ANALYSIS OF FOREST FIRE IN MARGALLA HILLS NATIONAL PARK USING MODIS DATA

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In

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By

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DECLARATION

I hereby declare that the work present in the following thesis is my own effort, except where acknowledged No part of the thesis has been previously presented elsewhere for any other degree.

Date __________

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Ammad Waheed Qazi

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List of Abbreviations and Acronyms

A ll	Total Area Affected By Forest Fire
AVHRR	Advanced Very High Resolution Radiometer
CDA	Capital Development Authority
CH	Chauntara Guzara
DRJ	Darra Janglan
E all	Total Events of forest fire
EOS	End of Season
FAO	Food and Agriculture Organization
FS	Faisal Masjid
GIS	Geographic Information System
GOP	Government of Pakistan
ICT	Islamabad Capital Territory
JB	Jabbi Guzara
KL	Kalanjar Guzara
LOS	Length of Season
LST	Land Surface Temperature
MF	Military Farms
MHNP	Margalla Hills National Park
ML	Malwan Guzara
MODIS	Moderate Resolution Imaging Spectroradiometer
MVSP	MultiVariate Statistical Package
NDVI	Normalized Difference Vegetation Index
NIR	Near Infrared

PCA	Principal Component Analysis
Peak	Peak value (maximum NDVI)
PFI	Pakistan Forest Institute
RF	Reserved Forest
RM	Rumili Guzara
RS	Remote Sensing
SAD	Shah Allah Ditta
SDLS	Standard Deviation of Length of Season
SDNDVI	Standard deviation of Normalized Difference Vegetation Index
SDSS	Standard deviation of Start of Season
SON	Sonari Guzara
SOPs	Standard Operating Procedure
SOS	Start of Season
SPOT	Satellite Pour l'Observation de la Terre
T all	Time of All Forest Fire Events
UCL	Unclassified
VI	Vegetation Index

ABSTRACT

Forest fires in Margalla Hills National Park (MHNP) are one of the most serious threats not only to its natural beauty but also to the native biodiversity The current study was aimed at analysing the spatiotemporal patterns of forest fire in MHNP and its relationship with vegetation phenology The records of forest fire occurrence (1996-2014) were obtained from Environmental Directorate Capital Development Authority (CDA) and analysed for the spatiotemporal trends The total 769 events (duration 3243 hours) of forest fire during prescribed time is approximated to have affected a sum of 2140 hectares of the land area Overall, the months of April (n=82), May (n=248) and June (n=282) represent the periods of most frequent forest fires The year wise variation in Forest Fire revealed that 2009 (n=133), 1998 (n=81) and 2006 (n=76) had frequent forest fires The information on the land surface phenology of the National Park was derived from Moderate Resolution Imaging Spectroradiometer (MODIS) based Normalized Difference Vegetation Index (NDVI) 16-day composite product (MOD13Q1) The phenological parameters such as Start of Season (SOS), End of Season (EOS, Length of Season (LOS) and Peak (NDVI) were derived using 'greenbrown' package in R Statistical Software and then correlated with frequency of fire occurrence using multivariate statistical procedures (Principal Component Analysis (PCA) The analyses revealed that the forest compartments where there were frequent fires, the peak values for NDVI showed increasing trend, whereas, LOS showed decreasing trend in such locations It was also obvious that the vegetation type plays important role in occurrence of fires The compartments led by *Carissa opaca* as dominant vegetation were found severely affected by forest fire, whereas, compartments with high abundance of *Dodonaea viscosa* were found least affected by the forest fire These results of forest fire analysis can be used both as a strategic planning tool to address fire risk concerns, and also as a tactical guide to help Environmental Directorate (CDA) to design fire mitigation measures

1. INTRODUCTION

Forests are one of the most important natural resource and have a vital role in maintenance of environmental balance. Forests provide many direct and indirect services important for the survival of human beings. The health of a forest in an area indicates the ecological conditions of that area. Forests are an important factor in the Earth's ecological balance, economy, biological diversity, water resources and air purity (Shahzad *et al.*, 2015).

Forests also face variety of threats, fire is one of them (Bakırcı, 2010). Fire has been closely associated with mankind from the beginning of civilization. The influence of human caused fires, doubtlessly date back to the arrival of first human in the subcontinent (Ahmed & Sharma, 2014).

Fire is an ecosystem process that effects terrestrial, aquatic, and atmospheric systems all over the world. Wildfires have received major attention because of ecological, economic, social, and political values in past few decades (Lentile *et al.*, 2006).

The main reasons of increase in fire activity are the rise in temperatures over the last few decades and direct human-induced changes in land use and fire suppression. It also effects vegetation patterns (Running, 2006). Climate condition, forest fuels, ignition agents, topography and human activities are five main causes that affect forest fire activity and forest dynamics. Forest fires have impacts on climatic conditions, plant ecosystems and human (Schoennagel *et al.*, 2004).

1.1. Impacts of Forest Fire

Forest Fire has both positive and negative impacts on natural habitat. Forest fires are considered vital natural processes that initiate natural vegetation succession. As a natural process it also serves an important function in maintaining the health of certain ecosystems (Saklani, 2008). The ecological role of fire is to influence several factors such as plant community development, soil nutrient availability and biological diversity (Kumar *et al.*, 2012), (Saklani, 2008). However uncontrolled and misuse of fire can cause tremendous adverse impacts on the environment and the human society (Ahmed & Sharma, 2014). Forest fires are a main source of carbon dioxide emissions with a substantial effect on the global carbon budget (Spracklen *et al.*, 2007).

Fire emissions possess direct and considerable impacts on atmospheric and biogeochemical cycles and the radiative budget of Earth at the global scale (Lentile *et al.*, 2006).

Globally, forest fire is one of the major serious threats to the protected areas Forest fires are non-desired guests which means that preventive and suppressive actions against the fire demands vast resources annually Fires are frequently anthropogenic induced large scale disturbances that affect adversely the biological diversity and establishments of National Parks In some ecosystems like boreal forests, fire is a natural disturbance issue and thus fundamentally contributes to the ecosystem processes (Mirza, 2012)

1.2. Importance of National Parks

A national park is moderately a huge area of stupendous scenic value and natural interests with the key main of protection and preservation of biodiversity in natural state to which access for public, education and research may be allowed There are presently 6.555 national parks on the planet and 21 exist in Pakistan which speak to various ecological districts of the nation and covering around 29.589 km, involving around 3% of the aggregate territory (10.060,96 km2) of the country The national parks are presently being considered as the environmental research laboratories They save the nature and guarantee the biological strength of the earth due to the increasing threats to nature such as climate change, global warming, forest fire, population expansion, habitat destruction and worldwide loss of biodiversity National parks are the perfect spots for Eco-tourism, animals and birds watch and nature photography National parks with their lavish green woodland segments keep up the carbon discharges in the bordering situations (Mirza, 2012) National parks and fire have an intimate and unbreakable relationship"

1.3. Forests and Forest Fires Situation in Pakistan

Pakistan is going through serious forest depletion As per FAO (FAO, 2009), 2 2% or around 16,870 km^2 zone of Pakistan is forested with 3,400 km^2 of planted forests

State and private/community owned are the two main categories of forests that exists in Pakistan A sum of 66% of the forest area is overseen by the State forest division, while 34% is in private possession (FAO, 2009) The state owned forest land has been legally categorized into five classes state, reserved, protected, un-classified and resumed lands The private/community forestland has been classified as guzara forests, communal forests (Wani, 2002)

Forest fires are very regular in Pakistan A study led by Pakistan Forest Institute (PFI) in 2000 stated that a region of 49,986 ha, i e 1 27% out of 3 950 million ha, overviewed was influenced every year by forest fires

Islamabad is the only premeditated city of Pakistan and its green temperament distinguishes it from other cities of the country as well as in the world (CDA, 2012a) Margalla Hills Range situated in Islamabad is of great concern as it has increased its scenic beauty and it has a lot of importance for diverse species Unfortunately, fire at the Margalla Hills has become a common aspect of summer season It not only destroys the natural beauty of the Hills but also has severe impacts on the wildlife (Iqbal, 2012)

During the summer season, the CDA makes struggles to conserve and preserve Margalla Hills In order to deal with the fire incidents and to overcome the threats of forest fire in Margalla Hills the CDA has taken certain concrete measures During the fire season CDA has to be vigilant to protect the rich biological diversity and fauna flora of Margalla Hills (CDA 2012b)

1.4. Phenology and Phenological Parameters

Phenology is the study of the times of recurring natural phenomena, i e , the date of emergence of leaves and flowers, and the date of leaf coloring and fall in deciduous trees (Tan *et al* , 2011)

Certain parameters linked with vegetation phenology can be measured effectively with time series of remotely sensed data One of them is start of season (SOS) Different trends of SOS can be derived from time series, including the time at which NDVI values increase beyond a certain threshold (White *et al* , 1997), the time at which the curve starts to increase (Moulin *et al* , 1997) and maximum growing season slope (Zhang *et al* , 2003) Other phonological parameters measured by time series include end of season (EOS), the date of NDVI (max) Length of growing season (LOS) can be measured as the difference between EOS and SOS Relative annual productivity has been calculated using average annual NDVI Trends and inter annual variability over the time series are dependent upon these measures of seasonality (Bradley & Mustard, 2008)

The NDVI is considered as a reliable indicator for land cover conditions and variations obtained from the visible (red) and near infrared (NIR) by using the following formula NDVI = (NIR−RED)/(NIR + RED) (Myneni *et al* , 1998), (Huemmrich *et al* , 1999), (Cuomo *et al* , 2001), (Lanfredi *et al* , 2003) In vegetation monitoring, NDVI was widely used over the years For example, (Lambin & Strahlers, 1994), (Lasaponara, 2006) found that NDVI suitably detects interannual variations in process occurring at the scale of the season

1.5. Problem Statement

Although fires are beneficial for some ecosystems, but they are known to cause biological, socio-economic damages and consequently biological diversity losses (Rowell & Moore, 2000) Forest fires have been a pervasive phenomenon in MHNP The monitoring and management of forest fires is the responsibility of Fire Division of CDA's Environment Directorate The record is maintained manually which includes date/time of fire incident, cause of fire and area burnt in the relevant forest compartment The forest division has developed an action plan to manage the forest fires that includes maintenance of standard operational procedures (SOPs) for fire management at departmental level including local community participation by making village fire prevention committees (CDA, 2012a) The departmental efforts for fire prevention so far have not been proved effective to reduce fire frequency and intensity in MHNP

1.6. Objectives of the Study

The present study was focused on following objectives

- To analyse the Spatio Temporal patterns of forest fire in Margalla Hills National Park
- To identify the impacts of forest fire on vegetation using MODIS data

2. LITERATURE REVIEW

2.1. Causes and Effects of Forest Fire

Over hundreds of years fire has been viewed by many as an environmental horror Fire has been linked with reduced soil fertility, destruction of biodiversity, global warming and damage to forests, land resources and of course human assets (Rights, 1999)

Forest fires occur either because of anthropological or natural causes The majority of fires around the globe are caused by human activity Lightning is probably the most common natural cause of fire It has been estimated that annually fires burn across up to 500 million hectares of woodland, open forests, tropical and sub-tropical savannahs, 10-15 million hectares of boreal and temperate forest and 20-40 million hectares of tropical forests (Goldammer, 1995)

Fire is one of the oldest tools known to humans It has been used as a management technique in land clearance for centuries For the thousands of farmers, ranchers and plantation owners on the edge of the agriculture frontier pushing into forests, fire is the obvious mechanism It is normally the least expensive and most effective way of clearing vegetation and of fertilising nutrient poor soils Fires are normally lit at the end of the dry season and under most normal conditions these fires can be controlled However if the rains fail, as they do in many parts of the tropics in El Niño years, the results can be catastrophic, as the fires burn out of control Fire is a paradox - it can kill plants and animals and cause extensive ecological damage, but it is also extremely beneficial, the source of forest regeneration and of nutrient recycling Fire, the experts say is nature's way of recycling the essential nutrients, especially nitrogen For many boreal forests, fire is a natural part of the cycle of the forest, and some tree species, notably Lodge pole Pine and Jack Pine are "serotinous" -their cones only open and seeds germinate after they have been exposed to fire Mountain ash, a flowering tree of temperate Australia, also requires a site to completely Burn and be exposed to full sunlight for the species to regenerate Fire in these circumstances is essential Burning quickly decomposes organic matter into mineral components that cause a spurt of plant growth, and can also reduce disease in the forest (Gorte, 2000) But it is important to remember that fires under extreme weather conditions can be devastating to these forests

In contrast, fire causes severe damage to tropical forest ecosystems, which are characterised by high levels of humidity and moisture They do not normally burn and are

2.2. Remote Sensing

Remote sensing (RS) is a technique that uses a sensing device to gather the information on given objects or phenomena from afar without physical contact Hand held cameras photographic instruments installed in aircrafts, and satellite sensors are devices that can be used in data gathering RS technology allows us to collect large scale data of biological phenomenon from inaccessible regions (Campbell & Wynne, 2011).

Remote Sensing technology offers an overview of the phenological condition of the earth surface in macro perspective, however it doesn t capture the detailed phenophases of individual plants Two major concerns of using remote sensed images in phenology are 1) the lack of ground observation data for validation, and 2) inconsistency of image quality (Badeck *et al*, 2004) Apart from ground observation, validation is also conducted by comparing the results with images with finer temporal and spatial resolution (De Beurs & Townsend 2008) To improve the image quality, new approaches have been developed to filter noise and optimize the satellite signal (Chai, 2011)

The Advanced Very High Resolution Radiometer (AVHRR) series is the first set of satellite sensors that have a frequent repeat cycle and synoptic information suitable to monitor land surface vegetation phenology across large areas (White *et al*, 1997) The Moderate Resolution Imaging Spectroradiometer (MODIS) provides a more comprehensive data source to study land surface phenology at continental and global scales The Moderate Resolution Imaging Spectroradiometer (MODIS) is carried by two platforms the Terra and Aqua satellites, launched in 1999 and 2002 MODIS is a multi-spectral sensor It has 36 bands with spatial resolution ranges from 250 to 1000 meters (Chai 2011)

2.3. Moderate Resolution Imaging Spectroradiometer (MODIS)

MODIS (Moderate Resolution Imaging Spectroradiometer) is a key instrument aboard the Terra (EOS AM) and Aqua (EOS PM) satellites Terra MODIS and Aqua MODIS are viewing the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands, or groups of wavelengths. The instruments capture data in 36 spectral bands ranging in wavelength from 0 4 μm to 14 4 μm and at varying spatial resolutions (2 bands at 250 m 5 bands at 500 m and 29 bands at 1 km) The design of the land imaging component combines characteristics of the Advanced Very High Resolution Radiometer (AVHRR) and the Landsat Thematic Mapper, adding spectral bands in the middle and long-wave infrared (Barnes *et al*, 1998) In our research, we use MODIS data to analyse the relationship of forest fire and NDVI (Normalized Difference Vegetation Index), LST (Land surface temperature) The NDVI and LST were considered useful for the forest fire risk assessment (Verbesselt *et al*, 2002) Usually the fuel moisture content is directly connect with the forest fire risk, high moisture content increased the heat required to ignite a fuel, since some of this energy is used to evaporate water Additionally, the most sensible variable for fuel moisture content is based on the combination of vegetation indices and surface temperature (Zheng *et al*, 2010)

3. RESEARCH METHODS

3.1. Study Area

Margalla Hills National Park (MHNP) was the study area chosen for current assessment (figure 3 1) It is situated in the Islamabad capital territory (ICT), forming its northern boundary Occupying an area of 15883 hectares, the park extends between 33 68° - 33 81° N latitudes and 72 86° – 73 17° E longitudes

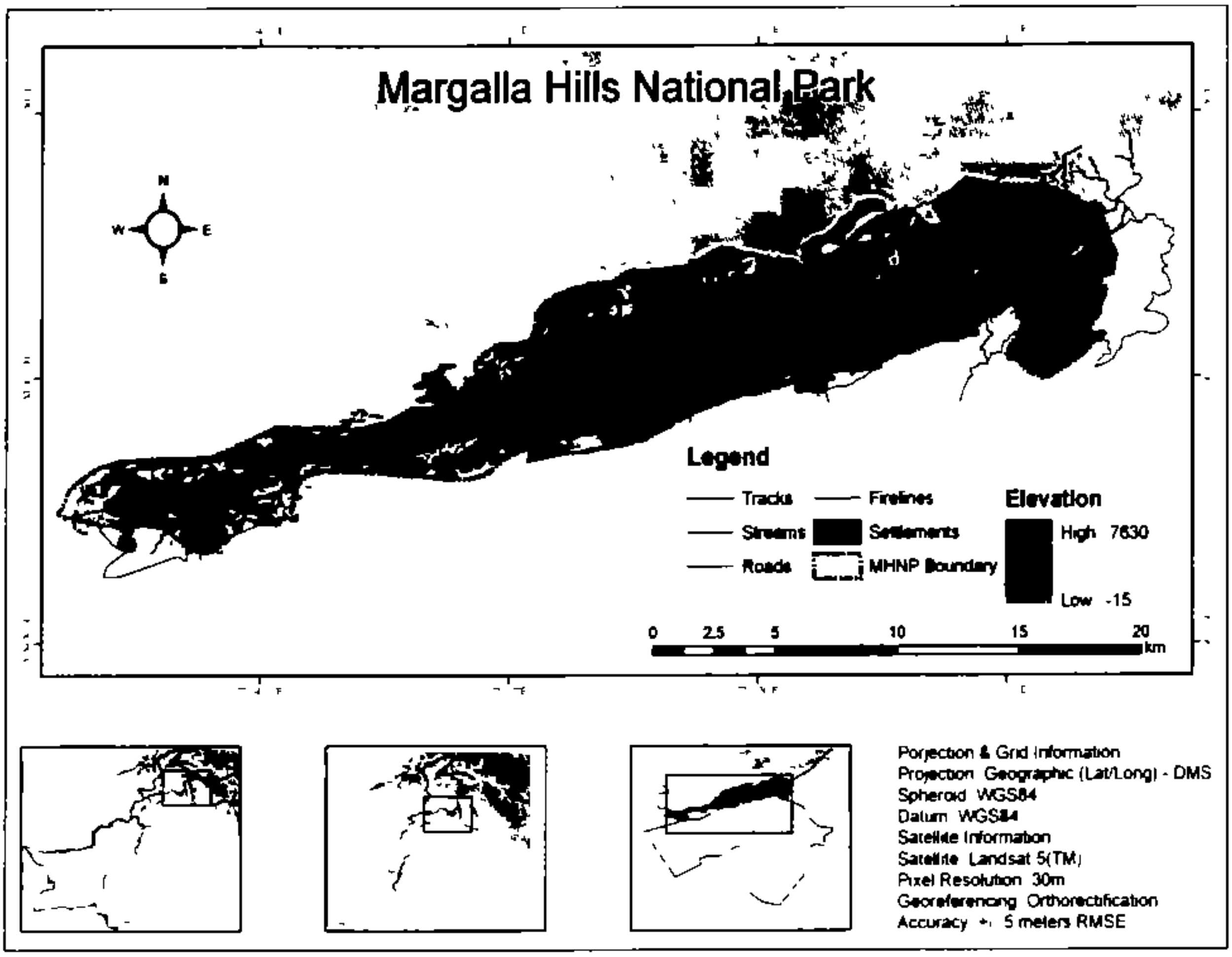

Figure 3. 3 Map of Study Area Margalla Hills National Park

The topography of the MHNP is rugged and include steep slopes and gullies The altitude differ from 465 m above mean sea level (m asl) to 1600 m asl The MHNP falls in the far end of monsoon zone and the heft of monsoon precipitation occurs in July and August, with monthly average of 267 and 309 mm respectively The average maximum and minimum temperature are 33 3 and 19 5°C, respectively The months of May and June are hottest months, when the temperature may raise up to 42°C and December and January are the coldest months when temperature falls below zero (Jabeen *et al*, 2009)

The vegetation of MHNP consists of subtropical, semi evergreen type forest The area hosts about 608 species of plants, 250 species of birds, 38 mammals, 13 taxa of reptiles and numerous taxa of insects The vegetation above 1000 m elevation falls in subtropical chir pine zone and comprises of pure stands of Chir (*Pinus roxburghii*) The dominant species include *Olea cuspidate* (Kao), *Acacia modesta* (Phulai), *Adhatoda vasica* (Bhaikar), *Carissa opaca* (Granda) and *Dodonaea viscosa* (Sunatha) (Mgt Plan, 1992)

3.2. Datasets

Forest fire is one of the most serious threats to biodiversity of MHNP In order to analyse the spatio-temporal pattern of forest fire in MHNP and its overall influence on vegetation, following data were used

(1) Forest fire data obtained from Directorate of Environment CDA, Islamabad and includes occurrence time and duration of forest, as well as, area affected by the fire between years 1996 to 2014

(2) Moderate Resolution Imaging Spectroradiometer (MODIS) based vegetation index data MOD13Q1 time-series i.e , 16 day composite vegetation index at resolution of 250 m was used as proxy to vegetation (available since Feb 2000 – and up till 2014 was obtained to make it comparable with forest fire data) The time-series comprised of 342 NDVI images (23 images/year, except 2000) was obtained from The Oak Ridge National Laboratory (https //daac ornl gov/MODIS/) and,

(3) Vegetation type (communities) data (Nimra & Sadaf, 2012) The study describes the spatial distribution of major vegetation types (seven plant communities based upon dominant species)

Table 3.1: Vegetation communities of Margalla Hills National Park representing dominant and codominant species along with elevation (Nimra & Sadaf, 2012)

S. No	Community	Elevation m (mean)	Dominant Species	Co dominant Species	Herbs	Shrubs	Trees
1	C1	727-1035 (838 9)	*Ailanthus altissima*	*Justicia adhatoda*	25	25	50
2	C2	621-1229 (821 3)	*Dodonaea viscosa*	*Carissa opaca*	35	10	55
3	C3	568-1168 (838 9)	*Carrisa opaca*	*Justicia adhatoda*	33	20	53
4	C4	542-1191 (757 9)	*Dodonaea viscosa*	*Carrisa opaca*	31	27	58
5	C5	829-1242 (1067l)	*Dodonaea viscosa*	*Justicia adhatoda*	31	27	58
6	C6	928-1090 (1017)	*Dodonaea viscosa*	*Punica granatum*	18	40	58
7	C7	758-1352 (1071)	*Dodonaea viscosa*	*Pinus roxburghii*	33	30	40

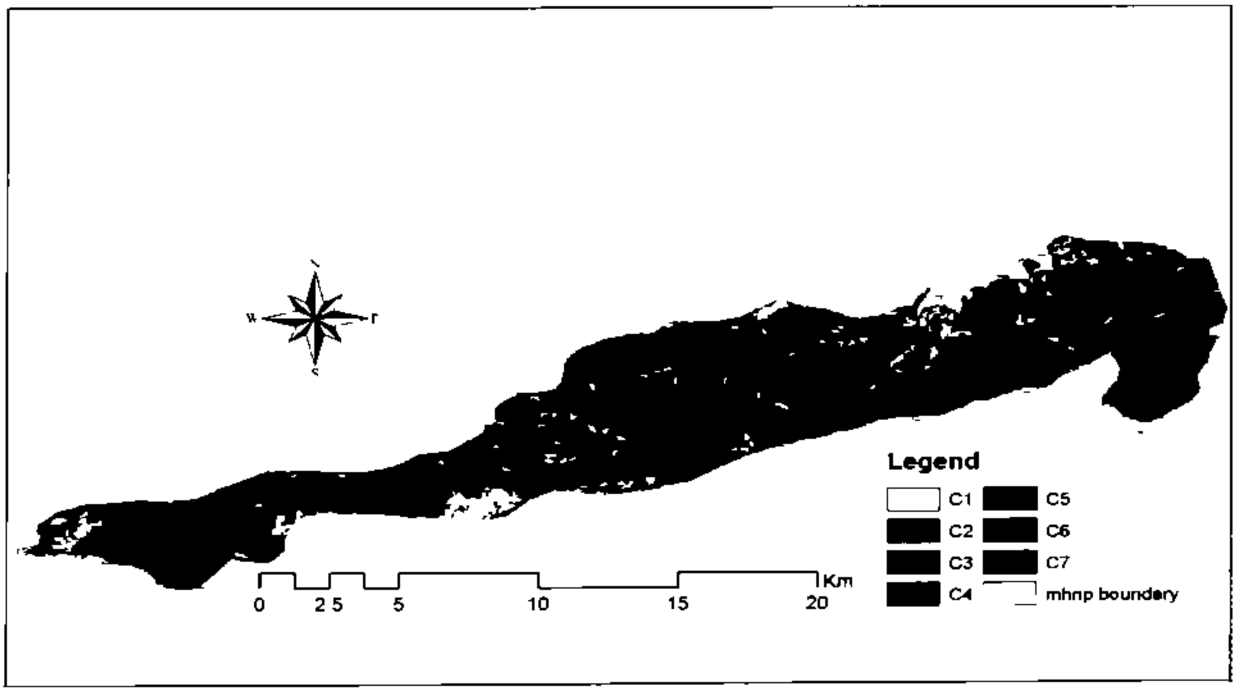

Figure 3 4· Map of Vegetation communities of MHNP The description of each community is given in table 3 1

3.2.1 Pre-processing of MODIS NDVI Time-Series Data

In order to select only cloud-free data of highest quality from MODIS time-series, quality assurance data available with the series were used to reject the pixels with 'VI Usefulness' index between 7 and 15 (Huete *et al*, 2002) The missing values were then replaced by linear interpolation of neighbouring values (Verbesselt *et al*, 2002) The MODIS time-series images were then smoothed by the means of temporal filtering in software TerrSet version 18 0 (IDRISI, 2015)

