ASSESSMENT OF THE EFFECTS OF FIRE ON VEGETATION CHANGES IN SERENGETI NATIONAL PARK

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A Dissertation Submitted to the Department of Geospatial Sciences and Technology in Partial Fulfillment of the Requirement for the award of Degree of Bachelor of Science in Geographical information systems and remote sensing of Ardhi University.

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The undersigned certify that they have proof read and hereby recommend for acceptance by the Ardhi University dissertation titled "**ASSESSMENT OF THE EFFECTS OF FIRE ON VEGETATION CHANGE IN SERENGETI NATIONAL PARK"** in partial fulfillment of the requirements for the award of degree of Bachelor of Science in Geographical Information Systems and Remote Sensing at Ardhi University.

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ACKNOWLEDGEMENT

I thank Almighty God for the grace, strength, knowledge and wisdom to go through the entire research to the very end. I really thank you for giving me guidance and being on my side throughout the research period.

I would like to extend my gratitude to my beloved mother Jane Chihekwe and my father Mr. Makomola, my brothers, Godfrey and Stanley and their families for their prayers, support and care they scarified over the years of my studies. Nothing to pay them than praying for them.

My very sincere word of thanks goes to my supervisors Dr. Atupelye and Mr. M. Mavura who supported me all the way to achieve this research, helped me to improve my ability to achieve the objectives and encouraged me wherever necessary to do so. May the almighty God give them more strength and life span on this beautiful world.

I would thank my friends Warda Ally, Pauline Mbita, Latifa Zalali, Calvin John, Hemed Lungo and Rehema Sendeu for their support in accomplishing this research, may the almighty God bless them for their kindness.

ABSTRACT

Fire has been a major problem facing protected areas repeatedly. Fire can be caused due to various reasons, can be human activities such as agricultural activities taking place nearby those areas, camp fires and in a very rare circumstance fire can be caused by natural causes like lightning strikes. Fire can be detected through various techniques include remote sensing techniques, and in most cases remote sensing approach has been employed in detecting burnt areas. One among of effects of fire is changes in vegetation.

In this research the normalized burnt ratio index (NBR) was used to assess the areas affected by fire in Serengeti national park for the time series of four years (2018 - 2021). In this research, change detection was done by using post-classification method and mapping burn areas Normalized Burnt Ratio was used (NBR). Also, sentinel 2A images used to assess land cover changes mapping for the period of four years. Accuracy assessment was done in all images and it was 83% for 2018 image, 87% for 2019 image, 78% for 2020 image and 81% for 2021 image.

In this research, Results shows the areas which were highly affected with fire and on how fire has influenced vegetation cover changes for the period of four years. And it shows that the areas which are highly affected with fire have been categorized into different levels based on severity of the damage imparted by the fire outbreak , furthermore areas that can be easily recovered have been depicted as well as those that can be hardly recovered from the damage.

The study based on assessing the effects of fire in vegetation change through identifying the areas which are affected by fire and compare it to the changes which have been observed for the period of four years. The Differenced Normalized Burnt Ratio (dNBR) index was used to identify the burnt areas and the areas was categorized based on the thresholds introduced by USGS in order to identify the levels of severity in a particular observed area.

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LIST OF ABBREVIATION

NBR	Normalized Burn Ratio
dNBR	differenced Normalized Burn Ratio
TANAPA	Tanzania National Park
USGS	United State Geological Survey
SWIR	Short wave infrared
NIR	Near Infrared

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CHAPTER ONE

INTRODUCTION

1.1 Background

The ancient Greeks considered fire as one of the classical elemental forces along with water, earth and air and indeed fire has helped shape of the world around us to such a great extent that it would be hard to argue the point (Peter & Robert, 2010). Also, fire is an important factor in the ecology and evolution of grassland and savanna ecosystems (Fuhlendorf and Engle 2004). Sometimes Fire that occur is uncontrolled fire that burnt in an area of combustible vegetation, such as forest or grassland. Fire can be caused by natural events such as lighting strikes or by human activities such as campfires or fireworks. Fire can have severe impacts on ecosystem, human communities and infrastructure.

Fire in parks can be caused by several reasons such as lightning strikes, human activities and dry conditions. Human activities can include campfires or fireworks. Natural causes such as lightning strike can ignite dry bush, and drought conditions can make it easier for fire to spread and become more intense. Climate change can also contribute to an increase in the frequency and severity of wildfires by causing drought conditions and higher temperatures (Chuvieco, 2012).

These fires sometimes lit by cattle farmers as part of their traditional management of savannahs where their animals graze. Some fires are started to stimulate new growth of nutritious grass for their animals, other are used to control the numbers of parasitic ticks or manage the growth of thorny scrub.

Fire severity can be detected either by traditional method or by using remote sensing techniques. Detecting fire by using traditional methods is difficult due to some constraints such as complex topology, steepness of the slopes, inaccessibility of an area and previous heterogeneous vegetation (Mallinis et al., 2018).

1.2 Problem statement

Fire have become increasingly frequent and intense in many national parks, posing significant threats to the ecological health and biodiversity of these protected areas. Assessing the effects of fire on vegetation is crucial for effective management and conservation efforts. Geographic Information System (GIS) technology offers valuable tools for analyzing spatial and temporal patterns of fire occurrence and their impacts on vegetation within national parks.

However, there is a need to develop a comprehensive understanding of the complex relationship between fire and vegetation dynamics, integrating with GIS techniques. This research aims to address this gap by employing GIS-based approaches to assess the effects of fire on vegetation in Serengeti national park.

1.3 Objectives

1.3.1 Main Objective

To assess the impacts of fire on vegetation change in Serengeti national park in order to come up with appropriate measures on how to overcome the effects of fire on vegetation.

1.3.2 Specific Objectives

i. To assess burn severity extent of Serengeti national park
ii. To map land cover in order to understand land cover pattern of the area

1.4 Significance

At the end of this research, it is expected that the results will be a detailed information on how fires affect vegetation dynamics which will help the responsible organization (TANAPA) to take appropriate measures on how to conserve the environment and also to develop policies which will be used to overcome the effects associated with vegetation dynamics.

1.5 Beneficiaries

i. Tanzania National Park (TANAPA)

This research findings will provide valuable information which will help TANAPA to improve their measures to overcome the effects of vegetation dynamics resulted from the effects of fires also it will help them to make policies which will be used to prevent fires.

ii. Researchers

The research findings will further help other researchers to give them light on how to start when they want to make more studies about the effects of fire.

iii. The ministry

The research findings will be useful by responsible ministry in making records of the fire occurrence and its effects in Serengeti National Park.

1.6 Description of study area

Serengeti National Park found in Northern Tanzania, and it is approximated to have 14,763km^{2}. It established in 1951. Is known for its massive annual migration of wildebeest and zebra. Seeking new pasture, the herds move north from their breeding grounds in the grassy southern plains. Many cross the marshy western corridors crocodile-infested Grumeti river, home to black eagles. The park extends across regions in northern Tanzania, bordering Kenya's Maasai Mara National Reserve to the north.

