CLIMATE-FOREST FIRE LINKAGES IN SELECTED PROTECTED AREAS IN KERALA

by

SREEDEVI K

(2014-20-132)

THESIS

Submitted in partial fulfilment of the requirements for the degree of

B.Sc.-M.Sc. (Integrated) CLIMATE CHANGE ADAPTATION

Faculty of Agriculture

Kerala Agricultural University

ACADEMY OF CLIMATE CHANGE EDUCATION AND RESEARCH

VELLANIKKARA, THRISSUR-680 656

KERALA, INDIA

2020

DECLARATION

I hereby declare that this thesis entitled "**Climate-forest fire linkages in selected protected areas in Kerala**" is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associate ship, fellowship or other similar title, of any other University or Society.

Vellanikkara, **SREEDEVI K**

Date: **(2014-20-132)**

CERTIFICATE

Certified that this thesis entitled "**CLIMATE-FOREST FIRE LINKAGES IN SELECTED PROTECTED AREAS IN KERALA**" is a record of research work done independently by Ms. SREEDEVI K under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associate ship to him.

Vellanikkara,

Date:

Dr. S. Gopakumar

(Major Advisor, Advisory Committee)
Professor
Department of Natural Resource Management,
College of Forestry, KAU,
Vellanikkara.

CERTIFICATE

We the undersigned members of the advisory committee of Ms. Sreedevi K (2014-20-132), a candidate for the degree of B.Sc.-M.Sc. (Integrated) Climate Change Adaptation, agree that the thesis entitled "**CLIMATE-FOREST FIRE LINKAGES IN SELECTED PROTECTED AREAS IN KERALA**" may be submitted by Ms. Sreedevi K (2014-20-132), in partial fulfilment of the requirement for the degree.

Dr. S. Gopakumar

(Major Advisor, Advisory Committee)
Professor
Department of Natural Resource Management,
College of Forestry, KAU,
Vellanikkara.

Dr. P.O. Nameer

(Member, Advisory committee)
Professor & Dean,
ACCER
KAU, Vellanikkara.

Dr. Kunhamu T. K

(Member, Advisory committee)
Professor and Head
Department of Silviculture and Agroforestry,
College of Forestry, KAU,
Vellanikkara.

Dr. A.V. Santhosh Kumar

(Member, Advisory committee)
Professor & Head
Department of Forest Biology and Tree Improvement
College of Forestry,
KAU, Vellanikkara.

EXTERNAL EXAMINER

ACKNOWLEDGEMENT

First and foremost, I am really thankful to God to complete my studies and for enabling/strengthening. I bow my head before the Almighty for giving me the opportunity, strength, zeal and good health in achieving my academic endeavor.

I express my deep and sincere gratitude to my research guide Dr. S. Gopakumar, Professor, Department of Natural Resource Management, College of Forestry for his patience, help, advice, inspiration, encouragement and constant support, throughout the successful completion of my thesis work. Working and learning under his guidance was a great pleasure and honor. I am very thankful for giving me an opportunity to work under his guidance.

I sincerely thank Dr. P. O. Nameer, Dean, ACCER for his meticulous help, patience during my course of research work and ensuring all essential facilities required for the successful completion of my thesis work. I also express my gratitude towards all teaching and non-teaching staffs of ACCER especially Mr. Jineesh V. K, Dr. Vipin P, Mrs. Krishnapriya, Sajitha chechi, Mini chechi.

I express my sincere gratitude to my advisory committee members Dr. T. K. Kunhamu, Professor & Head, Department of Silviculture and Agroforestry, College of Forestry, KAU and Dr. A. V. Santoshkumar, Professor & Head, Department of Forest Biology and Tree Improvement, College of Forestry, KAU for providing all the support and suggestions for the completion of my research work. I also express my gratitude towards all teaching and non-teaching staffs of College of Forestry.

I express my gratitude to Mr. Vishnu B. R for his treasured knowledge, support, suggestions and help in statistical analysis. I also extend my gratitude to Mrs. Indu V S for the motivation, advices, help and suggestions in GIS lab works. I express my gratitude to Mr. Anand Sebastian, Project Scientist, IRTC for suggestions and help in GIS analysis.