3.3. Data Analysis

3.3.1. Forest Fire Data Analysis

The forest fire data was compiled in MS Excel for analysis and visualization The numbers of fire event, affected area and duration of fire were summarized for each compartment for year wise and month wise comparison

3.3.2. Analysis of Land Surface Phenology

The MODIS time-series was subjected to analysis to extract phenological metrics in R for windows using greenbrown package (Forkel *et al*, 2013) Following parameters were extracted for every year

a) Start of Season (SOS)

b) End of Season (EOS)
c) Length of Season (LOS)
d) Maximum NDVI Value (PEAK)

The metrics were than summarized for each respective compartment and compared with fire occurrence data for each compartment using Principal Component Analysis (PCA)

3.3.3. Statistical Trends of Phenological Parameters

The trends in phenological metrics were derived by linear regression using the following equation

$$Y = bx + a$$

Where Y is the predicted score, b is the slope of the line, A is the Y intercept and X is independent variable The statistical variables like Mean, Median, Mode and Standard deviation of each parameter were derived for each compartment using R for windows version 3 1 2

3.3.4. Impacts of Forest Fire on Vegetation Phenology

In order to understand the impacts of forest fire on vegetation phenology in MHNP, a correlation analysis was applied to examine the relationship between fire data and phenological parameters (Zhao *et al*., 2015) Out of three variables of forest fire i e total number of fire events (E all), total duration of fire (T all) and total affected area (A all), T all was chosen to be representative of forest fire as all the related variables were highly correlated with each other The phenological parameters chosen were Mean of SOS, EOS, LOS, NDVI, and Standard Deviation (SD) of SOS, LOS and NDVI

The relationship of T all with phenological parameters were established using Principal Component Analysis (PCA). The PCA was carried out in R for windows For each of the compartment, the dominant vegetation was determined by taking Mode of the individual cell values of vegetation type raster laying under each of the compartment Thus each compartment represented the dominant vegetation type The vegetation types were than overlaid upon sites in PCA biplot (Figure 4 25) to have a visual display of correlation of vegetation types with phenological parameters or forest fire

3.3.5. Cartography

All the raster analysis were performed in R statistical software version 3 1 2 ("sp" and "raster" packages) and the cartography was done in software ArcGIS 10 2 (ESRI, 2013)

4. RESULTS

4.1. Analysis of Forest Fire

4.1.1. Margalla Hills National Park

Margalla Hills National Park (MHNP) is situated in the Islamabad capital territory (ICT), forming its northern boundary Occupying an area of 15883 hectares, the park extends between 33 68° - 33 81° N latitudes and 72 86° – 73 17° E longitudes

For the purpose of management MHNP is divided into 85 compartments in 4 categories (Figure 4.1) These are Reserved Forests (RF, n= 41), Military Farms (MF, n= 25), Guzara (n= 15), and Unclassified (UCL, n= 4)

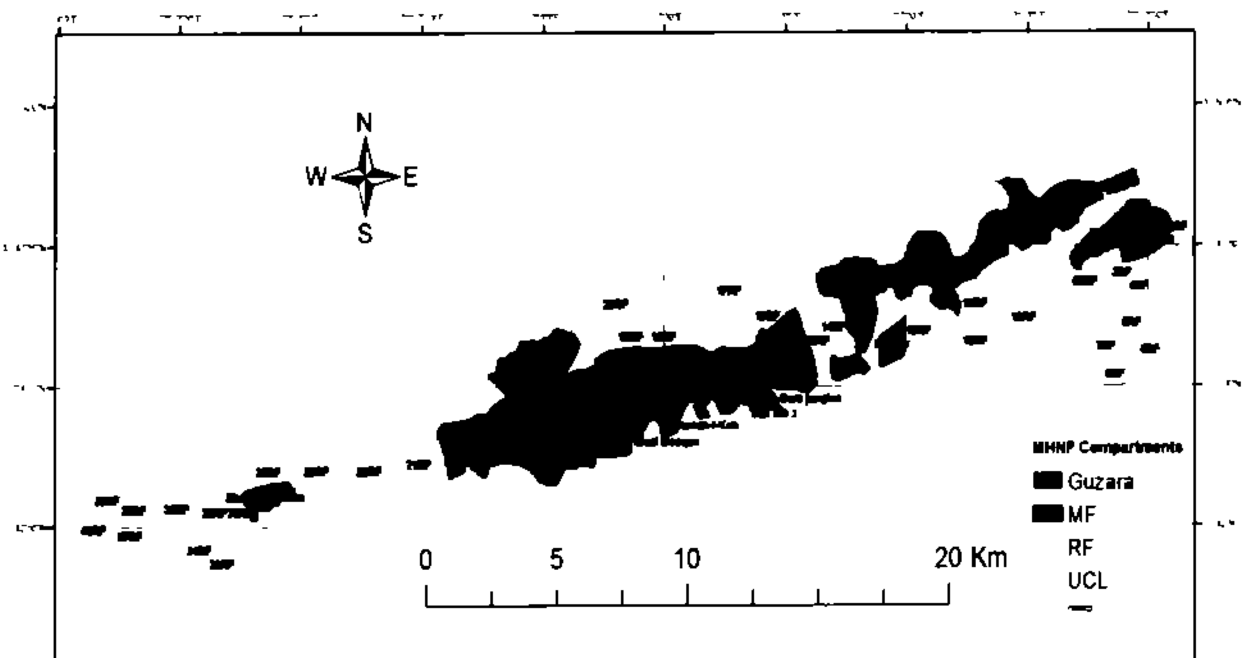

Figure 4. 6: Compartments of Margalla Hills National Park (CDA, 2014)

4.1.2. Forest Fire Events (1996-2014)

The results of forest fire analysis revealed that 769 events of forest fire occurred in Margalla Hills National Park (MHNP) between 1996 and 2014 (figure 4 2) The total area burnt during these events is approximated to be 2140 hectares and spread over duration of 3243 hrs There were 11 compartments which were affected once or not affected at all by forest fire (RF 20, RF 21, RF 22, RF 23, RF 31, RF 33, RF 34, RF 37, RF 38, RF 39 and RF 41) Whereas some compartments had multiple events of forest fire The results shows that MFs are most affected by forest fires, (n= 488/769) events of forest fire occurred in MFs, which are 63% of total events The compartments where most events occurred are MF 15 (n=52), MF 10 (n=45), MF 23 (n=34) and MF 22 (n-32)

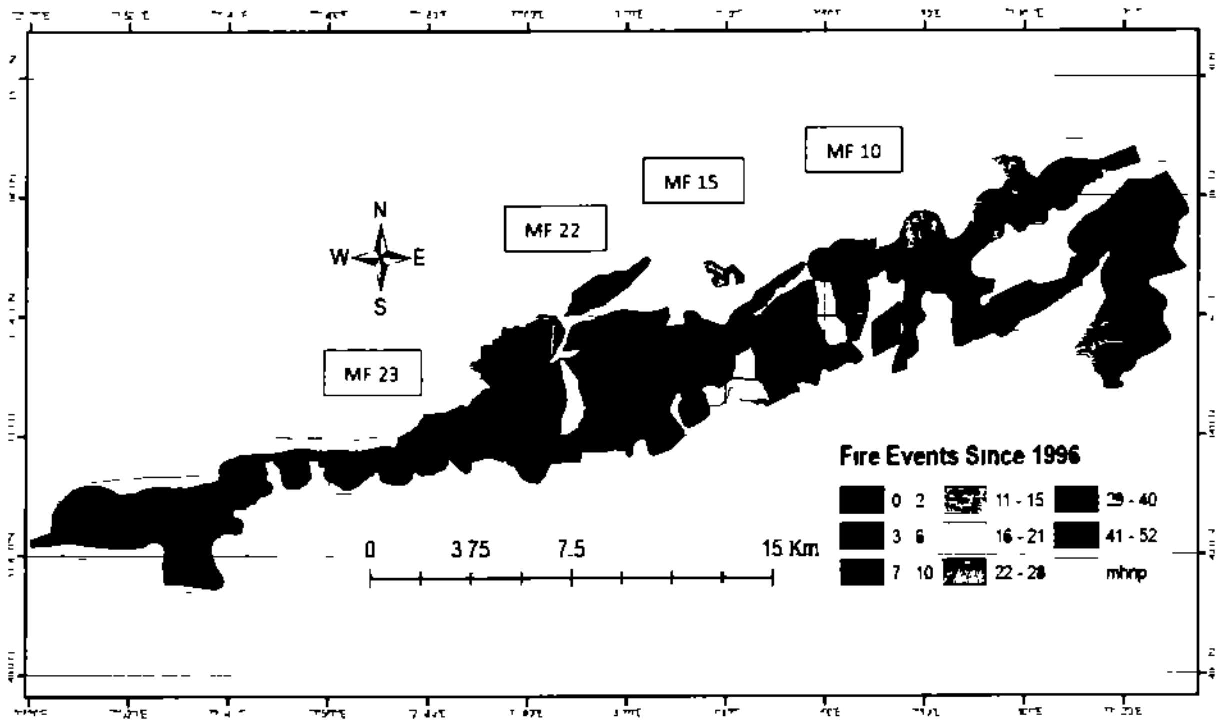

Figure 4. 7: Total number of Forest Fire Events in MHNP (1996 to 2014)

4.1.3. Overall Area Affected by Forest Fire (1996-2014)

The overall affected area of MHNP by forest fire is 2140 hectares (1996-2014) The most affected compartments were MF 23 (n= 166 63) and MF 22 (n=131 27) Whereas there were 11 compartments which were not affected by forest fire (Figure 4 3)

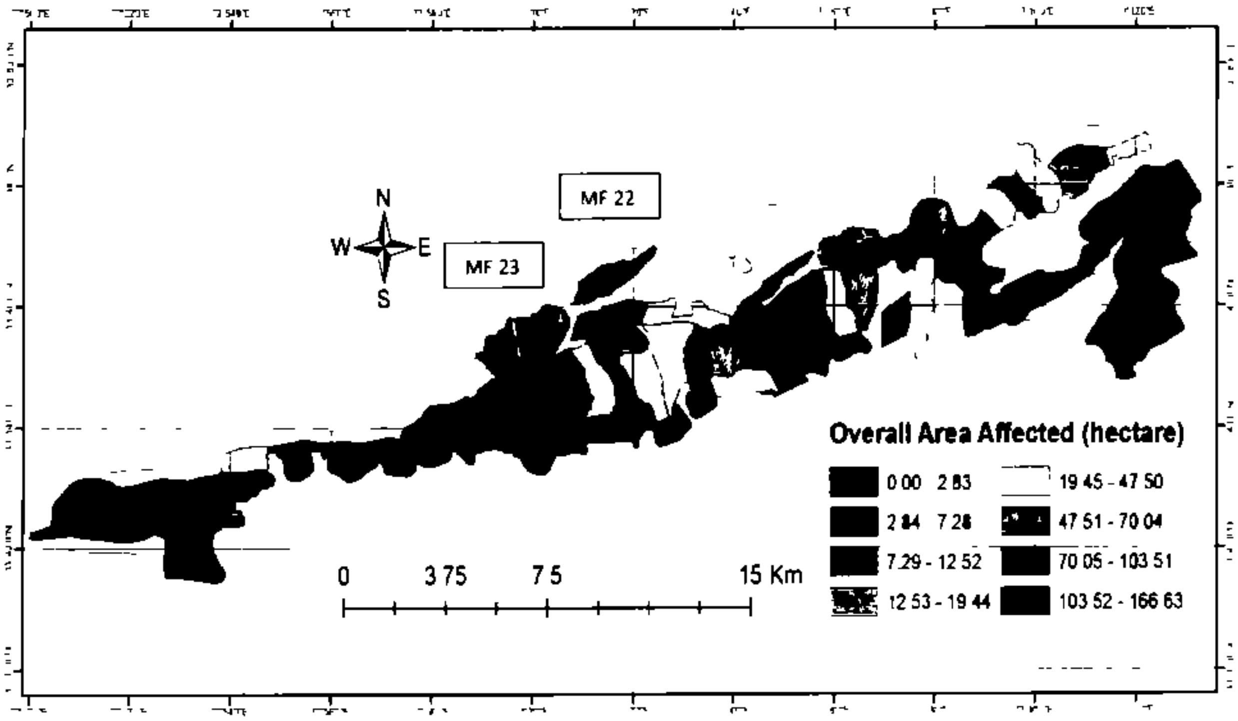

Figure 4. 8: Overall area of MHNP affected by Forest Fire (1996 to 2014)

4.1.4. Duration of Forest Fire Events (1996-2014)

Total duration of forest fires in MHNP is 3243 hrs (1996-2014) The compartments with high duration of forest fire are MF 22 (n=212 3hrs), MF 23 (n=185 2hrs) and MF 10 (n=199hrs) There are 11 compartments with 0hrs of forest fire as they were affected once or not affected at all (figure 4 4).

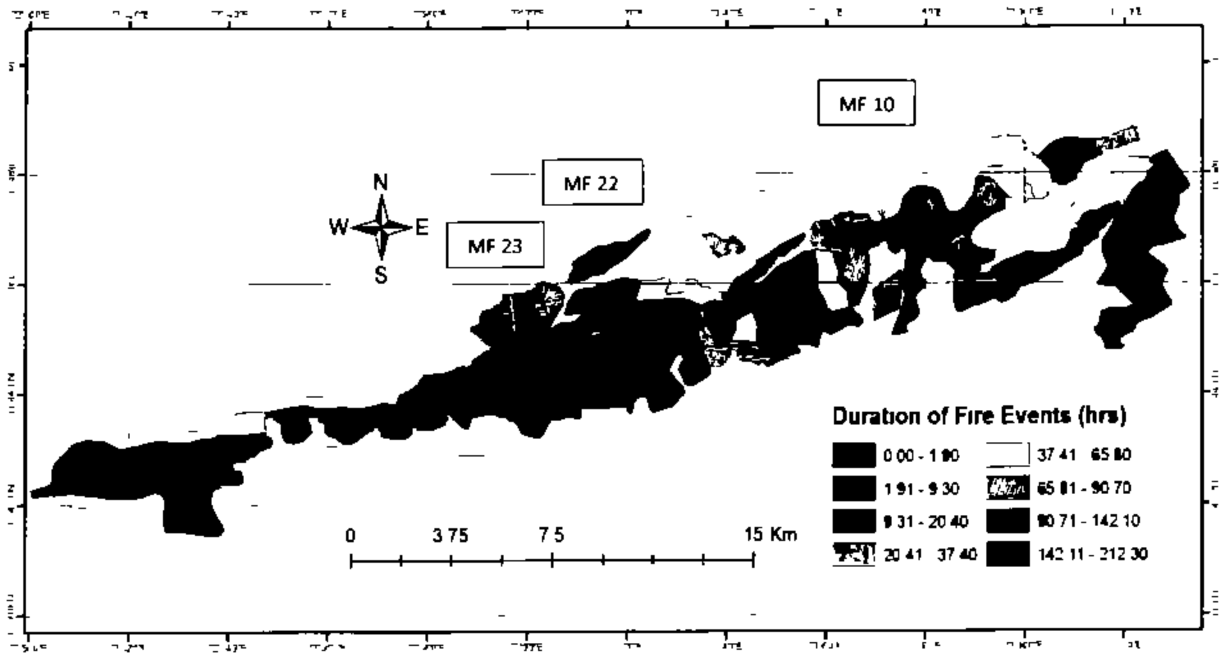

Figure 4. 9: Total duration of Forest Fire Events in compartments of MHNP (1996 to 2014)

4.1.5. Number of Forest Fire Events (Year wise comparison)

The results revealed that MHNP was affected 769 times by forest fire between 1996 to 2014 Most forest fire events occurred in 2009 (n=133) where as 2013 (n=6) experienced less forest fire (figure 4 5)

The year wise comparison (Figure 4 6 (a,b,c,d,e)) of fire events in comparmnets of MHNP from 1996 to 2014 revealed that in 2009, 241 hectares of area was burnt, MF 23 (n=12) was most affected compartment (figure 4 6 d) In 1998, 81 events occurred and 318 hectares of areas was affected, MF 15 and RF 18 (n=8) were most affected compartments (figure 4 6 a) In 2014, 18 events occurred and 14 7 hectares of area was affected, MF 07 (n=4) was most affected by forest fires (figure 4 6 e)

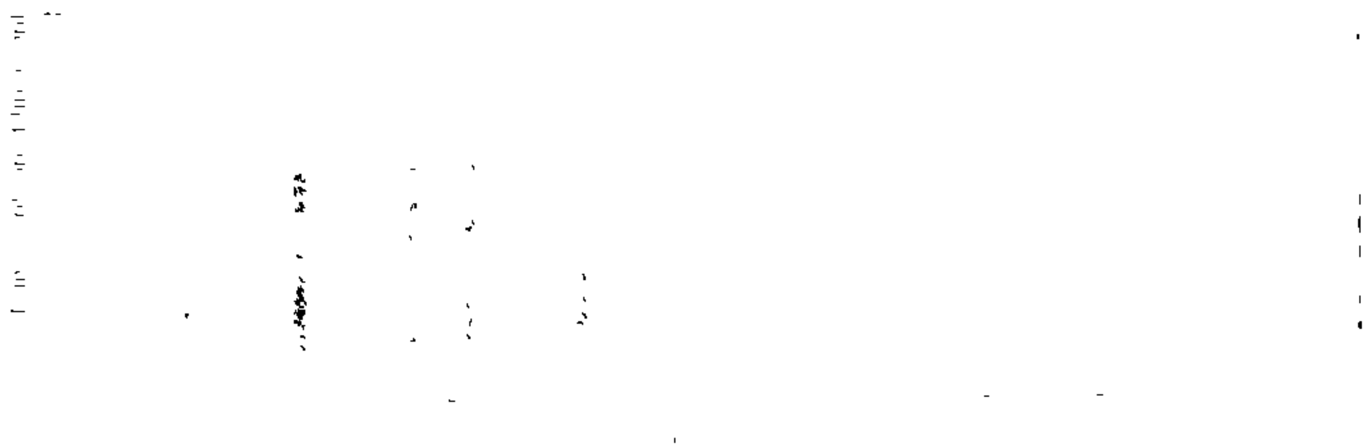

Figure 4 10. Total number of Forest Fire Events in MHNP year wise comparison (1996-2014)

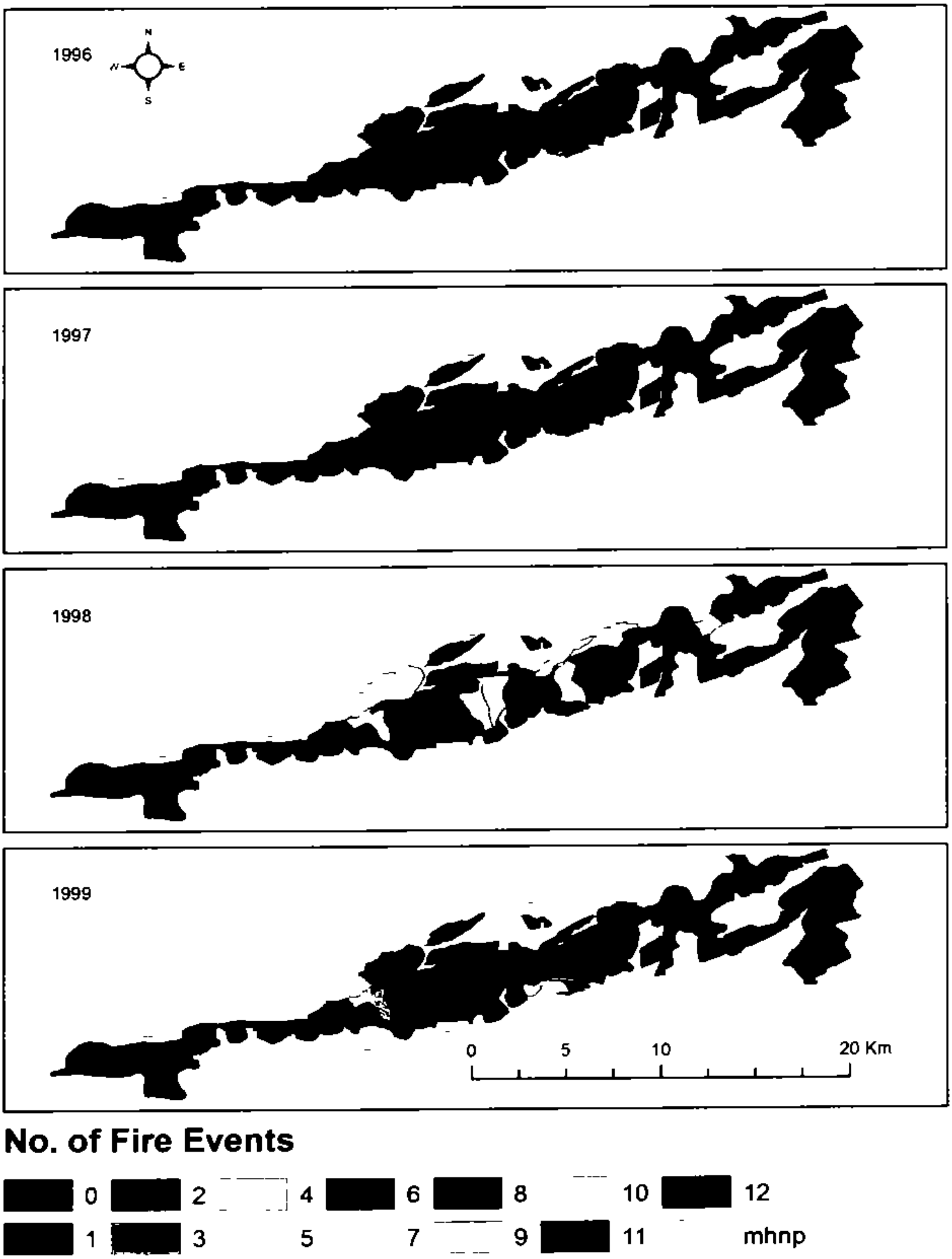

Figure 4.6 f: Total number of Forest fire events in compartments of MHNP year wise comparison (1996-1999)

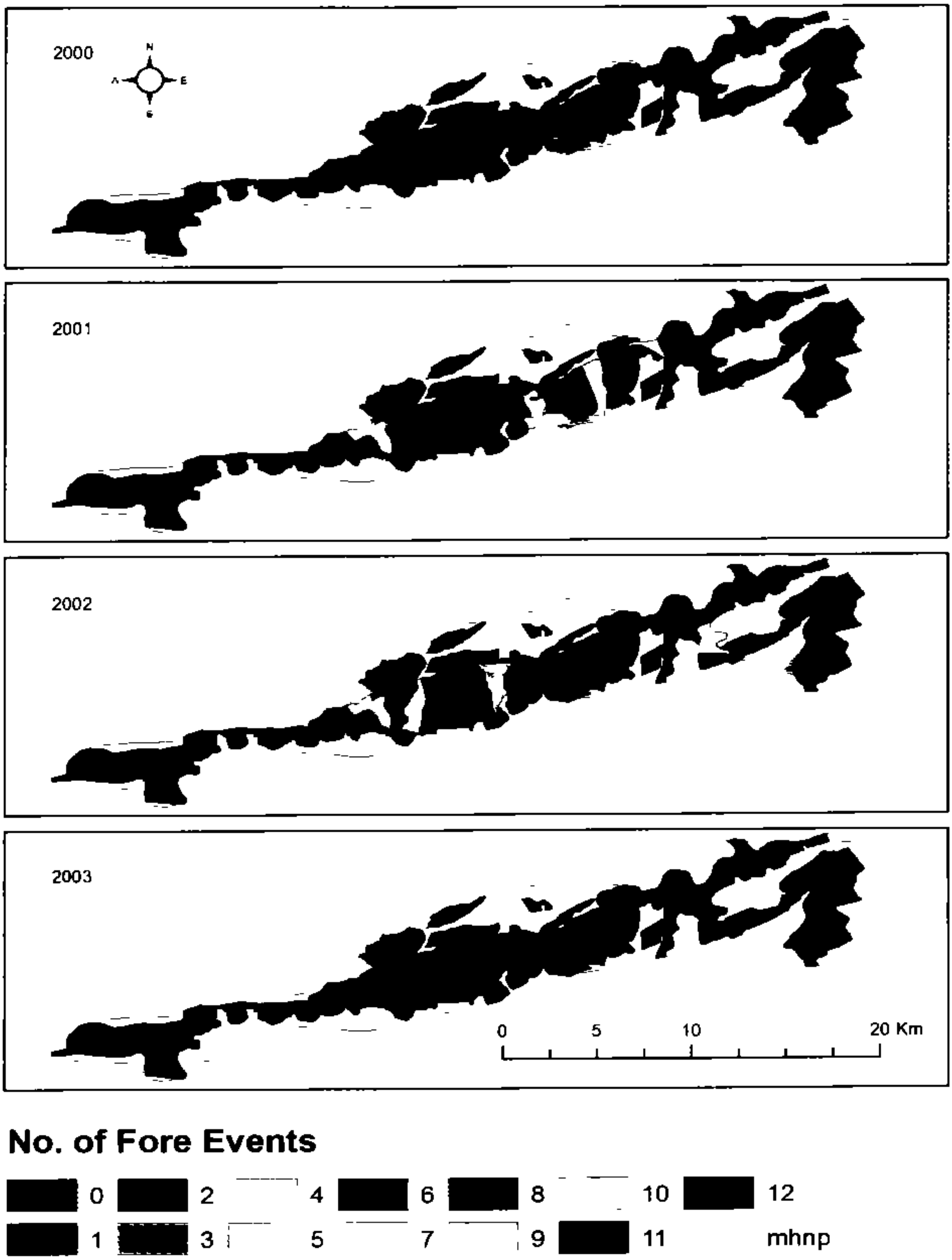

Figure 4.6 g Total number of Forest fire events in compartments of MHNP year wise comparison (2000-2003)

