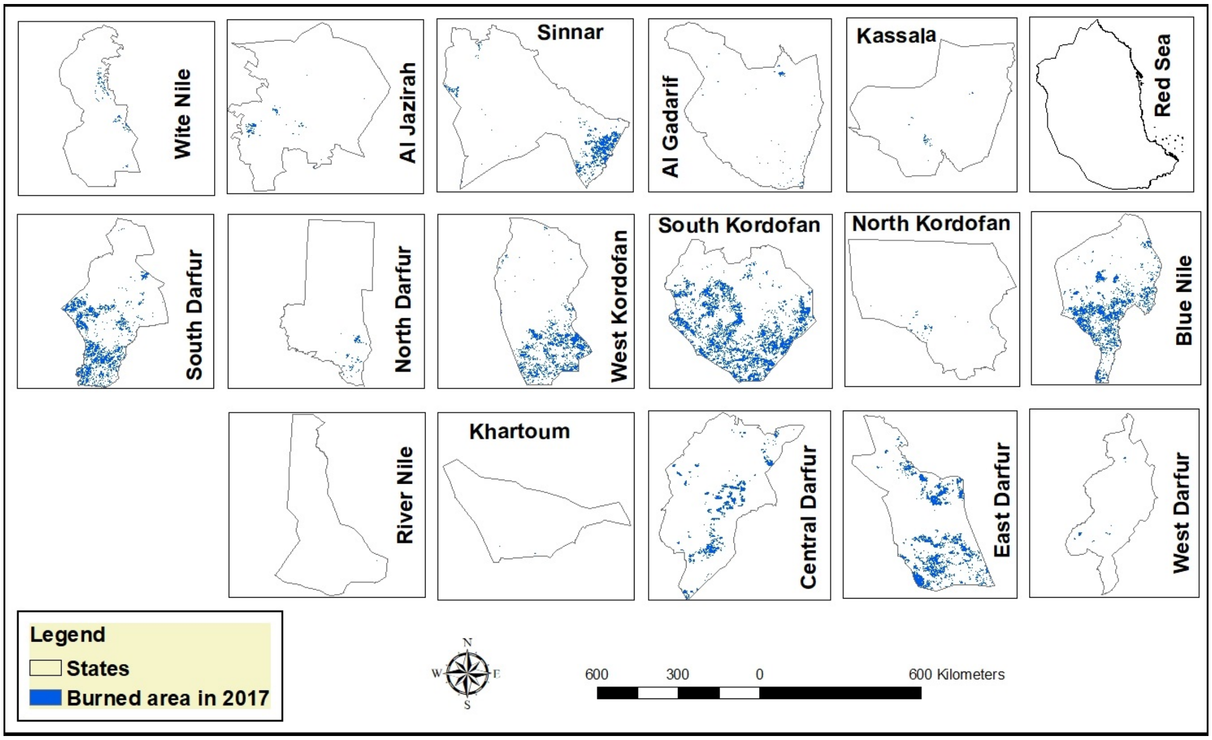


FIGURE 48: DISTRIBUTION OF BURNED AREA IN THE STATES IN 2017

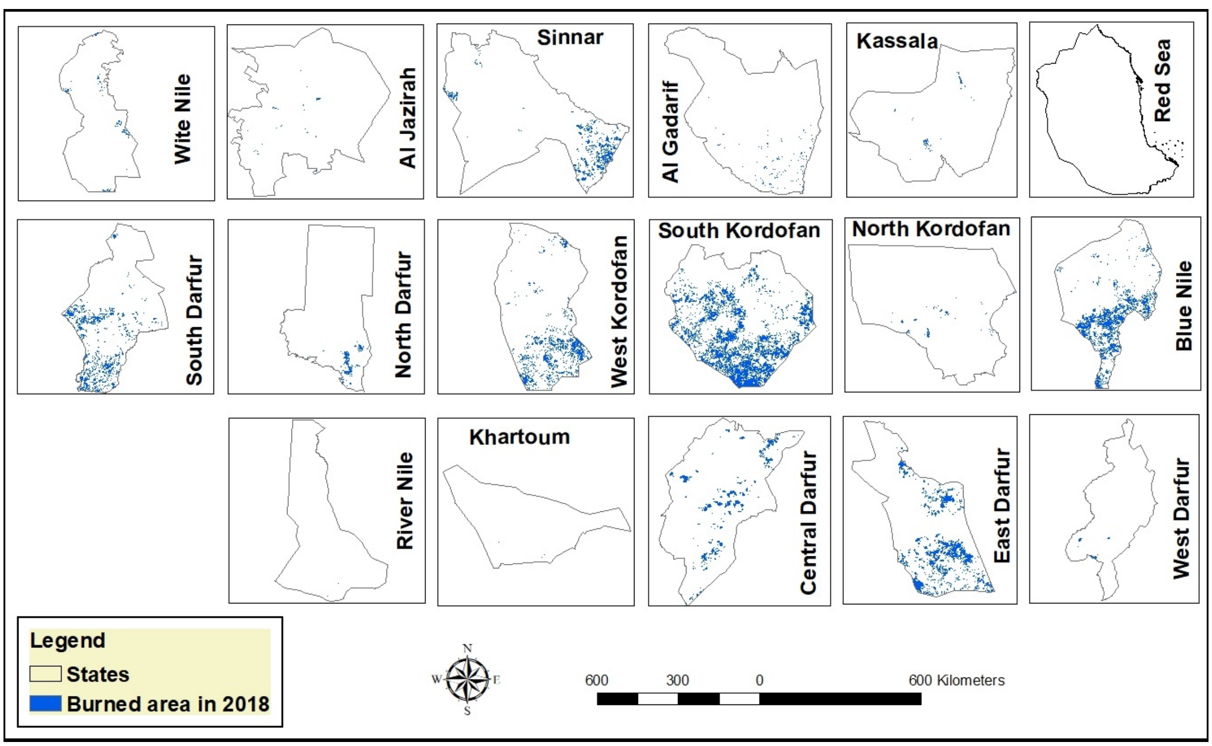


FIGURE 49: DISTRIBUTION OF BURNED AREA IN THE STATES IN 2018

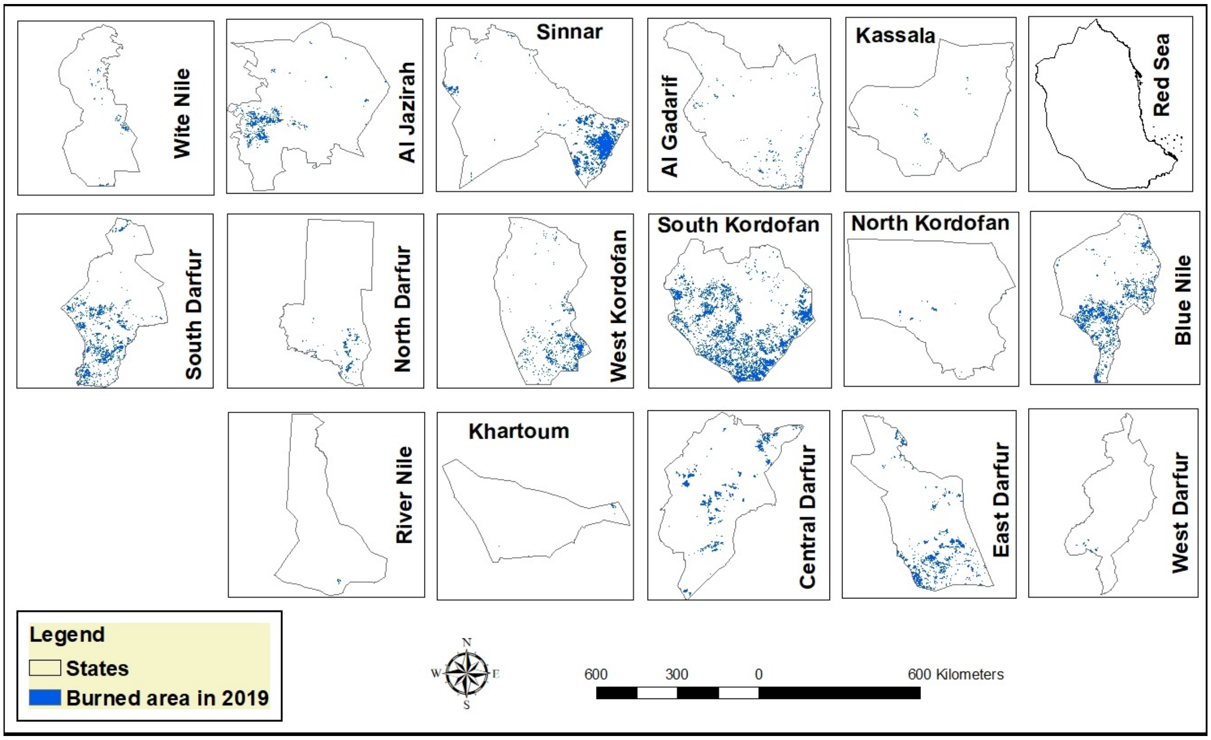


FIGURE 50: DISTRIBUTION OF BURNED AREA IN THE STATES IN 2019

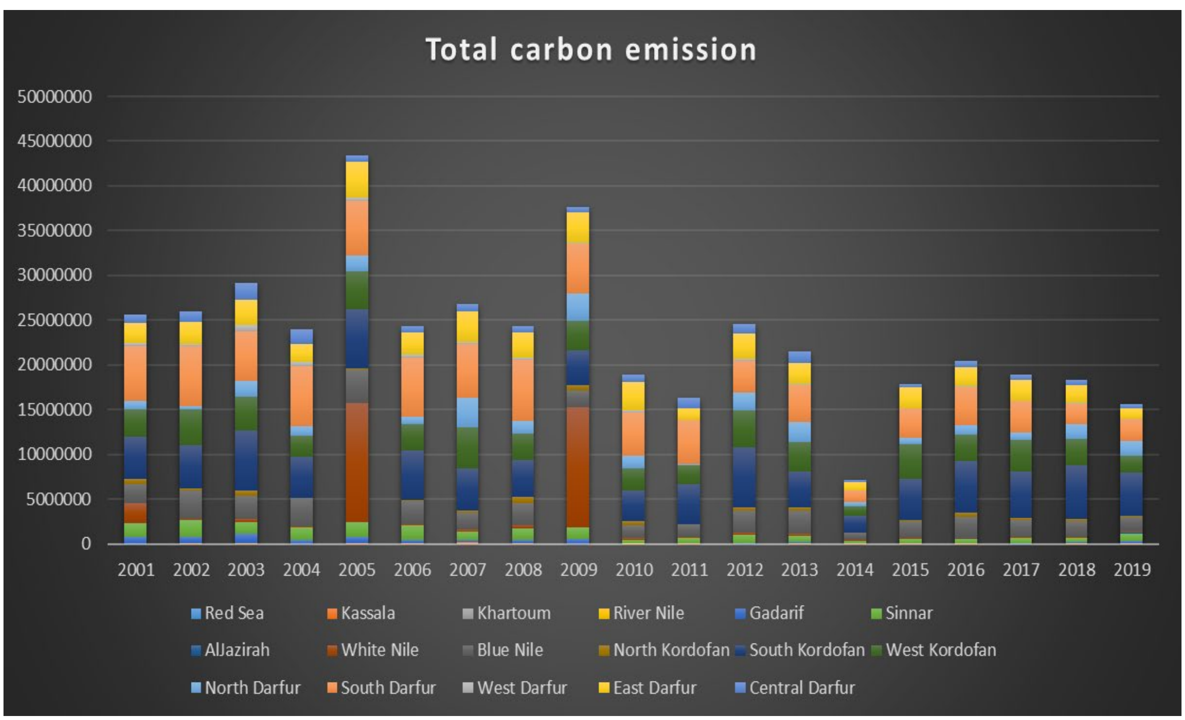


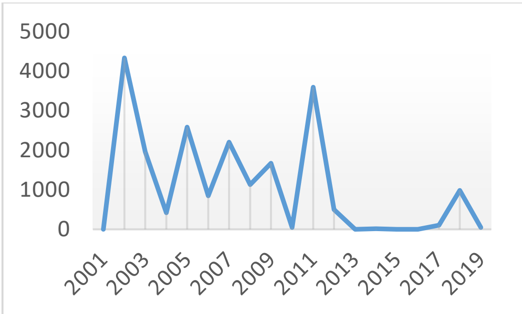
FIGURE 51 : TOTAL CARBON (GG) EMISSION OF BURNED AREA WITHIN ROS STATES DURING 2001-2019

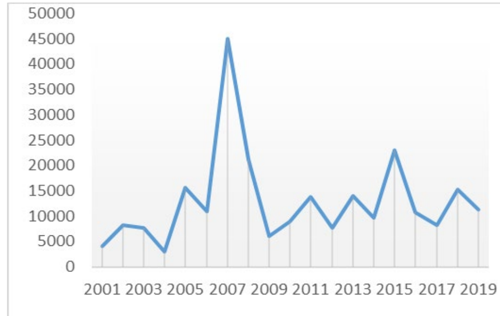
Annex 3: Distribution of Burned Area (ha) in Different States During 2001-2019

State / Year	Red Sea	Kassala	Khartoum	River Nile	Al Gadarif	Sinnar	Geziraa	White Nile	Blue Nile
2001	0	3999.94	0	0	244317.3	443239.502	1029.654	659160.7	659160.72
2002	4337.8	8232.376	0	0	239573.7	548785.181	1114.692	48010.36	935509.84
2003	1962.913	7717.036	1198.847	15737.46	325041.7	369832.145	21997.99	88359.98	800876.97
2004	422.5206	2945.321	524.3072	0	117705	433241.265	13587.43	24607.5	939730.82
2005	2588.592	15583.51	0	0	224612.7	475057.649	13511.06	4003572	1121016.5
2006	850.9922	10966.71	0	0	134933.2	464152.904	1301.238	44380.08	778527.69
2007	2205.068	44967.02	8869.858	2363.207	64714.09	301122.531	1065.312	66451.73	552787.63
2008	1127.661	21175.45	0	393.7929	101795.4	380089.512	12870.7	94759.85	760029.38
2009	1669.668	6151.593	0	1033.071	162906.2	377334.712	2283.831	4013231	596465.74
2010	50.37771	8967.817	0	684.0023	27483.37	107105.272	1760.456	42108.03	430628.05
2011	3595.922	13821.73	0	0	20931.04	163192.99	1041.521	33157.06	412858.94
2012	499.5652	7710.9	208.5273	28.97565	15184.95	288186.316	692.8648	50462.3	771457.84
2013	0	14066.39	747.93	43.14043	50572.41	222783.936	3175.433	61318.33	779349.75
2014	14.69738	9605.348	275.8996	0	16460.6	66841.532	1826.031	33072.19	235632.23
2015	0	22988.6	451.172	0	13286.62	115950.697	9016.306	49627.93	554863.05
2016	0	10793.15	1126.998	571.526	10962.15	136718.695	32611.66	34734.21	696402.47
2017	101.7198	8279.784	722.1523	58.78864	25071.83	151939.407	12133.56	42350	571696.81
2018	983.9055	15316.84	528.1453	3045.17	37710.26	141469.568	5159.23	42393.09	514295.78
2019	44.00687	11237.17	3689.533	13911.44	67608.79	255136.002	65160.99	38944.93	444408.95

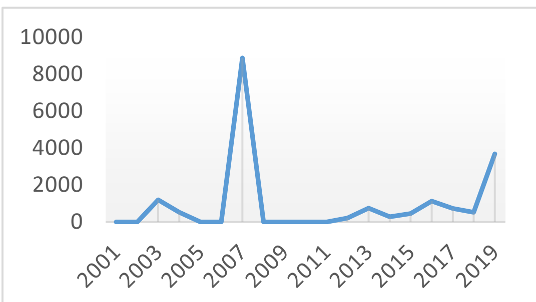
State / Year	North Kordofan	South Kordofan	West Kordofan	North Darfur	South Darfur	West Darfur	East Darfur	Central Darfur
2001	166944.2	1421540	910548	269445.8	1864523	83290.62	672460.9	306224.8
2002	60973.75	1467011	1188258	124630.4	1987581	101831.4	736931.5	339762.5
2003	163113.3	2010251	1133970	526577.3	1659206	193563.8	848206.3	567387.9
2004	12356.39	1360986	710122.4	329932.8	2025600	126778	613819.8	467215.8
2005	25455.99	1981400	1276152	532782.3	1834478	100085.3	1187958	235954.3
2006	26417.32	1669540	898612.7	240064.7	1985461	79162.65	770122	182646.8
2007	84732.61	1396151	1380571	997288.2	1786126	77874.58	1032907	244369.1
2008	195680.1	1239420	886566.7	418303.5	2067436	71570.86	833504.7	226488.7
2009	155767.4	1186112	962800.4	929742.8	1642276	40990.49	1043640	163969.8
2010	143692.9	1044592	714141	433898	1455676	56897.33	951448.6	261021.7
2011	23801.01	1327540	631409.8	56956.76	1451981	30407.68	385874	353090
2012	100221.3	2004487	1222172	631852.5	1059406	38182.51	873386.7	298861.7
2013	110129.3	1177640	981038.4	674202.2	1259172	19949.55	721422.7	393484.4
2014	16858.44	577867.9	288111.9	159081.9	376832.7	7410.844	288374.2	67722.81
2015	31283.37	1400102	1136532	237331.1	986945.4	3486.06	681001.2	132525
2016	112393.8	1742244	871422.3	347433.3	1263142	13040.85	659015.9	187287.5
2017	44496.05	1585566	1054831	247340.3	1047408	7387.974	692809.7	194246.6
2018	90556.28	1778465	896784.2	485398.3	684431.9	8923.156	632228.6	149814.4
2019	37251.84	1453572	580278.9	465728.9	756578.3	6460.932	354031.1	145542.2

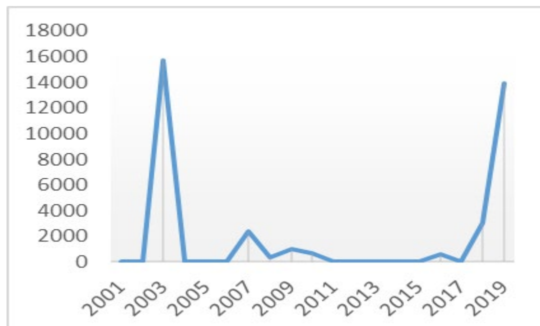
Annex 4: Analysis of Fire Trends Within the States During 2001-2019