I would like to express my sincere thanks to Kerala FD; Cardamom Research Station, Pampadumpara; Aromatic and Medicinal Plants Research Station, Odakkali nd Irrigation Design and Research Board (IDRB), Trivandrum for providing required data.

I express my heart-felt indebtedness to my batchmates Saranya, Varna, Ancy, Anagha, Punya, Kavya, Pooja, Anu and Jibin of PHOENIX-2014 for the help, support selfless encouragement throughout the bright and dark phase of my research work.

My heartfelt thanks to my dearest seniors Gokul chettan and Angel chechi for help and support for the completion of thesis work.

I am also grateful to all my teachers whose guidance and inspiration made it possible for me to see this day at various stages of education; I was able to enter a stage where I could write this study because of their goodness.

I feel a profound sense of respect to my father Kalidasan and my mother Syamala for their unconditional love, support and motivation. Their patience and sacrifice remain as my biggest strength and inspiration through my life. I do express my token of love to my brother Sreenath for his support, love, care and affection.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND EXPANSIONS

BB	:	Biomass Burning
BC	:	Black carbon
DEM	:	Digital Elevation Model
FD	:	Forest Department
FSI	:	Forest Survey of India
GIS	:	Geographical Information System
GPS	:	Global Positioning System
IPCC	:	Intergovernmental Panel on Climate Change
IUCN	:	International Union for Conservation of Nature
JFM	:	Joint Forest Management
NTFP	:	Non – Timber Forest Product
OA	:	Organic Aerosols
RS	:	Remote Sensing
TOA	:	Top of the Atmosphere
UNFCC	:	United Nations Framework Convention on Climate Change
USGS	:	United States Geological Survey
WLS	:	Wildlife Sanctuary

INTRODUCTION

CHAPTER 1

INTRODUCTION

In addition to anthropogenic activities, climate change is the primary causative cause inducing forest fires (Lazaridis *et al*., 2008). Forest fire occurs both in natural and anthropogenic ways, but most of the fires in Kerala are man-made. Forest fires are the main threat to the productivity and sustainability of forests. Approximately 2-3% of the forest land is hit by fire every year and more than 34,000 ha of forest areas are burned in India. (Malik *et al.,* 2013). The three conditions that need to be present for a fire to burn are carbon, oxygen and heat sources. Fuel is any flammable substance, like trees, grass, brush, etc. The fire is likely to be more intense in an environment with a higher fuel load. Heat sources allow the wildfire to spark and bring fuel to temperatures that are high enough to burn. Lightning, burning campfires or cigarettes, hot temperatures, and even hot sunshine will provide enough heat to start a wildfire in some situations.

Wildfires are of three basic types, namely crown fires, surface fires and ground fires (Alexander and Cruz, 2011). The crown fires are the most intense and dangerous wild land fires and they burn trees up their entire length to the top. Just soil litter and duff burn from the surface flames. Those are the simplest fires to put out and do the least forest damage. Ground fires arise in dense humus, peat and related dead plant accumulations that become dry enough to ignite. Ground fires are also called underwater or subsurface fires.

Man-made fires are related to land clearing and deforestation. Human-induced forest fire stems from woods' illegal burning activities for grabbing farmlands through encroachments and in India most of the fire outbreaks have an anthropogenic connection.

Forest fire affects the availability of food and water that make the wild animals move out from the forest to the nearby fields where the human being lives. Forest fire not only affects the wild species in the forest but also affects the water resources like springs, small lakes and streams. Periodical forest fires lead to the extinction of streams and tributaries of bigger rivers. The extinction of these small running freshwater resources affects the properties of soil through which it flows. When the origin of the stream is affected by forest fire, the pathway of the stream towards the river is also affected. This can be one main reason for drought experiences in different states, including Kerala. To prevent such a situation, we need to protect our forests, because humans are, knowingly or unknowingly, becoming a reason for a forest fire.