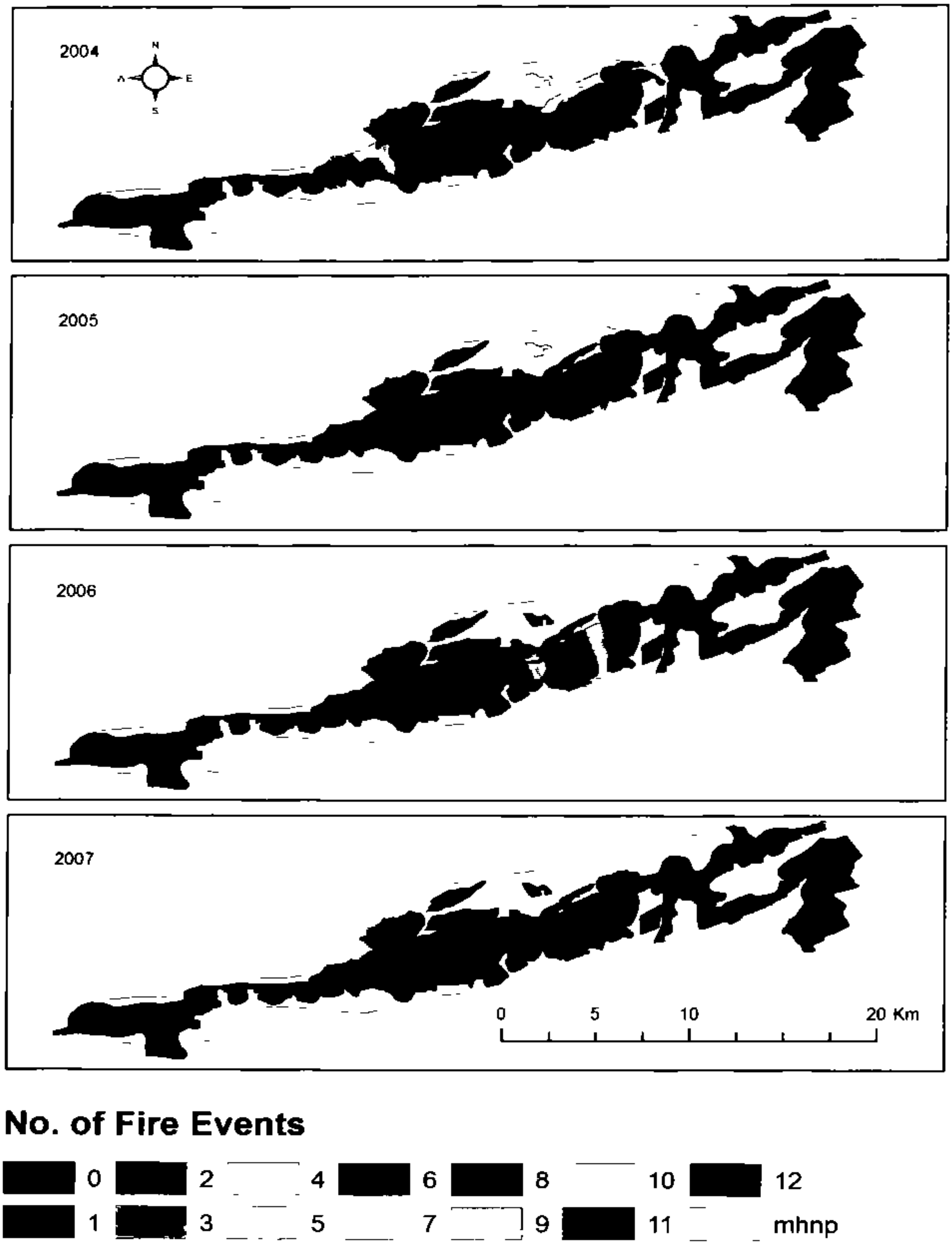

Figure 4.6 h Total number of Forest fire events in compartments of MHNP year wise comparison (2004-2007)

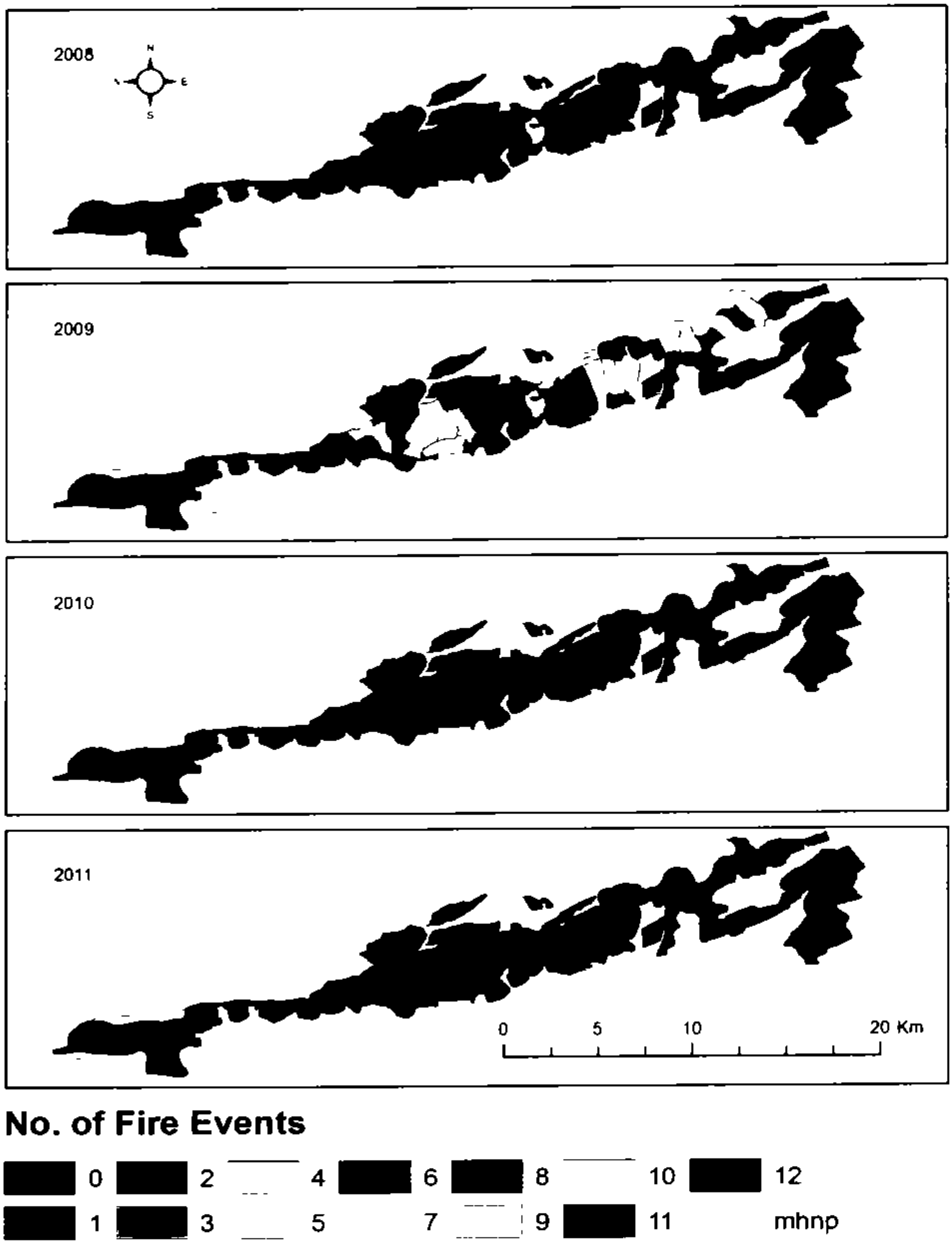

Figure 4.6 i: Total number of Forest fire events in compartments of MHNP year wise comparison (2008- 2011)

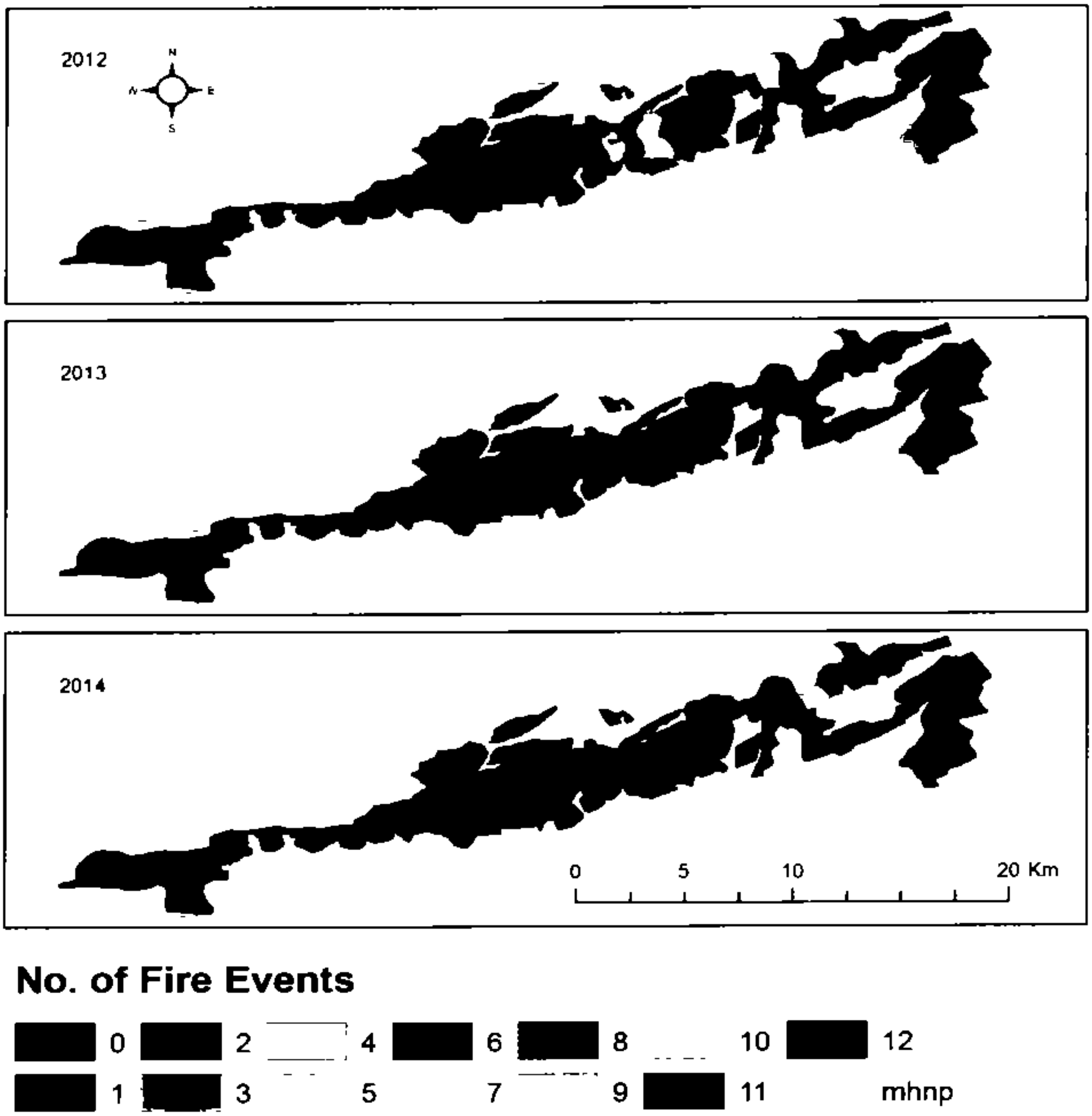

Figure 4.6 j. Total number of Forest fire events in compartments of MHNP year wise companson (2012-2014)

4.1.6. Number of Forest Fire Events (Month wise comparison)

The results revealed that the months of April, May and June are fire prone (figure 4.7). In June (n=282/769) events of forest fire occurred, and the most affected compartment was RF 18 where 21 events occurred (figure 4.8b). In May (n=248/769) events of forest fire occurred, and most affected compartments were MF 10, MF 15 and MF 24 where forest fire occurred 15 times (figure 4.8b). In April (n=82/769) events of forest fire occurred. The results also revealed that in months of Septrember and October no fire event occurred (figure 4.8c).

Figure 4.7: Total number of forest fire events in MHNP month wise comparison (1996-2014)

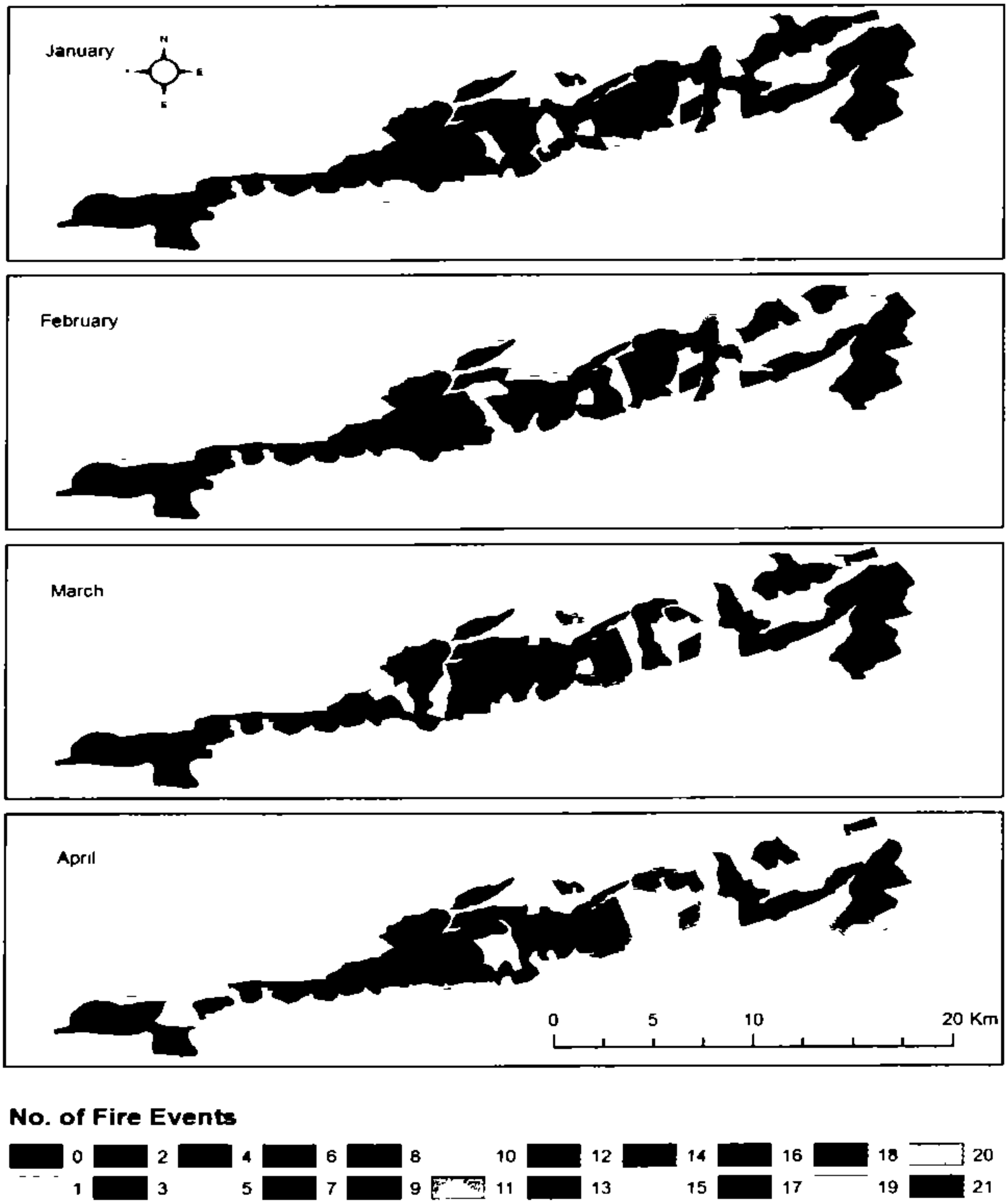

Figure 4.8 d: Total number of Forest fire events in compartments of MHNP month wise comparison (1996-2014)

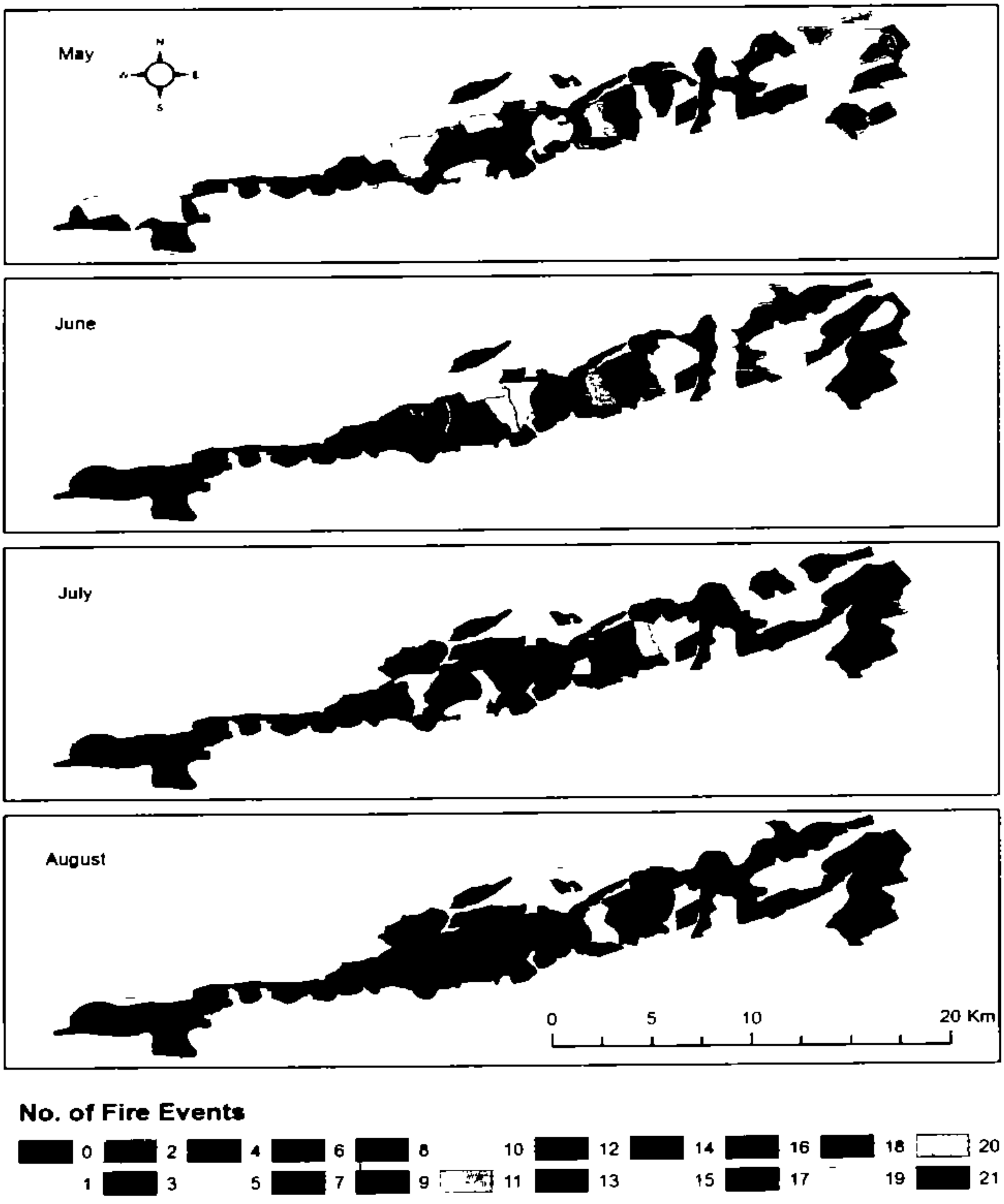

Figure 4.8 e· Total number of Forest fire events in compartments of MHNP month wise comparison (1996-2014)

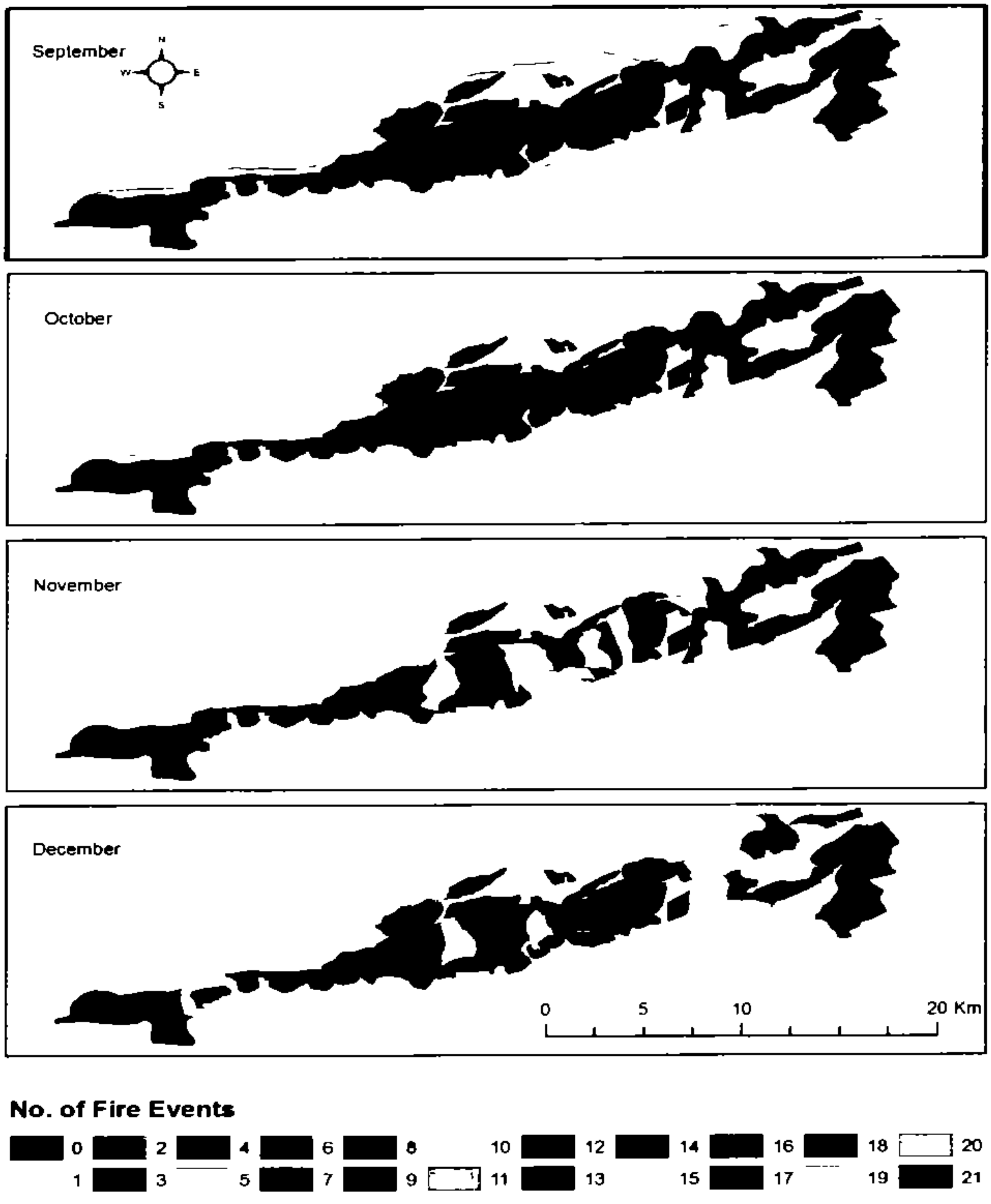

Figure 4.8 f: Total number of Forest fire events in compartments of MHNP month wise comparison (1996-2014)

4.1.7. Overall Area Affected by Forest Fire (Year wise comparison)

The results revealed that the overall affected area of MHNP was 2140 hectares (1996-2014) The most affected year was 1999, in which 348 81 hectares of area was affected by forest fire (Figure 4 9) The year wise comparison (1996-2014) of compartments of MHNP (figure 4.10 (a, b, c, d, e)) revealed that in 1999, MF 14 (n=56 56 hectares) was most affected compartment (figure 4 10(a)) In 1998, total affected area was 318 79 hectares and most affected compartment was RF 16 (n=35 hectares) In 2009, total affected area was 241 7 hectares and RF 15 (n=19 hectares) was most affected compartment by forest fire (figure 4 10(d))

The results showed that the year 2011 was less affected by forest fire, 2 13 hectares of area was affected in 13 events by forest fire, MF 25 (n=0 5 hectares) was most affected compartment (figure 4 10(d)) In 2014, 14 76 hectares area was affected in 18 events by forest fire, MF 18 (n=4 23 hectares) was most affected compartment (figure 4 10(e))

Figure 4.9: Overall affected area of MHNP by forest fires year wise comparison (1996-2014)