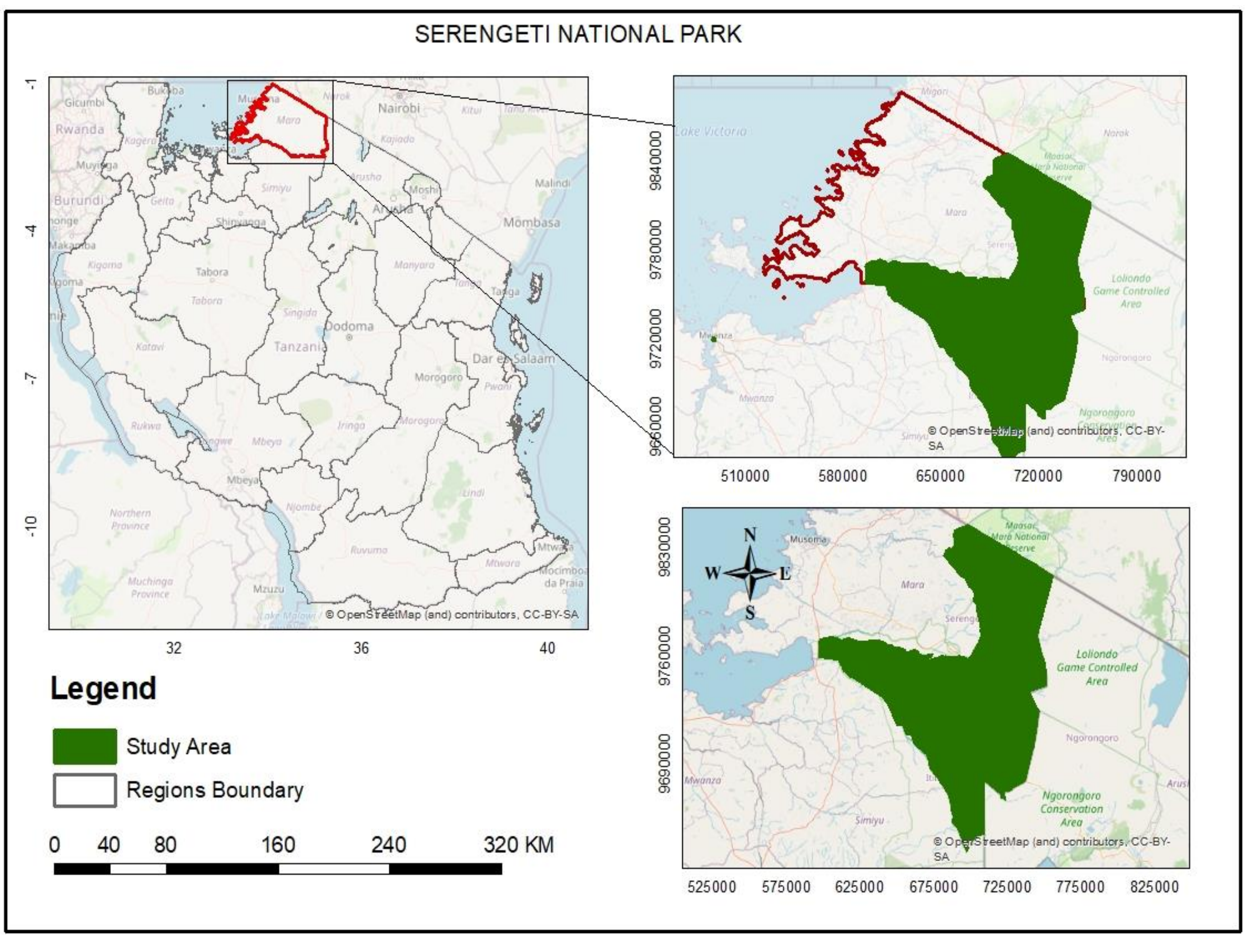

Figure 1.1 Location map

CHAPTER TWO

LITERATURE REVIEW

2.1 Remote Sensing

Remote sensing is the science and art of obtaining information about an object area or phenomenon through the analysis of data acquired by a device that is not in contact with the object area or phenomenon under investigation.

It involves two main processes which are data acquisition and analysis of the data acquired by using various electromagnetic energy sensor system. It involves the study of earths features from images taken from space using satellites or from nearer the earth using aircrafts.

2.2 Image classification

Image classification is the process of extracting information from multiband raster images such as satellite images. Different land cover classes are assigned to different pixels. The process of assigning and labelling group of pixels or individual pixels in satellite image based on their spectral values (Lillesand, keifer 1994). There are two types of classification that are

i. Supervised classification
ii. Unsupervised classification

2.2.1 Supervised classification

This is a type of classification that requires a prior knowledge of the area. It uses the training sample data of known classify pixels of unknown identity. Here the analyst selects representative samples of known cover types. And this type of classification mostly used for quantitative analysis of remote sensing data.it involves using suitable algorithms to label the pixel in an image to represent a particular land cover type classes (Richards, 1986).

2.2.2 Unsupervised classification

This does not require a prior knowledge of the study area; the computer automatically groups the pixels into separate clusters based on their spectral signatures. The analyst only specifies a number of classes and in unsupervised classification relies on unsupervised machine learning algorithms for its implementation (Olaode et al, 2014)

Supervised classification was used in this study in classifying a study area into several land cover classes.

2.3 Accuracy assessment

Accuracy assessment should be done by using ground truthing data which was collected on the field. Also, accuracy assessment includes user accuracy, producer accuracy, and overall accuracy. (Congalton, 1999). It is important to perform accuracy assessment in order to get results which are accurate. The accuracy assessment can be done through several ways which are error matrix method, which calculates the correspondence between the classification results and the reference image, whereas the overall accuracy is obtained by dividing the sum of pixels, which are correctly identified by the total number of pixels. Also, the other accuracy indicator is kappa coefficient, which is the measure of how the classification results compare to value assigned by chance, whereby if the kappa coefficient is zero there is no agreement between the classified and reference image, and when kappa is equal to one then classified image is totally identical to reference image. Thus, the higher the kappa coefficient, the more accurate is the classification.

2.4 Change detection

Change detection is the process of identifying differences in an object through observing it at different time seasons (Mausel et al 2003). Change detection can be useful in determining advancement or development of objects. In change detection there are various factors which are mostly observed which are the distribution of the observed object, the area of changes and the rate of changes. In this research post-classification method was used. The process of change detection has the following procedures;

i. Image selection
ii. Image registration
iii. Radiometric correction
iv. Multitemporal analysis

2.5 Normalized burnt ratio (NBR)

This is an index designed to highlight burnt areas in large fire zones. It is calculated by combining both near infrared (NIR) and short-wave infrared (SWIR) portion of an electromagnetic spectrum.

Burnt areas demonstrate low reflectance in the NIR and high reflectance in the SWIR. The difference between the spectral responses of healthy vegetation and burnt areas reach their peak in the NIR and the SWIR region of the spectrum.

NBR uses the ratio between NIR and SWIR bands, while high values attained indicates healthy vegetation, low values indicate bare ground and recently burnt areas and non-burnt areas are normally attributed to values close to zero (Bang , Mihai , Lauren , & Cristina , 2018). In burned areas NBR values decline at the same time as the fire severity rises (Escuin, Navarro, & Fernandez, 2007)

$$NBR = \frac{NIR - SWIR}{NIR + SWIR} \quad \text{......} \quad 1.1$$

$$dNBR = NBR(prefire) - NBR(postfire) \quad \text{......} \quad 1.2$$

The thresholds of normalized burn ratio for each level of burn severity were obtained from USGS earth explorer.

Severity Level	dNBR Range (scaled by 10^3)	dNBR Range (not scaled)
Enhanced Regrowth, high (post-fire)	-500 to -251	-0.500 to -0.251
Enhanced Regrowth, low (post-fire)	-250 to -101	-0.250 to -0.101
Unburned	-100 to +99	-0.100 to +0.99
Low Severity	+100 to +269	+0.100 to +0.269
Moderate-low Severity	+270 to +439	+0.270 to +0.439
Miderate-high Severity	+440 to +659	+0.440 to +0.659
High Severity	+660 to +1300	+0.660 to +1.300

Figure 1.1 severity levels

2.6 Forest fire

Forest fire are described into three types, ground fire which burn below the surface of the ground in the soil, Surface fire which burn primarily as a surface fire and spreading along the ground on the forest floor and Crown fire which are fires in the tops of trees (Sabuncu & Ozener, 2018). A case study of this research is affected by surface fire.

2.7 Fire intensity and severity

Fire intensity describes the physical combustion process in terms of organic matter, it represents the energy that is released this combustion process while Severity is more in gauging the fire impact that is the degree to which an area has been altered or disrupted by the fire. The impact can be described as the amount of damage, the physical, chemical and biological changes and the degree of alteration that fire causes to an ecosystem (Harris, Veranerbeke, & Hook, 2011).

CHAPTER THREE

METHODOLOGY

In order to attain the goal of this research, sentinel 2A images were used, these data were preprocessed in order to prepare them for analysis. From preprocessed data, selected spectral index which is NBR were calculated and also image classification process was done over the study area. NBR Index were reclassified in thresholds that corresponds to different fire severity. Then the analysis was done by assessing the areas which are affected and the rate of vegetation change in the identified area. Figure 3.1 shows a methodology flow chart.

3.2 Data sources and software

Figure 3.1 data type and sources

Data type	Format	source
Sentinel 2A	TIFF	Google Earth Engine

Figure 3.2 software utilized

Software	Uses
Quantum GIS (qgis)	This software used in data processing and map making.
Google Earth Engine	This software used in data processing such as creation of burn severity map.