Satellite-based remote sensing (RS) technology and GIS tools have been effective in better prevention and management of fires through the creation of early warnings for fire-prone areas, monitoring fires on a real-time basis and estimation of burn scars (Giri *et al.,* 2019). This study was also an attempt to exploit the capabilities of RS and GIS techniques and to suggest an appropriate methodology for forest fire risk zone mapping. Such maps will help forest department officials to prevent or minimize fire risk activities within the forest and take proper action when a fire breaks out (Malik *et a*l., 2013)

Forest fire study is necessary for forest management. Understanding the timing of the forest fires, its size, frequency etc. helps to understand the relationships of forest fire with various weather parameters. Time series analysis of past climatic data will additionally help in the prediction of possible future fire scenarios. All this information is crucial for firefighting at ground level. It was in this background, this study was proposed with the objective of characterizing the nature of the forest fires that had occurred during the last five years in selected protected areas (PAs) in Kerala, namely Peechi-Vazhani wildlife sanctuary, Chimmony Wildlife sanctuary, Choolanur Peafowl Sanctuary, Idukki wildlife sanctuary and Thattekadu Bird sanctuary. This study also tried to understand the size, frequency and severity of these fires and to establish possible linkages with various recorded climate variables (monthly precipitation, monthly temperature and monthly wind velocity). Past climatic data was used to find the trends and to predict fire scenarios to prepare forest fire risk zonation maps.

REVIEW OF LITERATURE

CHAPTER 2
REVIEW OF LITERATURE

2.1 Fire

The interaction between fuel, energy and environment can be described as fire. Fire is simply defined as, a state, process or instance of combustion in which fuel or other substance is ignited and combined with oxygen, resulting in flame, heat and flaming. The nature and extent of any fire that evolves either into a destructive force or into a useful tool depends on the fuel supply (Shafizadeh, 1968).

Biomass burning is an important source of CO_2, CH_4, N_2O, black carbon etc. (Hao *et al.*, 1990). CO_2, CH_4, and N_2O are also important "greenhouse" gasses that affect the global climate (WMO, 1985).

Black carbon (BC) in soot is the dominant absorber of visible solar radiation in the atmosphere. According to formation of BC, the type of formation are classified in two ways, they are indoor formation and outdoor formation. BC is largely produced due to cooking with biofuels such as wood, dung and crop residue in indoor environments. Outdoor formation is due to combustion of fossil fuels (diesel and coal) and open burning of biomass (related to deforestation and burning of crop residues) (Ramanathan and Carmichael, 2008).

2.1.1 Forest fires

Forests are one of the most valuable natural resources for human life and social advancement. (Jinzhu *et al.*, 2007). Forests can absorb atmospheric carbon dioxide, maintain humidity levels in the atmosphere moderate the temperature and regulate rainfall, restrain soil erosion and also form the basis for the conservation of fauna and flora (Morancho, 2003). The protected areas are one of the cornerstones of the conservation of the world's remaining biodiversity (DeFries *et al.*, 2005).

Natural causes as well as anthropogenic behaviour can cause forest fires (Ajin *et al.*, 2016). Based on the origin of forest fires there are two types, natural and anthropogenic. Natural forest fires are produced by lightning. Most forest fires are caused by human activities. The majority of forest fires are intended for land conservation, timber harvesting and socio-economic conflicts over property and land use rights, deforestation, grazing land management, use of non-wood forest products, settlement fires (fires from settlement example cooking etc.) and other traditional fire uses (religious) (Rawat, 2003).

A forest fire is one of the greatest global environmental hazards to wildlife sanctuaries. Due to forest fires, valuable and ecologically vulnerable forest lands have been destroyed over the years. The disappearance of biodiversity is serious indeed.

Forest fires are one of the main natural threats, being a significant environmental threat that is considered a potential hazard with human, biological, environmental and ecological implications (Somashekar *et al.*, 2009). The repeated occurrence of forest fires has been one of the main factors for the loss and extinction of several of our valuable plants and animal species. Forest fires do not only kill animals but also have long-term effects such as stress, loss of habitat, territories, shelter and food. That leads to conflict between humans and animals (Saklani, 2008). The reasons for forest fires are varying throughout the world. Forest fires can cause extensive damage to the biodiversity, ecosystem and landscape. It endangers human and animal life. It can also cause atmospheric pollution because, during forest fires, a significant amount of gaseous and particulate matter pollutants will get emitted into the atmosphere (Lazaridis *et al.*, 2008).

The fire has long-been an important part of the forest environment and has played a significant role in shaping the flora, fauna and also plays a role in nutrient recycling (Chandra and Bhardwaj, 2015). Forest fire plays a significant part in defining forest habitats. But regular fires can do either good or harm. The fire causes species extinction, altering of species composition and succession stages which gives significant changes to ecosystem functions (Jaiswal *et al.*, 2002; Kanga *et al.*, 2013).