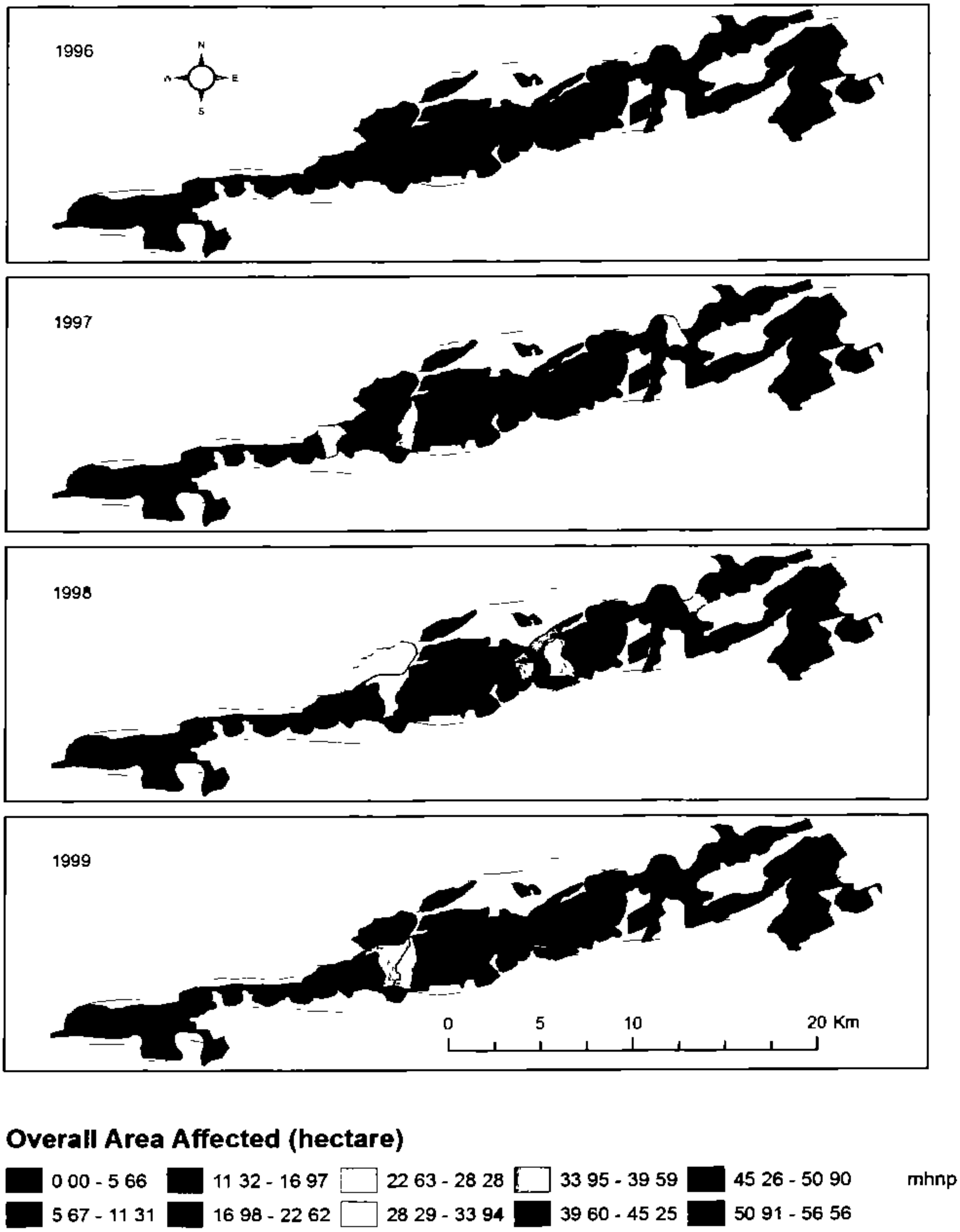

Figure 4.10 f: Spatial variability in overall affected area of MHNP by Forest fires year wise comparison (1996-1999)

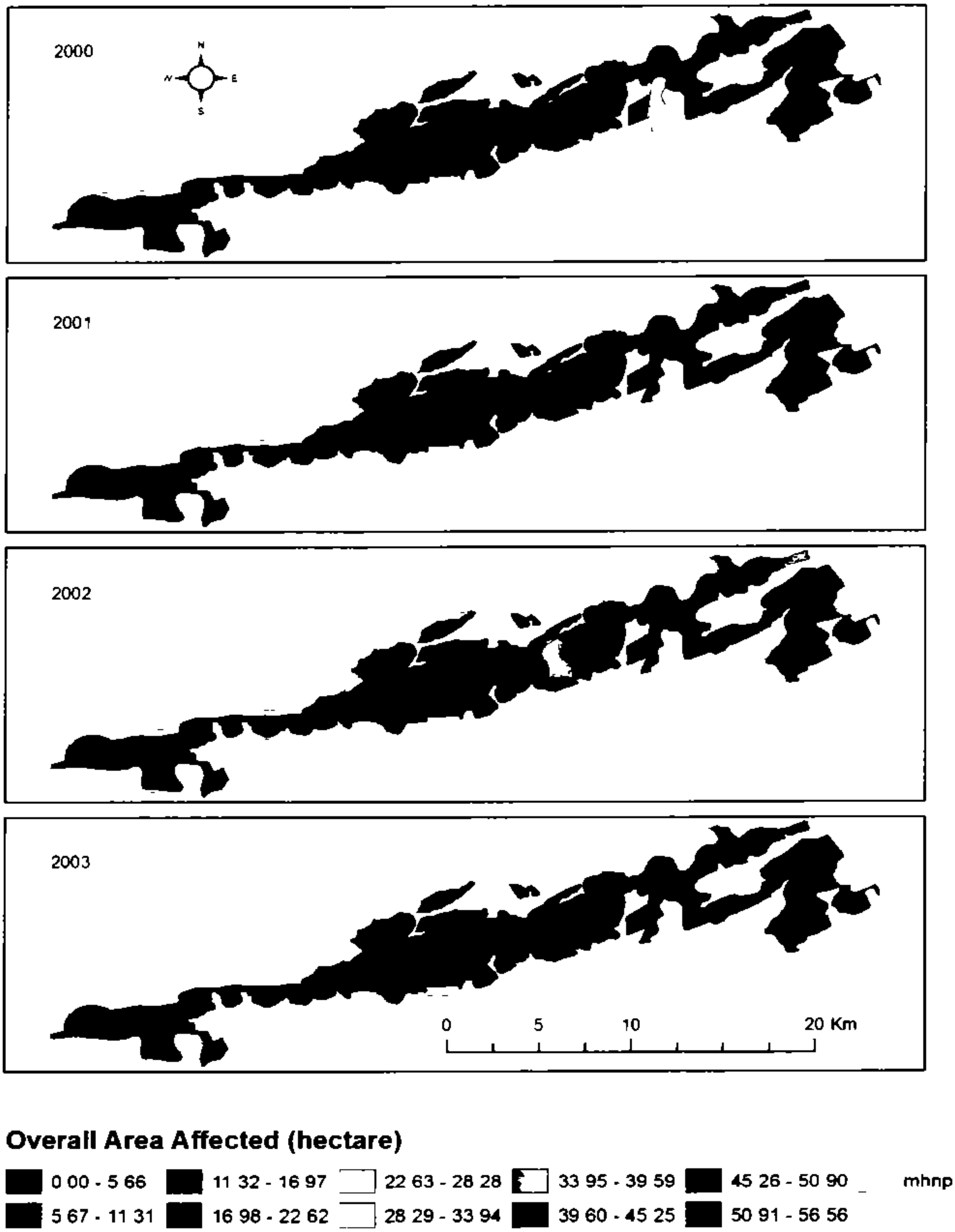

Figure 4 10 g: Spatial vanability in overall affected area of MHNP by Forest fires year wise companson (2000 to 2003)

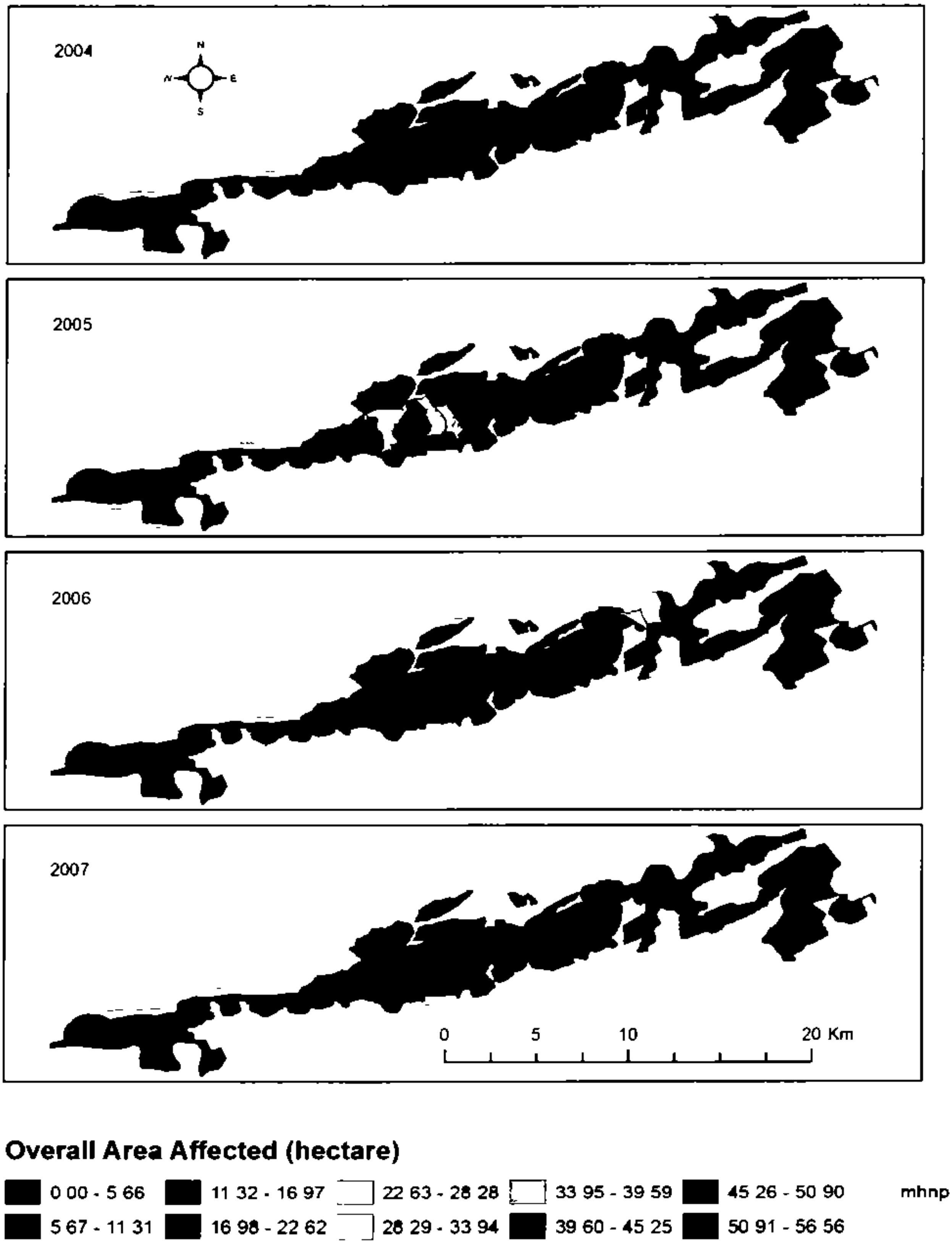

Figure 4.10 h Spatial variability in overall affected area of MHNP by Forest fires year wise comparison (2004 to 2007)

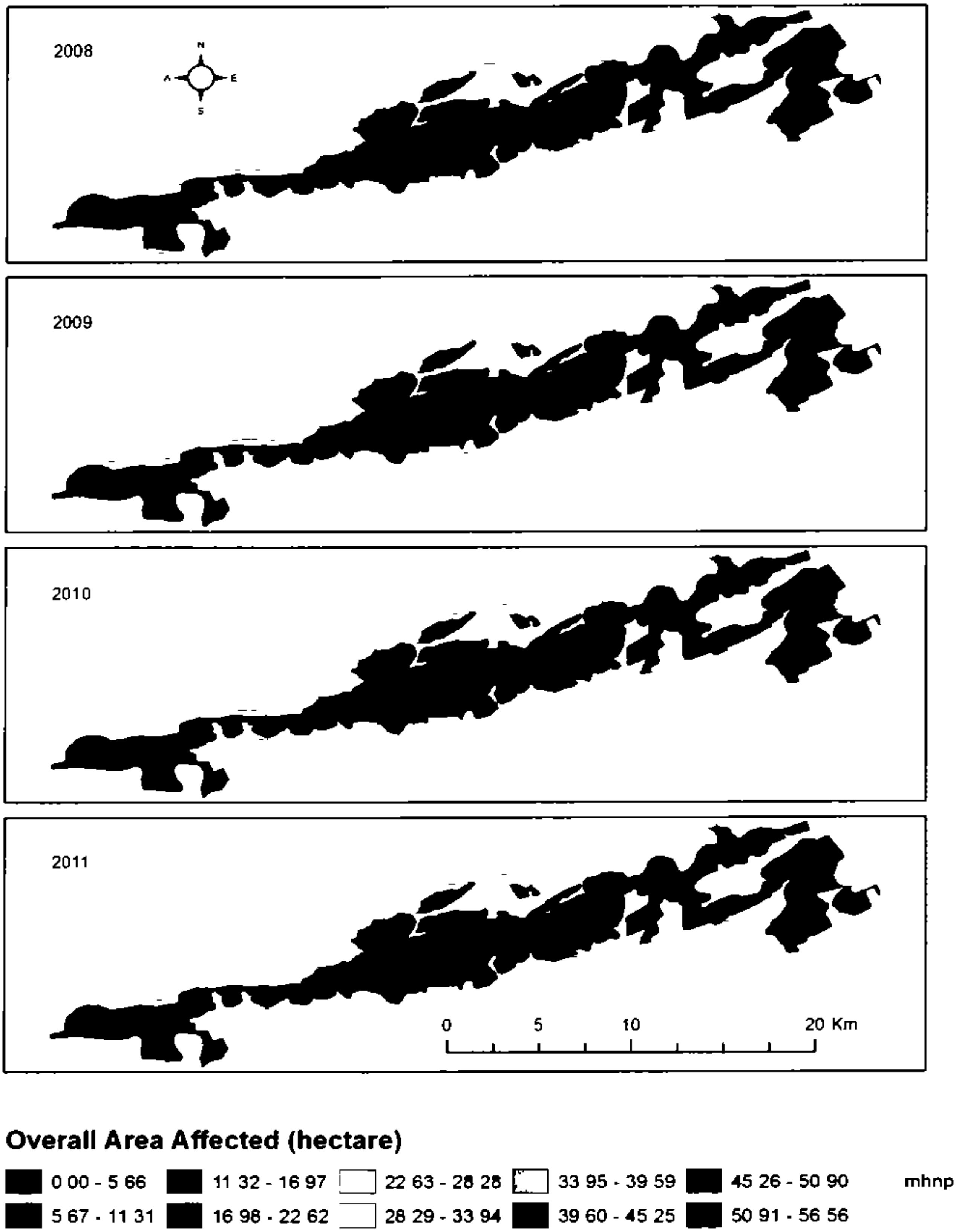

Figure 4.10 i: Spatial variability in overall affected area of MHNP by Forest fires year wise comparison (2008 to 2011)

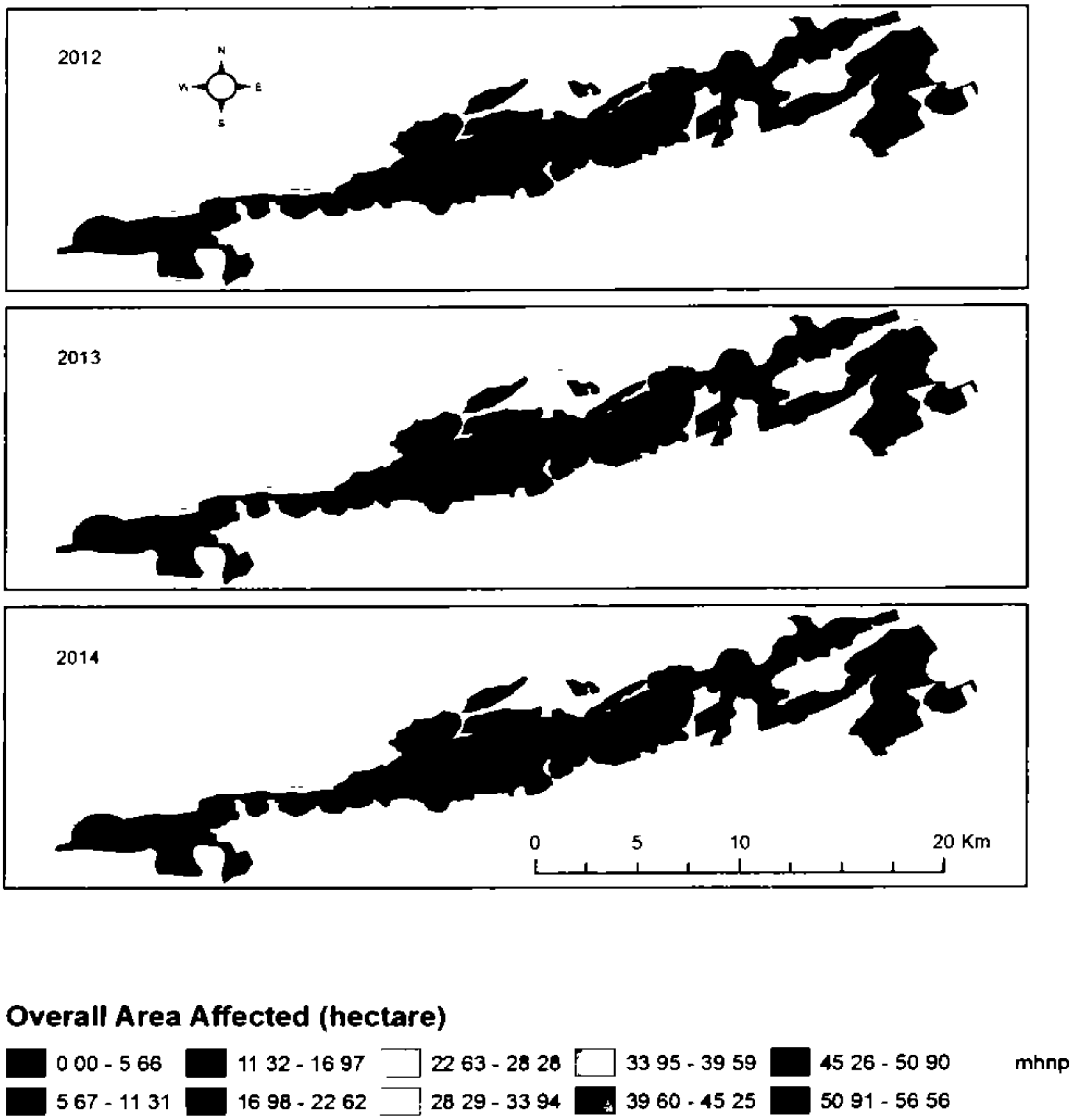

Figure 4 10 j: Spatial variability in overall affected area of MHNP by Forest fires year wise comparison (2012 to 2014)

4.1.8. Overall Area Affected (Month wise comparison)

The overall affected area of MHNP was 2140 hectares between 1996 and 2014 (figure 4.11). The figure 4.12 (a, b, c) shows the comparison of affected comparments month wise. The results revealed that the months of April, May and June are fire prone. (n=786/2140) hectares of area was affected in June and most affected compartment was MF 23 with affected area of 122.88 hectares (figure 4.12 b). (n=596/2140) hectares of area was affected in May and most affected compartment was MF 10 with affected area of 55.18 hectares (figure 4.12 b) and (n=327/2140) hectares of area was affected in April.

The results revealed that no fire event occurred in the moths of September and October, and no area was affected in these two months as shown in (figure 4.12c)

Figure 4.11 Overall affected area of MHNP by forest fires month wise comparison (1996-2014)

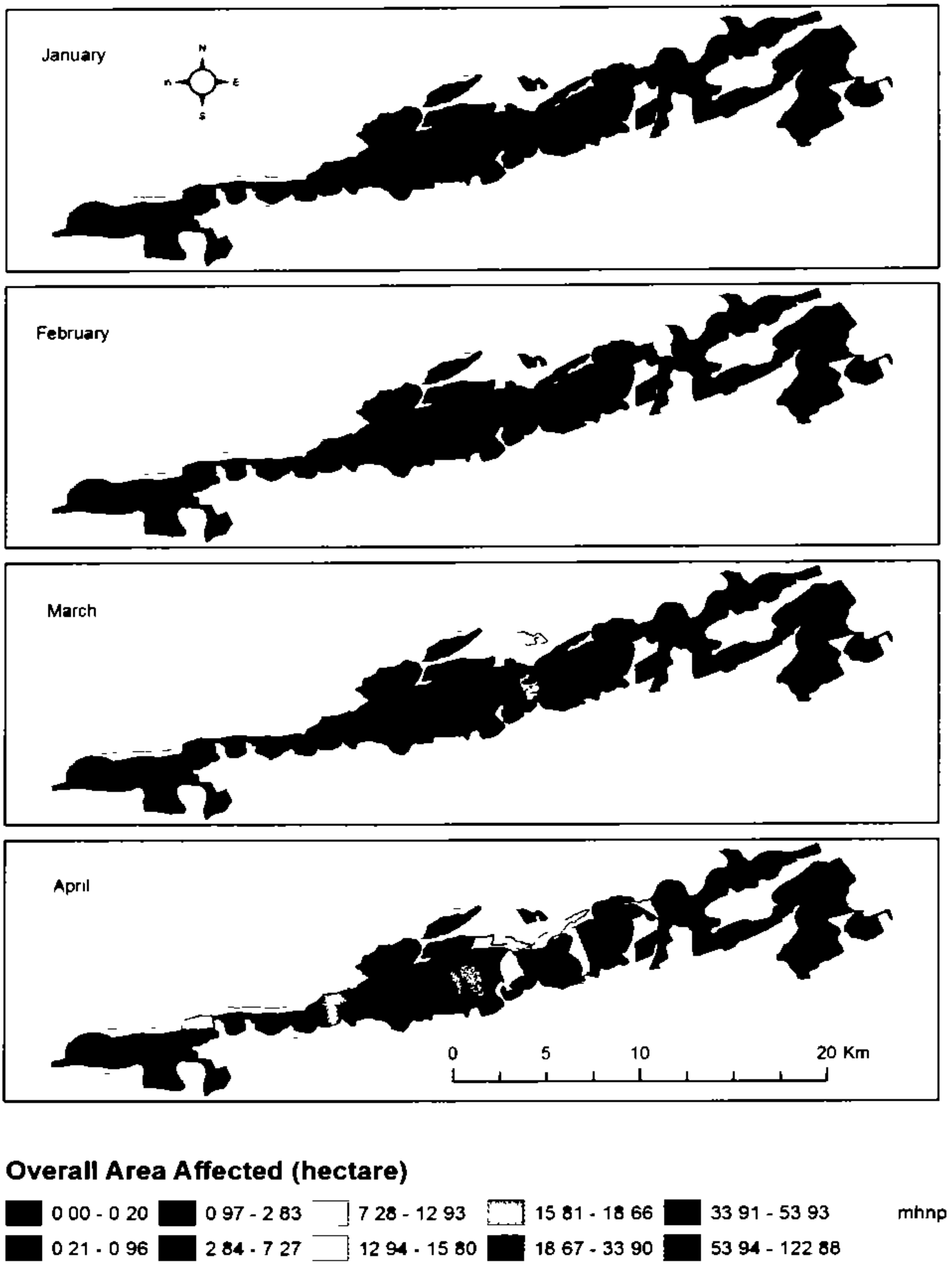

Figure 4.12 d· Spatial variability in overall affected area of MHNP by Forest fires month wise comparison (1996-2014)

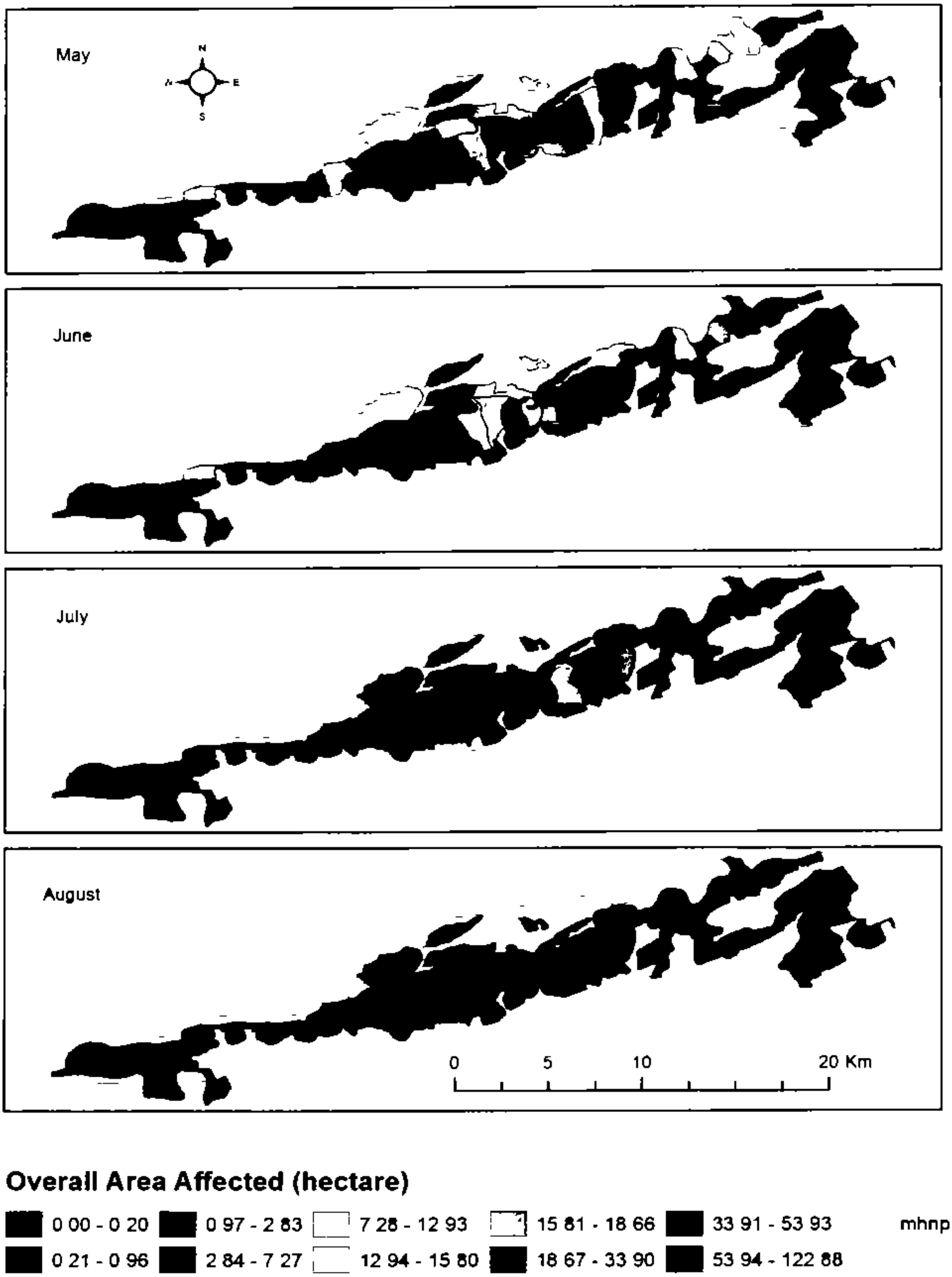

Figure 4 12 e· Spatial variability in overall affected area of MHNP by Forest fires month wise comparison (1996-2014)