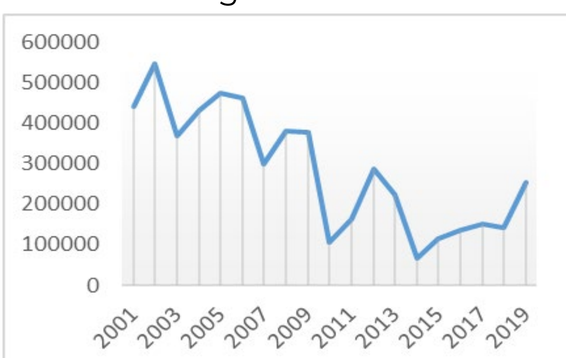


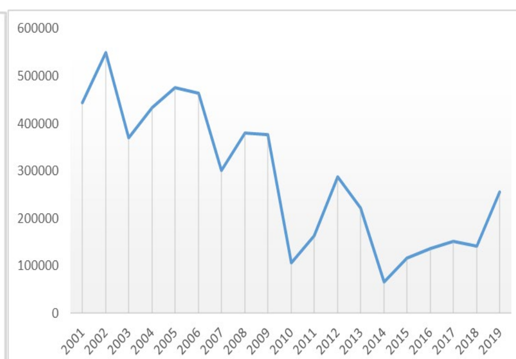
Fire trend in Red Sea state during 2001-2019 Fire trend in Kassala state during 2001-2019



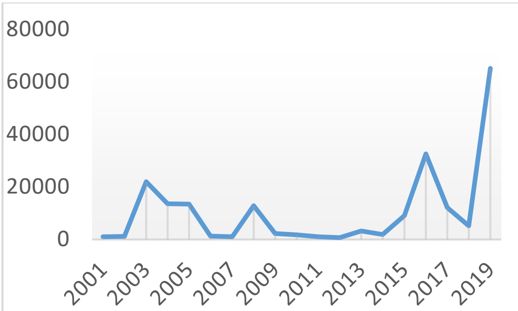


Fire Trend in Khartoum state during 2001-2019 Fire trend in River Nile state during 2001-2019

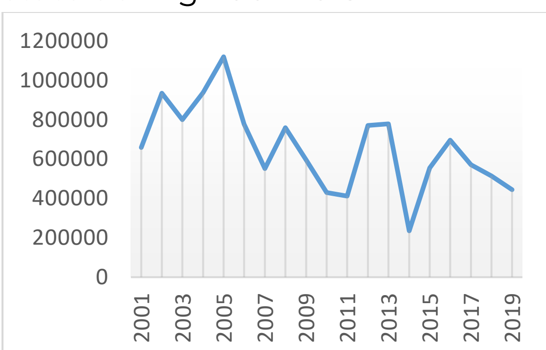


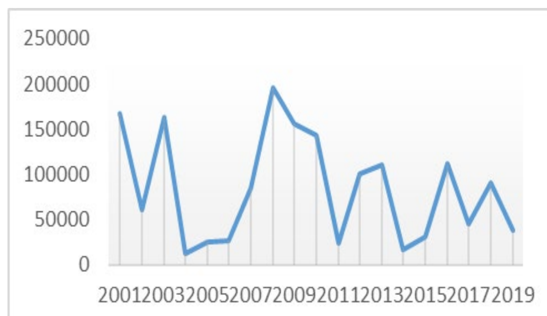


Fire trend in AL Gadarif state during 2001-2019 Fire trend in Sinnar state during 2001-2019

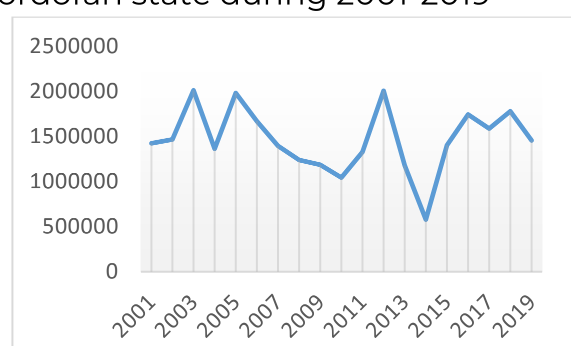


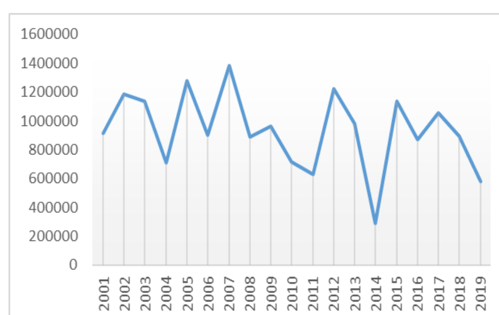
Fire Trend in Gezira state during 2001-2019 Fire trend in White Nile state during 2001-2019



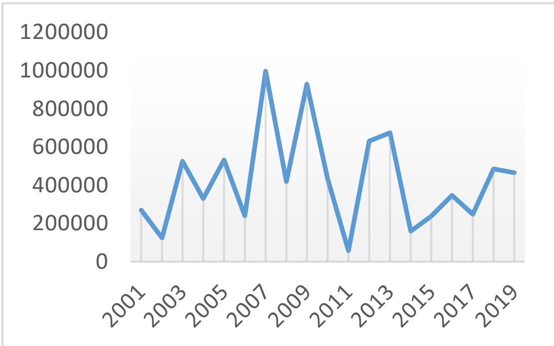


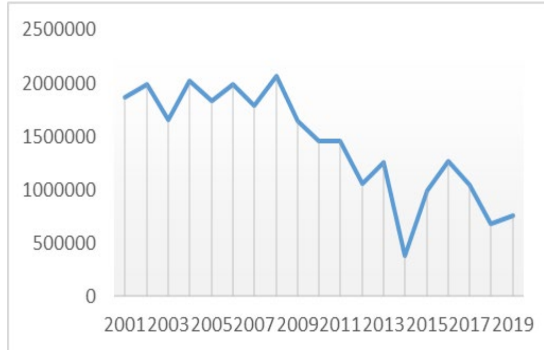
Fire Trend in Blue Nile state during 2001-2019 Fire Trend in North Kordofan state during 2001-2019



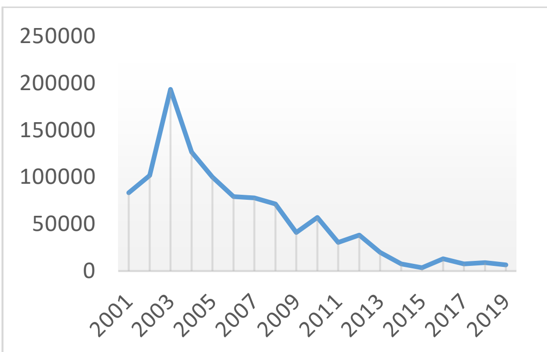


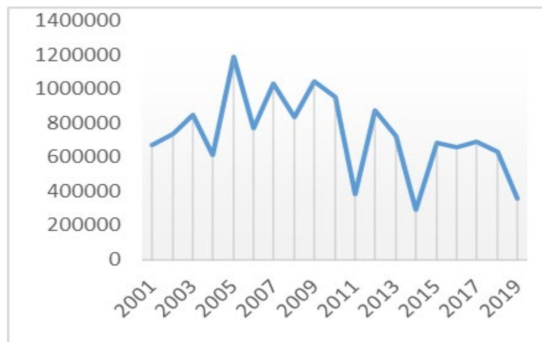
Fire Trend in South Kordofan state during 2001-2019 Fire Trend in West Kordofan state 2001-2019



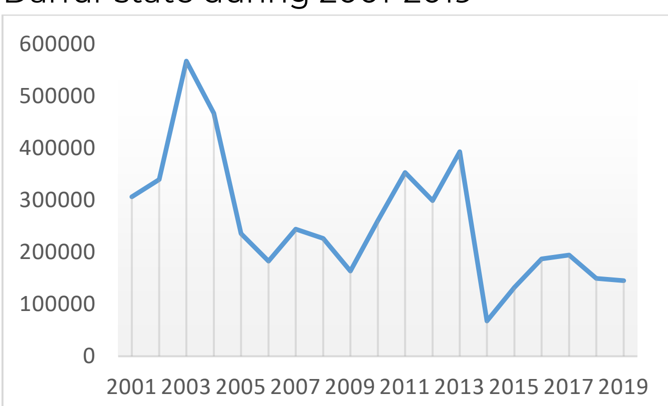


Fire Trend in North Darfur state during 2001-2019 Fire Trend in South Darfur state 2001-2019



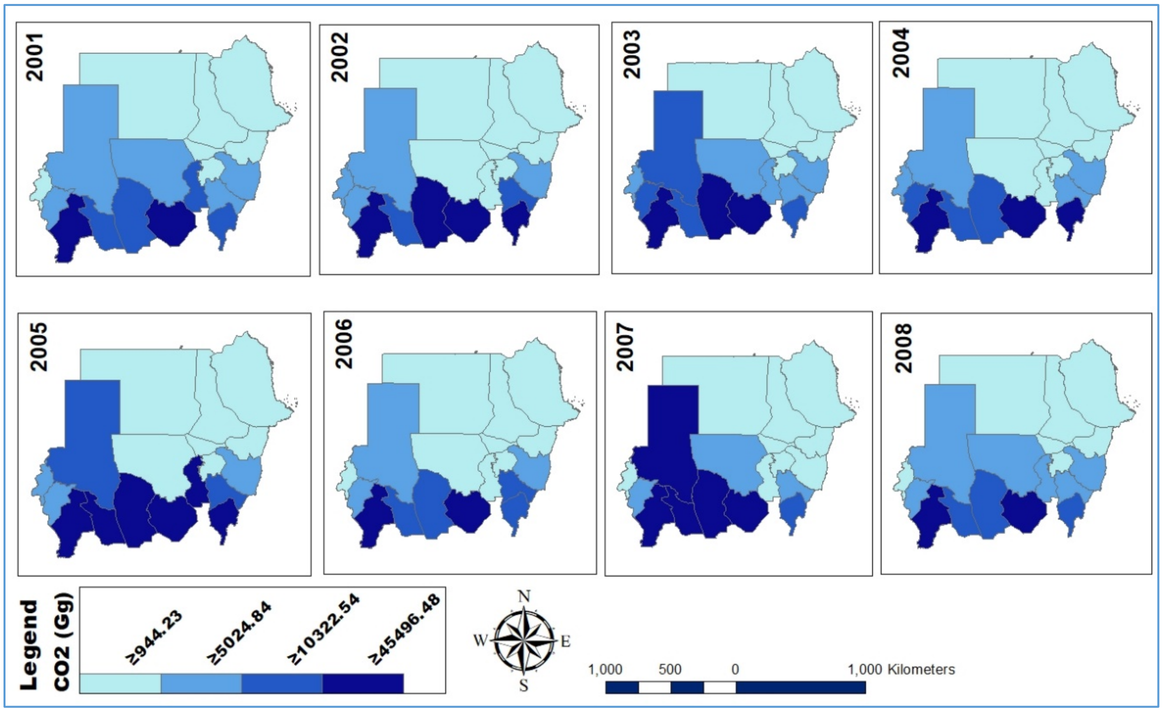


Fire Trend in West Darfur state during 2001-2019 Fire Trend inEast Darfur state during 2001-2019

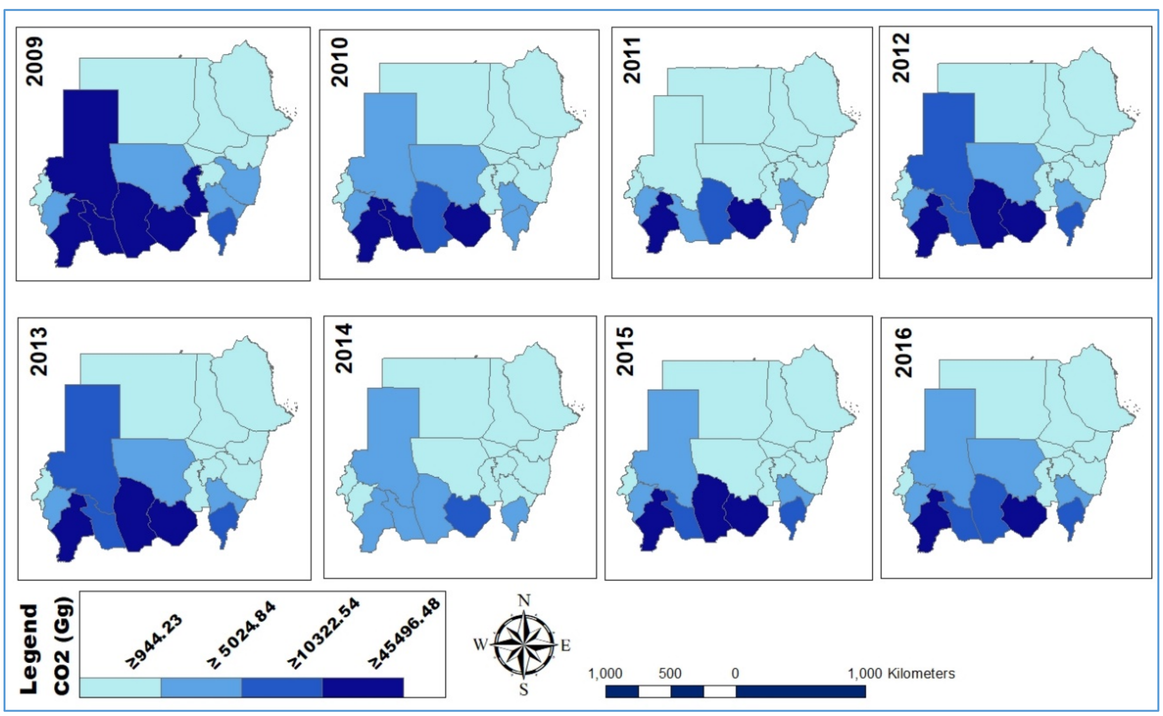


Fire Trend in Central Darfur state during 2001-2019

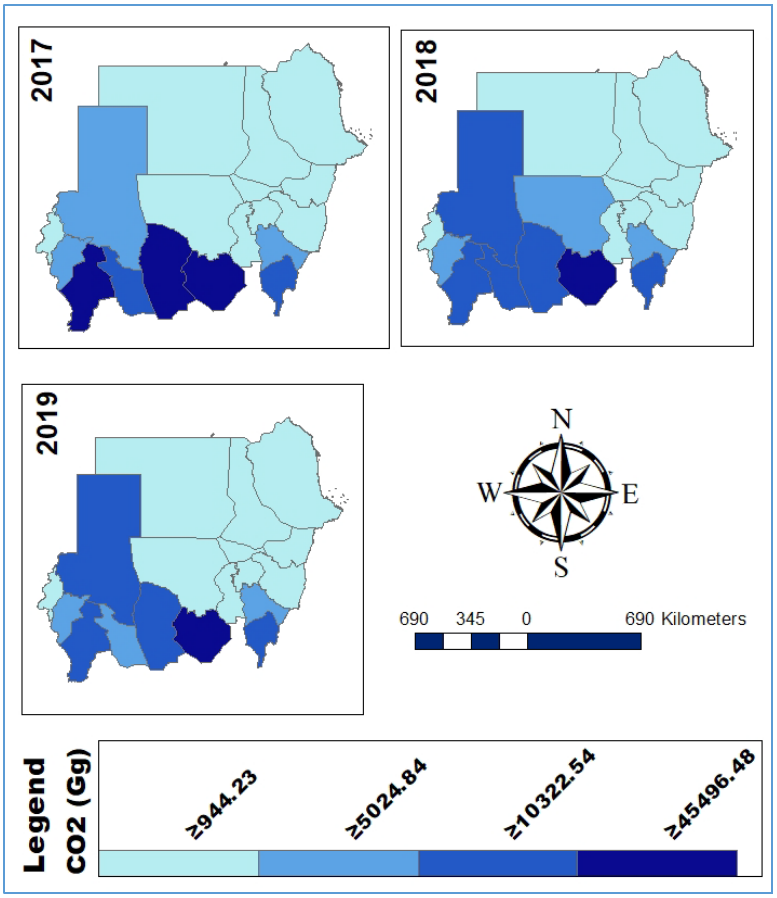
Annex 5: Total CO2 (Gg) Emission of Burned Area Within Sudan States



Total CO2 (Gg) Emission of burned area within Sudan States during 2001-2008



Total CO2 (Gg) Emission of burned area within RoS States during 2009-2016



Total CO2 (Gg) Emission of burned area within Sudan States during 2016-2019

Annex 6: Emission of CO_2 Gg of Burned Area per State

Emission of CO2 Gg of burned area per state

CO2 (Gg) Emission/State									
Name / Yr	2001	2002	2003	2004	2005	2006	2007	2008	2009
Gezira	11.6728	12.63685	249.3829	154.0356	153.1697	14.75164	12.07704	145.9103	25.89093
Blue Nile	7472.657	10605.52	9079.24	10653.37	12708.54	8825.875	6266.745	8616.167	6761.907
Central Darfur	3471.555	3851.76	6432.263	5296.649	2674.925	2070.598	2770.32	2567.617	1858.864
East Darfur	7623.436	8354.315	9615.795	6958.644	13467.43	8730.583	11709.67	9449.129	11831.35
Gadarif	2769.734	2715.957	3684.875	1334.377	2546.35	1529.687	733.6393	1154.016	1846.806
Kassala	45.34582	93.32735	87.48513	33.38999	176.6644	124.3255	509.7742	240.0581	69.73829
Khartoum	0	0	13.59088	5.943873	0	0	100.5542	0	0
North Darfur	3054.606	1412.887	5969.608	3740.324	6039.952	2721.524	11305.88	4742.149	10540.14
North Kordofan	1892.583	691.2365	1849.154	140.0798	288.5849	299.4832	960.5816	2218.351	1765.876
Northern	0	0	0	0	0	0	0	0	0
Red Sea	0	49.176	22.2528	4.789957	29.34589	9.647378	24.99803	12.78387	18.92839
River Nile	0	0	178.4096	0	0	0	26.79079	4.464282	11.71153
Sinnar	5024.839	6221.371	4192.648	4911.493	5385.55	5261.927	3413.713	4308.932	4277.701
South Darfur	21137.4	22532.45	18809.79	22963.46	20796.79	22508.42	20248.64	23437.74	18617.86
South Kordofan	16115.46	16630.96	22789.45	15428.99	22462.38	18926.95	15827.64	14050.84	13446.5
West Darfur	944.2344	1154.424	2194.36	1437.234	1134.63	897.4371	882.8347	811.3718	464.6937
West Kordofan	10322.54	13470.83	12855.39	8050.39	14467.25	10187.23	15651.02	10050.67	10914.91
White Nile	7472.657	544.2754	1001.704	278.966	45386.99	503.1202	753.3382	1074.257	45496.48
	87358.72	88341.13	99025.4	81392.14	147718.6	82611.56	91198.22	82884.46	127949.4
CO2 Gg Emission/State									