Forest fires usually occur in the summer season from January to May, when trees start littering the forest floor with dry leaves and twigs making the entire forest into a potential fire danger zone, especially the deciduous forest. A forest fire can reduce large chunks of the forest to ash in a very short time in ideal conditions of high temperature and winds. The organic matter needed to maintain a favorable level of humus in a soil is destroyed which affects vegetation and the food chain thereafter. A forest fire can make large-scale impact on the ecosystem (Kulkarni, 2018). Flannigan *et al.*, (2013) remarked that fire season length changes were also most pronounced at the end of the century and for northern high latitudes where fire season lengths will increase by more than 20 days per year. Implications from this study are fire seasons will be more severe in the future and that conventional fire management approaches may no longer be effective.

In one of California's largest wildfire outbreaks, about 60,000 ha of forest is bur nt, resulting in 86 deaths and loss of about 19,000 structures (FSI, 2019).

2.1.1.1 Forest fires in India

According to IUCN (2008), a Protected Area is a clearly defined geographical area, recognized, dedicated and managed by legal or other effective means to achieve long-term nature conservation with the associated ecosystem services and cultural values. They occupy about 5% of India's geographical area and consist of both national parks and sanctuaries. They are managed solely for conservation under the rule of law (Chopra, 1998).

In India, most of the forest fires are man-made. According to Singh *et al*., (2016) frequent man-made fires in the Central Himalayas, especially Uttarakhand, are an integral part of the chir-pine, banj oak forest zone (generally between 800 and 2000 m altitude). Man-made forest fires are also a major pollutant source, including black carbon, considered a major cause of glacier melting in the Himalayas.

The majority of induced fires in the Indian forests are caused primarily by timber harvesting, land conversion, cultivation, cattle grazing, fodder and entry to the forest interior. Sometimes, fires set on the agricultural land for clearing crop residues, which spread into the forests (Sowmya and Somashekar, 2010). The Western Ghats, India's extensive biodiversity hotspot is located in the southern part of peninsular India. Currently, the entire region of Western Ghats is under serious threat due to increased human activity and over exploitation of natural resources. The increasing biotic pressure has led to frequent forest fires, resulting in forest fragmentation and degradation. Many of these fragmented forest landscapes are highly endangered and show alarming signs of the accelerated loss of biodiversity. Statistics attest that more than 25,000 hectares of forest in Kerala was destroyed by forest fire between 1991 and 2003 (Jose *et al*, 2010).

The closed evergreen mountain forests found in India's Western Ghats at altitudes above 1800 m have a distinct kind of vegetation and are called shola forests. Although these forests are located in areas that are relatively inaccessible, they are still under anthropogenic pressure, leading to continued habitat degradation and biomass and biodiversity loss (Chandrashekara *et al.*, 2006).

In some cases, people dependent on forests are the root cause of the fires. According to a case study of Nanda and Sutar (2003) In Orissa, the trade in non-timber forest products (NTFPs) accounts for a substantial part of the livelihood of forest dependents. The two most important NTFPs from a commercial standpoint are mahua flowers and kendu leaves. The new, regenerated kendu leaves are used in the bidi market. In forest areas, fire is used to initiate pairing of kendu plants and to encourage the collection of mahua flowers. These activities are among the common reasons for forest fires.

The 2016 forest fire tragedy in Uttarakhand and Himachal Pradesh, the 2018 Mount Abu forest fire incident in Rajasthan, Vaishnodevi forest fire incident in Jammu and Kurangani forest fire incident in Tamil Nadu, are some recent examples in India (FSI, 2019)

2.1.1.2. Forest Fires in Kerala

The Kerala forest area is estimated to be about 7,870 sq.km. They comprise the Southern Tropical, Wet Evergreen and Semi Evergreen forest covering an area of 3,470 sq. km. (Jayanarayan, 2001). According to FSI report 2019, total area of India’s forest cover is 7, 12,249 km ^{2}. In Kerala, 3213.24 km^2 of forests covered by its network of protected areas, which includes 17 Wild Life Sanctuaries (2855.5822 km^2), 5 National Parks (356.1550 km^2) and 1 Community Reserve (1.5 km^2) (Kerala Forest and Wild Life Department, 2018).