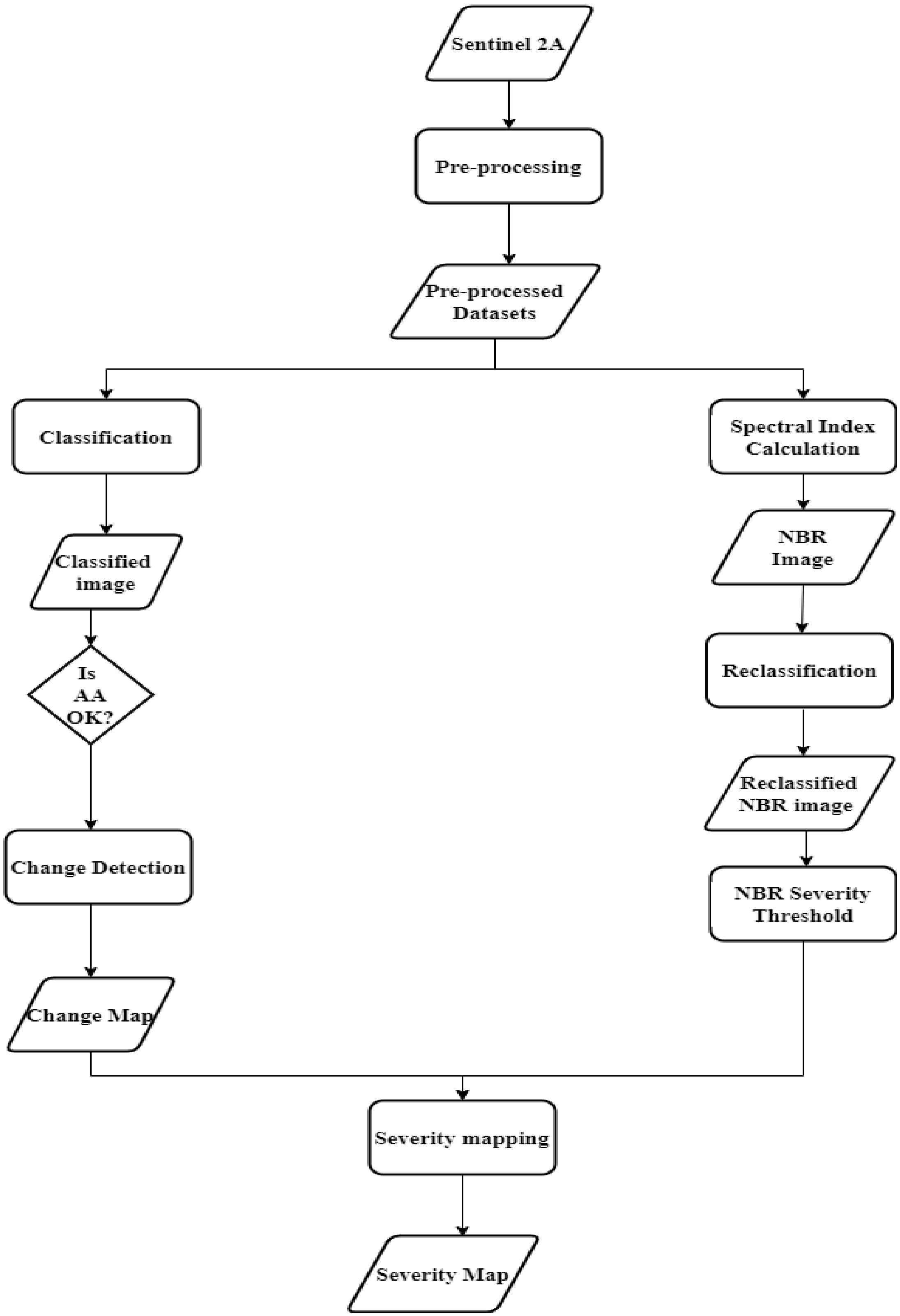

Figure 2.1 Methodology flow chart

3.3 Methods

3.3.1 Data Collection

The data used in this study include sentinel 2A images, These images were acquired at 01/05/2018-30/08/2018 , 01/05/2019 - 30/08/2019, 01/05/2020 – 30/08/2020and 01/05/2021 – 30/08/2021.

3.3.2 Image classification

A set of multiband images were classified into three classes which are water, vegetation and bare land as shown in figure 3.2. Supervised classification was used in this study where the training samples were clustering to assign pixels to classes. An algorithm used were Random Forest

3.4 Land cover maps

They are the land cover maps of years 2021, 2020, 2019 and 2018 which shows the land cover of Serengeti national park composed with three main classes

3.5 Fire severity mapping

Fire severity mapping is a process of assessing and categorizing the severity of a fire's impact on an area, typically a forest or other vegetation-covered landscape. It involves analyzing various factors, such as burn severity, vegetation mortality, and ecological impacts, to classify different levels of fire severity

The following are the key steps followed in mapping fire severity

1. Remote Sensing Data acquisition: Satellite imagery, such as multispectral or hyper spectral data, is commonly used to assess fire severity. In this research sentinel 2A used.

2. Pre- and Post-Fire Imagery: A comparison of pre- and post-fire satellite imagery is performed to identify changes in the landscape caused by the fire. This allows for the identification of burned areas and the assessment of fire severity.

3. Spectral Indices: Various spectral indices, such as the Normalized Burn Ratio (NBR), differenced Normalized Burn Ratio (dNBR), and Burned Area Index (BAI), are calculated using remote sensing data. In this research (dNBR) was calculated.

4. Field Data Collection: Ground-based data collection is often conducted to validate and calibrate the remote sensing-derived fire severity maps. Field surveys may involve

assessing vegetation mortality, measuring tree damage, or collecting other ecological indicators.

5. Classification and Mapping: Based on the remote sensing data and derived indices, fire severity classes or categories are defined. These classes range from low severity (minimal or no impact) to high severity (significant impact with extensive vegetation loss). Classes was classified based on dNBR severity level established by USGS

6. Validation and Accuracy Assessment: The accuracy of the fire severity maps is assessed by comparing them with ground-truth data collected during field surveys. Statistical methods, such as error matrices and kappa coefficients, are often used to quantify the accuracy of the maps.

CHAPTER FOUR

RESULTS, ANALYSIS AND DISCUSSION

4.1 Results

In this research, a land cover map of Serengeti National Park was obtained and the area was covered by three land cover classes which were bare land, water, and vegetation. Bare land and vegetation occupy most part of the area.

4.1.1 Landover maps

The following are the land cover maps of Serengeti National Park which shows the main land cover types which cover the whole area and the class which occupy which are water, vegetation and bare land.