Name / Yr	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Gezira	19.95763	11.80733	7.854747	35.99869	20.70103	102.2145	369.7061	137.5536	58.48824	738.7056
Blue Nile	4881.868	4680.426	8745.727	8835.194	2671.274	6290.273	7894.852	6481.111	5830.378	5038.097
Central Darfur	2959.105	4002.848	3388.082	4460.784	767.748	1502.386	2123.208	2202.101	1698.389	1649.957
East Darfur	10786.21	4374.509	9901.256	8178.497	3269.189	7720.254	7471.015	7854.123	7167.337	4013.517
Gadarif	311.5686	237.2873	172.146	573.3203	186.6077	150.6254	124.2738	284.2299	427.507	766.4553
Kassala	101.6648	156.6917	87.41557	159.4654	108.8922	260.6131	122.3578	93.86479	173.6412	127.3916
Khartoum	0	0	2.363996	8.479001	3.12777	5.114767	12.77635	8.186768	5.987385	41.82684
North Darfur	4918.938	645.6974	7163.074	7643.177	1803.452	2690.534	3938.721	2804.004	5502.777	5279.793
North Kordofan	1628.992	269.8231	1136.171	1248.494	191.1178	354.6478	1274.166	504.4349	1026.602	422.3101
Northern	0	0	0	0	0	0	0	0	0	0
Red Sea	0.571113	40.76562	5.663383	0	0.166619	0	0	1.153159	11.15417	0.498889
River Nile	7.754276	0	0.328486	0.489067	0	0	6.479174	0.666465	34.52195	157.7088
Sinnar	1214.212	1850.057	3267.06	2525.618	757.7573	1314.489	1549.928	1722.48	1603.787	2892.381
South Darfur	16502.45	16460.56	12010.08	14274.76	4272.01	11188.63	14319.77	11874.07	7759.147	8577.043
South Kordofan	11842.15	15049.82	22724.11	13350.46	6551.071	15872.43	19751.16	17974.96	20161.79	16478.6
West Darfur	645.0236	344.7205	432.8607	226.1605	84.01394	39.52015	147.8392	83.75468	101.1585	73.24515
West Kordofan	8095.947	7158.055	13855.31	11121.66	3266.216	12884.44	9878.986	11958.23	10166.51	6578.403
White Nile	477.3629	375.8891	572.0721	695.1428	374.927	562.6131	393.7687	480.106	480.5945	441.504

Annex 7: Percentage of Burned Area from Total Burned Area and from State Area Each Year

Percentage of burned area from total burned area and from state area for each year

Year	Red Sea/Burned area	%BA from state area	% BA from T.B.A	Kassala/Burned area	% BA from state area	% BA from T.B.A	Khartoum/ Burned area	% BA from state area	% BA from T.B.A
2001	0	0.000000	0	3999.940477	0.087549	0.051907601	0	0	0
2002	4337.8	0.020001	0.055666	8232.376155	0.180187	0.105644278	0	0	0
2003	1962.913	0.009051	0.022472	7717.035794	0.168908	0.088346148	1198.847	0.056739694	0.013725
2004	422.5206	0.001948	0.005885	2945.321023	0.064466	0.041023611	524.3072	0.024814692	0.007303
2005	2588.592	0.011936	0.019866	15583.5119	0.341087	0.119595269	0	0	0
2006	850.9922	0.003924	0.011678	10966.70971	0.240036	0.150494017	0	0	0
2007	2205.068	0.010167	0.027411	44967.01897	0.984223	0.55897381	8869.858	0.419797395	0.110259
2008	1127.661	0.005200	0.015424	21175.44983	0.463481	0.289629791	0	0	0
2009	1669.668	0.007699	0.014794	6151.593185	0.134644	0.054504605	0	0	0
2010	50.37771	0.000232	0.000887	8967.817055	0.196285	0.157879787	0	0	0
2011	3595.922	0.016581	0.073242	13821.72628	0.302525	0.281521043	0	0	0

2012	499.5652	0.002303	0.006785	7710.900153	0.168774	0.104724957	208.5273	0.009869293	0.002832
2013	0	0.000000	0	14066.39206	0.30788	0.217439845	747.93	0.035398434	0.011562
2014	14.69738	0.000068	0.000685	9605.347715	0.210239	0.447595349	275.8996	0.013057927	0.012857
2015	0	0.000000	0	22988.60368	0.503167	0.427663869	451.172	0.02135331	0.008393
2016	0	0.000000	0	10793.14729	0.236237	0.176361484	1126.998	0.053339172	0.018415
2017	101.7198	0.000469	0.001789	8279.783617	0.181225	0.145605756	722.1523	0.034178411	0.0127
2018	983.9055	0.004537	0.01793	15316.84008	0.33525	0.279122154	528.1453	0.024996347	0.009625
2019	44.00687	0.000203	0.000936	11237.17067	0.245955	0.239109804	3689.533	0.174620182	0.078508

Percentage of burned area from total burned area and from state area for each year

Year	River Nile/Burned area	% BA from state area	% BA from T.B.A	Al Gadarif/Burned area	% BA from state area	% BA from T.B.A
2001	0	0	0	244317.3	3.811219	3.170529
2002	0	0	0	239573.7	3.737222	3.074397
2003	15737.46	0.124848725	0.180166	325041.7	5.070476	3.721142
2004	0	0	0	117705	1.836135	1.639442
2005	0	0	0	224612.7	3.503838	1.723785
2006	0	0	0	134933.2	2.104885	1.851662
2007	2363.207	0.018747843	0.029376	64714.09	1.009505	0.804445
2008	393.7929	0.003124046	0.005386	101795.4	1.587954	1.392319

2009	1033.071	0.008195578	0.009153	162906.2	2.541249	1.443388
2010	684.0023	0.005426341	0.012042	27483.37	0.428726	0.483849
2011	0	0	0	20931.04	0.326513	0.426324
2012	28.97565	0.00022987	0.000394	15184.95	0.236877	0.206233
2013	43.14043	0.000342243	0.000667	50572.41	0.788902	0.781754
2014	0	0	0	16460.6	0.256777	0.76704
2015	0	0	0	13286.62	0.207264	0.247175
2016	571.526	0.004534042	0.009339	10962.15	0.171004	0.179123
2017	58.78864	0.000466383	0.001034	25071.83	0.391107	0.440906
2018	3045.17	0.024158007	0.055493	37710.26	0.58826	0.687202
2019	13911.44	0.110362549	0.296014	67608.79	1.054661	1.438612

Percentage of burned area from total burned area and from state area for each year

Year	Sinnar/ Burned area	% BA from state area	% BA from T.B.A	Gezira/ Burned area	% BA from state area	%BA from T.B.A	WhiteWhite Nile/ Burned area	% BA from state area	% BA from T.B.A
2001	443239.5	10.99394288	5.75196	1029.653812	0.042524	0.013361914	659160.7	16.49645721	8.55399
2002	548785.2	13.61185749	7.04244	1114.692342	0.046036	0.014304602	48010.36	1.201529218	0.616106
2003	369832.1	9.173174911	4.233911	21997.98698	0.908501	0.251837296	88359.98	2.211337237	1.011563
2004	433241.3	10.74595045	6.034358	13587.43212	0.561151	0.189251196	24607.5	0.615838555	0.342743
2005	475057.6	11.783148	3.645818	13511.05563	0.557997	0.103690255	4003572	100.1952264	30.72531
2006	464152.9	11.5126709	6.36948	1301.237999	0.05374	0.017856635	44380.08	1.110676128	0.609019
2007	301122.5	7.468927939	3.743179	1065.312202	0.043997	0.013242631	66451.73	1.663051255	0.826045

2008	380089.5	9.427594707	5.198721	12870.70204	0.531551	0.176040593	94759.85	2.371503351	1.296089
2009	377334.7	9.359265711	3.343277	2283.831154	0.094321	0.020235297	4013231	100.4369398	35.55819
2010	107105.3	2.656598157	1.885605	1760.456221	0.072706	0.0309931	42108.03	1.053814867	0.741318
2011	163193	4.047776421	3.323916	1041.521218	0.043014	0.021213713	33157.06	0.829803798	0.675343
2012	288186.3	7.148063023	3.913979	692.8648	0.028615	0.009410086	50462.3	1.262892516	0.68535
2013	222783.9	5.525847445	3.443819	3175.433096	0.131143	0.049086196	61318.33	1.534580521	0.947866
2014	66841.53	1.657911763	3.114719	1826.03144	0.075414	0.085090431	33072.19	0.827679803	1.541116
2015	115950.7	2.875996679	2.157065	9016.30644	0.372367	0.167733045	49627.93	1.242011222	0.923243
2016	136718.7	3.391118148	2.234002	32611.65678	1.346838	0.532878874	34734.21	0.869274316	0.567562
2017	151939.4	3.768646874	2.67196	12133.56354	0.501108	0.213377157	42350	1.059870547	0.744754
2018	141469.6	3.508956994	2.578031	5159.229671	0.213073	0.09401778	42393.09	1.060948925	0.772539
2019	255136	6.328295703	5.428904	65160.98946	2.691102	1.38652619	38944.93	0.974653664	0.828689

Percentage of burned area from total burned area and from state area for each year

Year	Blue Nile/ Burned area	% BA from state area	% BA from T.B.A	North Kordofan/ Burned area	% BA from state area	% BA from T.B.A	South Kordofan/ Burned area	% BA from state area	% BA from T.B.A
2001	659160.7	17.74897423	8.55399	166944.2	0.884654	2.16645	1421540	17.89121	18.44746
2002	935509.8	25.19012341	12.00519	60973.75	0.323106	0.782463	1467011	18.46351	18.82584
2003	800877	21.56491462	9.168598	163113.3	0.864354	1.867353	2010251	25.3006	23.01375
2004	939730.8	25.30378032	13.08895	12356.39	0.065478	0.172105	1360986	17.1291	18.95636
2005	1121017	30.18519287	8.603213	25455.99	0.134894	0.195361	1981400	24.93749	15.2062
2006	778527.7	20.96312397	10.68358	26417.32	0.139988	0.36252	1669540	21.01249	22.91077

2007	552787.6	14.88470563	6.871565	84732.61	0.449006	1.05329	1396151	17.57168	17.35521
2008	760029.4	20.46502676	10.39539	195680.1	1.036928	2.676438	1239420	15.59909	16.95232
2009	596465.7	16.06080973	5.284831	155767.4	0.825427	1.380137	1186112	14.92816	10.50924
2010	430628.1	11.5953604	7.581272	143692.9	0.761443	2.529735	1044592	13.14702	18.3902
2011	412858.9	11.11689814	8.409114	23801.01	0.126124	0.484779	1327540	16.70815	27.03935
2012	771457.8	20.77275662	10.47749	100221.3	0.531083	1.361148	2004487	25.22806	27.22377
2013	779349.8	20.98525921	12.04727	110129.3	0.583586	1.70239	1177640	14.82154	18.20409
2014	235632.2	6.34478099	10.98012	16858.44	0.089335	0.785579	577867.9	7.272928	26.92781
2015	554863.1	14.94058979	10.32228	31283.37	0.165774	0.581974	1400102	17.6214	26.04652
2016	696402.5	18.75176881	11.37931	112393.8	0.595586	1.83653	1742244	21.92752	28.4685
2017	571696.8	15.39386617	10.05369	44496.05	0.235789	0.782494	1585566	19.95561	27.88328
2018	514295.8	13.84825013	9.372125	90556.28	0.479867	1.650227	1778465	22.3834	32.40937
2019	444409	11.96643367	9.456343	37251.84	0.197401	0.792662	1453572	18.29436	30.92979

Percentage of burned area from total burned area and from state area for each year

Year	West Kordofan/ Burned area	% BA from state area	% BA from T.B.A	North Darfur/ Burned area	% BA from state area	% BA from T.B.A	South Darfur/ Burned area	% BA from state area	% BA from T.B.A
2001	910548	8.01668101	11.81627	269445.8367	0.836598	3.496623779	1864523	23.3686458	24.19609
2002	1188258	10.46170333	15.24865	124630.3648	0.386963	1.599354145	1987581	24.91095811	25.50619
2003	1133970	9.983738955	12.98191	526577.2952	1.634961	6.028360777	1659206	20.79533287	18.99491
2004	710122.4	6.252086396	9.89087	329932.7894	1.024403	4.595436019	2025600	25.38746213	28.21336
2005	1276152	11.23554226	9.793794	532782.3029	1.654227	4.088824332	1834478	22.99208211	14.07866

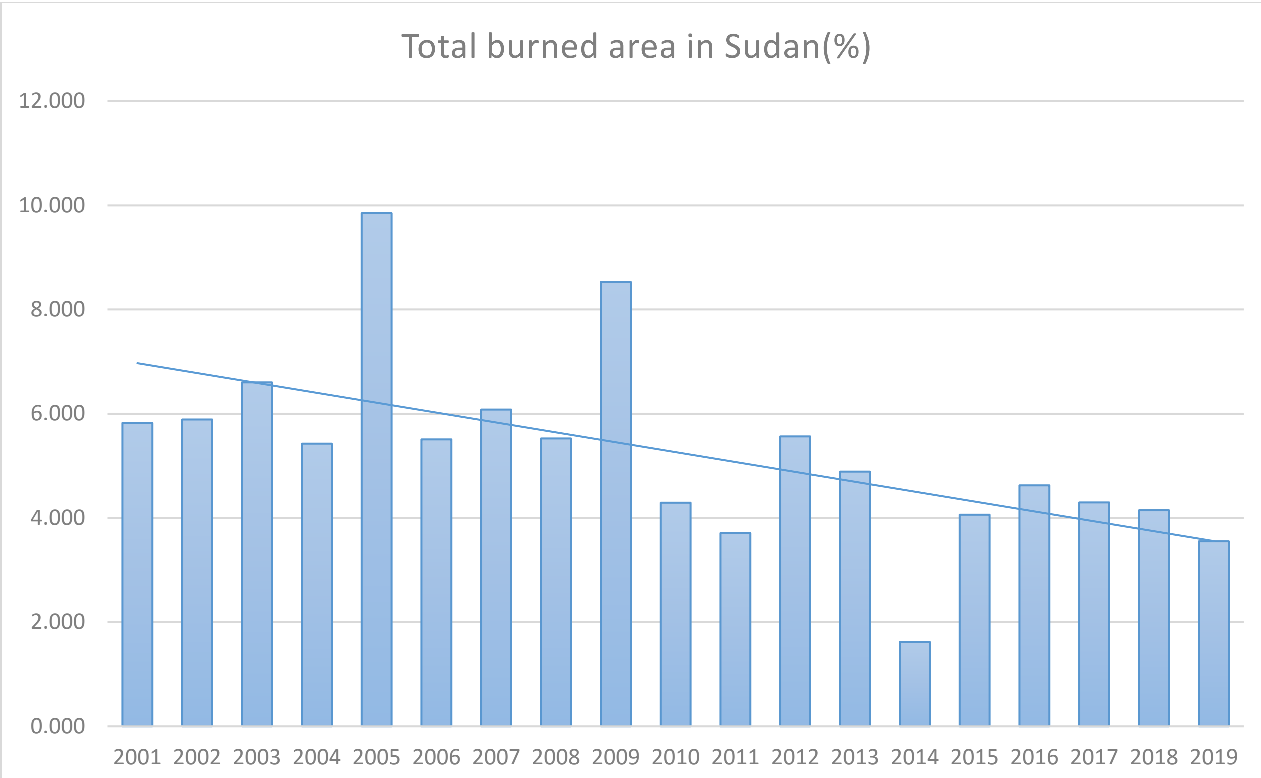
2006	898612.7	7.911599675	12.33149	240064.7444	0.745373	3.29436163	1985461	24.88439407	27.24609
2007	1380571	12.1548781	17.16154	997288.21	3.096464	12.39704128	1786126	22.38606508	22.20289
2008	886566.7	7.805543386	12.12612	418303.5289	1.298784	5.721397402	2067436	25.91181308	28.27761
2009	962800.4	8.476723218	8.530645	929742.8253	2.886743	8.237746461	1642276	20.58314465	14.55096
2010	714141	6.287466786	12.57256	433897.975	1.347203	7.638840012	1455676	18.24443873	25.6274
2011	631409.8	5.559081771	12.86056	56956.76445	0.176844	1.160095883	1451981	18.19812744	29.57397
2012	1222172	10.76029485	16.59883	631852.512	1.961828	8.581452961	1059406	13.27785504	14.38823
2013	981038.4	8.637295084	15.165	674202.2303	2.093319	10.42189268	1259172	15.78159025	19.46442
2014	288111.9	2.536605265	13.4256	159081.9299	0.493931	7.412988477	376832.7	4.722959508	17.55986
2015	1136532	10.00629939	21.14325	237331.1259	0.736885	4.415141912	986945.4	12.36968973	18.36044
2016	871422.3	7.672208518	14.23916	347433.3401	1.07874	5.67710768	1263142	15.83134911	20.63991
2017	1054831	9.28698543	18.54994	247340.2952	0.767963	4.349651183	1047408	13.12748595	18.4194
2018	896784.2	7.895501296	16.3423	485398.269	1.507105	8.845519675	684431.9	8.578196009	12.47255
2019	580278.9	5.108913264	12.34745	465728.8794	1.446034	9.909998208	756578.3	9.482428273	16.09883

Percentage of burned area from total burned area and from state area for each year

Year	West Darfur/ Burned area	% BA from state area	% BA from T.B.A	East Darfur/ Burned area	% BA from state area	% BA from T.B.A	Central Darfur/ Burned area	% BA from state area	% BA from T.B.A
2001	83290.62485	3.564257	1.08087	672460.9	12.05034	8.726588	306224.8	8.038146	3.973908
2002	101831.3696	4.357672	1.30678	736931.5	13.20564	9.456881	339762.5	8.918484	4.360098
2003	193563.833	8.283181	2.215957	848206.3	15.19966	9.710433	567387.9	14.89346	6.495569
2004	126777.9547	5.425211	1.765814	613819.8	10.99951	8.549528	467215.8	12.26403	6.507568