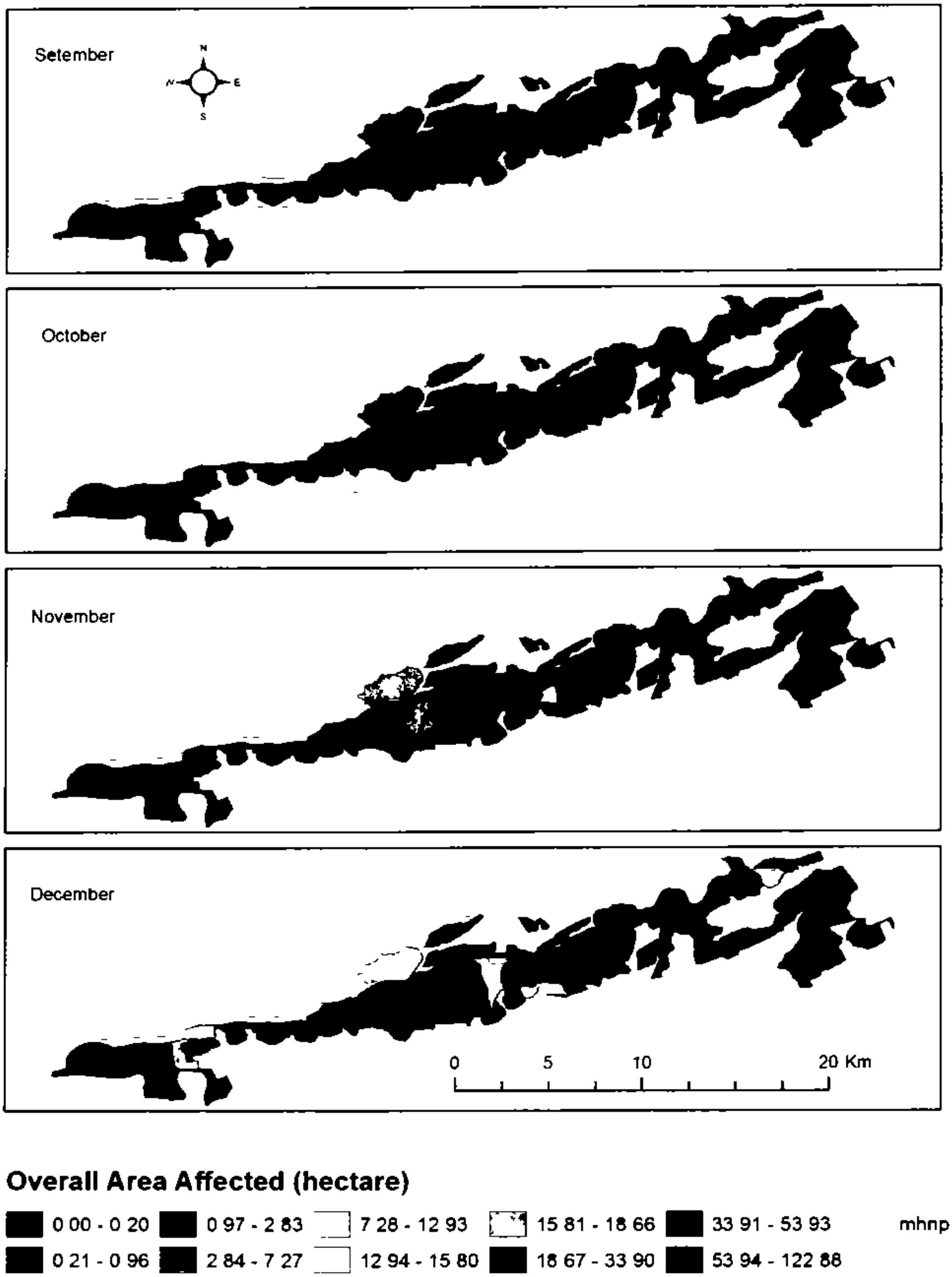

Figure 4.12 f. Spatial variability in overall affected area of MHNP by Forest fires month wise comparison (1996-2014)

4.1.9. Duration of Forest Fire (Year wise comparison)

The results revealed that total duration of fire events in MHNP was 3243 hrs from 1996 to 2014, and year 2009 was most affected year in terms of Duration of fire (figure 4 13)

Figure 4 14(a ,b, c, d, e) shows the duration of fire in compartments of MHNP from 1996 to 2014 In 2009, the duration of forest fire was 588 22 hrs in 133 events and affected the area of 241 hectares, and MF 22 (n=75 33 hrs) was most affected compartment (figure 4 14 d) In 1999, the duration of forest fire was 428 07 hrs in 66 events and affected the area of 348 hectares and MF 11 (n=49 hrs) was most affected compartment (figure 4 14 a)

In 2014, the duration of forest fire was 48 83 hrs and MF 07 (n=18 58 hrs) was most affected compartment (figure 4 14 e)

Figure 4.13: Total duration of forest fire in MHNP year wise comparison (1996-2014)

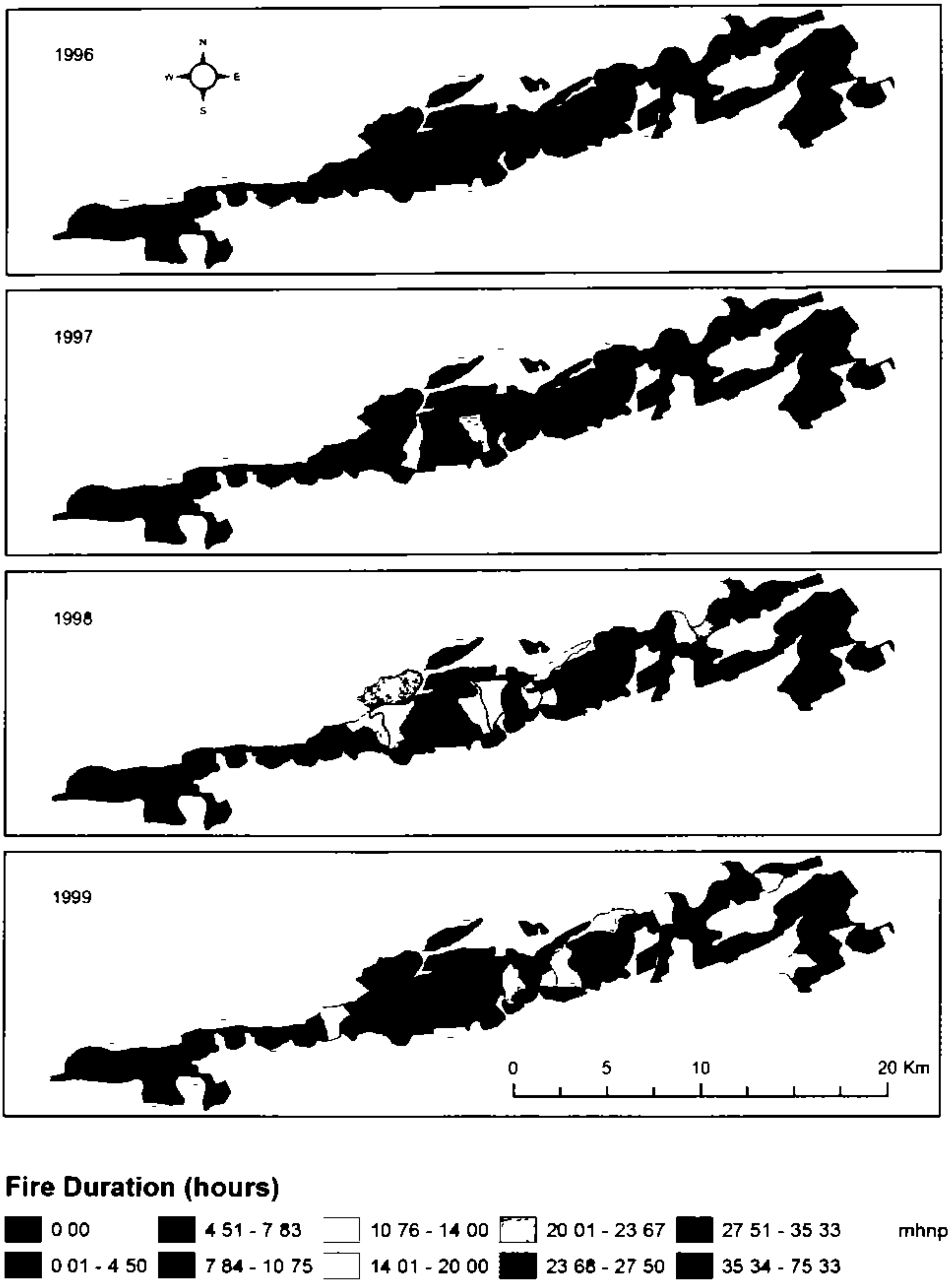

Figure 4.14 f: Spatial variability in total duration of forest fire occurrence in MHNP year wise comparison (1996-1999)

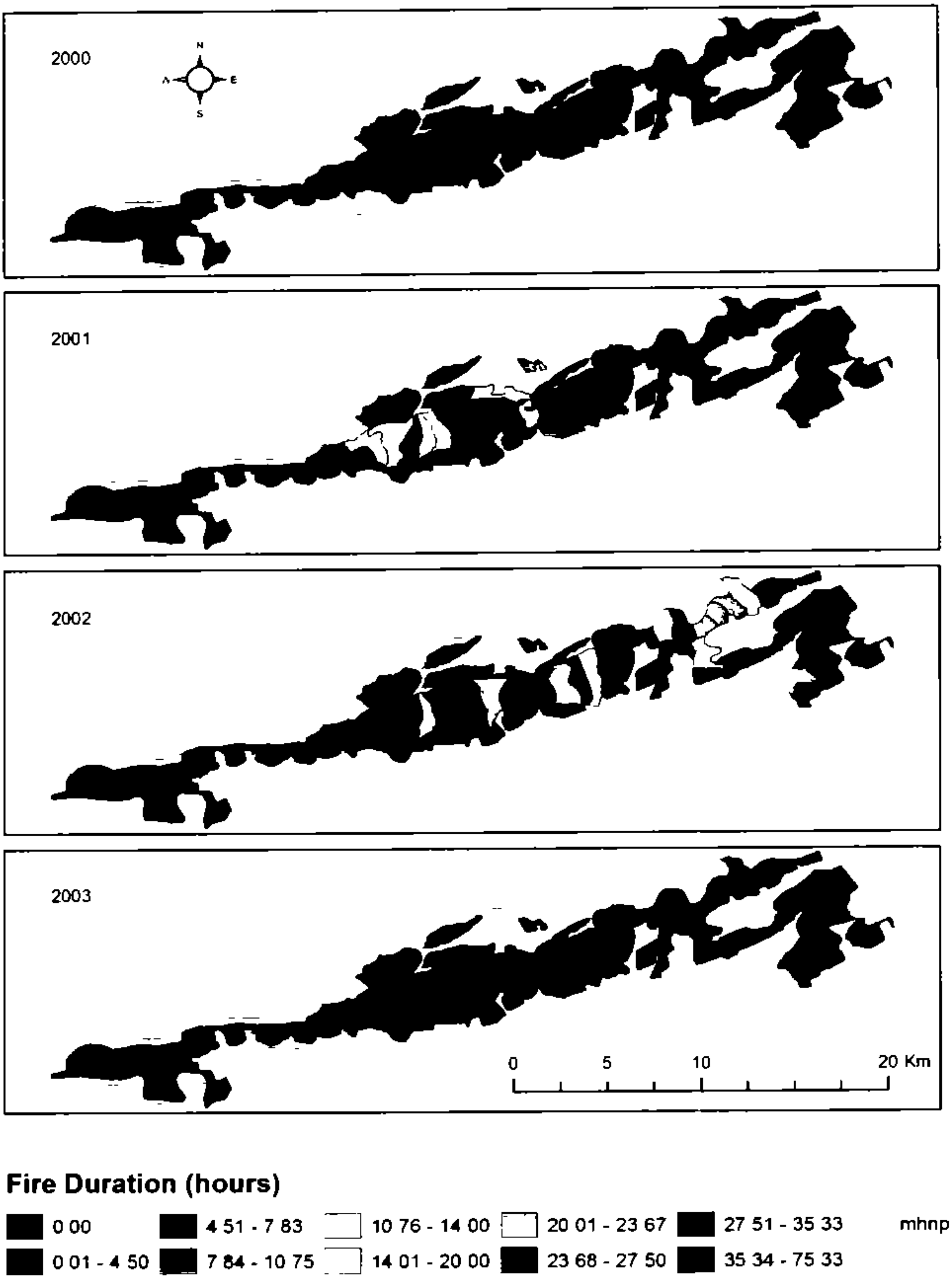

Figure 4.14 g: Spatial variability in total duration of forest fire occurrence in MHNP year wise comparison (2000-2003)

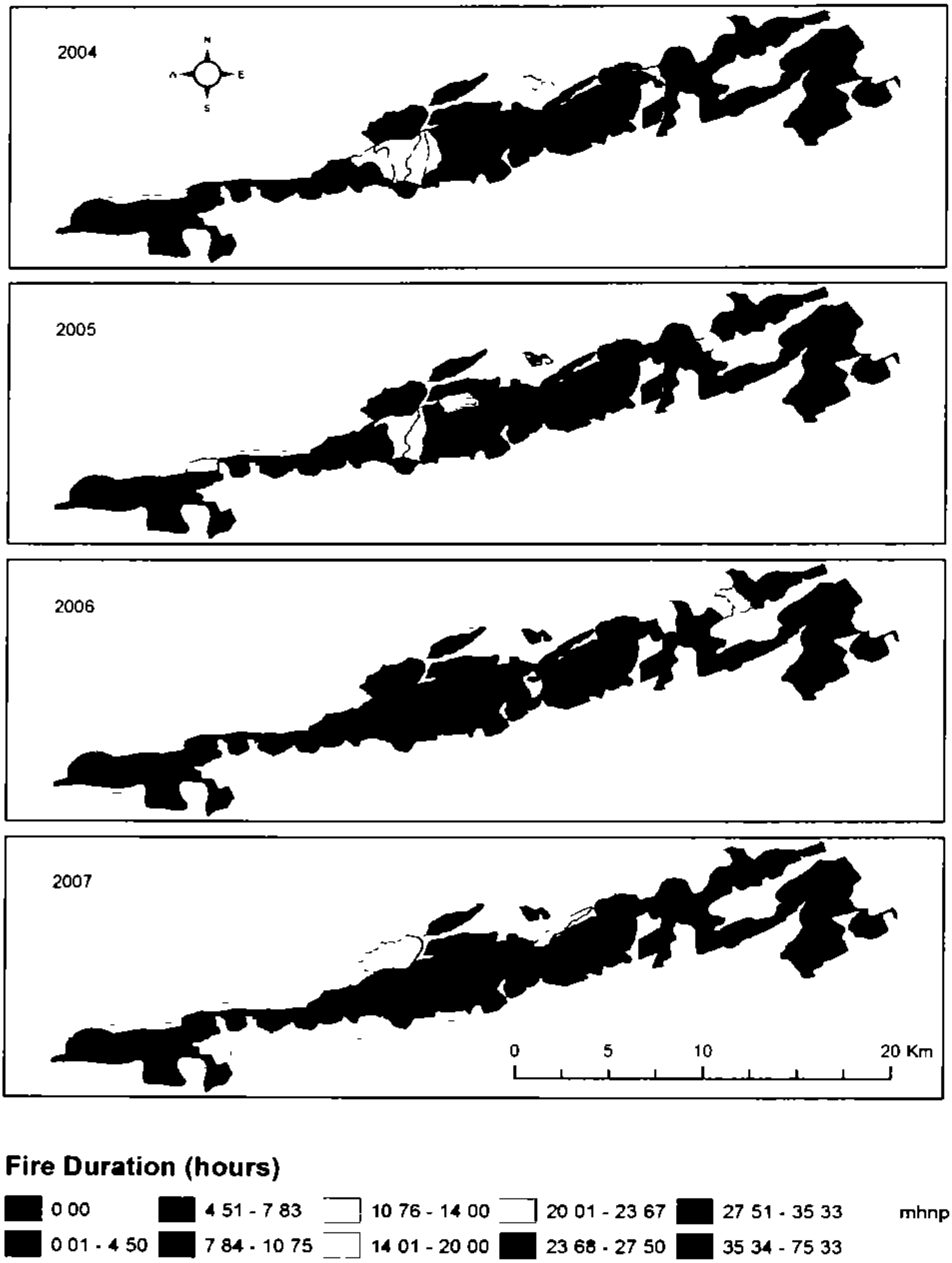

Figure 4.14 h: Spatial variability in total duration of forest fire occurrence in MHNP year wise comparison (2004-2007)

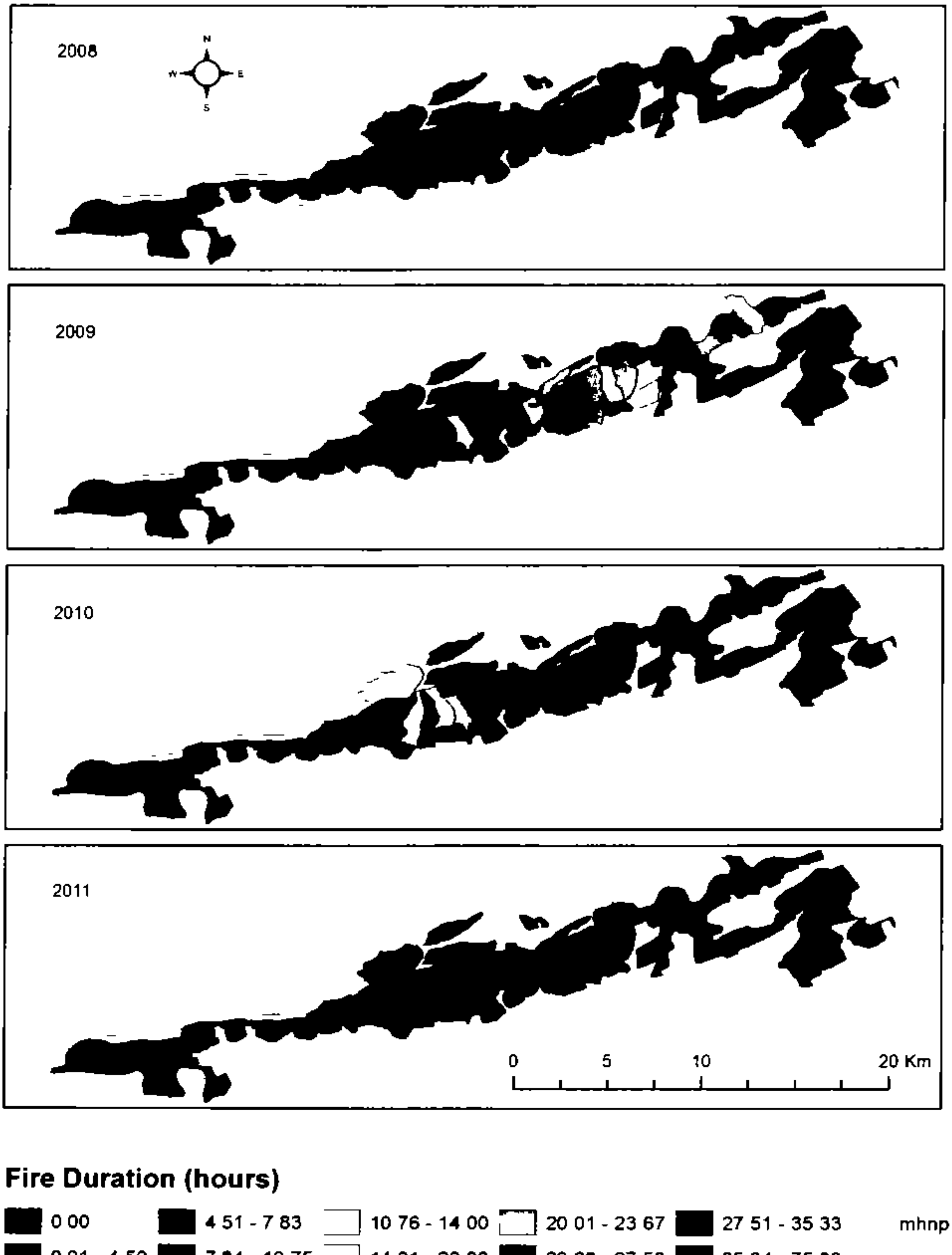

Figure 4.14 i: Spatial variability in total duration of forest fire occurrence in MHNP year wise comparison (2008-2011)

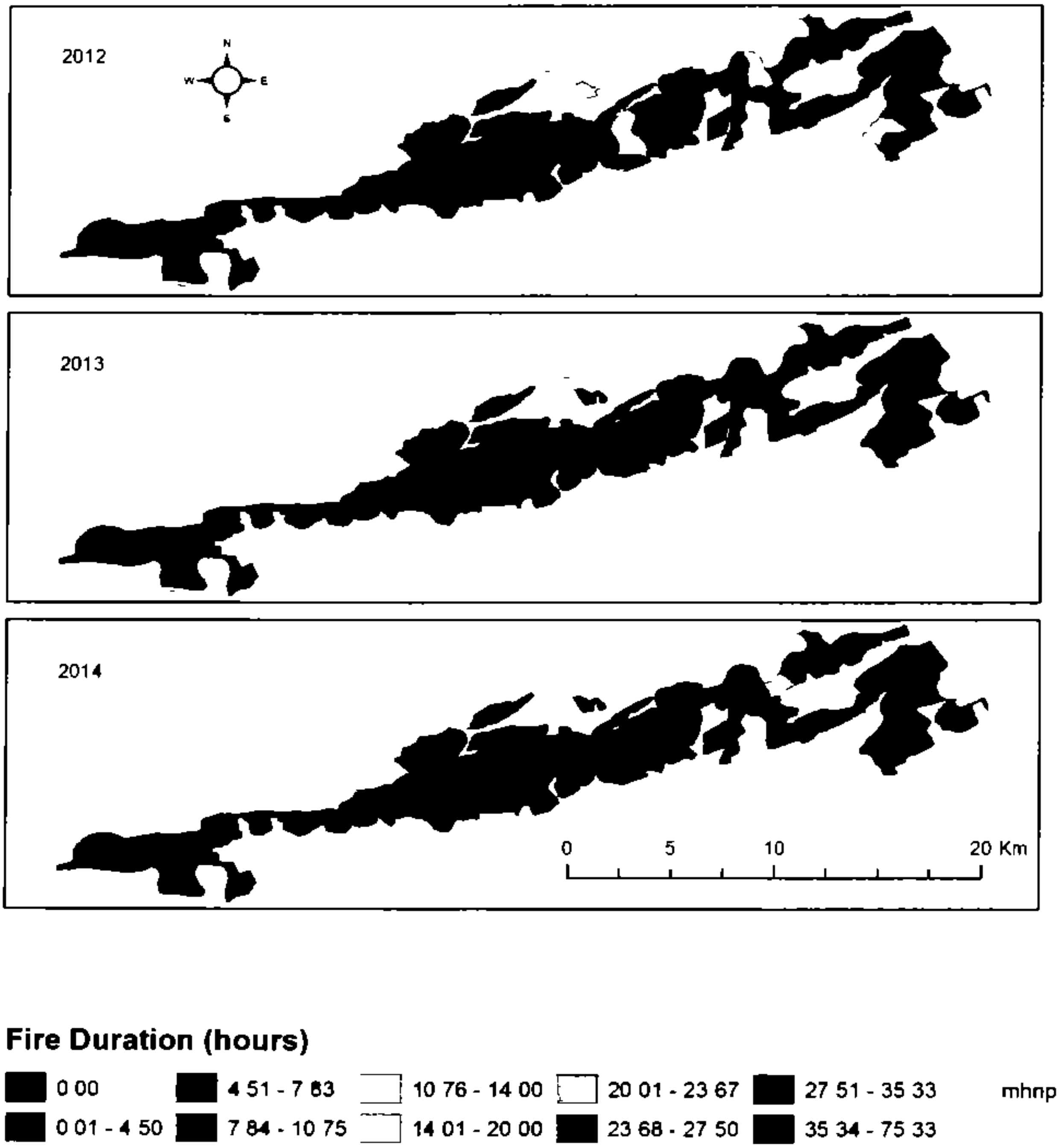

Figure 4.14 j: Spatial variability in total duration of forest fire occurrence in MHNP year wise comparison (2012-2014)

4.1.10. Duration of Forest Fire (Month wise Comparison)

The results revealed that Total duration of fire events in MHNP was 3243 hrs from 1996 to 2014, and most affected months were May and June (figure 15)