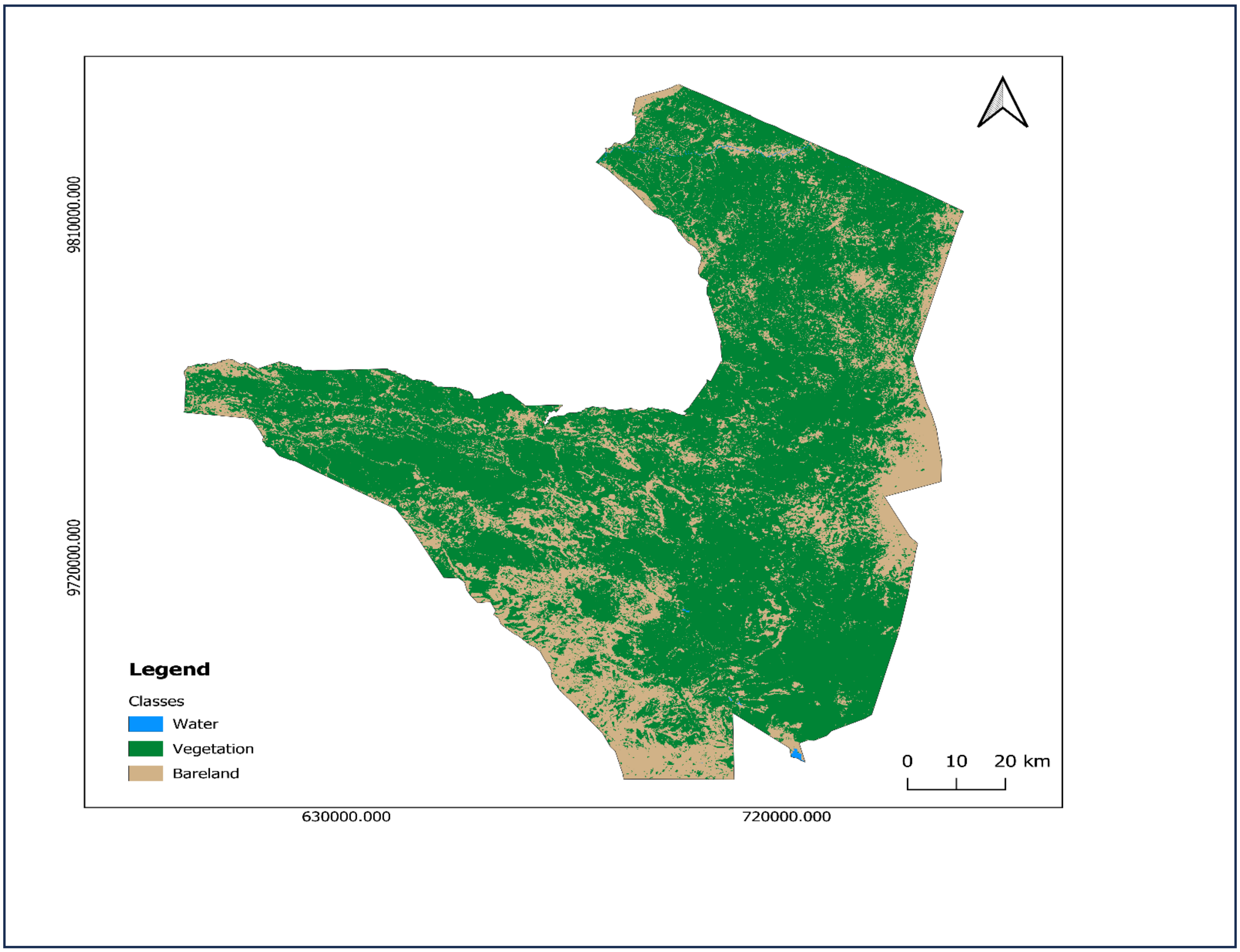

Figure 4.1 2018 land cover map

This is the land cover map of 2019 of Serengeti National Park which shows the area covered by water, vegetation and bareland.