2005	100085.3374	4.282954	0.768102	1187958	21.28792	9.11695	235954.3	6.193604	1.810825
2006	79162.64764	3.387609	1.086334	770122	13.80041	10.56823	182646.8	4.794326	2.506426
2007	77874.5761	3.332488	0.968039	1032907	18.50945	12.83981	244369.1	6.414485	3.037691
2008	71570.85559	3.062733	0.978919	833504.7	14.93621	11.40036	226488.7	5.94514	3.097827
2009	40990.48513	1.754107	0.363186	1043640	18.70178	9.246901	163969.8	4.304071	1.452812
2010	56897.33245	2.434809	1.001686	951448.6	17.04973	16.7504	261021.7	6.851603	4.595327
2011	30407.68491	1.301237	0.619344	385874	6.914772	7.859486	353090	9.268318	7.19174
2012	38182.50604	1.633945	0.518573	873386.7	15.65088	11.86183	298861.7	7.844871	4.058965
2013	19949.549	0.853701	0.308382	721422.7	12.92772	11.15183	393484.4	10.32864	6.082525
2014	7410.843867	0.317132	0.345335	288374.2	5.167597	13.43782	67722.81	1.777667	3.155785
2015	3486.060499	0.149179	0.064852	681001.2	12.20338	12.66887	132525	3.47867	2.465402
2016	13040.85235	0.558057	0.213089	659015.9	11.80941	10.76841	187287.5	4.916141	3.060303
2017	7387.974054	0.316154	0.129923	692809.7	12.41499	12.18354	194246.6	5.098813	3.415962
2018	8923.155952	0.381849	0.162609	632228.6	11.32939	11.52124	149814.4	3.932503	2.730101
2019	6460.932114	0.276483	0.137479	354031.1	6.344154	7.533241	145542.2	3.820362	3.096916

Annex 8: Total Burned Area in RoS 2001-2019



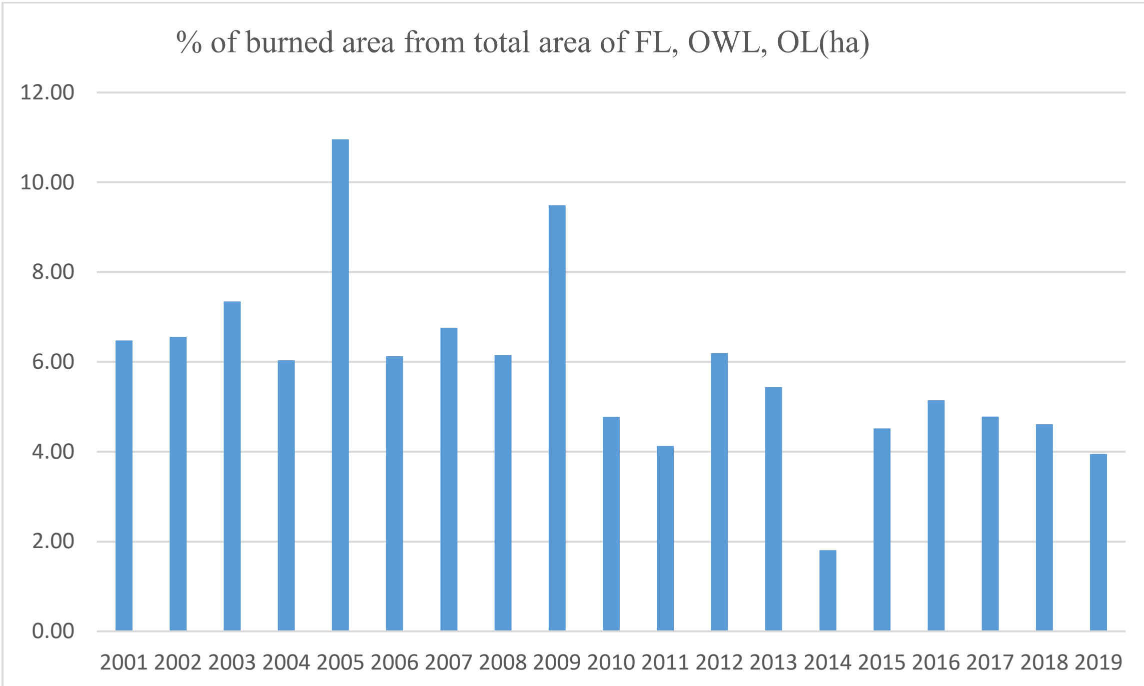
Total Burned Area in Sudan 2001-2019 (ha)

Year	Area(ha)	%
2001	7705885.842	5.824
2002	7792543.328	5.890
2003	8734999.687	6.602
2004	7179575.298	5.426
2005	13030207.66	9.848
2006	7287140.012	5.508
2007	8044566.338	6.080
2008	7311212.621	5.526
2009	11286373.35	8.530
2010	5680155.292	4.293
2011	4909660.083	3.711
2012	7363001.517	5.565
2013	6469095.877	4.889
2014	2145989.17	1.622
2015	5375390.661	4.063
2016	6119900.477	4.625
2017	5686439.777	4.298
2018	5487504.261	4.147
2019	4699585.914	3.552

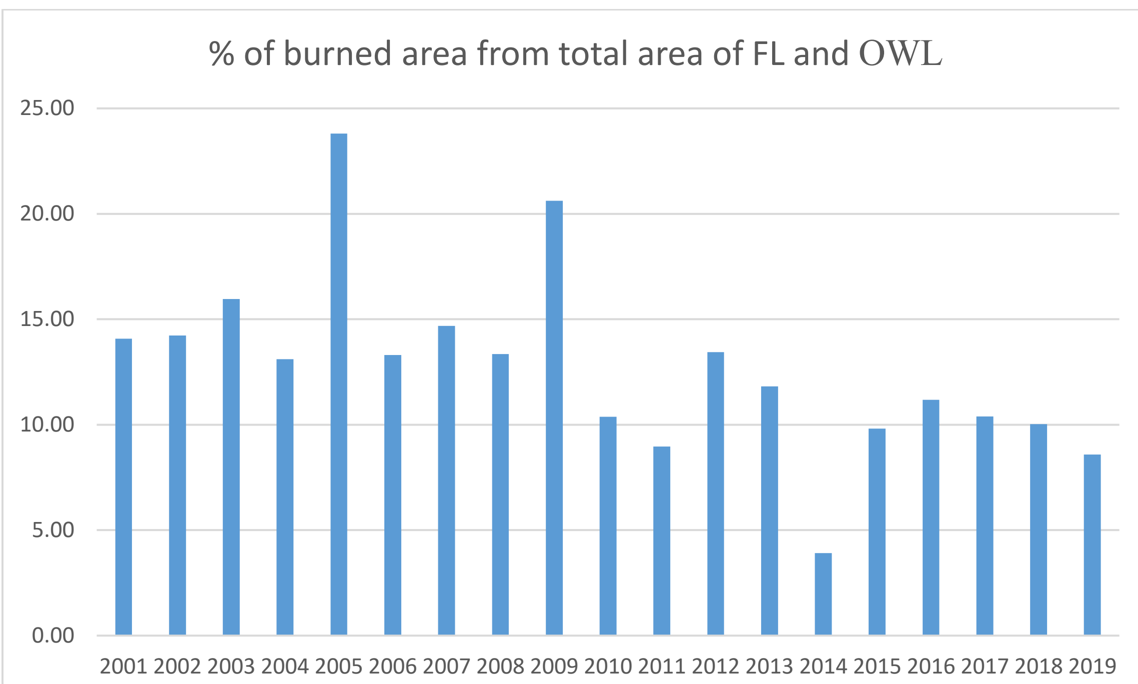
Percentage of Burned Total Area from FL, OWL and OL and from FL and OWL Only

Year	Area(ha)	% BA from FL,OWL and OL	% BA from FL and OWL
2001	7705885.842	6.480	14.075
2002	7792543.328	6.553	14.234
2003	8734999.687	7.346	15.955
2004	7179575.298	6.038	13.114
2005	13030207.66	10.958	23.801
2006	7287140.012	6.128	13.311
2007	8044566.338	6.765	14.694
2008	7311212.621	6.148	13.354
2009	11286373.35	9.491	20.615
2010	5680155.292	4.777	10.375
2011	4909660.083	4.129	8.968
2012	7363001.517	6.192	13.449
2013	6469095.877	5.440	11.816
2014	2145989.17	1.805	3.920
2015	5375390.661	4.520	9.819
2016	6119900.477	5.146	11.178
2017	5686439.777	4.782	10.387
2018	5487504.261	4.615	10.023
2019	4699585.914	3.952	8.584

Annex 9: Percentage of Burned Area



Percentage of burned area from total FL, OWL and OL area (ha)



Percentage of burned area from total FL and OWL area (ha)

Annex 10: Consultations

Questionnaire on Wildland fires – field observation 2019

Is the state facing annual fire incidence Yes ☐ No ☐

1. If answer is yes, mention the responsible organization for fire management.

   Locality ☐ Range and pasture ☐ Forest National Corporation ☐

   Mention other organizations

   ....

   ....

2. What are the activities carried out for protection against fires

- Cleaning firebreaks. ☐ Yes ☐ No
- Awareness or training program. Yes ☐ No ☐
- Early warning with areas subjected to be burned Yes ☐ No ☐
- Early detection of fire incidence via patrolling and monitoring from towers.

  Yes ☐ No ☐
- Good communication system for quick announcing of fires incidence.

  Yes ☐ No ☐
- Readiness of trained fire brigades. Yes ☐ No ☐
- Means for transporting the fire brigades to the place of fire. Yes ☐ No ☐
- Availability of the necessary equipment for firefighting. Yes ☐ No ☐
- Recovery activities after fire incidence. Yes ☐ No ☐

- Mention any other activities.

....

3. What are the useful activities, which carried out by using fires?

- Land cleaning and preparing for planting crops. Yes ☐ No ☐
- Improve the grass growth in the rangeland. Yes ☐ No ☐
- Fighting tics. Yes ☐ No ☐
- Used for cocking. Yes ☐ No ☐
- Honey collection. Yes ☐ No ☐
- Opening roads, livestock and wildlife routs. Yes ☐ No ☐
- Mention other useful applications for fire.

....

4. What are the negative impacts of fires

- Consume the available grasses for grazing animals. Yes ☐ No ☐
- Destroy property of the people such as homes. Yes ☐ No ☐
- Threatening the life. Yes ☐ No ☐
- Cause soil deterioration. Yes ☐ No ☐
- Change the type of trees and grasses species from valuable to inferior ones.

  Yes ☐ No ☐
- Reduces Gum production. Yes ☐ No ☐
- Increase poverty rates. Yes ☐ No ☐
- Increase the GHG emission. Yes ☐ No ☐

- Negatively affect the human health. Yes ☐ No ☐
- Cause stagnated condition in the markets around the burned area.

  Yes ☐ No ☐

- Mention other negative impacts.

………

………

5. What are the trees, bushes and grasses species those disappear or their number reduced when fire frequency increases.

5.1. Put √ mark in front of trees or bushes species those disappear or their number reduced when fire frequency increases.

Talih ☐	Syal ☐	Hashab ☐	Kitir ☐
Sider ☐	Higlig ☐	Marakh ☐	Oshar ☐
Gimbil ☐	Gibash ☐	Abanos ☐	Mahogani ☐
Gidaim ☐	Sunot ☐	Aradaib ☐	Tabaldi ☐
Habeel ☐	Himmad ☐	Jughan ☐	

Mention other trees and bushes species those disappear or their number reduced

………

…………………………………………………………

Is the disappearance of these species cause negative impacts? Yes ☐ No ☐

What are the negative impacts due to the disappearance of these species?

Loss of foder ☐ loss of shade ☐ loss of fruits ☐

Soil erosion ☐

Mention other negative impacts caused by disappearance of these species

....

....

5.2. Put √ mark in front of grasses species those disappear or their number reduced when fire frequency increases.

Umassabi ☐ Begale ☐ Difra ☐ Simamah ☐

Danabkadis ☐ Haskanit ☐ Dirasah ☐ Nal ☐

Gaw ☐

Mention other grasses species those disappear or their number reduced

....

....

Is the disappearance of these species cause negative impacts? Yes ☐ No ☐

What are the negative impacts due to the disappearance of these species?

Loss of fodder ☐

Mention other negative impacts.

....

....

6. What are the trees, bushes and grasses species, which are fire resistant ones?

6.1. Put √ mark in front of trees or bushes species those are fire resistant ones

Talih ☐	Syal ☐	Hashab ☐	Kitir ☐
Sider ☐	Higlig ☐	Marakh ☐	Oshar ☐
Gimbil ☐	Abanos ☐	Gibash ☐	Mahogani ☐
Miskate ☐	Umsuroj ☐	Tabaldi ☐	Gana ☐
Himmad ☐	Gugan ☐	Aradaib ☐	Laout ☐

Mention other trees and bushes species those are fire resistant ones

....

....

6.2. Put √ mark in front of the grasses species those are fire resistant ones

Simama ☐	Bigale ☐	Umassabi ☐	Gaw ☐
Sanamakah ☐	Kulkul ☐		

Mention other grasses species those are fire resistant ones

....

....

7. What are the fire causes?

a. Fire caused by farmers

- Cleaning of agriculture land. Yes ☐ N0
- Early burning to cultivate water millon. Yes ☐ No
- Burn to create buffer zone around their crops to eliminate grazing.

  ☐ Yes ☐ No
- Burn their farms to eliminate grazing in order to prevent transmission of diseases by animal such as Booda. Yes ☐ No
- Mention other causes of fires by farmers

……

……

b. Fires caused by Nomads

- Burn to remove old grasses in order to improve the growth of the grasses in the next season. Yes ☐ No ☐
- Burn to control tics. Yes ☐ No ☐
- Burn to control insects. Yes ☐ No ☐
- Careless in extinguishing fire set for cocking. Yes ☐ No ☐
- Mention other fire causes by Nomads

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c. Fires cause by honey collectors

- Burn to use smoke to repel bees from hive. Yes ☐ No ☐

- Careless in extinguishing fire set for cocking. Yes ☐ No ☐
- Mention other fire causes by honey collectors

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d. Fire caused by poachers

- Use fires to repel wildlife toward network trap. Yes ☐ No ☐
- Burn some area to attract some types of birds to the area to search for insects and then trap for them. Yes ☐ No ☐
- Careless in extinguishing fire set for cocking. Yes ☐ No ☐
- Mention other fire causes by poachers

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e. Burn caused by charcoal producers

- Careless in extinguishing fire set for cocking. Yes ☐ No ☐
- Fire spark that spread from the kiln. Yes ☐ No ☐
- Mention other fire causes by charcoal producers

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f. Fire caused by military operations

- Burn grasses to allow clear vision. Yes ☐ No ☐
- Burn due to the fire bullets. Yes ☐ No ☐

- Mention other fire causes by military operations

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g. Fire caused by the travelers

- Smoking. Yes ☐ No ☐
- Careless in extinguishing fire set for cocking. Yes ☐ No ☐
- Mention other fire causes by travelers

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h. Mention any other causes of fires

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8. What are the legislations and laws that help in protection against fires?

- Prohibit ignition of fire inside forest. Yes ☐ No ☐
- Prohibit ignition of fire inside range. Yes ☐ No ☐
- Prohibit ignition of fire inside Natural reserve. Yes ☐ No ☐
- Compulsory participation of the citizens in firefighting process. Yes ☐ No ☐
- Mention other legislations and laws that help in protection against fires

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Annex 11: Stakeholder Consultations

Lists of Stakeholders to consulted

- State – Director of rangeland Sennar State
- Director of rangeland South Kordofan
- Director of rangeland North Darfur
- Director of rangeland Blue Nile
- Director of rangeland South Darfur
- FNC- Gadaref State
- FNC- Blue Nile –Damazeen
- FNC – Sennar
- Range Unit – Khartoum
- Range Unit – Khartoum
- Metrological Unit Khartoum

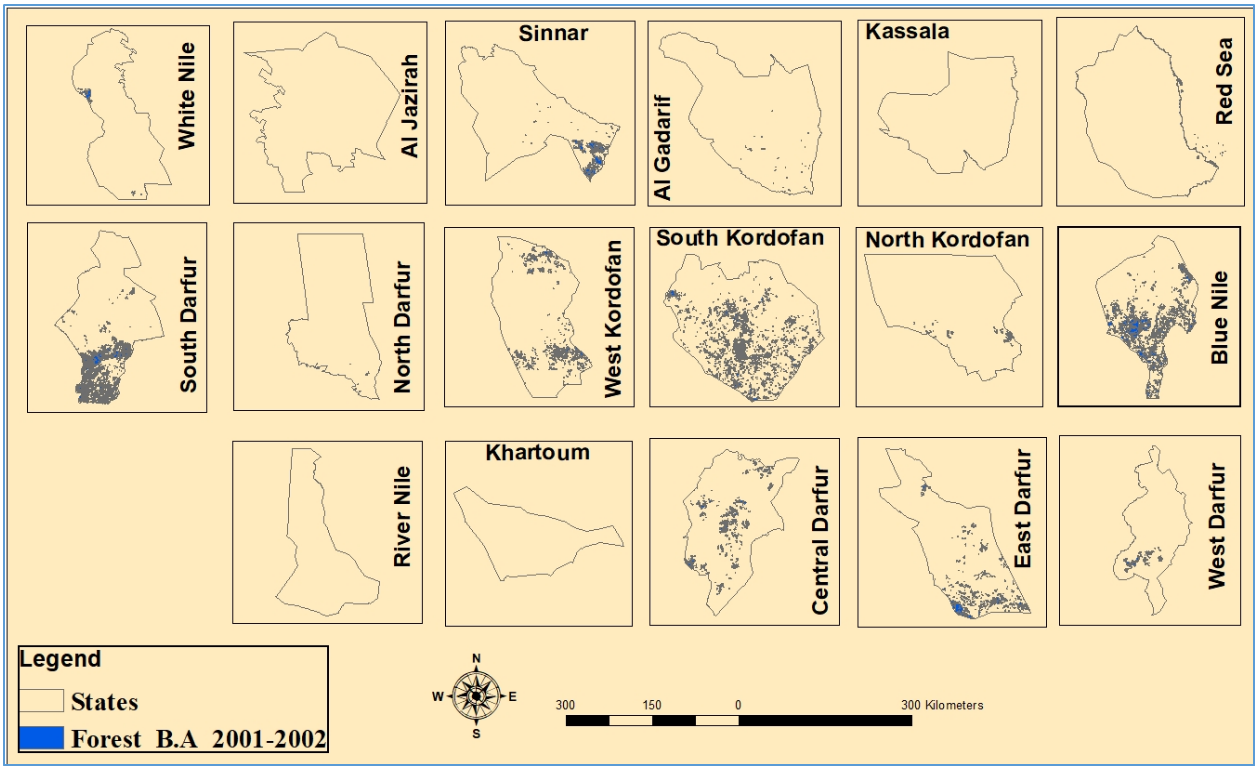
Checklist of Topics and Themes

1. The main fire causes drivers
2. The role and Responsibilities- state local level
3. The management activities and who do what
4. Seasonality of fire, why
5. The early warning system and how to work
6. The socio- impact of the fire
7. Structure of fire management