Figure 4 16(a, b, b) shows the duration of fire in compartments of MHNP from 1996 to 2014 In months of May.the duration of forest fire was 1201 95 hrs and most affected compartment was MF 10 (n=99 67 hrs) In June, the duration of forest fire was 1155 37 hrs in 282 events, and MF 23 (n=96 hrs) most affected compartment (fighur 16 b)

The results also revealed that in months of September and October no fire event occurred (figure 4 16 c)

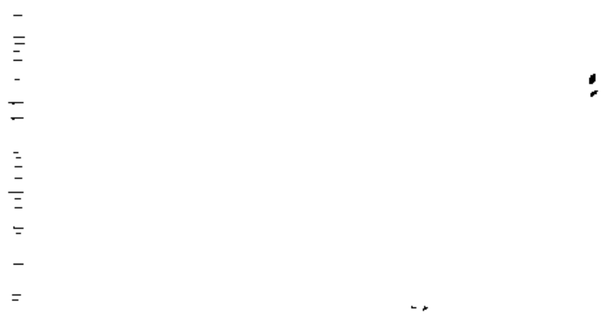

Figure 4.15: Total duration of forest fire in MHNP month wise comparison (1996-2014)

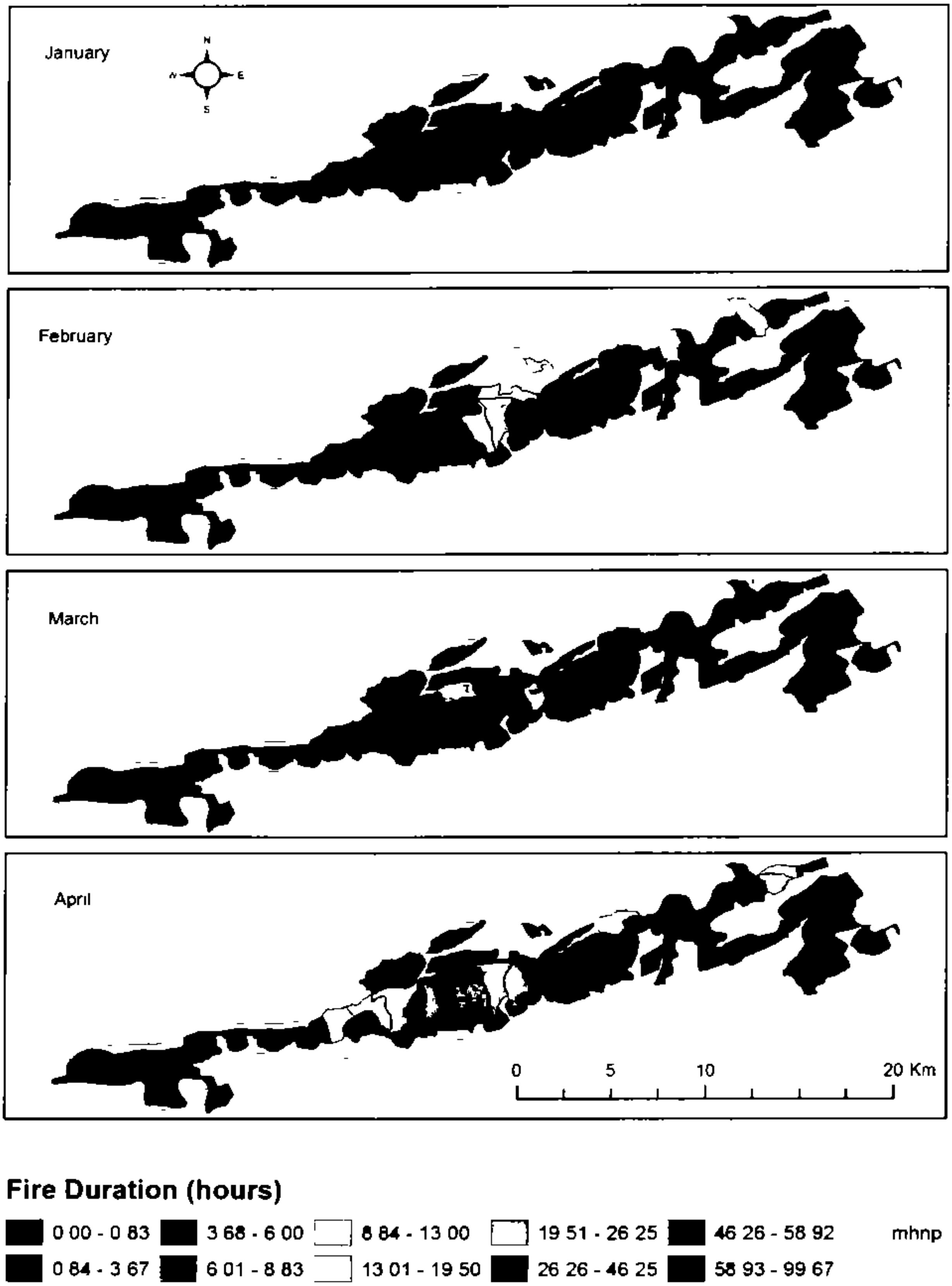

Figure 4 16 d Spatial variability in total duration of forest fire occurrence in MHNP month wise comparison (1996-204)

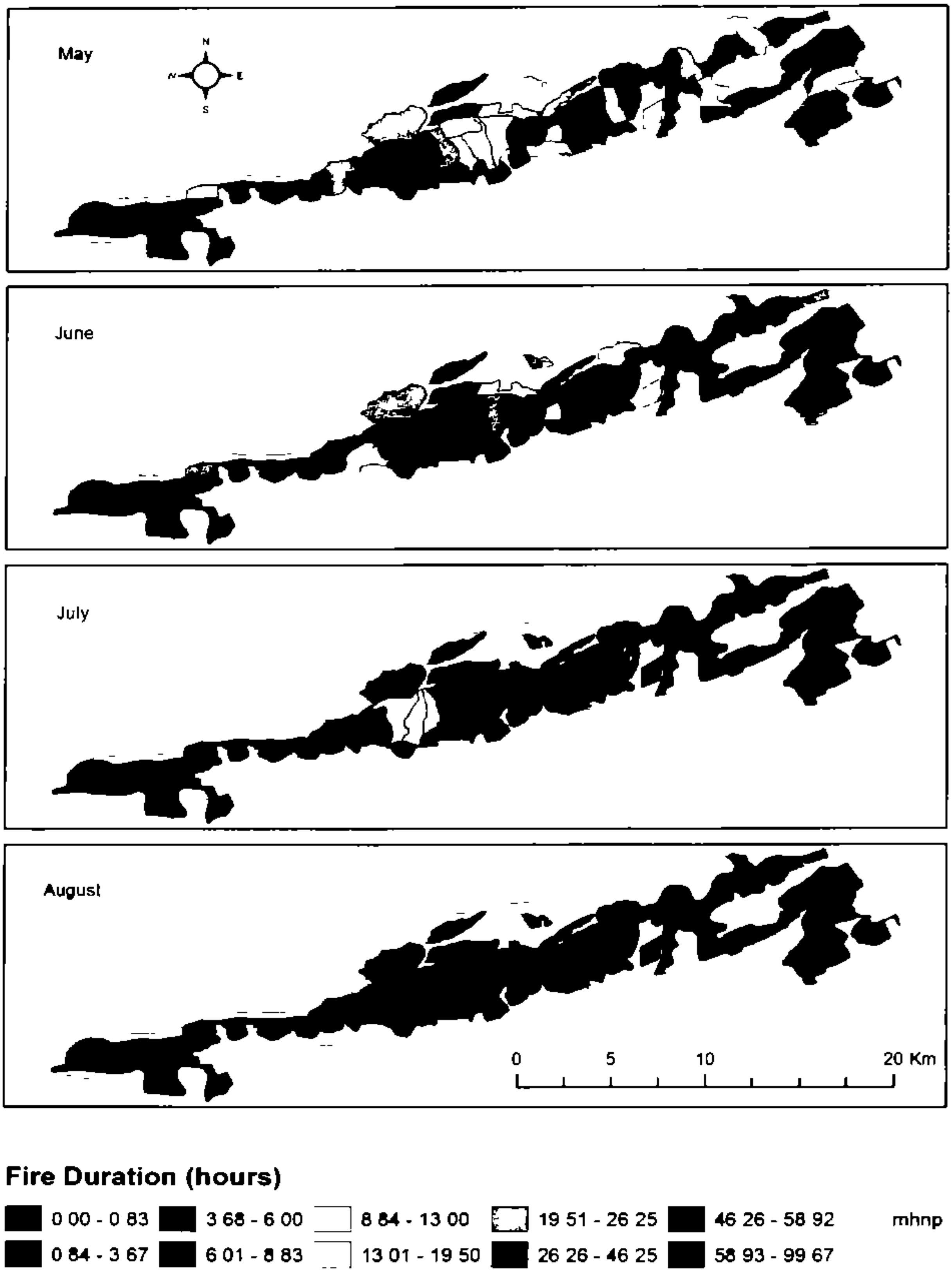

Figure 4.16 e: Spatial variability in total duration of forest fire occurrence in MHNP month wise comparison (1996-204)

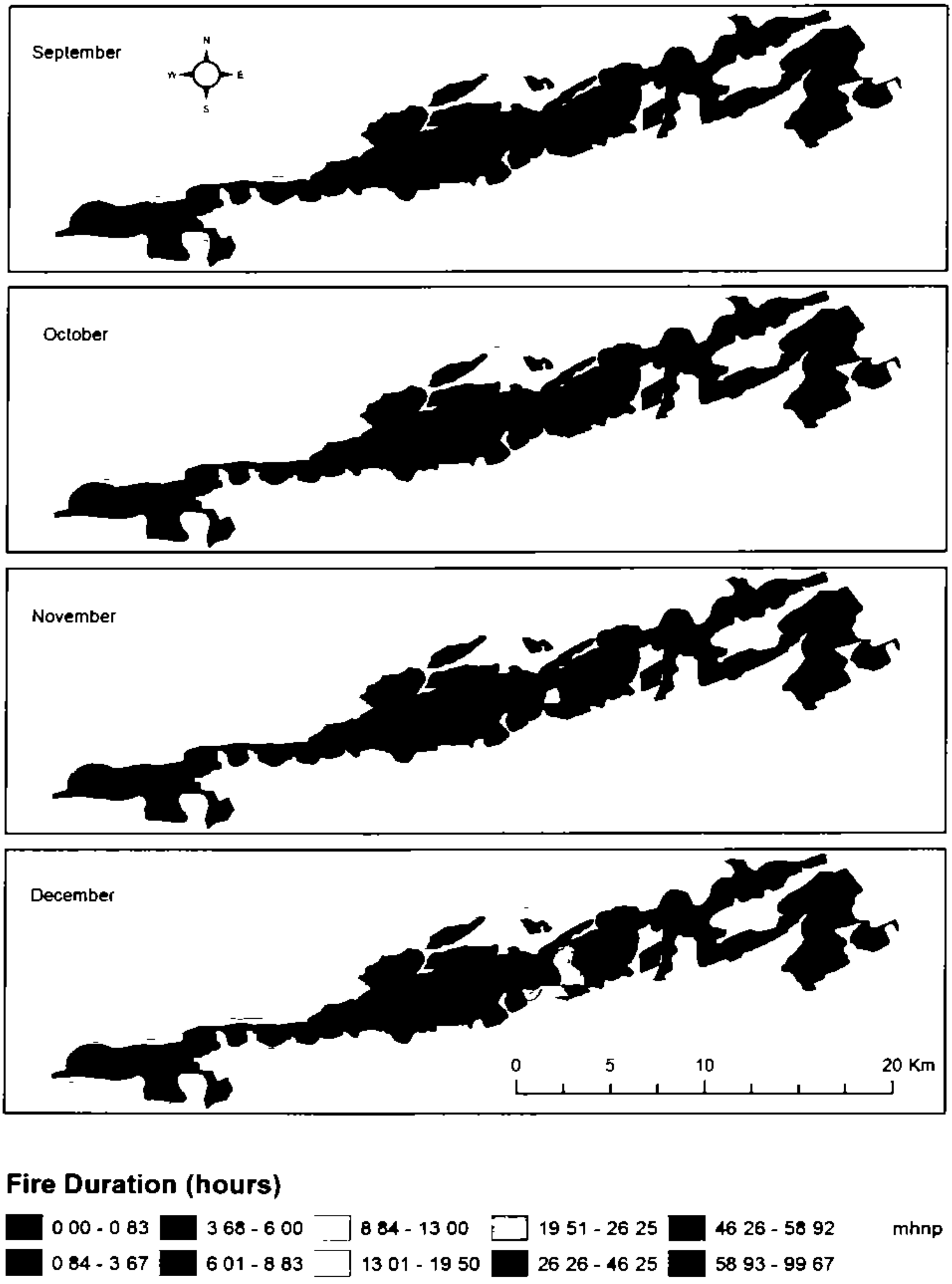

Figure 4 16 f: Spatial variability in total duration of forest fire occurrence in MHNP month wise comparison (1996-204)

4.2. Phenological Trends in Margalla Hills National Park

4.2.1. Start of Season (SOS)

The results of phenological parameters revealed that in majority of compartments SOS occurred in April, and in some areas SOS occurred in May The areas which showed SOS in April are mostly RFs (RF 22- RF 38) The Year wise comparison of SOS in every compartment of MHNP from 2000 to 2014 (figure 4.17(a, b)) revealed that the in years 2002, 2009 and 2012 SOS occurred in May In other years the SOS usually occurred in April

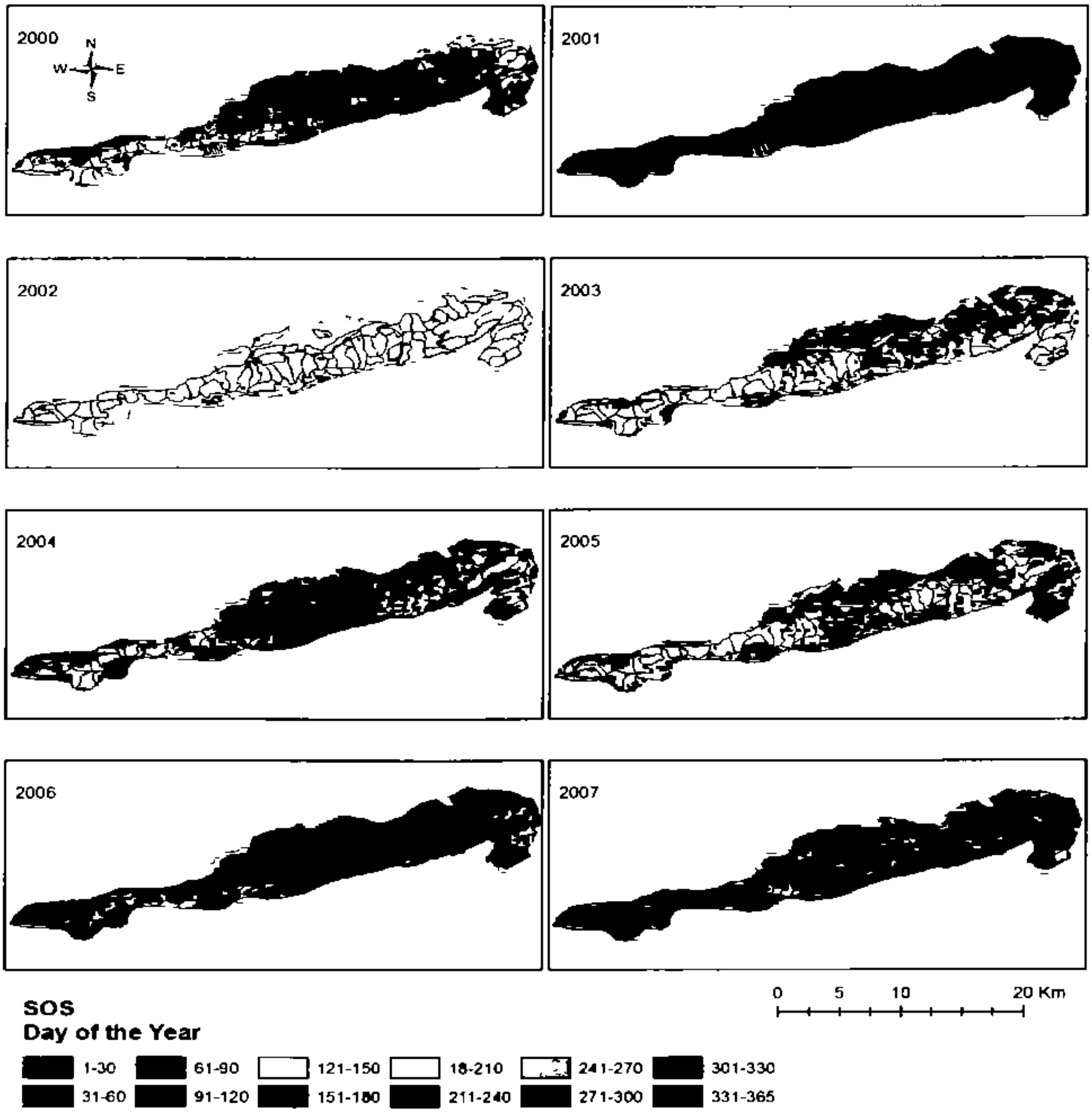

Figure 4.17 c: Spatial variability in Start of growing Season in MHNP derived from MODIS NDVI time-series (2000-2007)

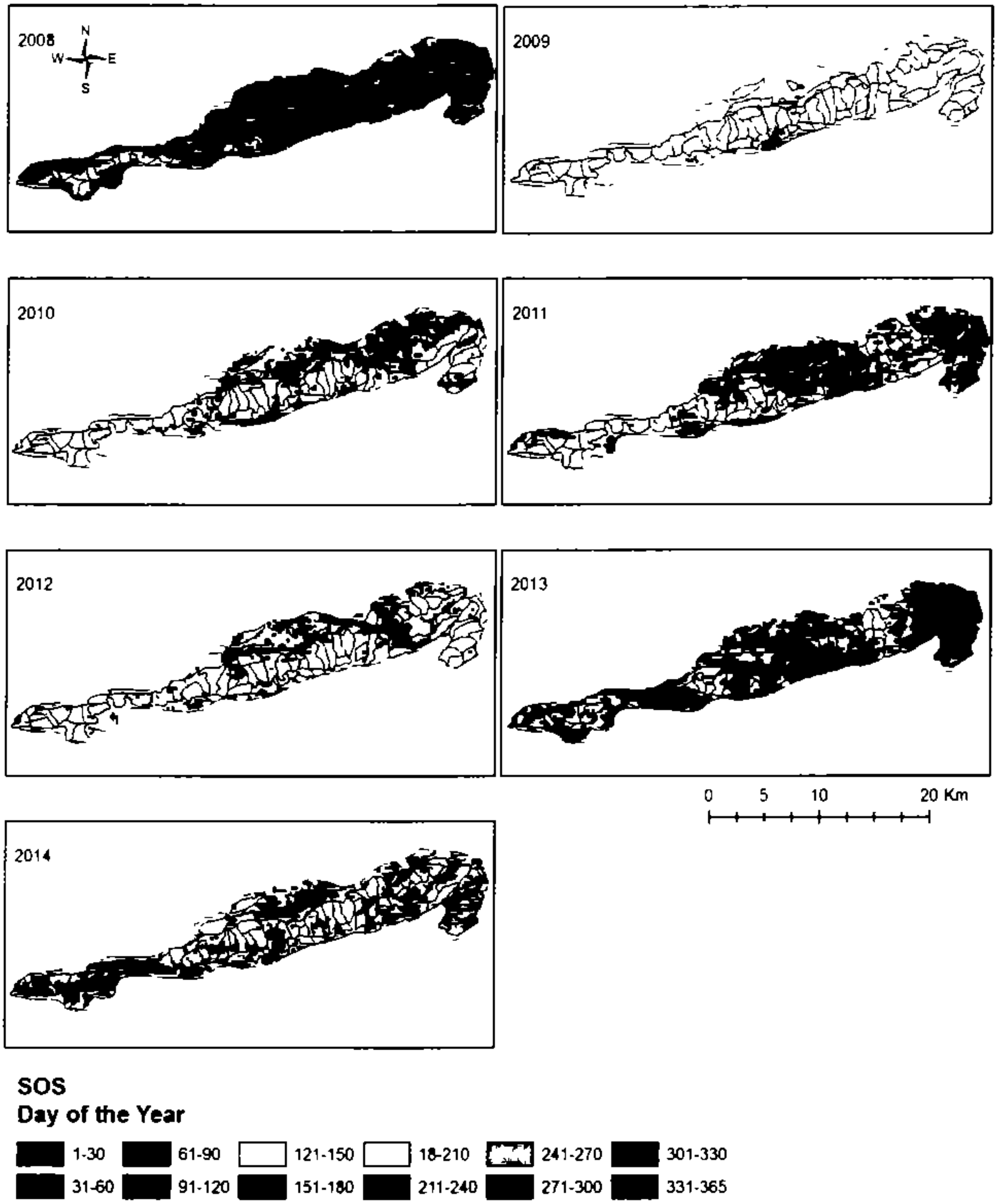

Figure 4.17 d: Spatial variability in Start of growing Season in MHNP derived from MODIS NDVI time-series data (2008-2014)

The phenological trends explained that SOS occurred in start of April in majority of study area The results revealed that MFs had early SOS avg than RFs The slope of SOS indicates the high increasing trends in most of the compartments like MF 22, MF 23 MF 15, MF 16 and RF 17 The other compartments like Nurpur Guzara, Ratta hottar, also showed a moderate increase in SOS Whereas a small area of MF 8, MF 9, MF 12 and MF 13 showed decreasing trend in SOS (figure 4 18)

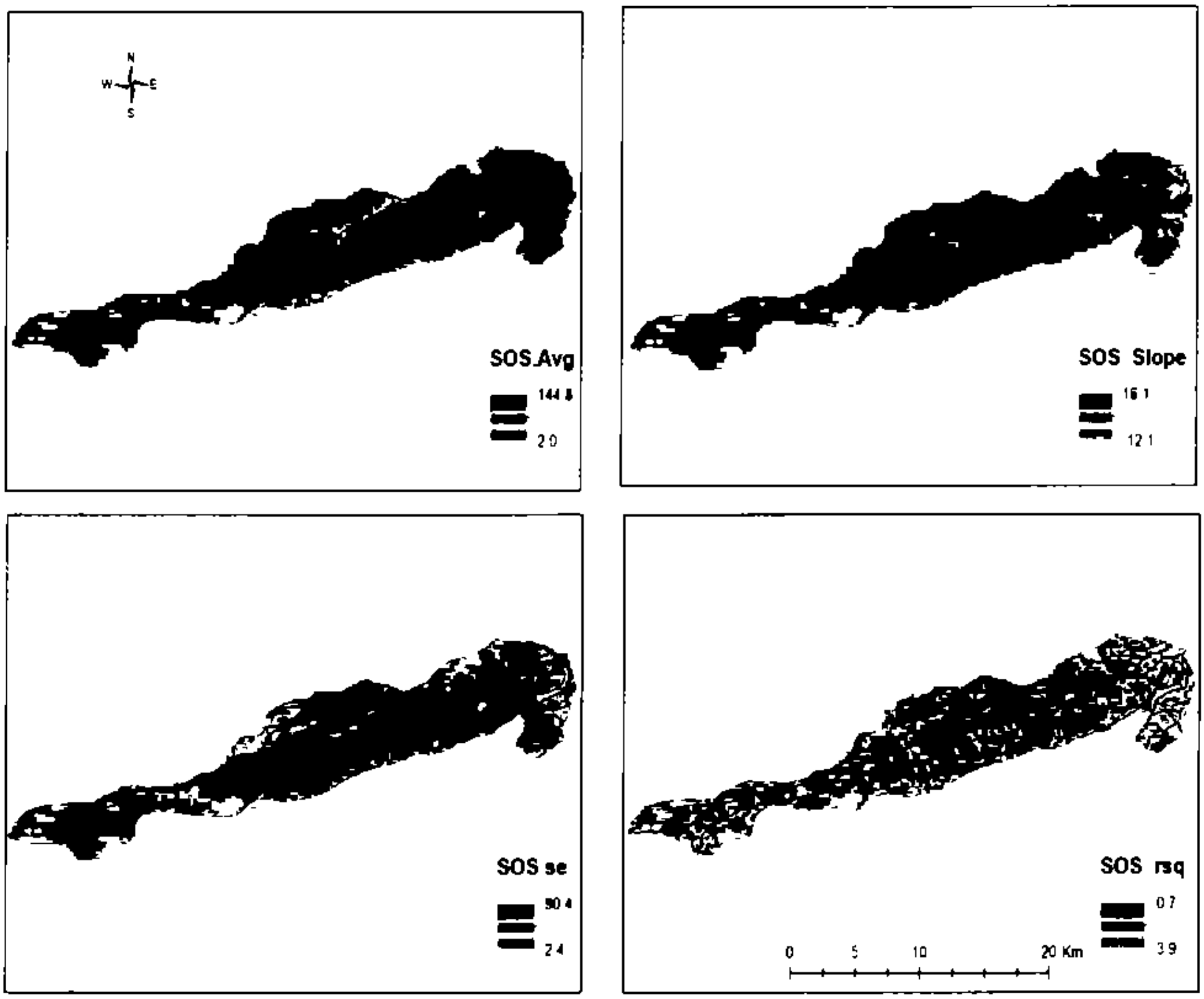

Figure 4.18. Spatial variability in phenological trends of Start of growing season derived from MODIS NDVI time-series data (2000-2014)

4.2.2. End of Season (EOS)

The results revealed a lot variations in EOS over the years The results revealed that RF 21 to RF 34 showed consistancy and EOS usually occurred in month of January Whereas the EOS varied in other compartments over the years