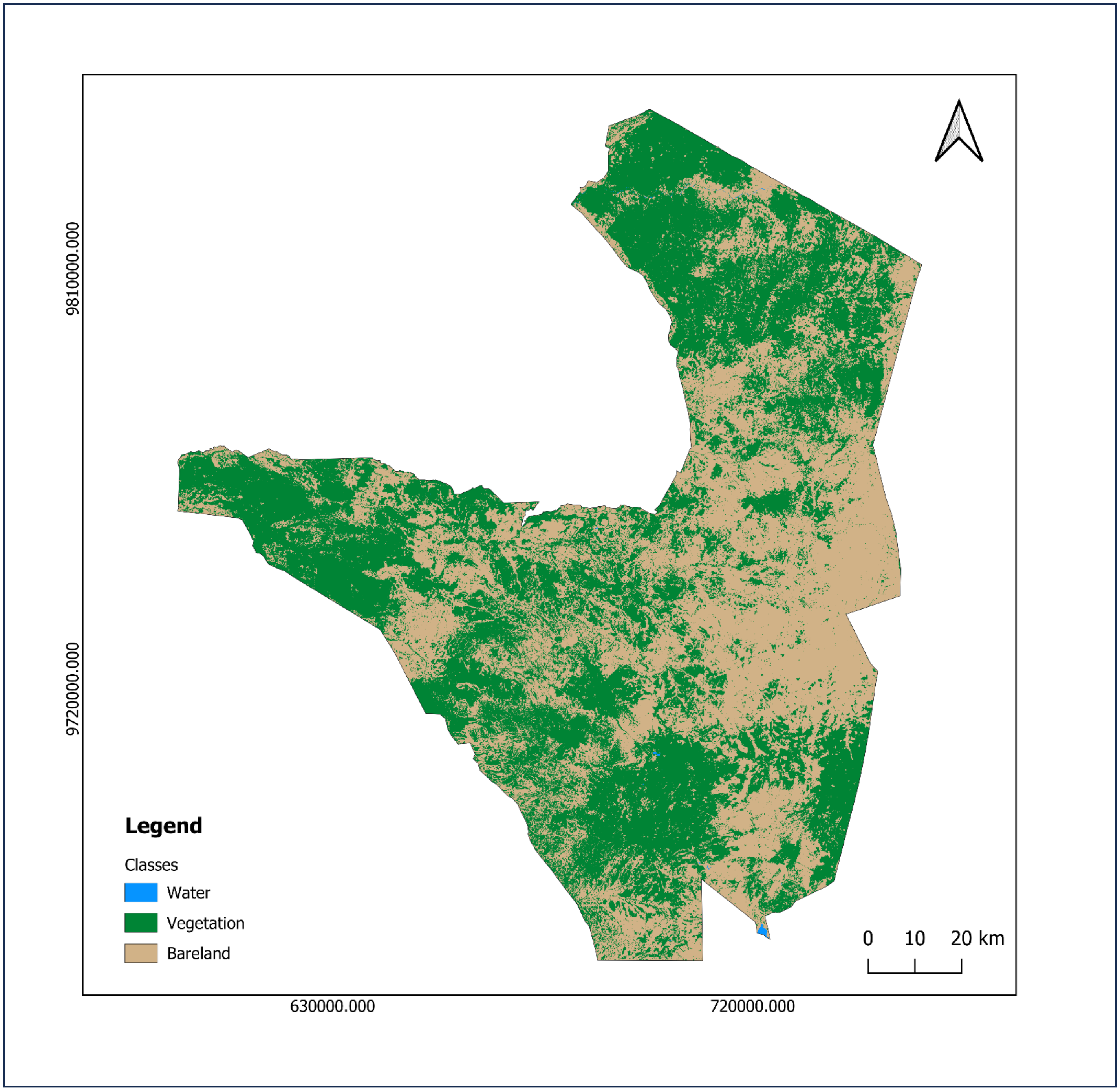

Figure 4.2 2019 land cover map

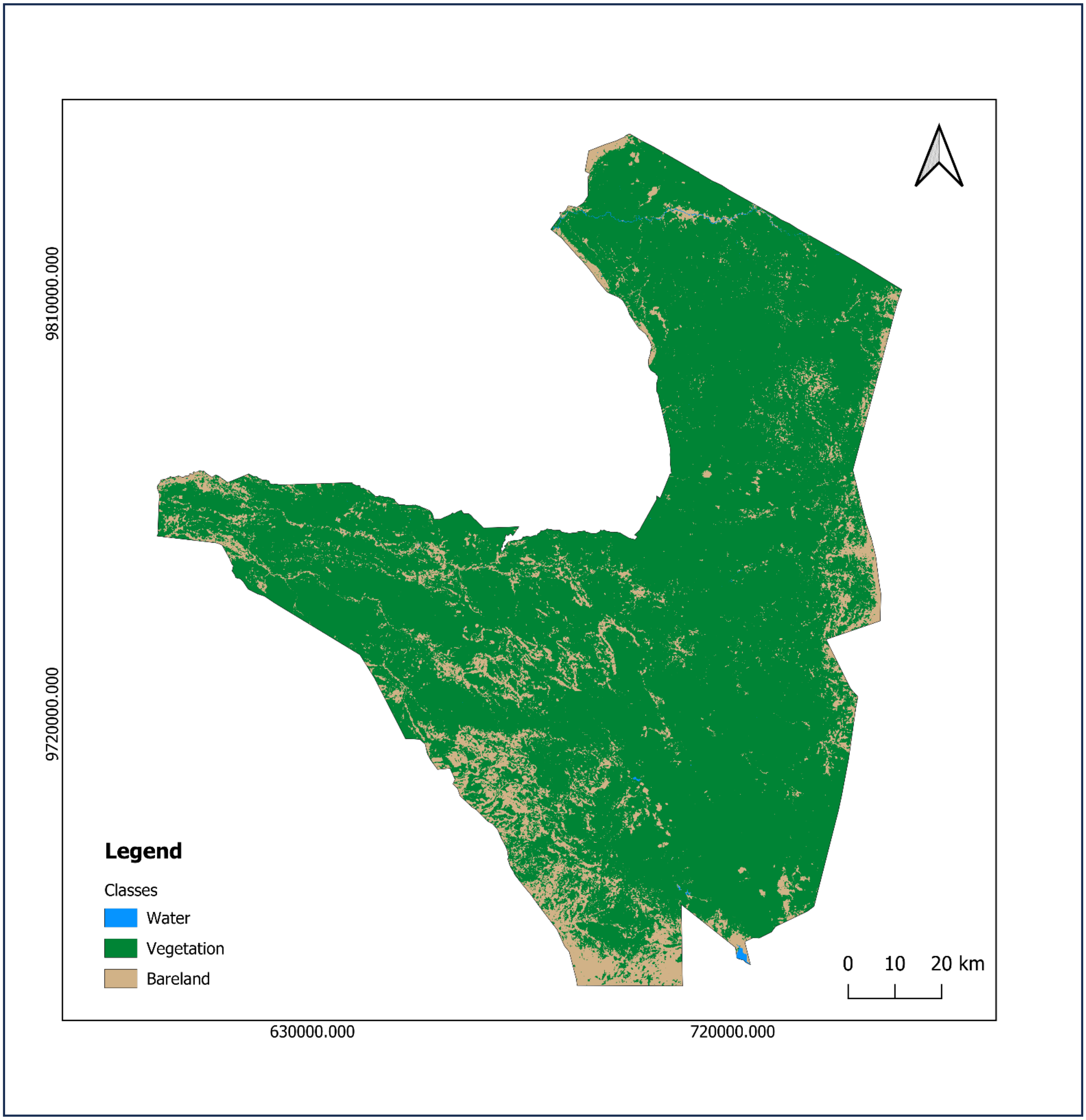

Figure 4.3 2020 land cover map

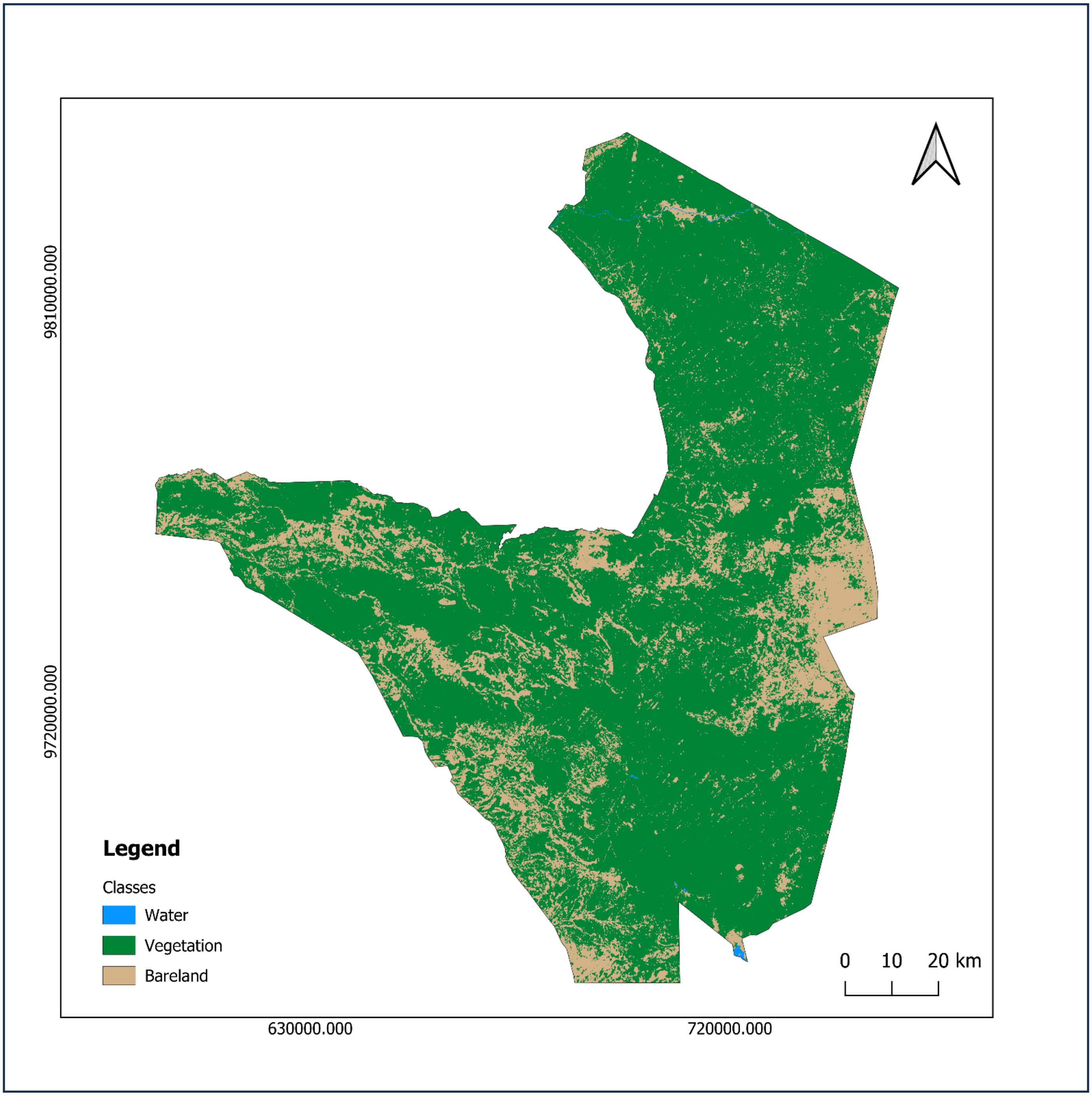

Figure 4.4 2021 land cover map

4.1.2 Change maps

These are the maps which shows the changes which have been occurs for the period of four years and the changes observed in land cover coverage for example some areas which was covered with vegetation changed to bare land due to various results including fire. The following are the change maps which shows the changes in land cover for the interval of two years