Stakeholders to be consulted based on the surveying analysis

Names	Organization	Contact number
Wedaad Elmain	Range administrative unit – Sennar State	0118782082
Harren	Range administrative unit – south Kordofan State	0910499025
Elnour Adam Mohamed	Range administrative unit – North Darfur State	0918174784
Harron Adam Harron	Range administrative unit – south Darfur State	0116638024
Ahmed Mohamed Elwad	Blue Nile State	0122803572
Gamal Eldeen Abaker	FNC – south Kordofan	0918027037 0123535373
Zahir Najumeldeen	FNC- Gadaref State	0920362233
Bashier Abaker Gendeel	FNC- Blue Nile	0918804636
Asma	FNC – Sennar	0918036514
Abdel Elmoneaim	Range – Khartoum	
Nafesa	Range – Khartoum	
Bashir Gendeal	FNC – Damazeen	0918804636

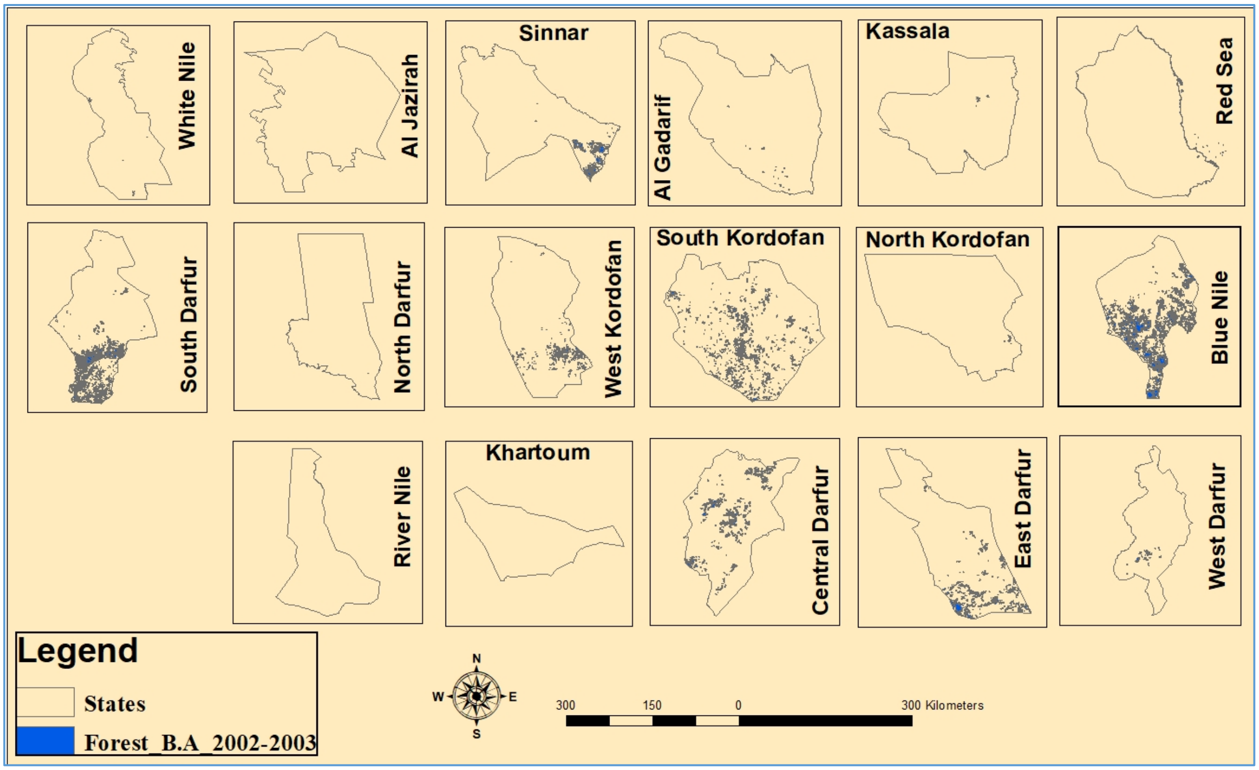
Annex 12: Distribution of Forest burnt areas within RoS States During 2001-2020



Spatial Distribution of burn area from forest burning/State detected by MOD64A1, 2001-2002

Forest burned area derived from MOD64A1 and Co2 emission (Gg), 2001-2002

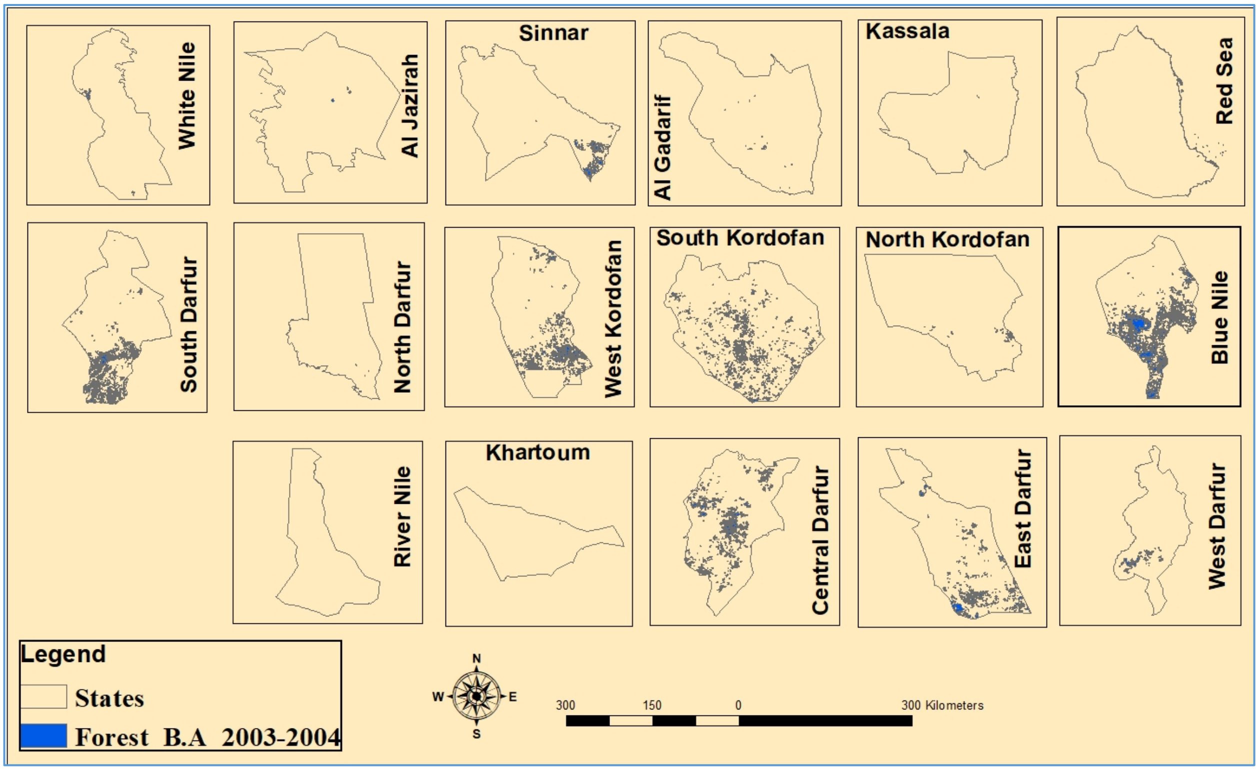
State	Forest_BA(ha)	Co2(Gg)	State	Forest_BA(ha)	Co2(Gg)
Blue Nile	419514.51	1968.88	Red Sea	3787.13	17.77
East Darfur	180415.28	846.73	River Nile	0.00	0.00
Gadarif	2837.89	13.32	Sinnar	103359.38	485.09
Gazira	74.98	0.35	South Darfur	600350.67	2817.58
Kassala	0.00	0.00	South Kordofan	378667.57	1777.17
Khartoum	0.00	0.00	White Nile	24427.62	114.64
North Darfur	9414.90	44.19	West Darfur	25412.92	119.27
North Kordofan	61589.85	289.06	West Kordofan	358637.97	1683.17
Northern	0.00	0.00	Central Darfur	99643.13	467.65



Spatial Distribution of burn area from forest burning/State detected by MOD64A1, 2002-2003

Forest burned area derived from MOD64A1 and Co2 emission (Gg), 2002-2003

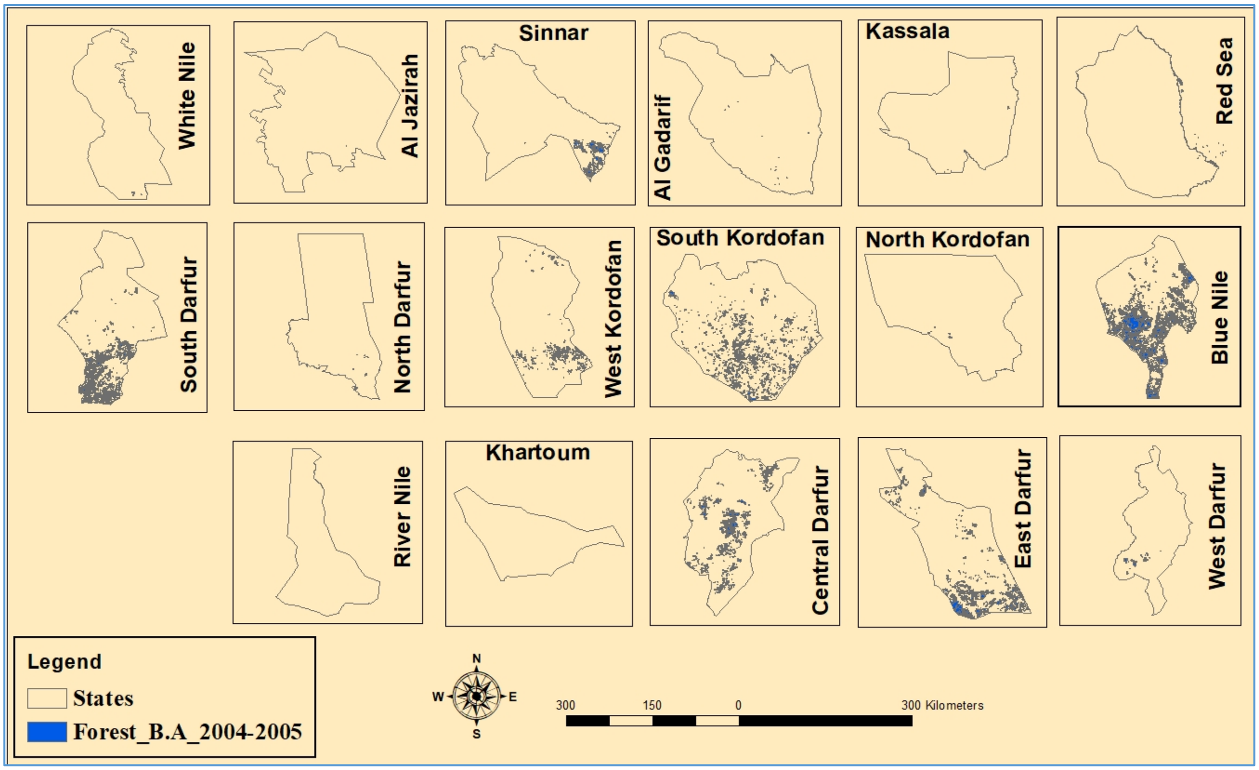
State	Forest_BA(ha)	Co2(Gg)	State	Forest_BA(ha)	Co2(Gg)
Blue Nile	495301.16	2324.56	Red Sea	1377.75	6.47
East Darfur	160541.26	753.46	River Nile	0.00	0.00
Gadarif	1712.70	8.04	Sinnar	72443.05	339.99
Gazira	62.86	0.30	South Darfur	453542.36	2128.58
Kassala	2412.33	11.32	South Kordofan	194029.10	910.62
Khartoum	0.00	0.00	White Nile	2016.01	9.46
North Darfur	52284.81	245.38	West Darfur	6333.67	29.73
North Kordofan	4774.17	22.41	West Kordofan	144644.00	678.85
Northern	0.00	0.00	Central Darfur	283466.00	1330.37



Spatial Distribution of burn area from forest burning/State detected by MOD64A1, 2003-2004

Forest burned area derived from MOD64A1 and Co2 emission (Gg), 2003-2004

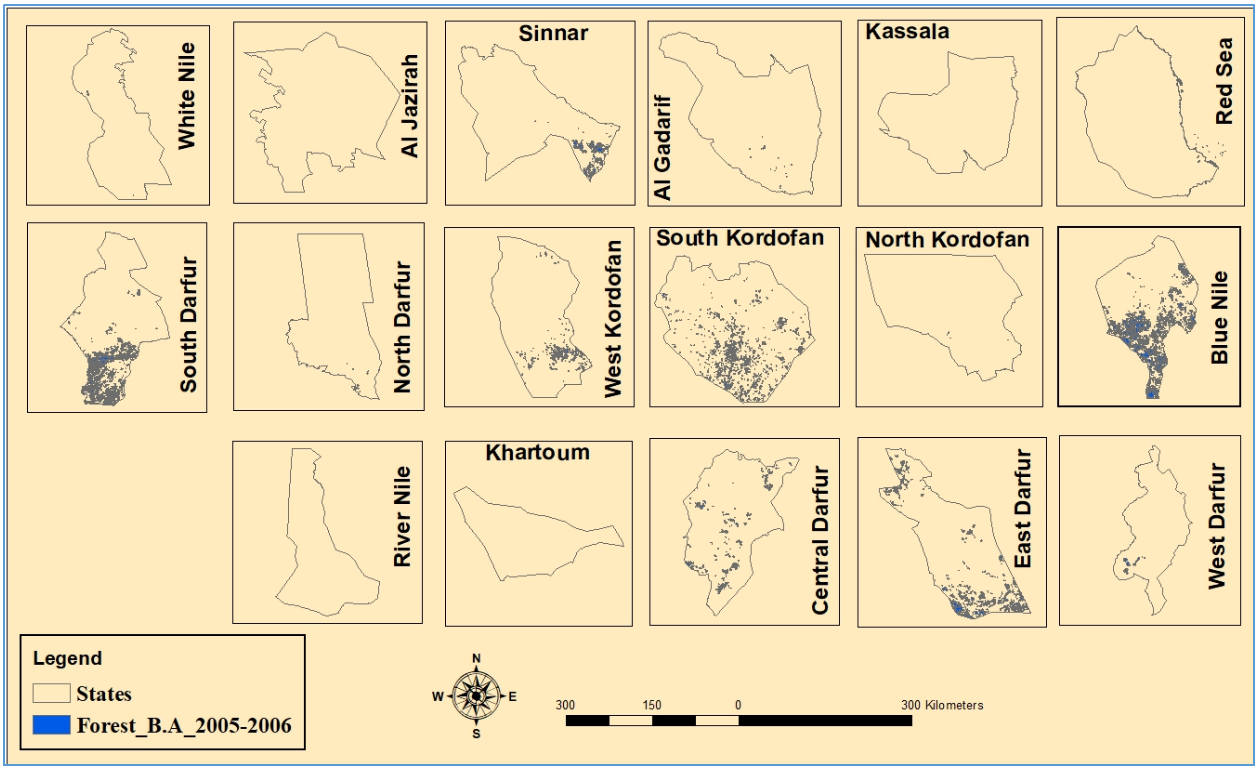
State	Forest_BA(ha)	Co2(Gg)	State	Forest_BA(ha)	Co2(Gg)
Blue Nile	561148.78	2633.60	Red Sea	380.42	1.79
East Darfur	182321.27	855.68	River Nile	0.00	0.00
Gadarif	2726.29	12.80	Sinnar	72485.64	340.19
Gazira	1953.10	9.17	South Darfur	393954.36	1848.92
Kassala	152.11	0.71	South Kordofan	228687.74	1073.28
Khartoum	15.19	0.07	White Nile	12979.01	60.91
North Darfur	178029.60	835.53	West Darfur	28846.64	135.38
North Kordofan	31687.18	148.72	West Kordofan	137715.11	646.33
Northern	0.00	0.00	Central Darfur	523739.46	2458.03



Spatial Distribution of burn area from forest burning/State detected by MOD64A1, 2004-2005

Forest burned area derived from MOD64A1 and Co2 emission (Gg), 2004-2005

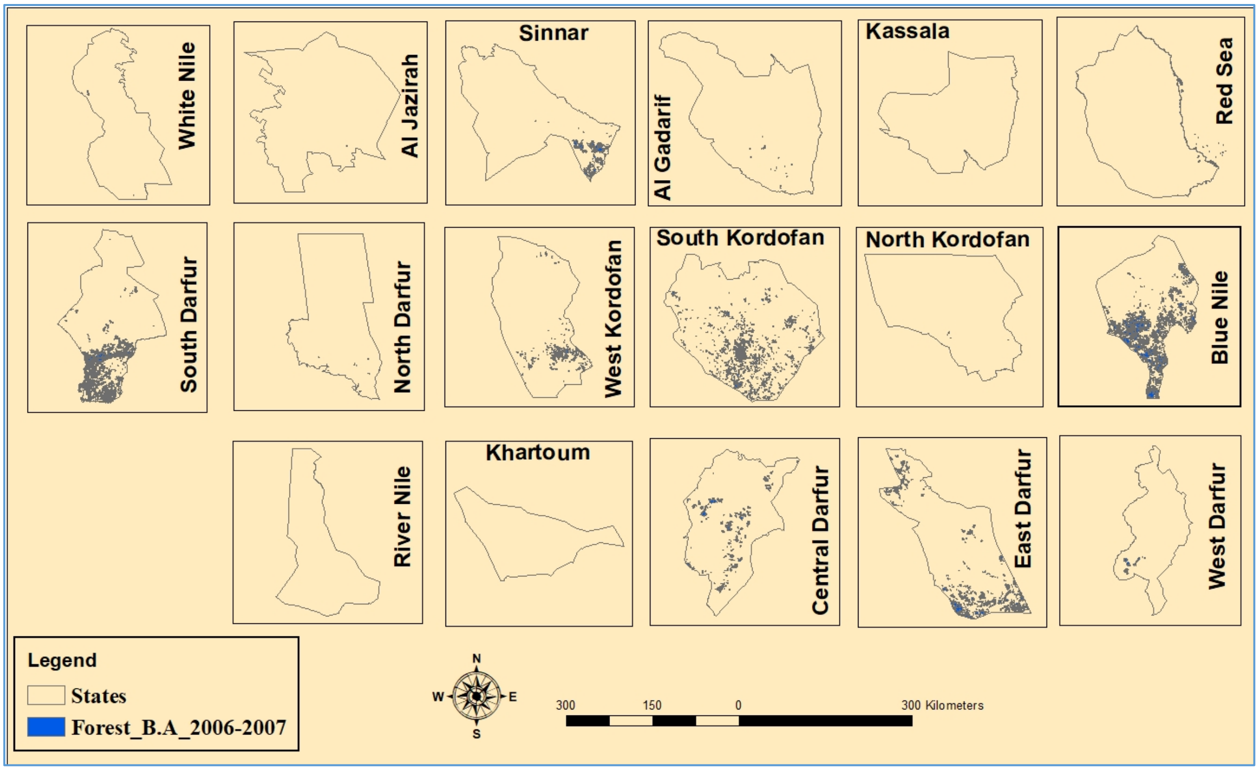
State	Forest_BA(ha)	Co2(Gg)	State	Forest_BA(ha)	Co2(Gg)
Blue Nile	643723.26	3021.14	Red Sea	1001.37	4.70
East Darfur	282500.78	1325.84	River Nile	0.00	0.00
Gadarif	652.00	3.06	Sinnar	77906.11	365.63
Gazira	14.70	0.07	South Darfur	387097.00	1816.74
Kassala	488.78	2.29	South Kordofan	224676.72	1054.46
Khartoum	0.00	0.00	White Nile	1089.31	5.11
North Darfur	11935.29	56.02	West Darfur	12395.24	58.17
North Kordofan	4508.09	21.16	West Kordofan	170372.69	799.60
Northern	0.00	0.00	Central Darfur	145977.01	685.10