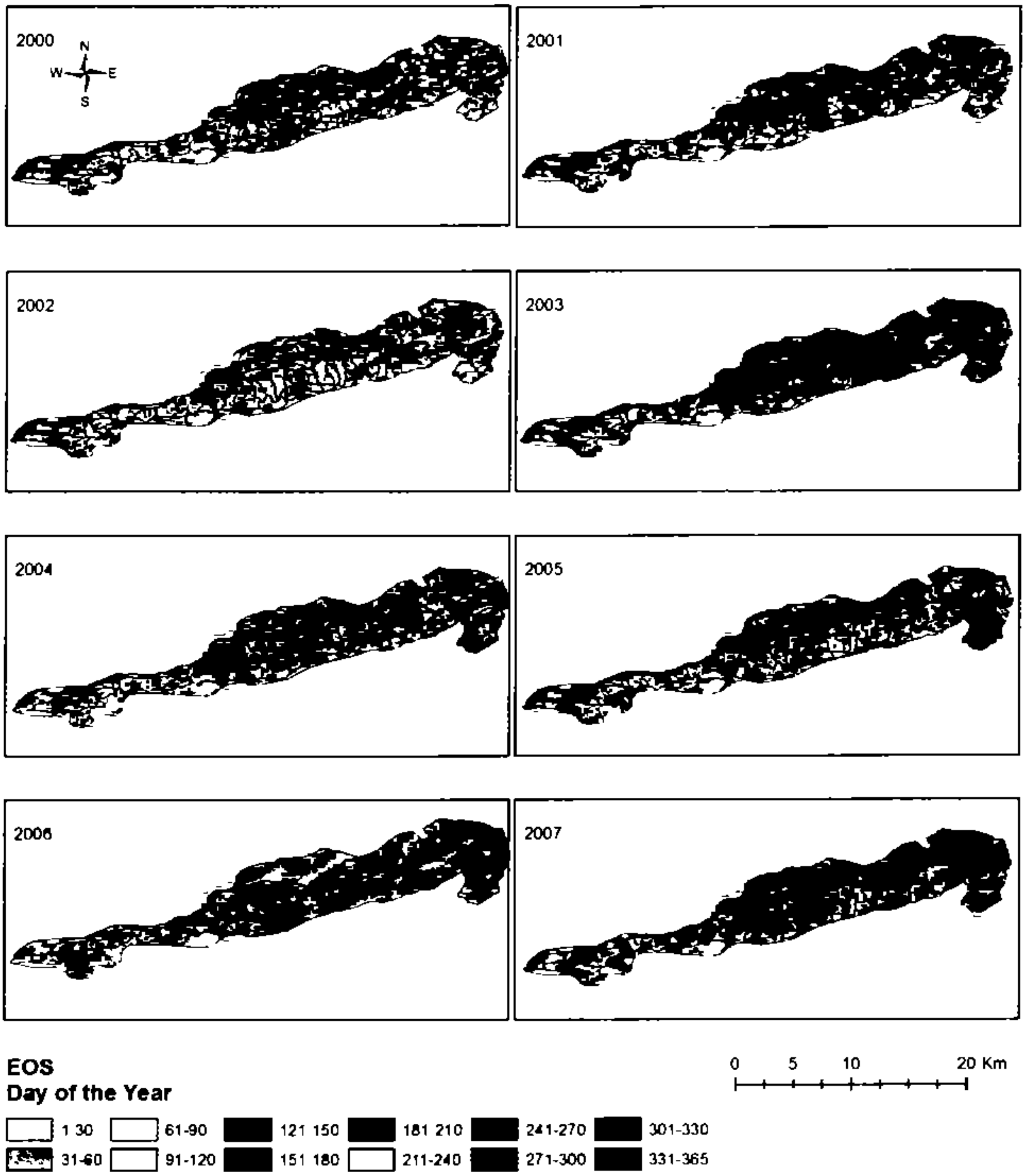

Figure 4.19 c: Spatial variability in End of growing Season in MHNP derived from MODIS NDVI time-series data (2000-2007)

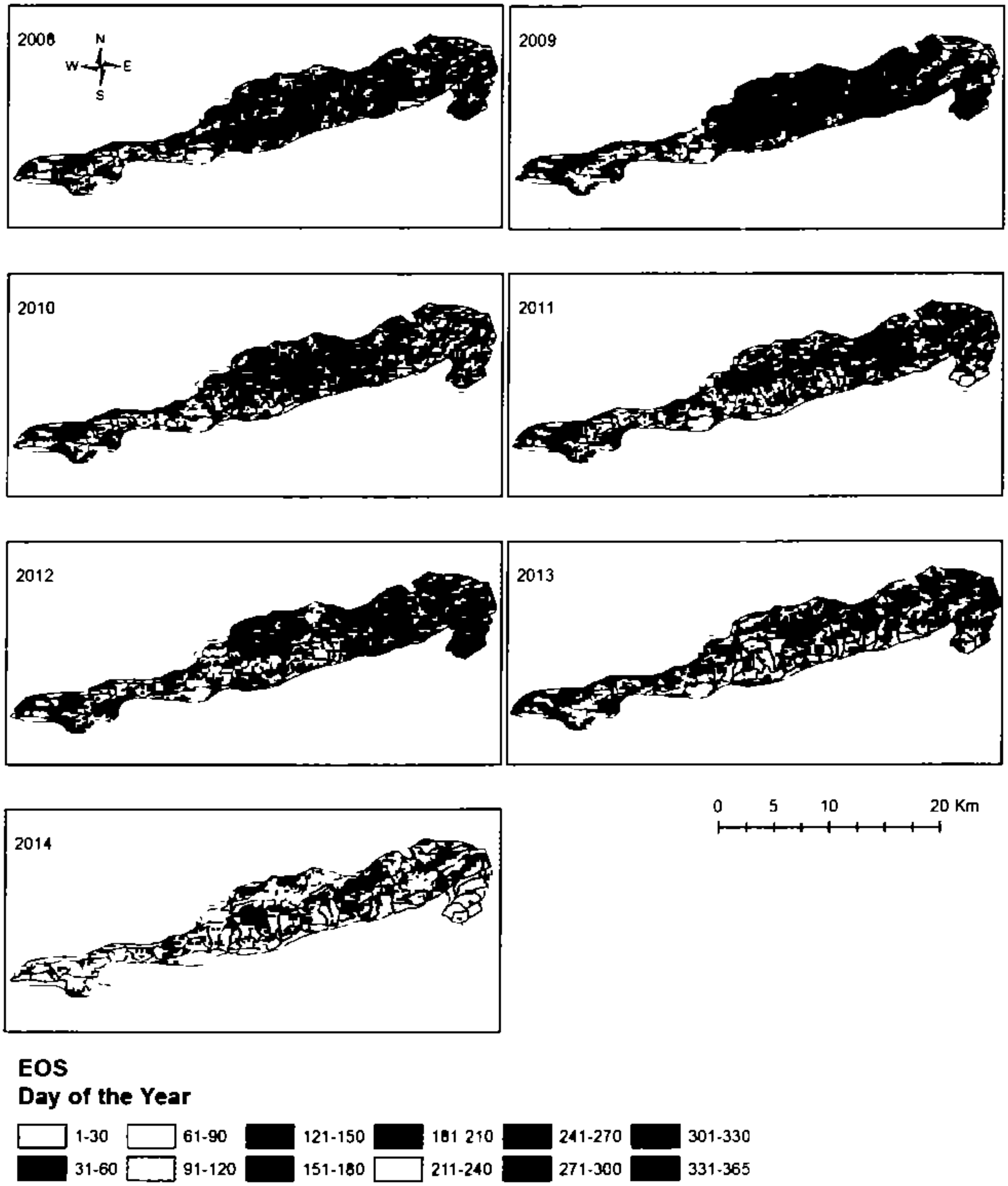

Figure 4 19 d Spatial variability in End of growing Season in MHNP derived from MODIS NDVI time-series data (2008-2014)

The EOS avg explained that some compartments had early EOS from mid-September to end of October These compartments are MF 22, MF 23, MF 12, Dara Janglan and Kalangar Guzara The compartments Jabbi Guzara, RF 3, RF 4, MF 2, MF 3, and MF 4 had EOS avg in November The compartments with late EOS avg are Shah Dara, RF.9, RF 30 and RF 32 where EOS ave occurred in month of January The Slope of EOS indicates the decreasing trends in overall area of MHNP (Figure 4.20)

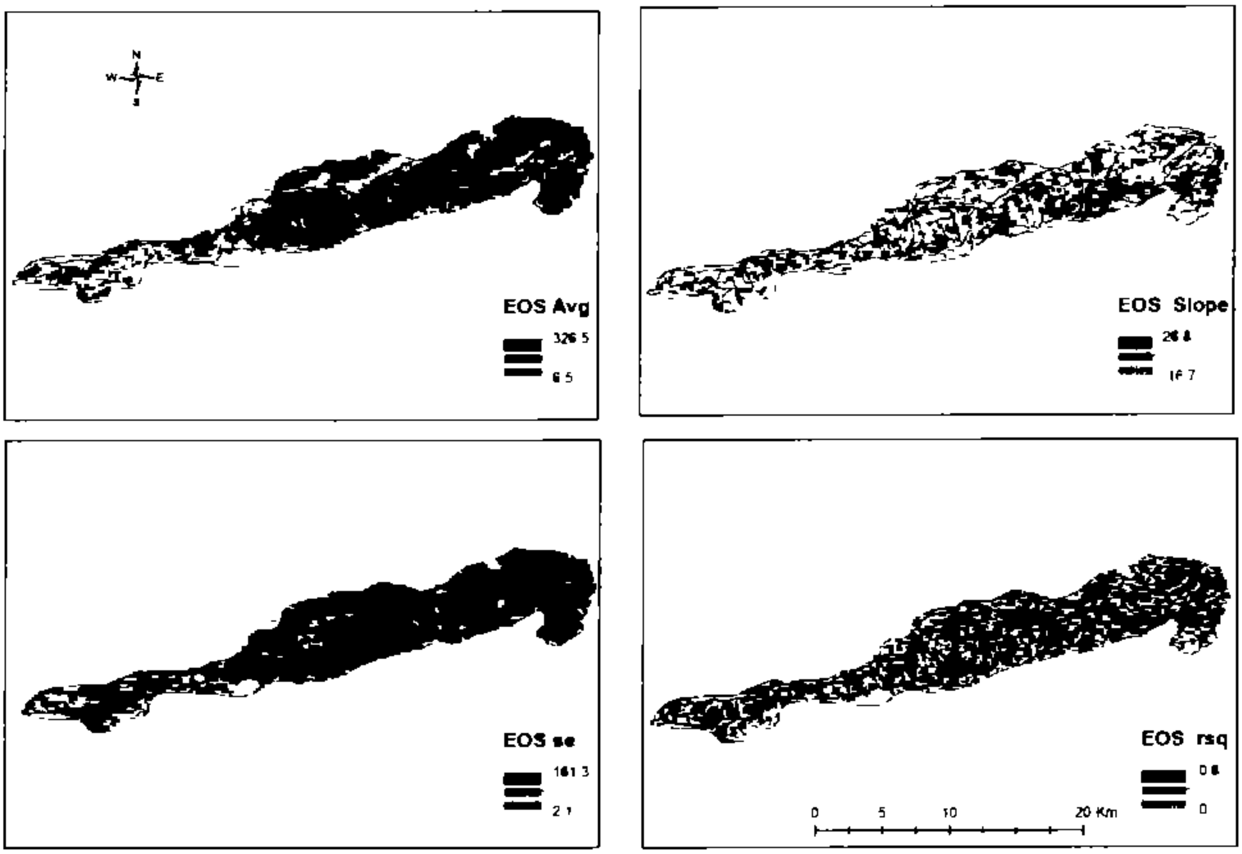

Figure 4.20: Spatial variability in phenological trends of Start of growing season derived from MODIS NDVI time-series data (2000-2014)

4.2.4. Length of Season (LOS)

The results showed that the LOS was maximum (n=337) in 2010 in RF 21 to RF 34 and Shah Allah Ditta (figure 4 21 b) The year 2014 showed small LOS (n=58) in MF 9 MF 10, MF 14, MF 15 and Jabbi guzara (figure 4 21 b)

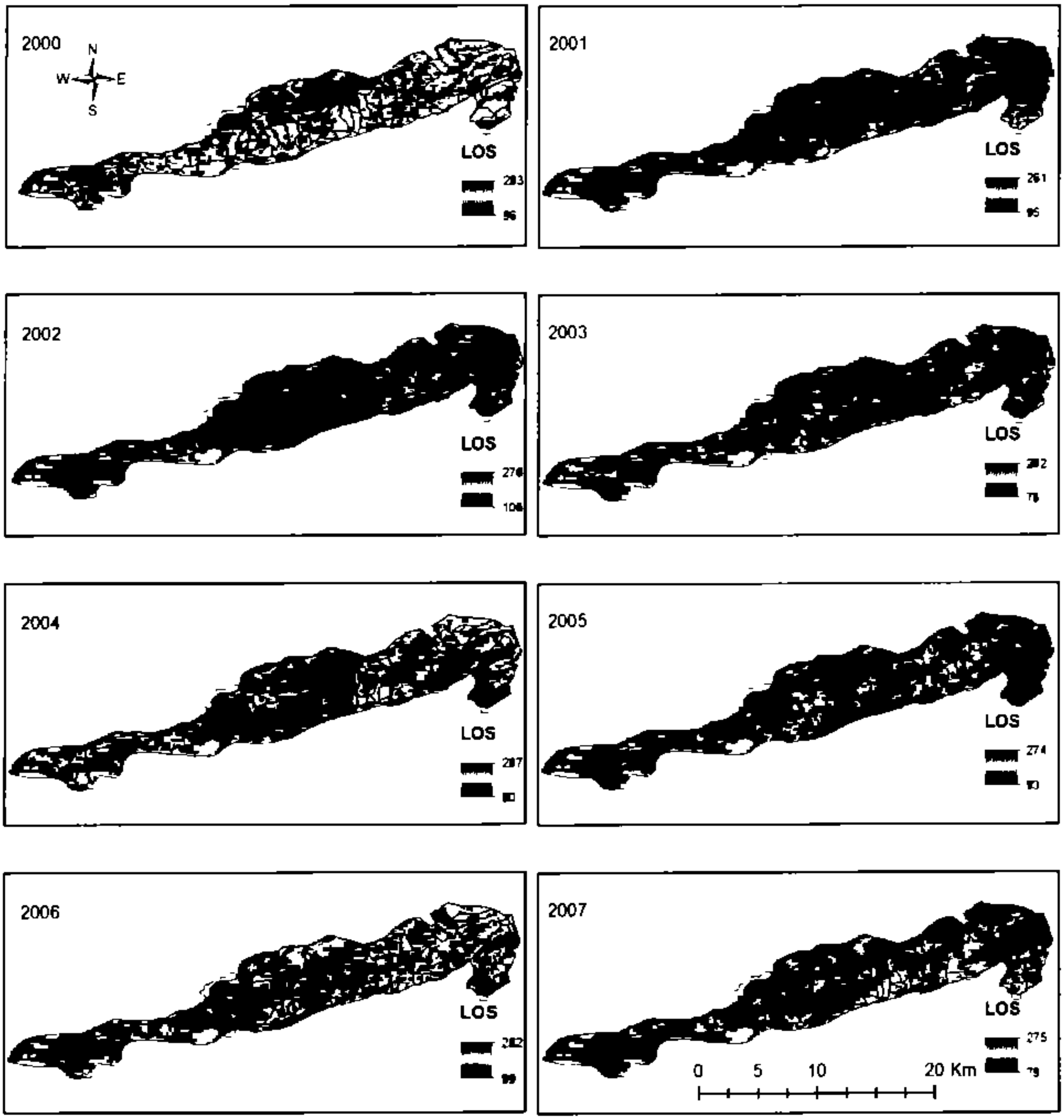

Figure 4 21 c: Spatial variability in Length of growing Season in MHNP derived from MODIS NDVI time-series data (2000-2007)

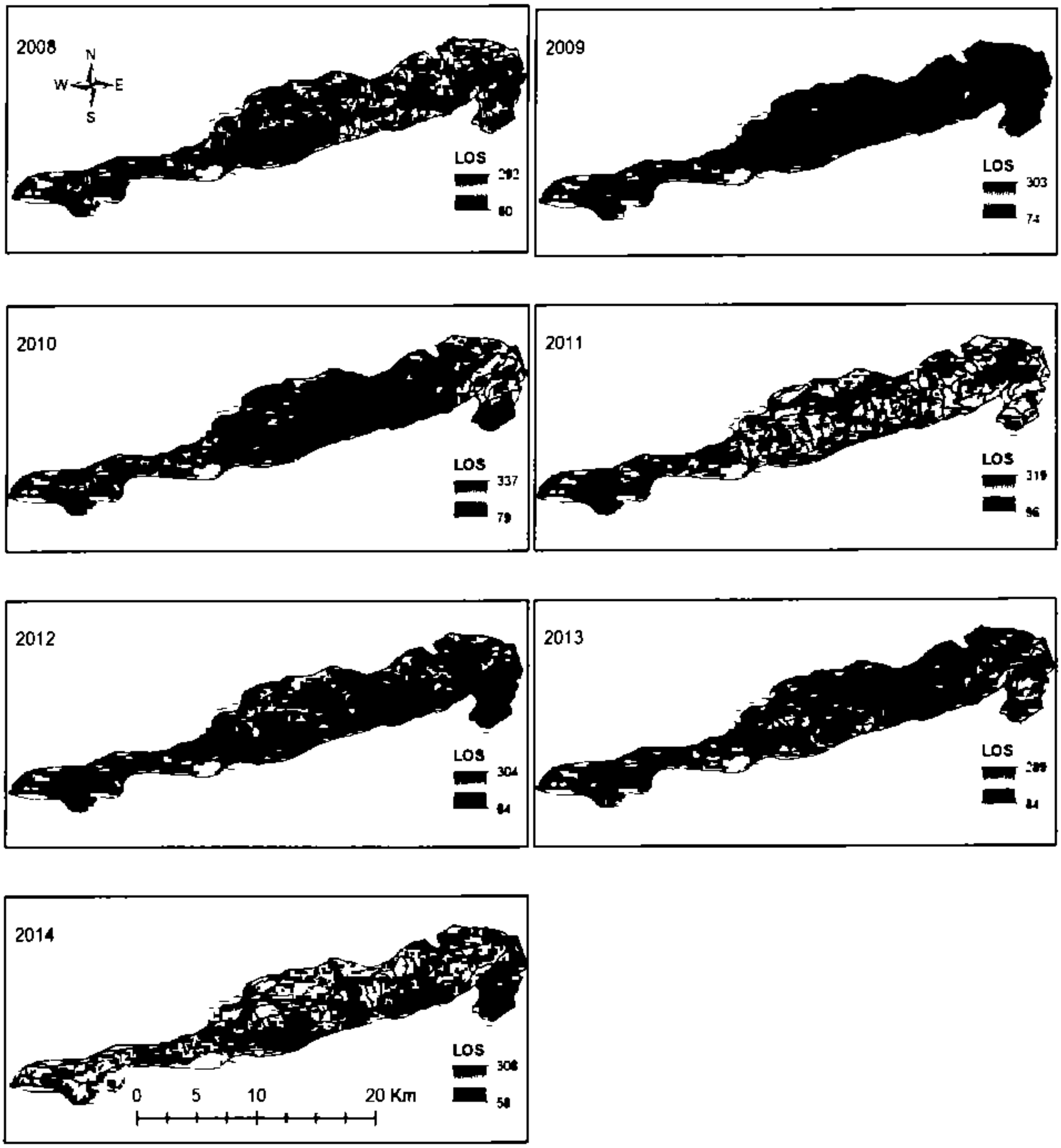

Figure 4 21 d: Spatial variability in Length of growing Season in MHNP derived from MODIS NDVI time-series data (2008-2014)

The phenological trends revealed that compartments Malwari Guzara, RF 16, RF 18 and RF 19 had small LOS avg (104 to 130 days) The compartments like RF 5- RF 8 and MF 12–MF 25 had 145-175 days of LOS avg Whereas some compartments showed the high values of LOS avg (220-256), these compartments are RF 2, RF 3, RF 4, RF 9, Shahdara, Mangial Guzara, Shah Allah Ditta and RF 30- RF 37 (figure 4 22)

The results shows that the average LOS in MFs is 104-180 days, whereas the average LOS in RFs is 200-256 days

The slope of LOS indicates decreasing trends in majority of the area Whereas MF 22, MF 23, RF 7, RF 8, Sonari Guzara, Faisal masjid and Daman e Koh showed increasing trend in LOS (figure 4 22)

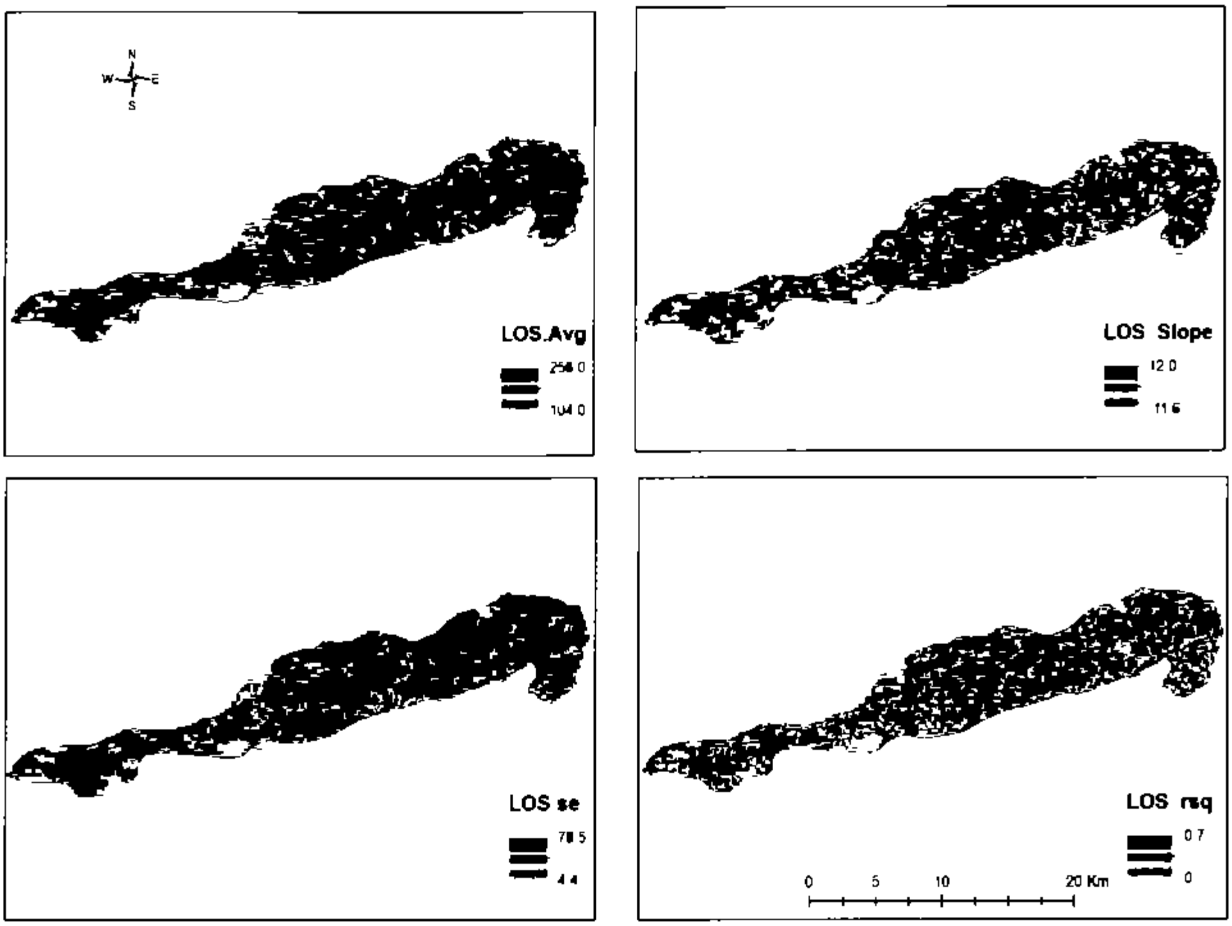

Figure 4 22 Spatial variability in phenological trends of Length of growing season derived from MODIS NDVI time-series data (2000-2014)

4.2.4. Peak NDVI

The results revealed that PEAK NDVI in MHNP between the years 2000 to 2014 was maximum in 2003 and 2013 with upper value of 0 85 and lower value of 0 31 (figure 4 23 a, b) In 2009, the Peak was low, with the upper value of 0 79 and lower value of 0 24 (figure 4 23 b)

The results revealed that MFs have maximum value of Peak NDVI, whereas the value of Peak NDVI is low RFs