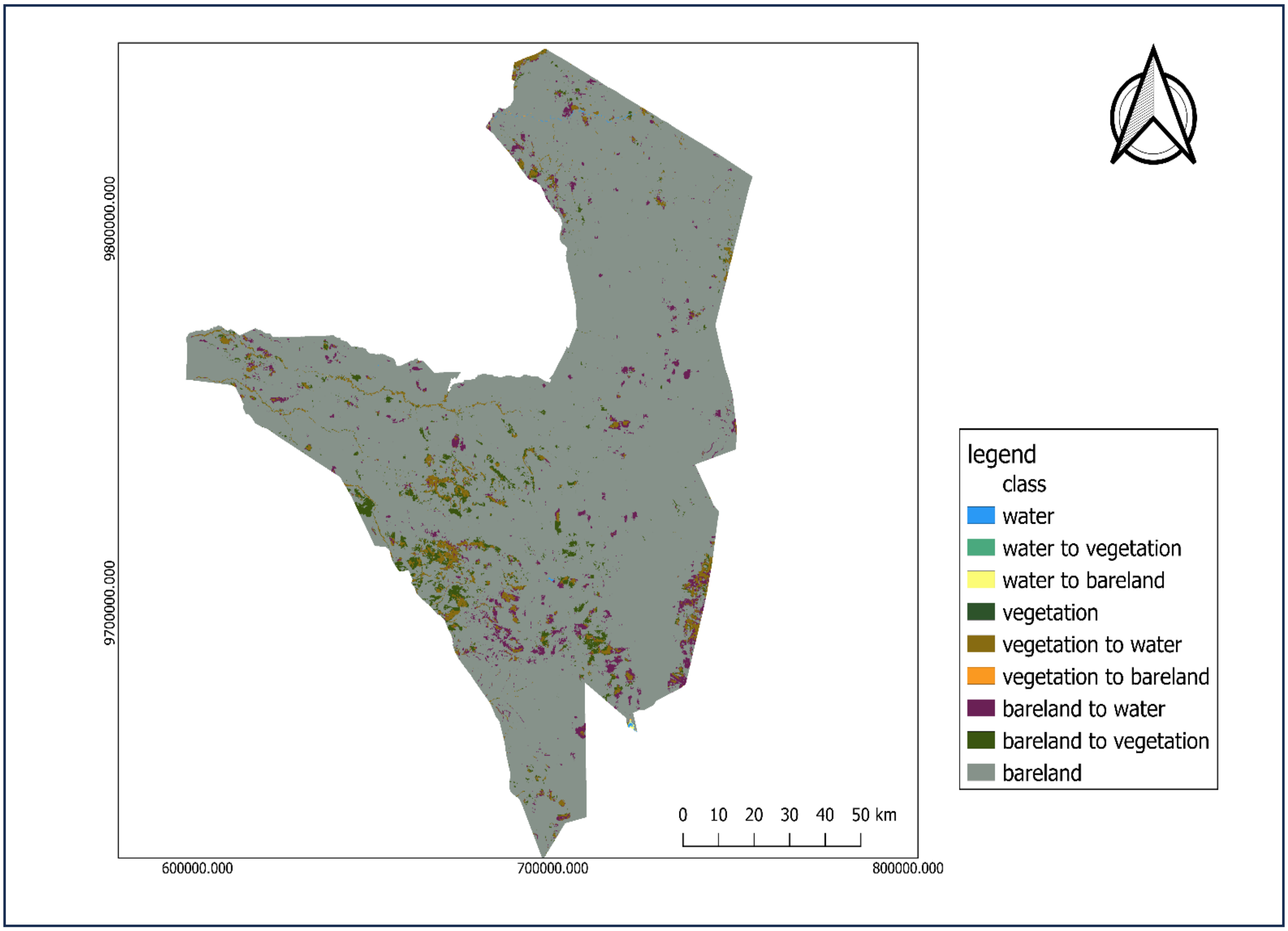

Figure 4.5 2018- 2019 change map

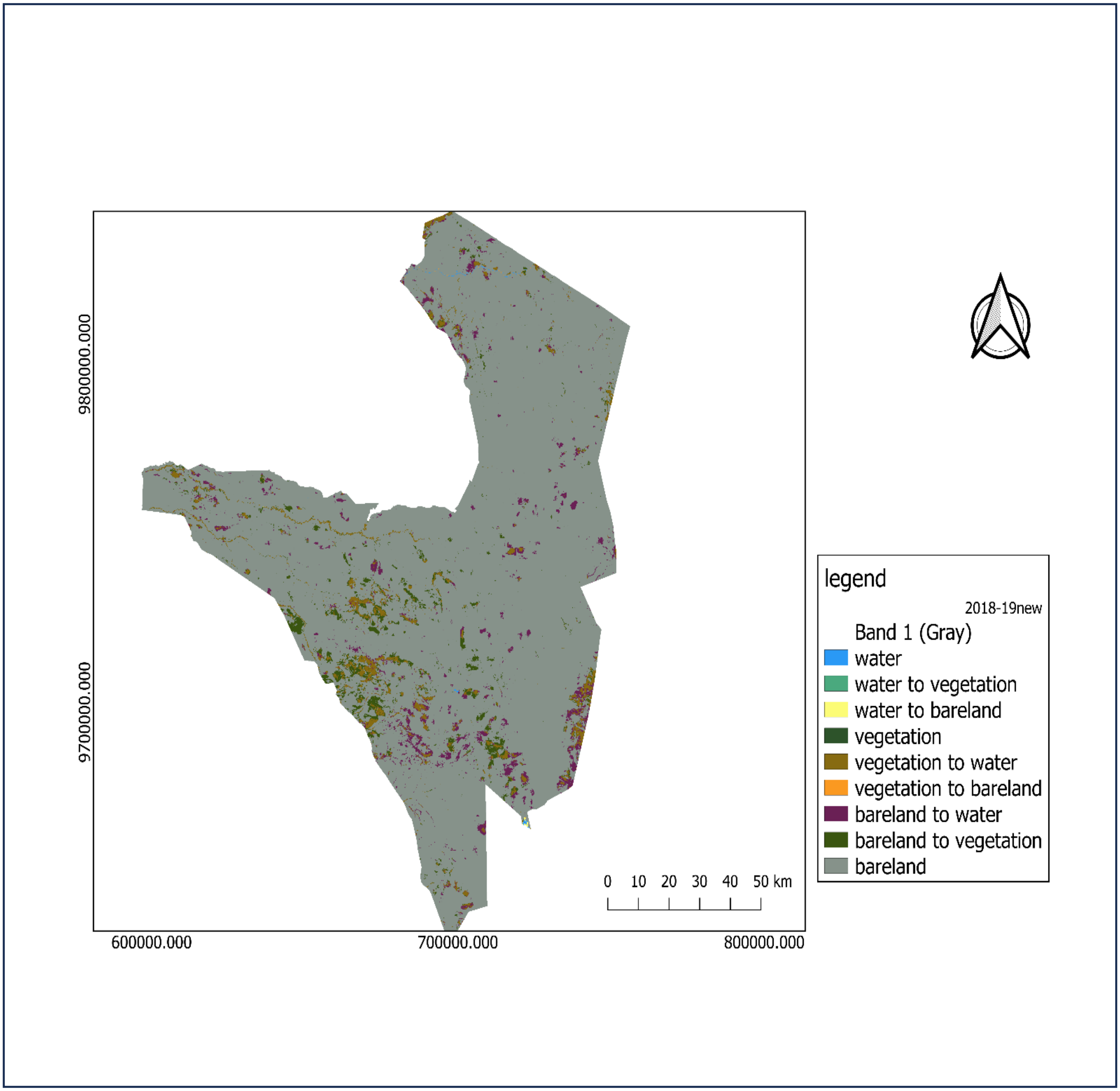

Figure 4.6 2020- 2021 change map

4.1.3 Burn severity maps

Also burn severity Map obtained which shows the areas which are affected by fire for the time period of four years, these map represented based on USGS thresholds of burn severity.