Spatial Distribution of burn area from forest burning/State detected by MOD64A1, 2005-2006

Forest burned area derived from MOD64A1 and Co2 emission (Gg), 2005-2006

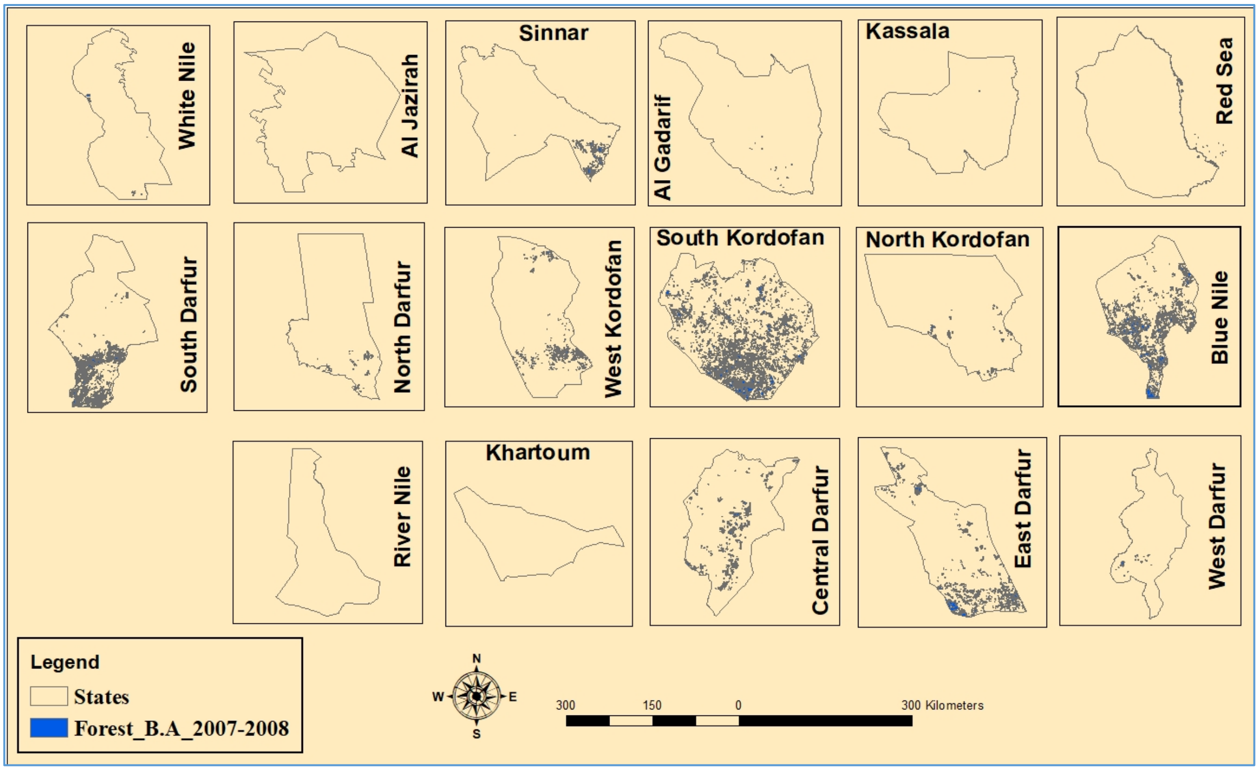
State	Forest_BA(ha)	Co2(Gg)	State	Forest_BA(ha)	Co2(Gg)
Blue Nile	477396.24	2240.53	Red Sea	3389.23	15.91
East Darfur	207226.45	972.56	River Nile	0.00	0.00
Gadarif	2389.73	11.22	Sinnar	63074.00	296.02
Gazira	0.00	0.00	South Darfur	432913.11	2031.76
Kassala	0.00	0.00	South Kordofan	187406.36	879.54
Khartoum	0.00	0.00	White Nile	2833.00	13.30
North Darfur	9803.91	46.01	West Darfur	13050.47	61.25
North Kordofan	939.77	4.41	West Kordofan	136673.26	641.44
Northern	0.00	0.00	Central Darfur	48078.57	225.64



Spatial Distribution of burn area from forest burning/State detected by MOD64A1, 2006-2007

Forest burned area derived from MOD64A1 and Co2 emission (Gg), 2006-2007

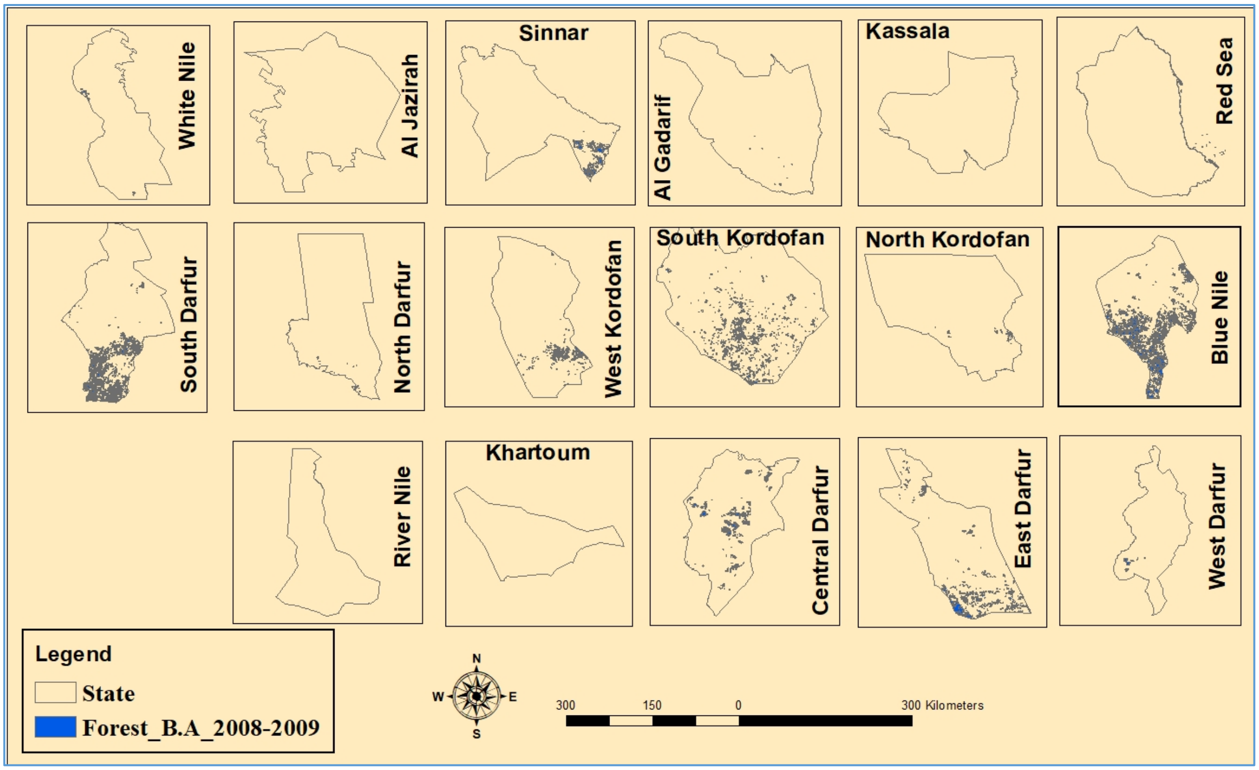
State	Forest_BA(ha)	Co2(Gg)	State	Forest_BA(ha)	Co2(Gg)
Blue Nile	477396.24	2240.53	Red Sea	3389.23	15.91
East Darfur	207226.45	972.56	River Nile	0.00	0.00
Gadarif	2389.73	11.22	Sinnar	63074.00	296.02
Gazira	108.59	0.51	South Darfur	432913.11	2031.76
Kassala	0.00	0.00	South Kordofan	187406.36	879.54
Khartoum		0.00	White Nile	2833.00	13.30
North Darfur	5179.99	24.31	West Darfur	13050.47	61.25
North Kordofan	939.77	4.41	West Kordofan	136673.26	641.44
Northern	0.00	0.00	Central Darfur	68582.08	321.87



Spatial Distribution of burn area from forest burning/State detected by MOD64A1, 2007-2008

Forest burned area derived from MOD64A1 and Co2 emission (Gg), 2007-2008

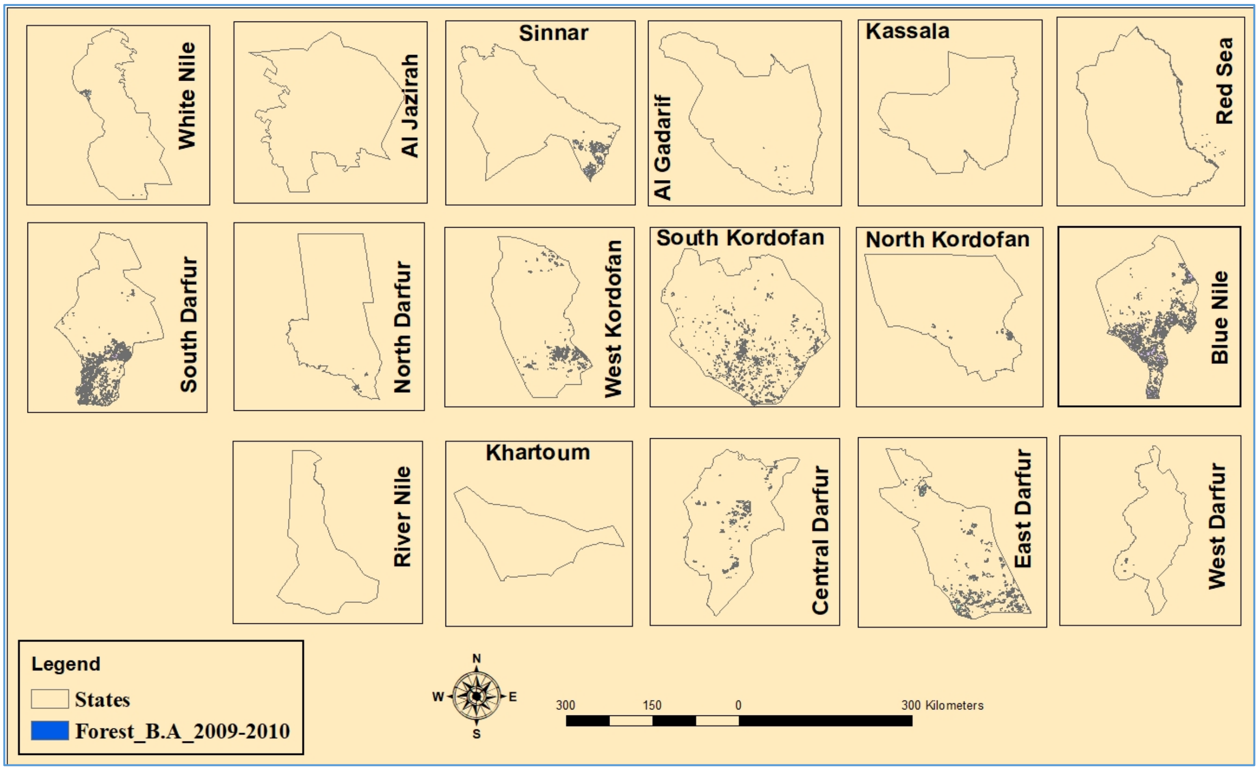
State	Forest_BA(ha)	Co2(Gg)	State	Forest_BA(ha)	Co2(Gg)
Blue Nile	413068.86	1938.63	Red Sea	835.15	3.92
East Darfur	227780.83	1069.03	River Nile	0.00	0.00
Gadarif	1552.76	7.29	Sinnar	51102.99	239.84
Gazira	0.00	0.00	South Darfur	449295.92	2108.65
Kassala	102.58	0.48	South Kordofan	20549.70	96.44
Khartoum	0.00	0.00	White Nile	7345.56	34.47
North Darfur	28157.80	132.15	West Darfur	5766.37	27.06
North Kordofan	72820.55	341.76	West Kordofan	193777.97	909.44
Northern	0.00	0.00	Central Darfur	80224.68	376.51



Spatial Distribution of burn area from forest burning/State detected by MOD64A1, 2008-2009

Forest burned area derived from MOD64A1 and Co2 emission (Gg), 2008-2009

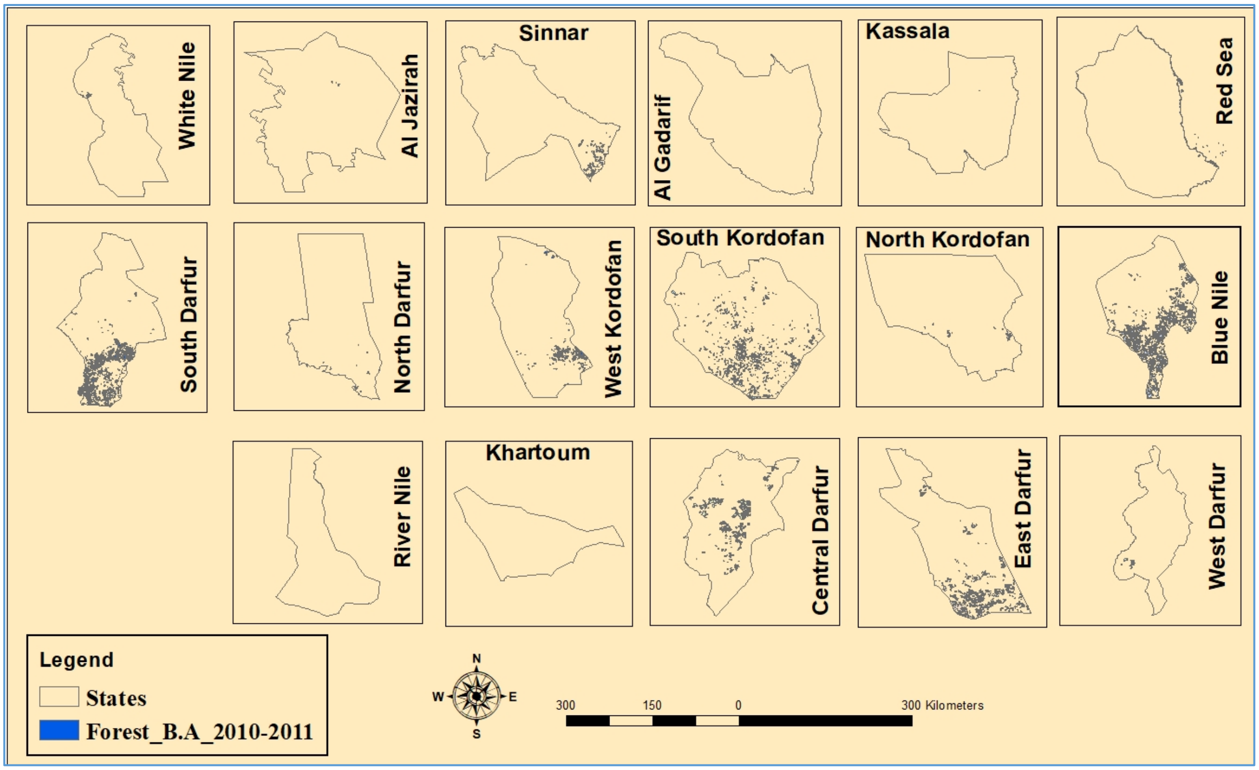
State	Forest_BA(ha)	Co2(Gg)	State	Forest_BA(ha)	Co2(Gg)
Blue Nile	442830.09	2078.30	Red Sea	0.00	0.00
East Darfur	156988.41	736.78	River Nile	0.00	0.00
Gadarif	1257.04	5.90	Sinnar	63695.32	298.94
Gazira	0.00	0.00	South Darfur	409042.72	1919.73
Kassala	0.00	0.00	South Kordofan	129956.67	609.92
Khartoum	0.00	0.00	White Nile	7985.15	37.48
North Darfur	12049.89	56.55	West Darfur	9078.26	42.61
North Kordofan	23083.48	108.34	West Kordofan	137353.31	644.63
Northern	0.00	0.00	Central Darfur	81016.63	380.23



Spatial Distribution of burn area from forest burning/State detected by MOD64A1, 2009-2010