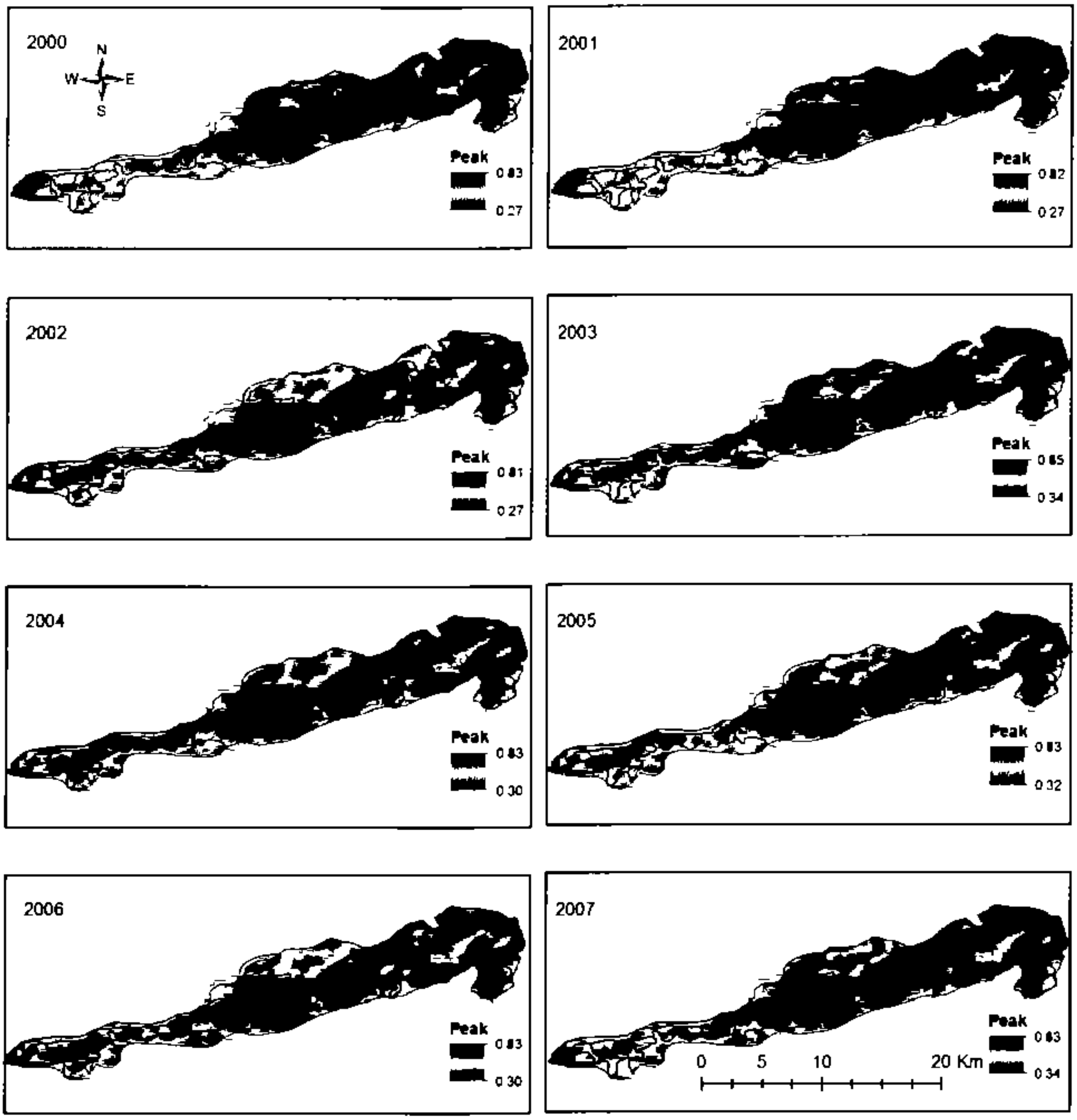

Figure 4 23 c: Spatial variability in Peak (NDVI) in MHNP derived from MODIS NDVI time-series data (2000-2007)

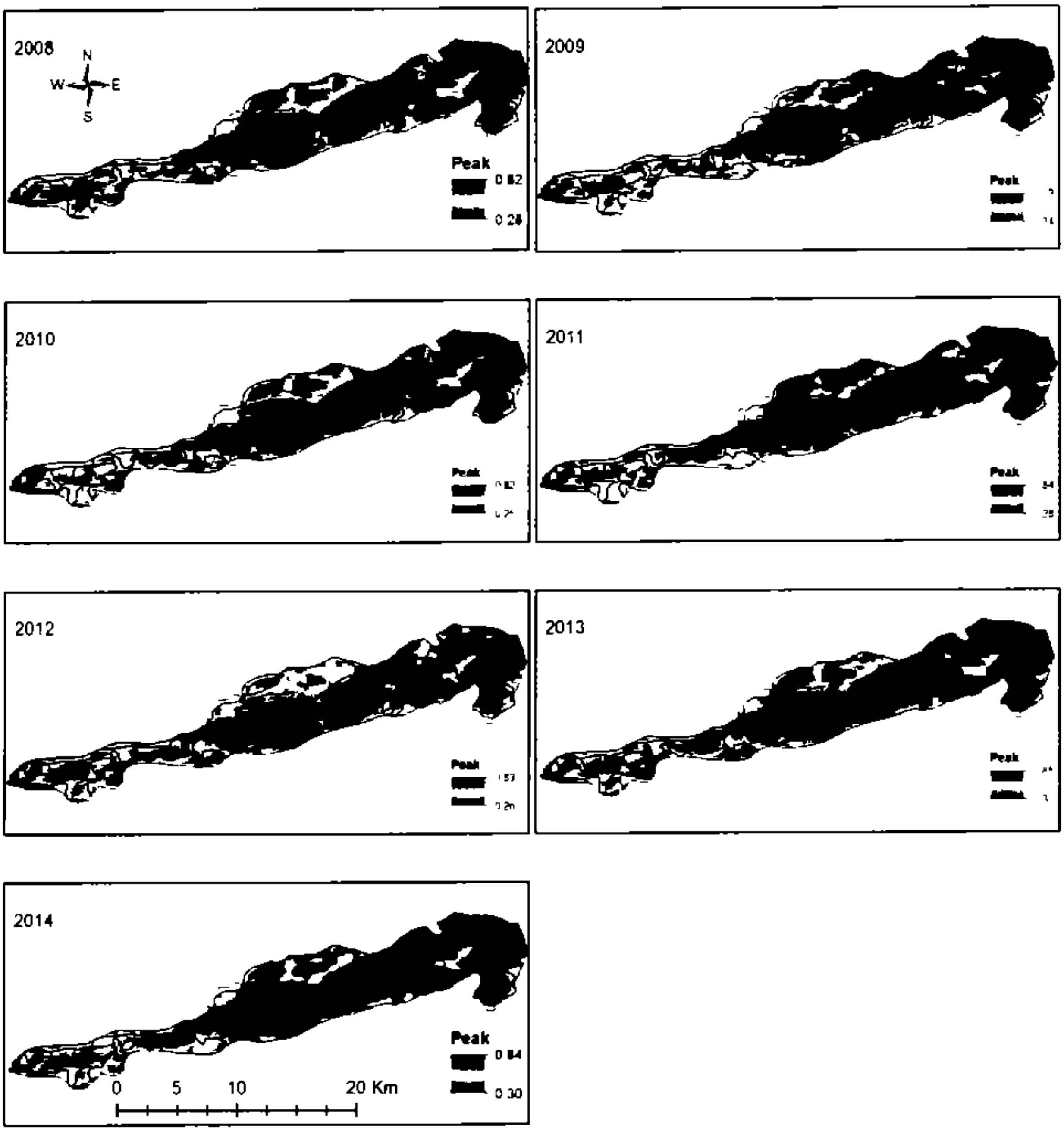

Figure 4.23 d Spatial variability in Peak (NDVI) in MHNP derived from MODIS NDVI time-series data (2008-2014)

The phenological trends showed that the Peak.avg ranges from 0 2 to 0 8 The areas near to the boundary have low peak value of 0 2 The results revealed that the Peak value in RFs is 0 5 to 0 6, whereas the Peak value in MFs is high which is 0 7 to 0 8 (Figure 4 24)

The slope of Peak indicates the increasing trends in majority of compartments, especially in MF 10 to MF 25 Whereas the Peak is decreasing in Shah Allah Ditta, RF 30 and RF 32 (Figure 4 24)

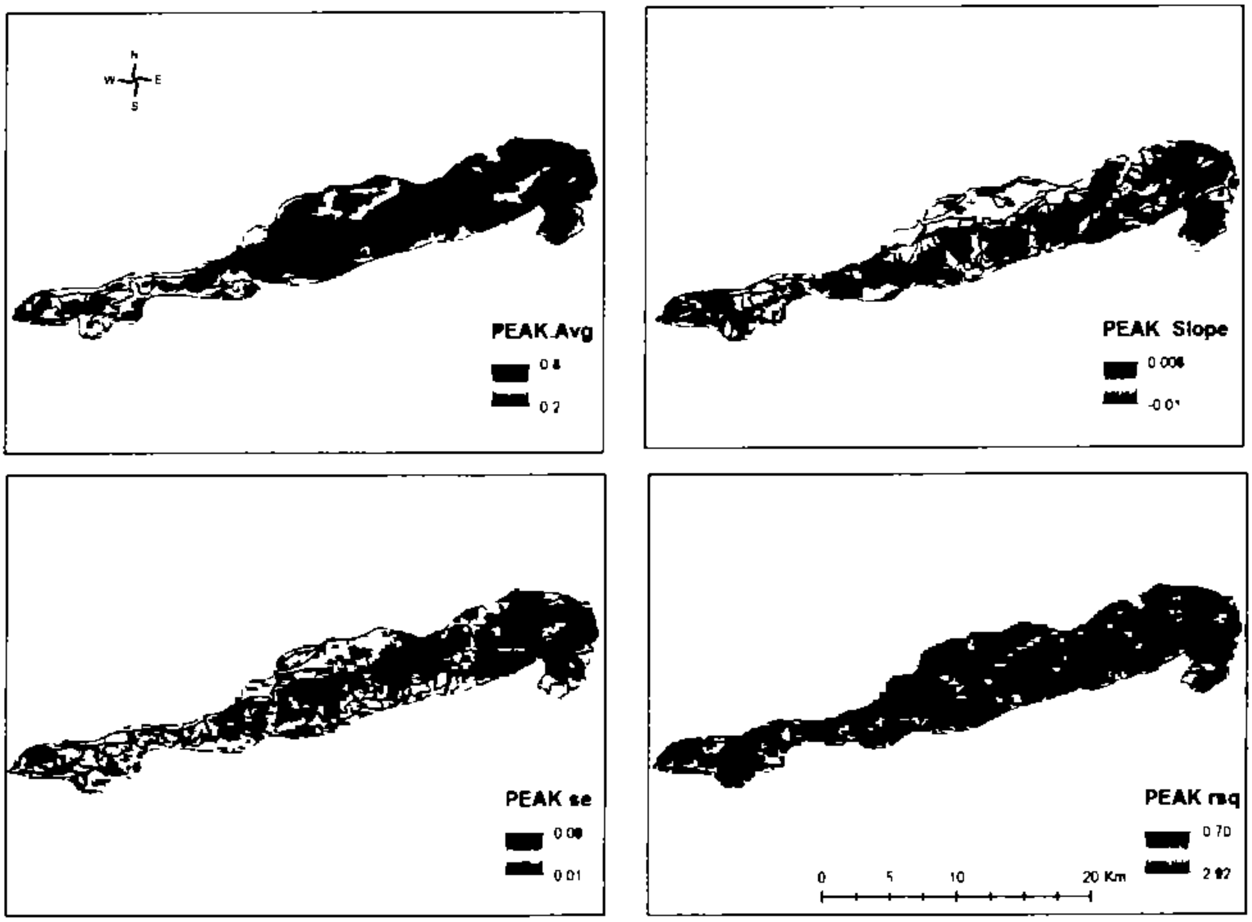

Figure 4 24· Spatial variability in phenological trends of Length of growing season derived from MODIS NDVI time-series data (2000-2014)

4.4. Principal Component Analysis (PCA)

The interrelationship between phenological parameters and forest fire was revealed by PCA whereby first three ordination axis accounted for 69.86% of the total variance in the data (Table 4.1). This verifies that the variables included in analysis were important in context of fire i.e., majority variance in the data got explained.

Table 4.1: Eigenvalues, percentage and cumulative percentage obtained from forest fire data (1996-2014) and phenological data (2000-2014)

	Axis 1	Axis 2	Axis 3
Eigenvalues	2.85	1.61	1.12
Percentage	35.66	20.18	14.02
Cum. Percentage	35.66	55.84	69.86

The PCA indicates that start of season (SOS), length of season (LOS), (NDVI), and SDSS can be significantly ($p<0.05$) related with forest fire. The axis 1 that explained 35.55% of total variance in the data was significantly ($p<0.05$) positively correlated with SDLS (0.48), SDNDVI (0.43) and SOS (0.38), while NDVI (-0.48), EOS (-0.34) and T all (-0.20) had negative relationship. The axis 2 contributed 20.18 % of total variation and showed positive correlation with the variables SOS (0.50) and LOS (0.7), while SDNDVI (-0.26) and SDSS (-0.29) had negative correlation with axis 2. The axis 3 which accounted for 14.02 % of total variance explained, the variables SDSS (0.71), T all (0.53), SDLS (0.31) and NDVI (0.20) showed positive correlation with axis 3 (Table 4.2).

Table 4.2 PCA variable loadings for forest fire (T all) and phenological parameters SOS, EOS, LOS, NDVI, SDLS, SDNDVI and SDSS. The bold values shows significant correlation at $p<0.05$

S. No	Variables	Description	Axis 1	Axis 2	Axis 3
1	SOS	Start of growing season. Time (day of year) at which NDVI curve starts to abruptly move upwards (small integral)	**0.38**	**0.50**	0.03
2	EOS	End of growing season. Time (day of year) at which NDVI curve abruptly move downwards (large integral)	**-0.34**	**0.23**	0.02
3	LOS	Difference between EOS and SOS	0.12	**0.70**	0.17
4	NDVI	MOD13Q1 time-series i.e., 16 day composite VI at 250 m resolution	**-0.48**	0.171	**0.20**
5	SDLS	Variations in LOS	**0.48**	0.05	**0.31**
6	SDNDVI	Variations in NDVI	**0.43**	**-0.26**	-0.15
7	SDSS	Variations in SOS	0.13	**-0.29**	**0.71**
8	T All	Duration of forest fire	**-0.20**	-0.05	**0.53**

The ordination biplot overlaid with 7 vegetation types in 5 groups (Section 3 2) indicate that the occurrence of fire shows different affinity towards the different kind of vegetation The group 1 has vegetation community 4 (dominated by *Dodonaea viscosa* and co-dominated by *Carrisa opaca*), group 2 has vegetation community 5 (*Dodonaea viscosa* and co-dominated by *Justicia adhatoda)* and vegetation community 6 (*Dodonaea viscosa* and co-dominated by *Punic agranatum*), group 3 has vegetation community 4 (*Dodonaea viscosa* and co-dominated by *Carrisa opaca*) and group 4 and group 5 have vegetation community 3 (dominated by *Carrisa opaca* and co-dominated by *Justicia adhatoda*) The ordination biplot revealed that group 1, group 2 and group 3 are on right side and represents the site with high valued of LOS, SOS and SDLS and indicates negative relationship with forest fire (T all) Whereas group 3 and group 4 are on left side and represents the site with high values of NDVI and EOS and indicates the positive relationship with forest fire (T all)

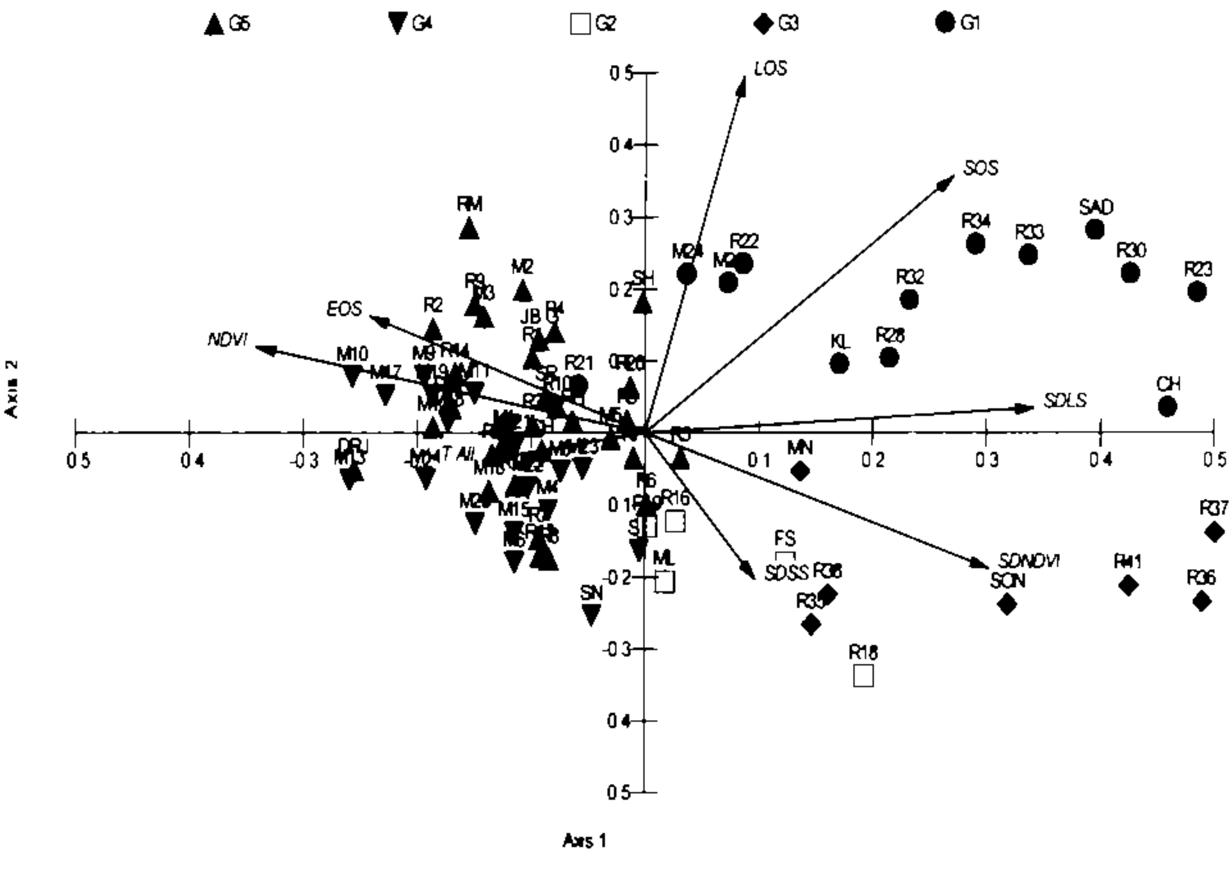

Figure 4.25: Biplot of Principal Component Analysis (PCA) variables loadings The forest fire variable is duration of forest fire (T all) and phonological parameters include Stat of Season (SOS), End of Season (EOS), Length of Season (LOS), NDVI, Standard deviation of Start of Season (SDSS), Standard deviation of Length of Season (SDLS), Standard deviation of NDVI (SDNDVI) Sites are overlaid in five groups based on vegetation type

5. DISCUSSION

5.1. Spatiotemporal Patterns of Forest Fire

The mapping of area affected by forest fire is one of the most common application of remote sensing at a local, regional and global level It is cost-effective provides timely and spatially comprehensive views of fire affected areas and their pattern of occurrence (Lentile *et al*., 2006), (Quintano *et al*., 2011)

Out of a wide range of forests, sub-tropical broadleaved evergreen shrub forests and sub-tropical Pine forests are the most fire prone environments in Pakistan ((Bukhari, 1997), (NIDM, 2011) The flora of the Margalla Hills National Park is primarily sub-tropical evergreen scrub forest on the lower slopes and sub-tropical pine forest at higher elevations

Military farms (MFs) are more affected than Reserved forests (RFs) in MHNP as 63% of total fire events (1996-2014) occurred in MFs The most affected compartments found in the study are MF 15 (n=52), MF 10 (n=45), MF 15 (40), MF 23 (n=34) and MF 22 (n=32) Mainly human settlements is near to MFs and road density is high as compared to RFs, so this can be the reason of human induced forest fire in these compartments The road density and distance to settlements are important causal factors of forest fire (Verma *et al*, 2013) Whereas MF 22, MF 23 are not well connected with the road network even though they have subjected to the maximum fire incidences The most plausible explanation is other topographic, weather and vegetation characteristics (Verma *et al*., 2013)

The presence of biomass or fuel wood in MFs is also a major factor of forest fire, as the measure of combustible material in a given zone expands, the measure of heat produced by the fire also increases (Prasad *et al*, 2008) found in a study that the best predictors of fires in the Deccan Plateau were forest area and biomass density In RFs density of *Dodonaea Viscosa* is high and in MFs density of *Carissa opaca* is high and majority of species are shrubs (Nimra & Sadaf, 2012)

The yearly patterns of forest fire in MHNP revealed that there is high forest fire events in a year following 3 or 4 years of low fire occurrence (figure 4 5) The most plausible explanation is vegetation cycle in the area. The months of Aril (n=82/769), May (n=248/769) and June (n=282/769) are found to be fire prone months The temperature reaches up to 42° in months of June and July The months of April, May and June are hottest months of the year and are also prone to fire This is due to the high litter content in the forest floor of the moist deciduous forest

Dry condition in summer season and less humidity making the condition forest fire prone From middle July to September the area receives highest rainfall causing less no of forest fire incidences From October to February the study area undergo in the winter season with low temperature hampering the forest fire incidences From February onward the leaf shedding started which increases the litter content of the forest floor Hot and dry condition afterward till middle June creates the condition fire prone (Verma *et al*., 2013)

In Jammu region of Jammu and Kashmir forest fires are prevalent in hot and dry summer months mostly in sub-tropical chir pine forests, when fuel in the form of dry branches, needles, grasses and scrub on the forest floor become highly flammable (Ahmed & Sharma, 2014)

Moreover, during summer when temperature is at peak and before the start of monsoon forests are put to fire by the local residents to increase the production of grasses for grazing their livestock The fire is also common practice during off season for clearing the land from bushes to increase agriculture area As the chir pine is rich in resin they easily get damaged by fire (Ahmed & Sharma, 2014) In northern Pakistan mostly natural forest is owned by village communities or local tribes Mistrust and rivalries within tribes/families and communities are also among the reasons of forest fires and thefts, however in this study this factor is not found It is very difficult to fight with the threat of forest fire in the absence of fire belts in most areas of natural forests (Verma *et al*, 2013)

5.2. Phenology and Forest Fire

The developments in remote sensing technology resulted in the success of phenology at large scale (Goward, 1989) (Moulin *et al*, 1997) compared the new technology (capturing vegetative signals from RS images) with traditional method of phenological research (using ground observation records) and revealed that collecting data from RS technology is more effective and efficient than measuring ground data

Remote sensing information and related investigation procedures give an extraordinary plausibility to evaluating changes, particularly those brought on by anthropogenic exercises over time (Huang *et al*, 2009), (Shahzad *et al*, 2015) Satellite images offer the likelihood to analyse spatial changes generally with synchronization of the current circumstance and ground realities

Due to their high quality of temporal and spectral resolution the MODIS and the SPOT VEGETATION have been widely used for both detecting active fires and mapping affected zones (Chu & Guo, 2013)

The phenological cycles of leaf onset and senescence as well as effects of climate on vegetation greenness are vegetation- and location-dependent (Atkinson *et al.*, 2012) Both precipitation and temperature played an important but different role in affecting vegetation phenology (Tang *et al.*, 2015)

The phenological trends indicates increase in slope of Start of Season (SOS) in MFs MHNP and decrees in Slope of End of Season (EOS), which suggests that Length of Season (LOS) is getting smaller It is also found that those compartments (MF 10-MF-25) where LOS is small are most affected by forest fire, whereas those compartments (RF 21-RF 41) where LOS is large are less affected by forest fire or not affected at all

The present study revealed that Peak NDVI has increased in MFs (MF 10-MF 15) Vegetation type is related to NDVI as evergreen vegetation shows high NDVI It is also found that forest fire is high in those compartments where Peak NDVI has increased The most plausible explanation is the availability of biomass, as the measure of combustible material in a given zone expands, the measure of heat produced by the fire also increases (Prasad *et al.*, 2008) and after the fire the nutrients availability increases in area which increases the vegetation growth

(Mitchell & Yuan, 2010) found that burned areas, especially the heavily or severely burned areas, rapidly regenerated via a combination of grasses and shrubs In another study (Cochrane, 1998) and (Numata *et al.*, 2011) found that burned forests recover rapidly and become difficult to separate from undisturbed forest more than one year after forest fire using remote sensing

The PCA also supported the results that vegetation type is important in forest fire analysis The most affected compartments showed high NDVI and shorter LOS The dominate vegetation in these compartments is *Carrisa opaca* and majority of vegetation is shrubs It is found in the study that those compartments where density of *Carissa opaca* is high are severely affected by forest fire, on the other hand, compartments with high density of *Dodonaea viscosa* are less affected by forest fire Similar results were found by Ahmed and Sharma (2014) in their study that *Carissa opaca* was the most dominant species in term of density for burnt sites and *Dodonaea viscosa* was dominant in unburnt sites

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

The present study focused on spatiotemporal patterns of forest fire from 1996 to 2014 and Phenological trends in Margalla Hills National Park The study reveals that the months of April, May and June are fire prone The Military farms (MFs) are more vulnerable to forest fire than Reserved forests (RFs) The possible causal factors of forest fire can be vegetation type and human interferencee The MODIS based estimates of phenological trends shows strong spatiotemporal patterns Phenology results reveals that MFs usually have shorter LOS and RFs have longer LOS It is found in the study that NDVI increased in those compartments which were highly affected by fire PCA revealed that compartments with *Carissa opaca* as dominant vegetation are highly affected by forest fire, whereas compartments with *Dodonaea viscosa* as dominant vegetation are less affected by forest fire

6.2. Recommendations

The spatiotemporal patterns of forest fire in MHNP suggested that April, May and June are fire prone months and Military Farms (MFs) are more vulnerable to forest fire than RFs For management of forest fire in MHNP, it is recommended that the Forest fire fighting activities to be enhanced during fire prone months Vegetation monitoring to assess as to which particular type of vegetation/ plant species are facilitating Forest fire and manage them accordingly

In recent time, GIS has developed as a capable device in conjunction with multitemporal remote sensing information for examining and observing the effect of numerous ecological elements Forestry in Pakistan needs to change rapidly to adopt to this new idea of forest management

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