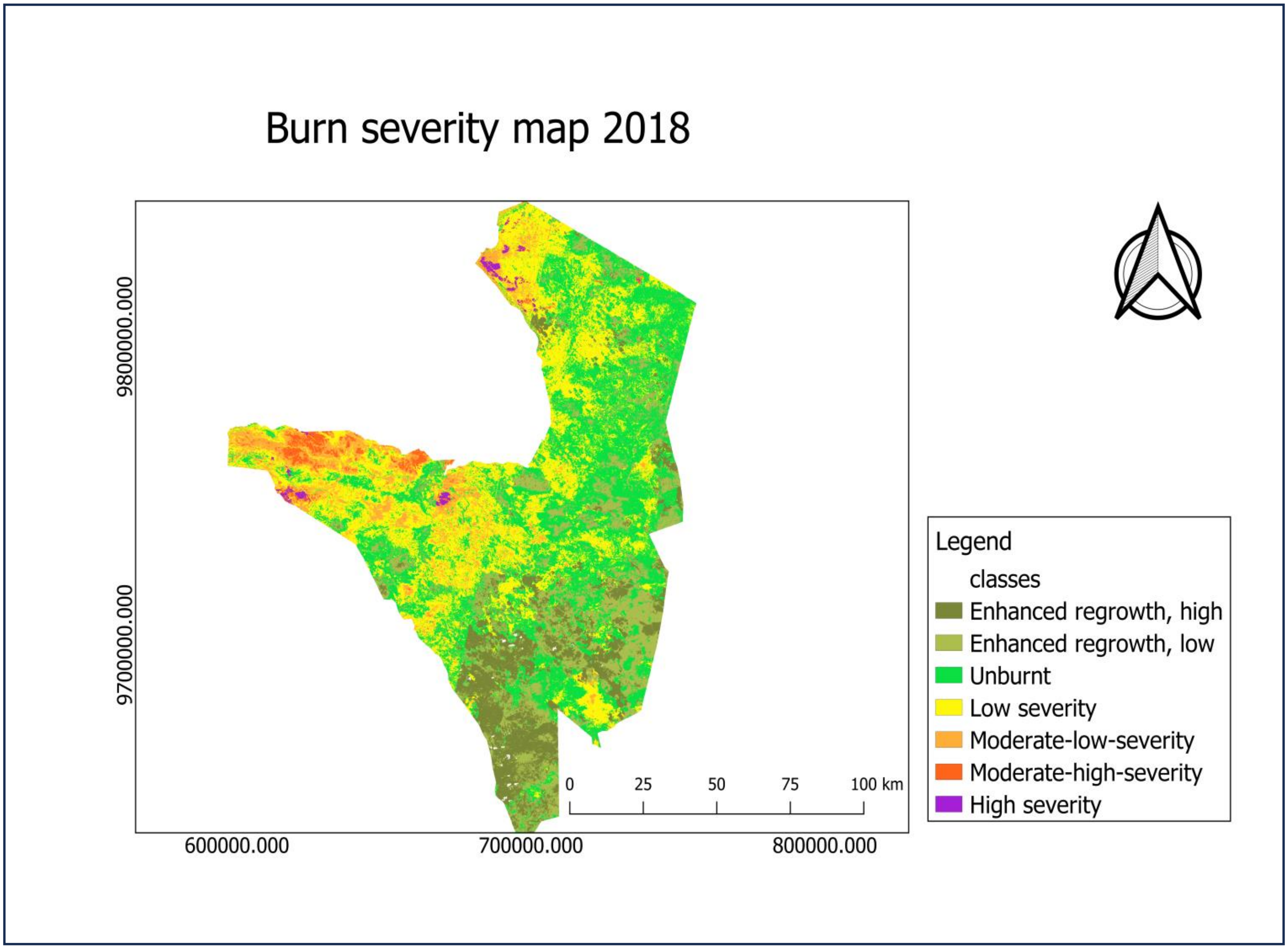

Figure 4.7 2018 burn severity map

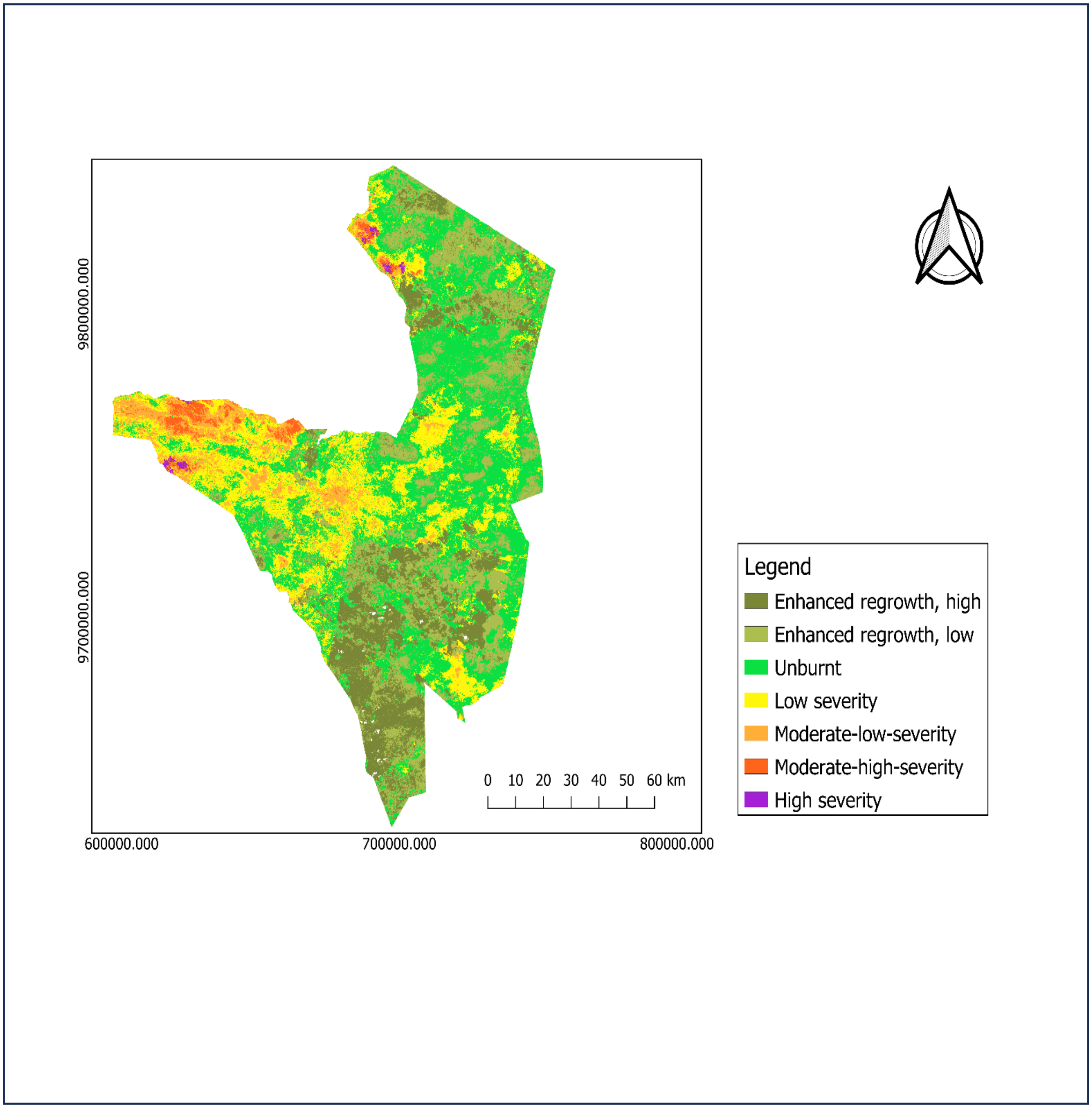

Figure 4.8 2019 burn severity map

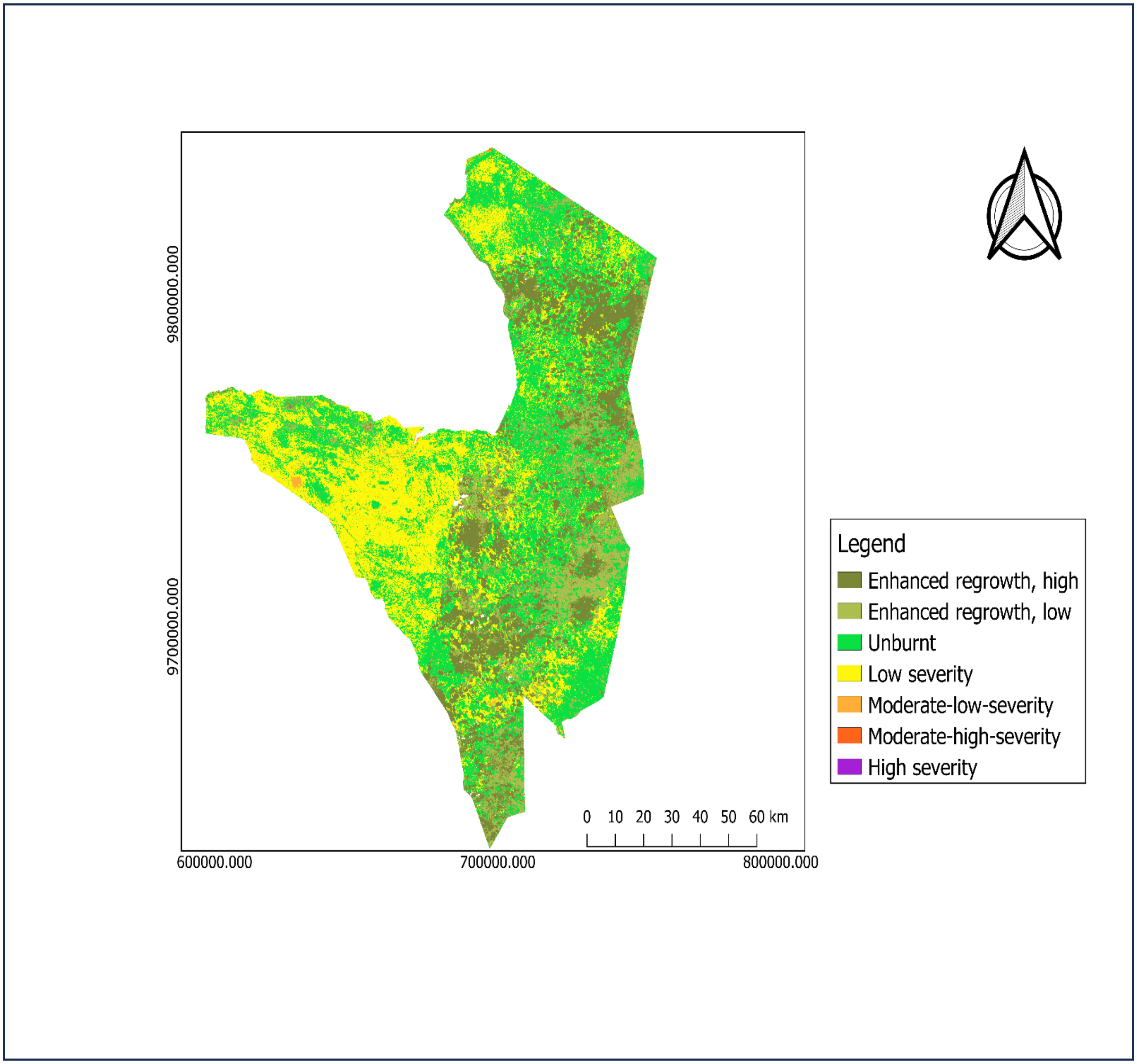

Figure 4.9 2020 burn severity map

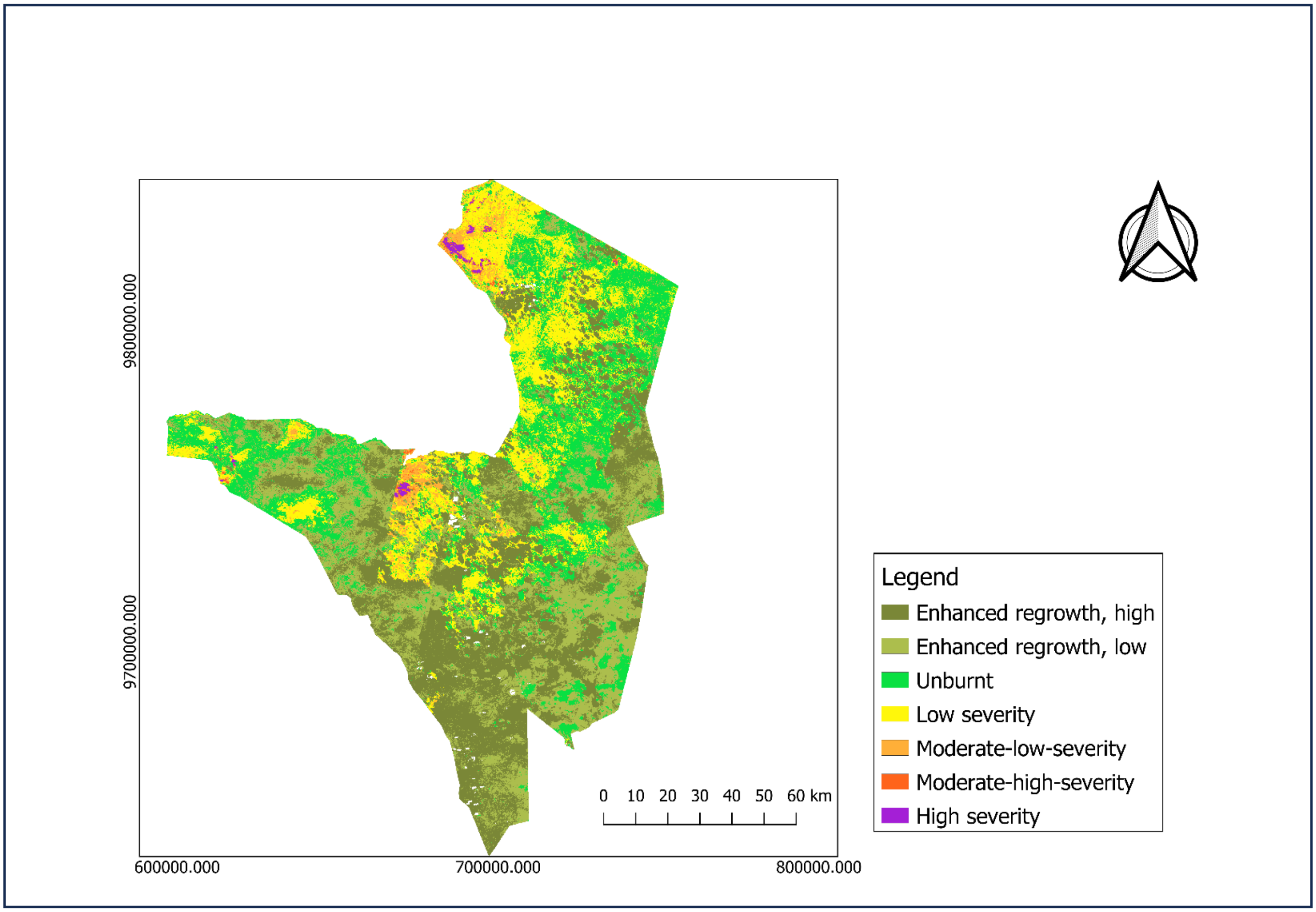

Figure 4.10 2021 burn severity map

4.2 Discussion of results

This study revealed a significant decline in the overall area coverage of vegetation after the incidence of fire. These results align with previous research indicating that fire can have substantial impacts on vegetation dynamics. The observed decrease in area coverage is a cause for concern as it suggests a loss of vegetative biomass and potential disruptions to ecosystem structure and function.

One possible mechanism contributing to the decrease in vegetation area coverage is the intensity and severity of the fire. High-intensity fires can lead to mortality of plants, resulting in a reduced area covered by live vegetation. Additionally, the heat generated by fire may induce changes in soil properties, such as increased soil temperature and altered nutrient availability, which can hinder post-fire regeneration and impede the recovery of vegetation.

The frequency of fire occurrences also plays a crucial role in vegetation change. In fire-prone ecosystems, frequent fire events can prevent the reestablishment of vegetation and result in a progressive reduction in area coverage over time. This cumulative effect of repeated fires disrupts the natural succession processes, leading to changes in the composition and structure of plant communities.

Furthermore, the type of vegetation affected by fire influences the magnitude of the decrease in area coverage. Some plant species are more susceptible to fire damage due to their specific characteristics, such as low fire resistance or lack of fire-adaptive traits. Consequently, areas dominated by these vulnerable species may experience a more pronounced reduction in area coverage compared to areas with fire-resistant vegetation.

Moreover, the reduced area coverage of vegetation can have effects on ecosystem processes. Vegetation plays a critical role in nutrient cycling, water retention, and soil stabilization. A decrease in area coverage may disrupt these functions, resulting in altered nutrient availability, increased soil erosion, and changes in local hydrological regimes.