Forest burned area derived from MOD64A1 and Co2 emission (Gg), 2009-2010

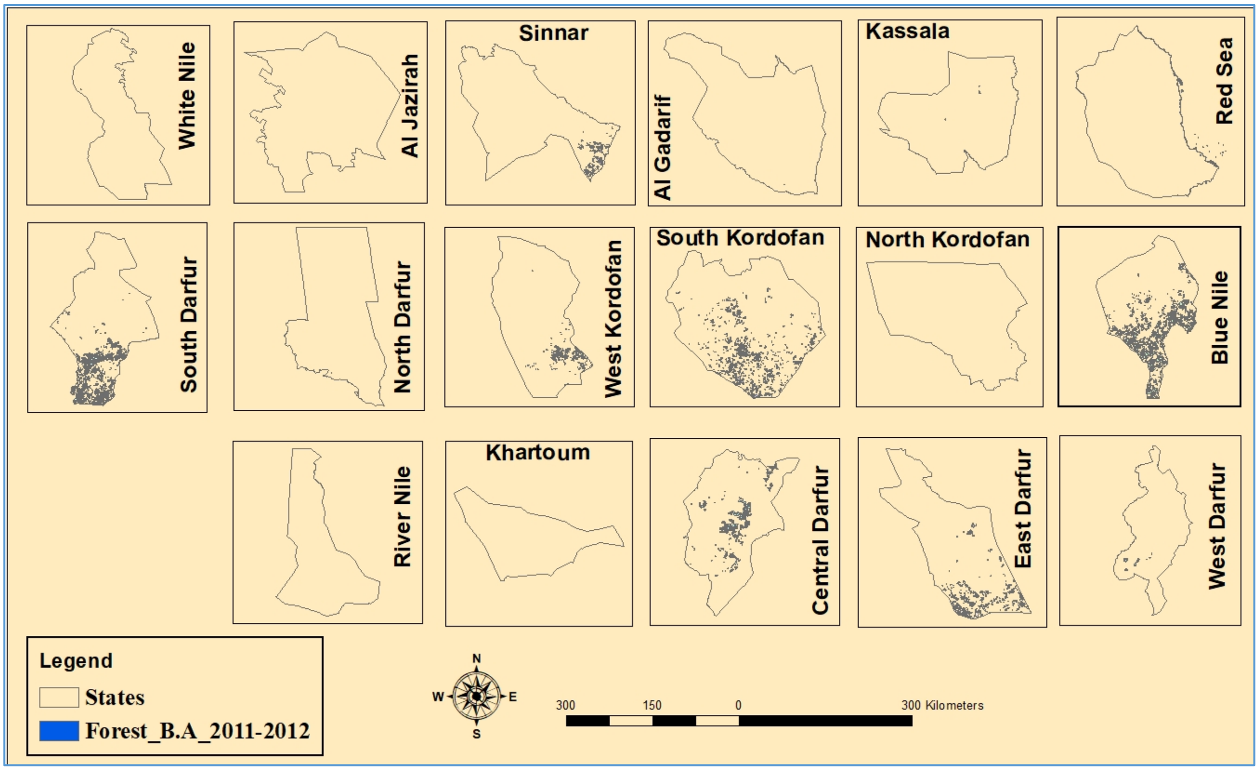
State	Forest_BA(ha)	Co2(Gg)	State	Forest_BA(ha)	Co2(Gg)
Blue Nile	356261.11	1672.02	Red Sea	0.00	0.00
East Darfur	152022.71	713.48	River Nile	0.00	0.00
Gadarif	724.10	3.40	Sinnar	61725.74	289.69
Gazira	0.00	0.00	South Darfur	347711.20	1631.89
Kassala	80.49	0.38	South Kordofan	127512.73	598.45
Khartoum	0.00	0.00	White Nile	12483.09	58.59
North Darfur	21469.57	100.76	West Darfur	3469.45	16.28
North Kordofan	29857.96	140.13	West Kordofan	168062.98	788.76
Northern	0.00	0.00	Central Darfur	48620.98	228.19



Spatial Distribution of burn area from forest burning/State detected by MOD64A1, 2010-2011

Forest burned area derived from MOD64A1 and Co2 emission (Gg), 2010-2011

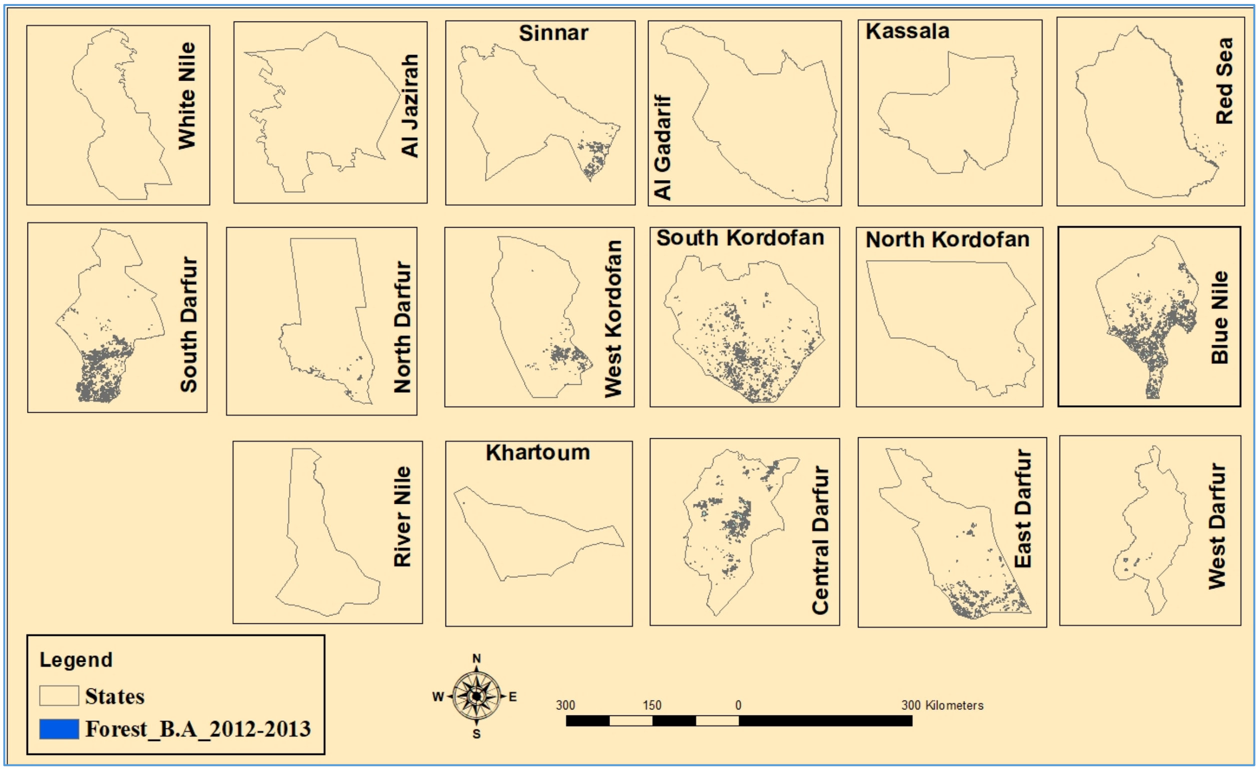
State	Forest_BA(ha)	Co2(Gg)	State	Forest_BA(ha)	Co2(Gg)
Blue Nile	311597.97	1462.40	Red Sea	3493.58	16.40
East Darfur	186590.31	875.71	River Nile	0.00	0.00
Gadarif	45.41	0.21	Sinnar	21055.66	98.82
Gazira	785.05	3.68	South Darfur	296287.11	1390.54
Kassala	1973.72	9.26	South Kordofan	143897.73	675.35
Khartoum	0.00	0.00	White Nile	4492.74	21.09
North Darfur	6291.99	29.53	West Darfur	5680.96	26.66
North Kordofan	22299.79	104.66	West Kordofan	120775.63	566.83
Northern	0.00	0.00	Central Darfur	116281.61	545.74



Spatial Distribution of burn area from forest burning/State detected by MOD64A1, 2011-2012

Forest burned area derived from MOD64A1 and Co2 emission (Gg), 2011-2012

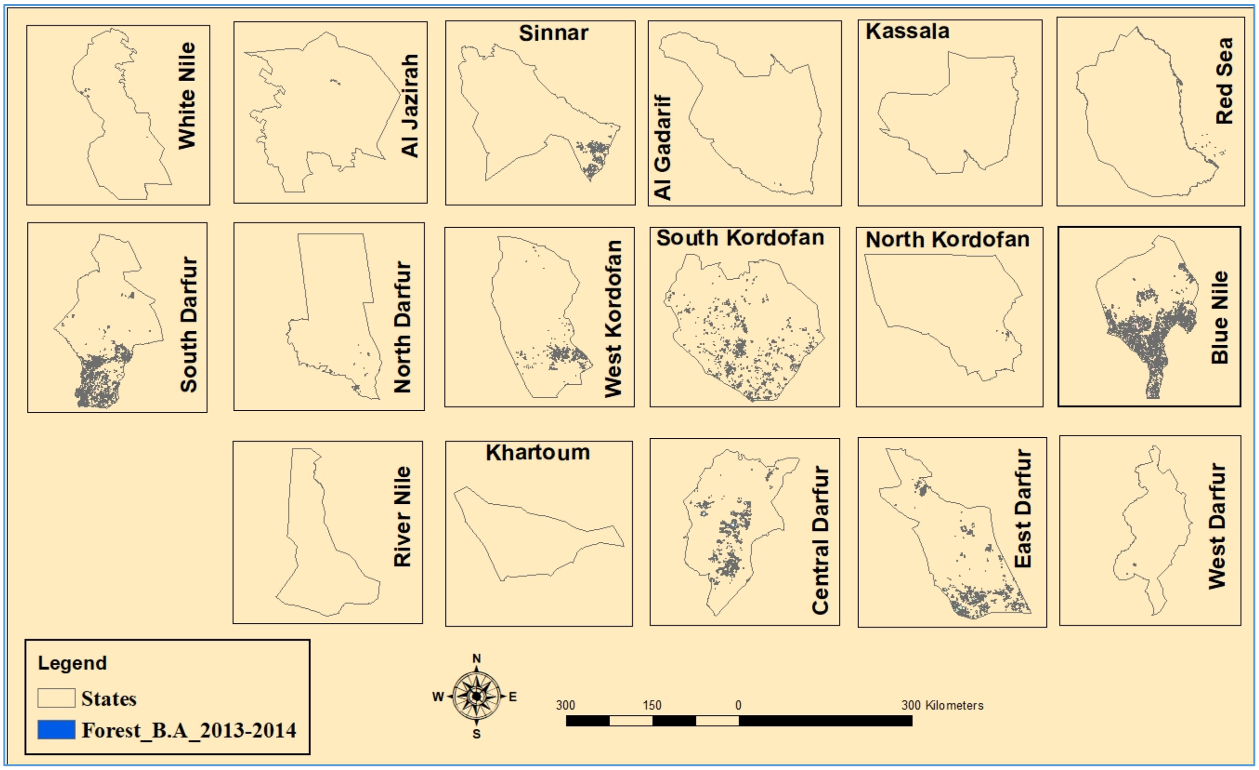
State	Forest_BA(ha)	Co2(Gg)	State	Forest_BA(ha)	Co2(Gg)
Blue Nile	290105.31	1361.53	Red Sea	200.25	0.94
East Darfur	122698.45	575.85	River Nile	0.00	0.00
Gadarif	141.76	0.67	Sinnar	33169.33	155.67
Gazira	0.00	0.00	South Darfur	328043.99	1539.59
Kassala	395.27	1.86	South Kordofan	157609.44	739.70
Khartoum	0.00	0.00	White Nile	113.90	0.53
North Darfur	1856.51	8.71	West Darfur	6504.85	30.53
North Kordofan	230.57	1.08	West Kordofan	108309.58	508.32
Northern	0.00	0.00	Central Darfur	95860.84	449.90



Spatial Distribution of burn area from forest burning/State detected by MOD64A1, 2012-2013

Forest burned area derived from MOD64A1 and Co2 emission (Gg), 2012-2013

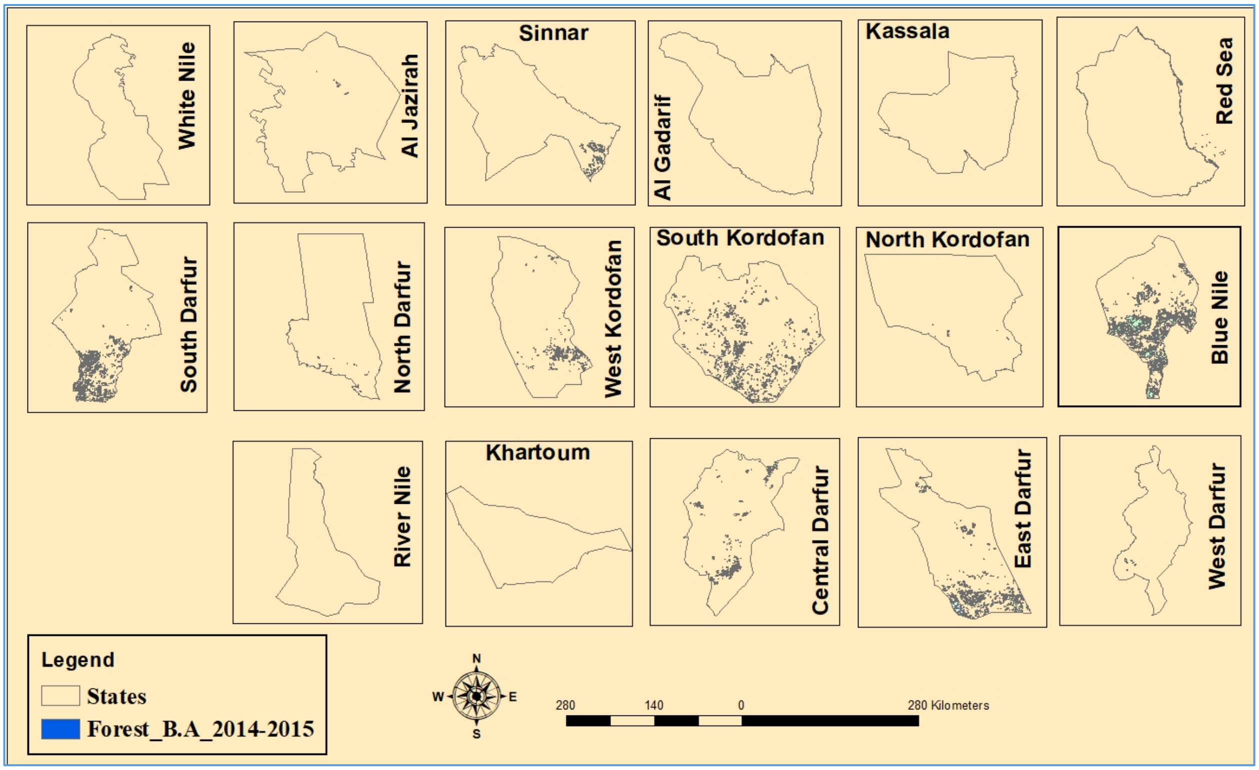
State	Forest_BA(ha)	Co2(Gg)	State	Forest_BA(ha)	Co2(Gg)
Blue Nile	525250.44	2465.12	Red Sea	0.00	0.00
East Darfur	215532.18	1011.54	River Nile	0.00	0.00
Gadarif	122.19	0.57	Sinnar	59372.88	278.65
Gazira	0.00	0.00	South Darfur	243515.58	1142.88
Kassala	0.00	0.00	South Kordofan	221463.45	1039.38
Khartoum	68.30	0.32	White Nile	1168.30	5.48
North Darfur	25690.68	120.57	West Darfur	10078.12	47.30
North Kordofan	11878.49	55.75	West Kordofan	206919.83	971.12
Northern	0.00	0.00	Central Darfur	113193.90	531.25



Spatial Distribution of burn area from forest burning/State detected by MOD64A1, 2013-2014

Forest burned area derived from MOD64A1 and Co2 emission (Gg), 2013-2014

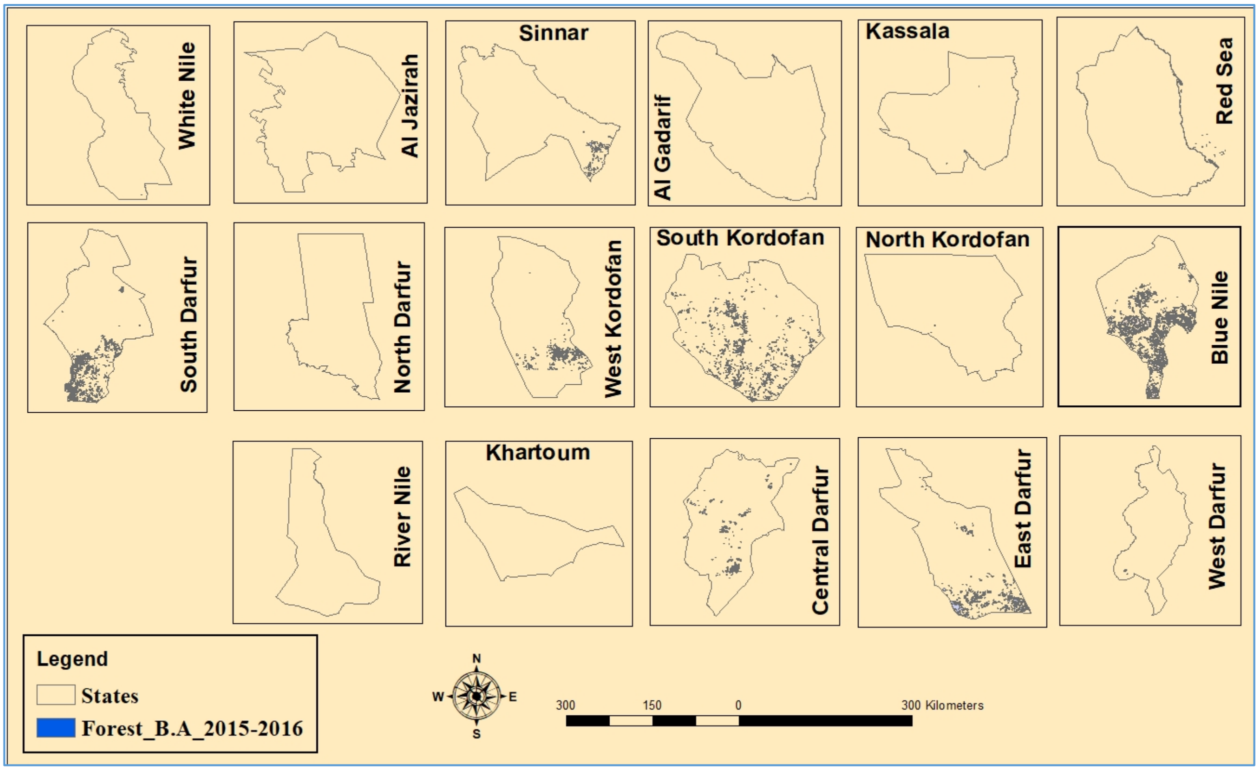
State	Forest_BA(ha)	Co2(Gg)	State	Forest_BA(ha)	Co2(Gg)
Blue Nile	565489.90	2653.98	Red Sea	0.00	0.00
East Darfur	174183.61	817.48	River Nile	0.00	0.00
Gadarif	286.21	1.34	Sinnar	53308.55	250.19
Gazira	1171.14	5.50	South Darfur	280235.07	1315.21
Kassala	0.11	0.00	South Kordofan	124202.00	582.91
Khartoum	0.00	0.00	White Nile	1507.09	7.07
North Darfur	18660.81	87.58	West Darfur	1470.05	6.90
North Kordofan	7371.89	34.60	West Kordofan	122459.02	574.73
Northern	0.00	0.00	Central Darfur	109590.32	514.33