To address the decrease in vegetation area coverage resulting from fire, effective fire management strategies are crucial. Prescribed burning, for example, can help reduce fuel loads and minimize the occurrence of severe wildfires, thereby mitigating the negative impacts on vegetation. Implementing fire breaks, fuel management techniques, and appropriate land-use planning are additional strategies that can aid in protecting vegetation cover and promoting post-fire recovery.

In conclusion, the research findings demonstrate a significant decrease in vegetation area coverage following the occurrence of fire. This decline has various implications, including habitat loss, altered ecosystem processes, and potential biodiversity impacts. By understanding this we can develop effective management strategies to mitigate the negative effects of fire on vegetation and promote the resilience and recovery of ecosystems. Further research is needed to explore these dynamics in different contexts and to refine our understanding of the relationship between fire and vegetation change.

CHAPTER FIVE

CONCLUSION AND RECCOMENDATION

5.1 Conclusion

The study based on assessing the effects of fire in vegetation change through identifying the areas which are affected by fire and compare it to the changes which have been observed for the period of four years. The Differenced Normalized Burnt Ratio (dNBR) index was used to identify the burnt areas and the areas was categorized based on the thresholds introduced by USGS in order to identify the levels of severity in a particular observed area.

From image classification process, it was found that Serengeti National Park was covered with three main land cover classes which were vegetation, water and bare land, where vegetation covers is about 40% of the whole area. Vegetation was affected mostly by fire than other land cover classes and the level of burning in vegetation differ from one area to another some areas are bunt severely, some areas were not much bunt and areas which are severely bunt experience low recovery rate compare to the areas which are low and medium severity.

5.2 Recommendations

While these research findings highlight the negative impacts of fire on vegetation area coverage, it is important to acknowledge the limitations of our study. Factors such as fire severity, fire history, and the specific characteristics of the study area can influence the magnitude and extent of the observed decrease. Future research should consider these factors to provide a more comprehensive understanding of the dynamics between fire and vegetation change.

Further research are highly recommended to use ground truthing data for validation in order to get more accurate results.

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