Spatial Distribution of burn area from forest burning/State detected by MOD64A1, 2014-2015

Forest burned area derived from MOD64A1 and Co2 emission (Gg), 2014-2015

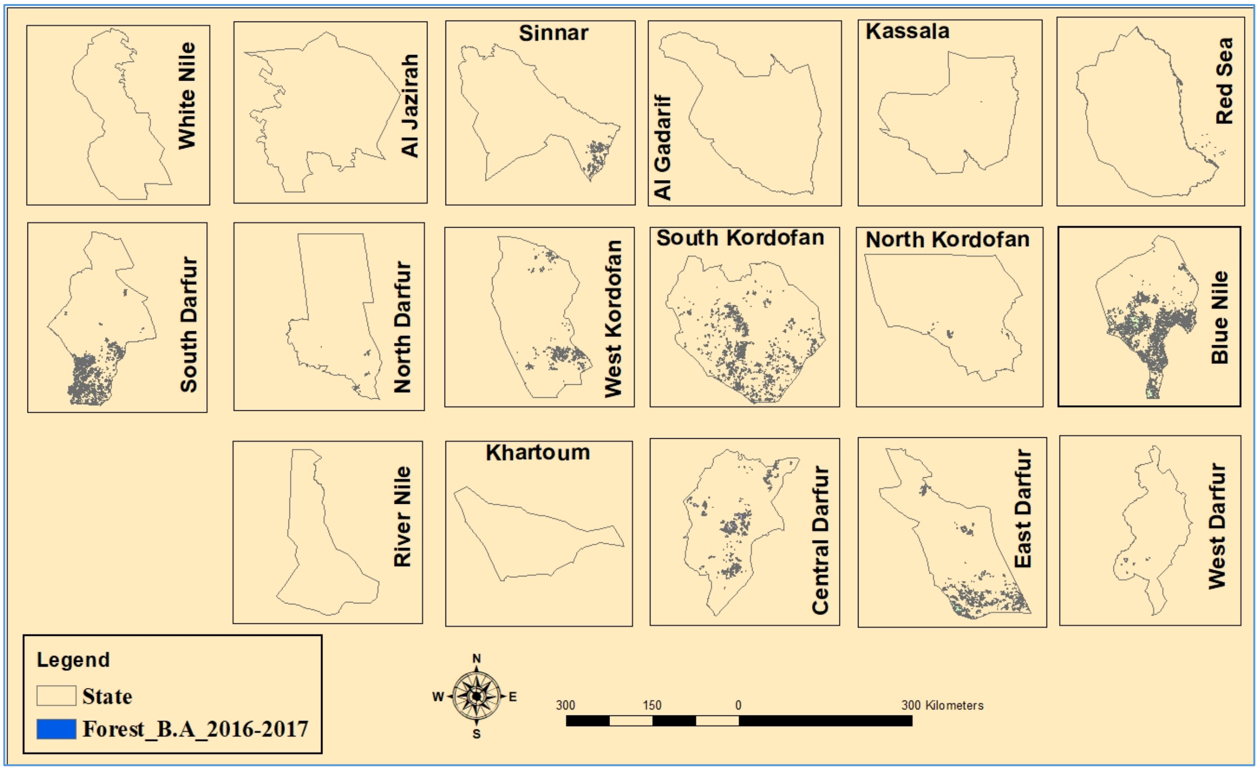
State	Forest_BA(ha)	Co2(Gg)	State	Forest_BA(ha)	Co2(Gg)
Blue Nile	462251.25	2169.45	Red Sea	0.00	0.00
East Darfur	195688.24	918.41	River Nile	0.00	0.00
Gadarif	18.07	0.08	Sinnar	30025.38	140.92
Gazira	1784.80	8.38	South Darfur	227711.48	1068.70
Kassala	0.00	0.00	South Kordofan	160358.20	752.60
Khartoum	72.46	0.34	White Nile	4.89	0.02
North Darfur	14403.89	67.60	West Darfur	3420.49	16.05
North Kordofan	4492.63	21.08	West Kordofan	120346.07	564.81
Northern	0.00	0.00	Central Darfur	45728.62	214.62



Spatial Distribution of burn area from forest burning/State detected by MOD64A1, 2015-2016

Forest burned area derived from MOD64A1 and Co2 emission (Gg), 2015-2016

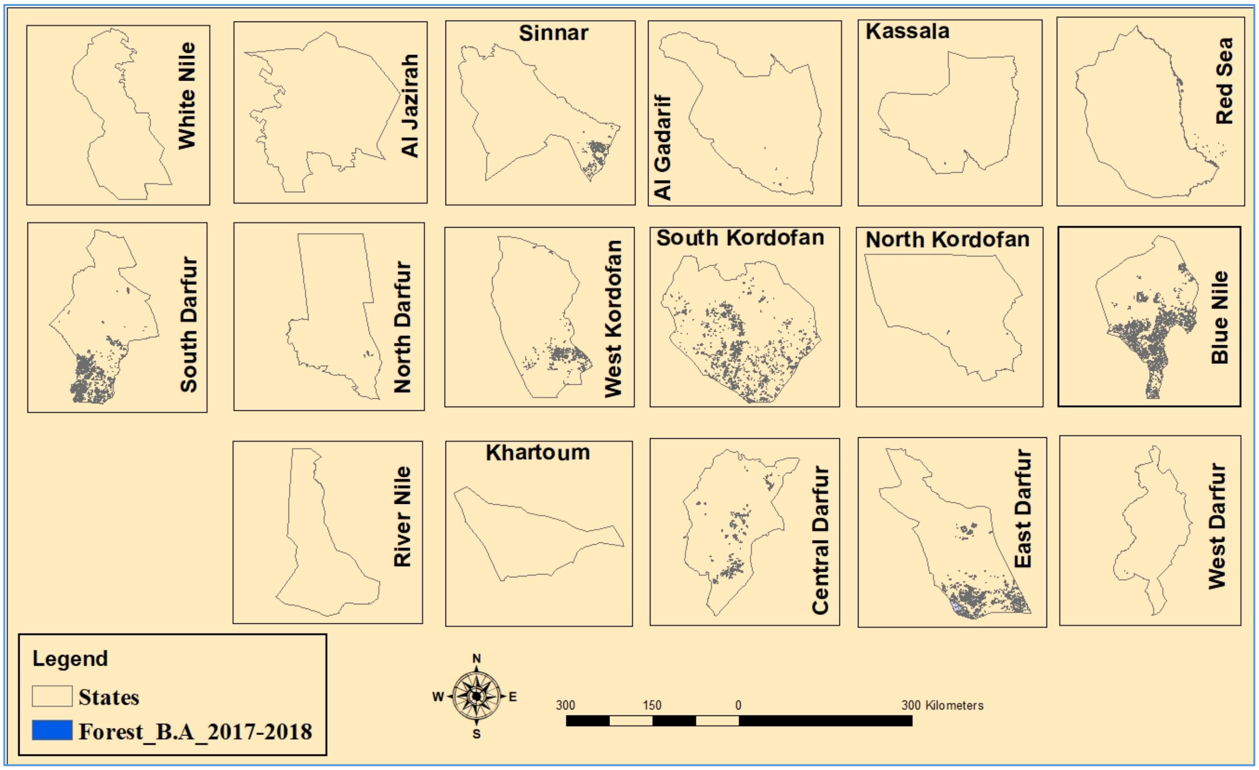
State	Forest_BA(ha)	Co2(Gg)	State	Forest_BA(ha)	Co2(Gg)
Blue Nile	412864.90	1937.67	Red Sea	0.00	0.00
East Darfur	139333.16	653.92	River Nile	0.00	0.00
Gadarif	30.33	0.14	Sinnar	20595.06	96.66
Gazira	0.00	0.00	South Darfur	210426.15	987.58
Kassala	132.17	0.62	South Kordofan	142544.07	668.99
Khartoum	0.00	0.00	White Nile	86.26	0.40
North Darfur	1172.31	5.50	West Darfur	1429.16	6.71
North Kordofan	841.04	3.95	West Kordofan	142310.97	667.90
Northern	0.00	0.00	Central Darfur	29657.27	139.19



Spatial Distribution of burn area from forest burning/State detected by MOD64A1, 2016-2017

Forest burned area derived from MOD64A1 and Co2 emission (Gg), 2016-2017

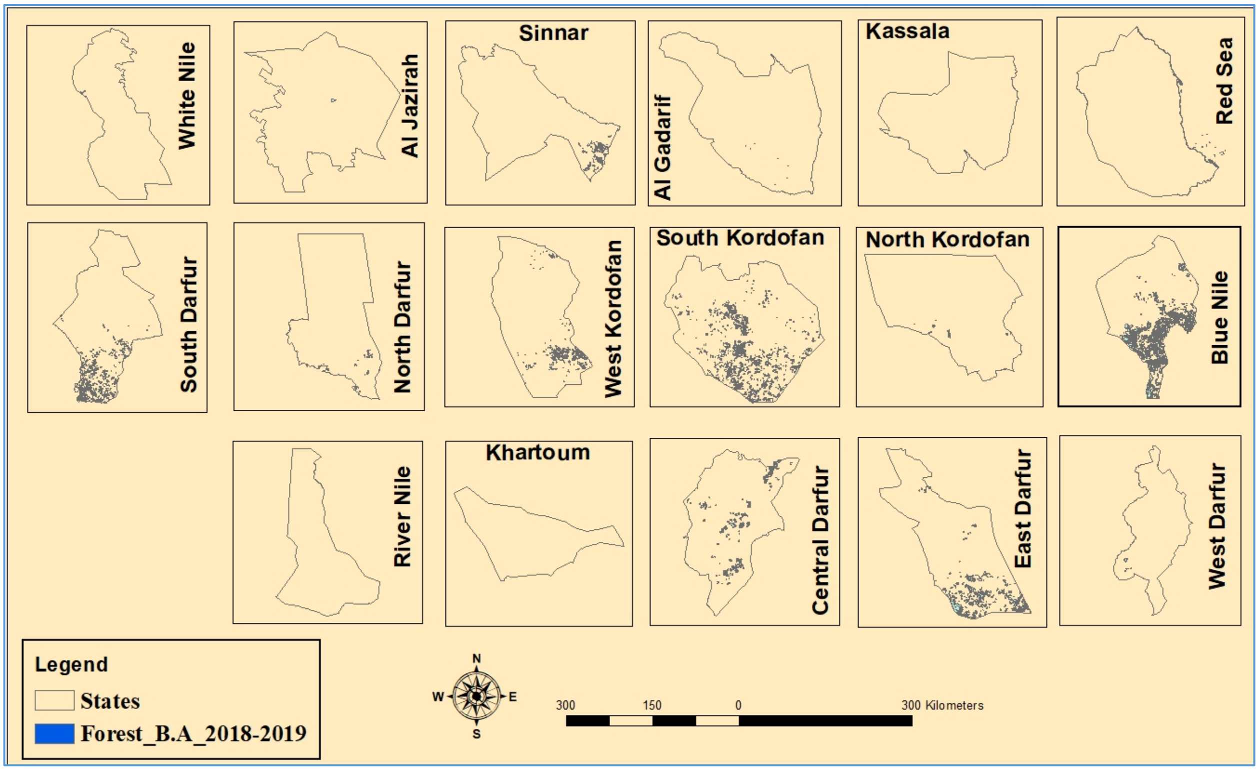
State	Forest_BA(ha)	Co2(Gg)	State	Forest_BA(ha)	Co2(Gg)
Blue Nile	496983.29	2332.46	Red Sea	0.00	0.00
East Darfur	157696.26	740.11	River Nile	0.00	0.00
Gadarif	8.55	0.04	Sinnar	29538.82	138.63
Gazira	0.00	0.00	South Darfur	314789.36	1477.38
Kassala	34.49	0.16	South Kordofan	193295.71	907.18
Khartoum	0.00	0.00	White Nile	0.00	0.00
North Darfur	15019.36	70.49	West Darfur	4994.17	23.44
North Kordofan	12523.03	58.77	West Kordofan	162885.34	764.46
Northern	0.00	0.00	Central Darfur	86947.08	408.06



Spatial Distribution of burn area from forest burning/State detected by MOD64A1, 2017-2018

Forest burned area derived from MOD64A1 and Co2 emission (Gg), 2017-2018

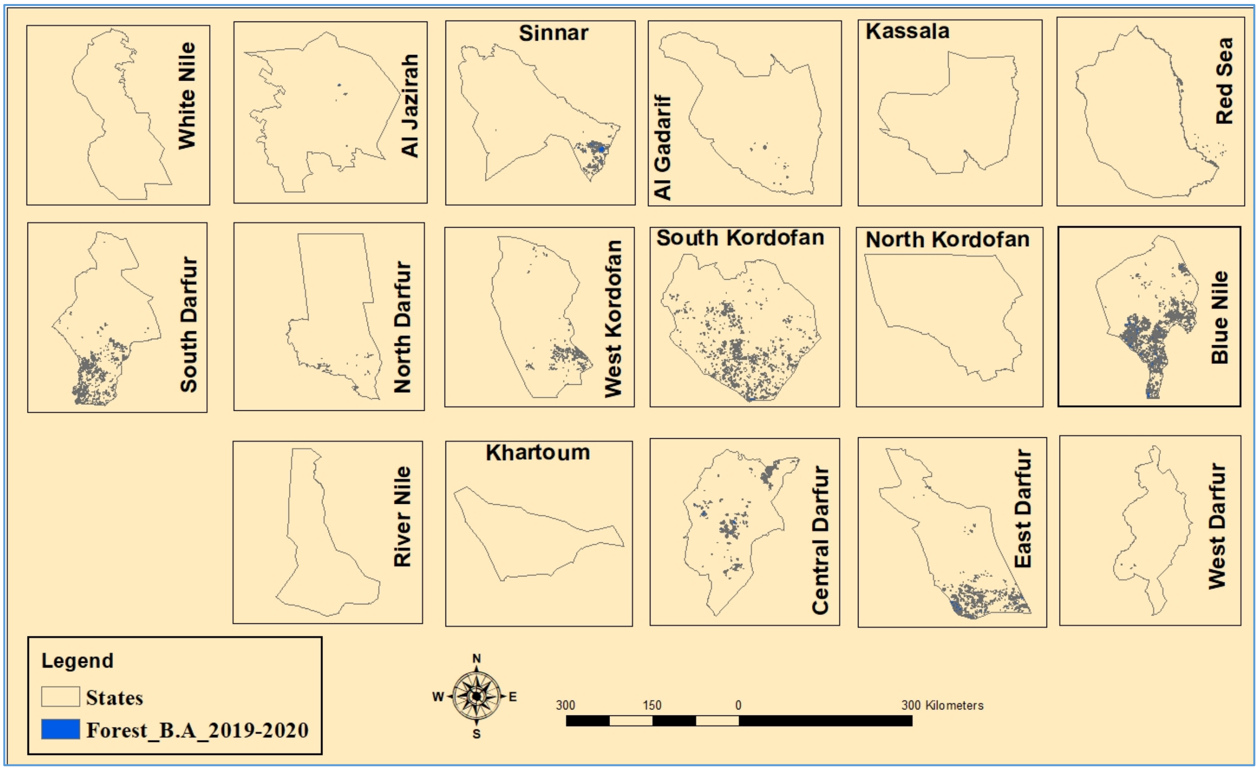
State	Forest_BA(ha)	Co2(Gg)	State	Forest_BA(ha)	Co2(Gg)
Blue Nile	399044.48	1872.81	Red Sea	7.41	0.03
East Darfur	219452.77	1029.94	River Nile	0.00	0.00
Gadarif	1258.68	5.91	Sinnar	37956.46	178.14
Gazira	14.78	0.07	South Darfur	222354.46	1043.56
Kassala	2436.95	11.44	South Kordofan	172504.28	809.60
Khartoum	0.00	0.00	White Nile	0.70	0.00
North Darfur	2948.94	13.84	West Darfur	72.37	0.34
North Kordofan	1215.08	5.70	West Kordofan	72.37	0.34
Northern	0.00	0.00	Central Darfur	44749.56	210.02



Spatial Distribution of burn area from forest burning/State detected by MOD64A1, 2018-2019

Forest burned area derived from MOD64A1 and Co2 emission (Gg), 2018-2019

State	Forest_BA(ha)	Co2(Gg)	State	Forest_BA(ha)	Co2(Gg)
Blue Nile	365068.23	1713.35	Red Sea	0.00	0.00
East Darfur	151274.17	709.96	River Nile	0.00	0.00
Gadarif	180.30	0.85	Sinnar	29052.72	136.35
Gazira	1216.99	5.71	South Darfur	125392.31	588.50
Kassala	0.00	0.00	South Kordofan	203553.02	955.32
Khartoum	0.00	0.00	White Nile	1458.23	6.84
North Darfur	18174.50	85.30	West Darfur	3253.63	15.27
North Kordofan	13872.87	65.11	West Kordofan	138331.38	649.22
Northern	0.00	0.00	Central Darfur	55436.48	260.18



Spatial Distribution of burn area from forest burning/State detected by MOD64A1, 2019-2020

Forest burned area derived from MOD64A1 and Co2 emission (Gg), 2019-2020

State	Forest_BA(ha)	Co2(Gg)	State	Forest_BA(ha)	Co2(Gg)
Blue Nile	314791.30	1477.39	Red Sea	237.66	1.12
East Darfur	149070.46	699.62	River Nile	0.00	0.00
Gadarif	3224.17	15.13	Sinnar	51568.16	242.02
Gazira	1019.45	4.78	South Darfur	151507.55	711.06
Kassala	533.07	2.50	South Kordofan	161073.86	755.96
Khartoum	0.00	0.00	White Nile	0.00	0.00
North Darfur	12957.81	60.81	West Darfur	721.14	3.38
North Kordofan	63.07	0.30	West Kordofan	96093.06	450.99
Northern	0.00	0.00	Central Darfur	64862.35	304.41

REPUBLIC OF SUDAN FIRE MANAGEMENT STRATEGY FRAMEWORK AND OUTLINE

FINAL REPORT 2021

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