Due to the growing demand for forest products, the forests are facing severe pressure from humans. Uncontrolled fire can lead to loss of forest resources, biodiversity destruction, land degradation, adverse health conditions and even death (Ajin *et al.*, 2016) and also lead to human animal conflict. According to Govind and Jayson (2018), Nair and Jayson (2016), Rohini et al., (2016), Jayson and Padmanabhan (2002) and Chowdhury *et al.*, (2016) the conflict between human and animal (Elephant, Tiger, Pea Fowl, Pig and Crocodile etc.) is a growing concern around the world. Weladji and Tchamba (2003) says that the causes of conflict between human and wild animals are the involvement of people in illegal activities in the forest areas, their lack of access to natural resources etc.

It is believed that forest burning support the growth of grasses. It is also a reason why burning helps to quickly collect non-timber forest products, hunting and other purposes (Kittur et al., 2014).

According to Balagopalan (1987), fire primarily has an effect on soil organic carbon, exchangeable bases, and exchange acidity. Organic carbon rises in semi evergreen while exchangeable bases decline. Organic carbon and exchangeable bases in moist deciduous soils are rising, and vice versa, in grassland. Soils in plantations with eucalyptus have higher organic carbon and lower exchangeable bases, while in teak, both decreases.

2.2 Forest Fires and Climate Change

According to UNFCC (2011), climate change is the change that is directly or indirectly attributed to human activity that alters the composition of the global atmosphere and that is in addition to the natural climate variability observed over comparable periods of time. Global climate change is the usual process on a geological-time scale, however, rising of greenhouse gas emissions like carbon dioxide which trap heat, causes increases in global temperature. This induces a series of climatic shifts that lead to extreme events such as droughts, floods and cyclones (Chandrashekara, 2014).

Climate change has a profound effect on global forestry and tends to accelerate with a rise in anthropogenic greenhouse gas emissions (IPCC, 2014). The vegetative growth is directly influenced by changing concentrations of atmospheric gases, mainly CO_2 and indirectly affected by changing composition of atmospheric gases on regional climate and local weather patterns (Raneesh and Santhosh, 2011).

At the end of the 21st century, global temperature increased by several degrees Celsius. Reducing the supply of surface water and renewable water in the most dry subtropical groundwater regions would intensify competition for clean water with increased food demand and major food security threats (Raghavan *et al*., 2016). The frequency of heavy rainfall events is declining in large parts of Central and Northern

India, while in peninsular, eastern and north eastern India, the rainfall events increased (Guhathakurta *et al.*, 2011).

The global mean surface temperature, powered by human population growth and unstinted economic development, could record an increase from 3.7°C to 4.8°C in 2100 compared to pre-industrial rates. The effects of climate change are reflected much more in coastal and marine ecosystems because they are particularly sensitive to three key climate change drivers: sea level, ocean temperature and ocean acidity (Biju, 2014). The rising global temperature increased the sea level and decreased the amount of snow or ice. Along with the permafrost melting, warming causes insect damage and forest fire. Climate warming provides significant positive carbon feed-backs that can increase the concentration of greenhouse gasses in the atmosphere and it will intensify warming (Schindler and Lee, 2010).

The wet extremes are projected to become more severe in many areas where mean precipitation is projected to increase, as is flooding in the Asian monsoon region and other tropical areas (IPCC, 2007). According to IPCC (2014) report, in the second half of the 20th century, anthropogenic forcing led to an intensification of extreme precipitation on a global scale. And the impacts of such climate-related extremes include alteration of ecosystems, disruption of food production and water supply, damage to infrastructure and settlements, human morbidity and mortality and consequences for mental health and human well-being.

If global climate change contributes to major problems within human society, there may be a tendency to perceive wildlife needs and human needs as contradictory rather than complementary. In these comparisons, human society's needs could dominate over wildlife and biodiversity needs (Mawdsley *et al.*, 2009). Climate change is threatening people's livelihoods particularly where they depend on natural resources that are vulnerable to climate change. Diminishing availability of natural resources and sustainability of agriculture and related industries, despite the already diminishing natural resource base (Rautela and Karki, 2015).

Mahadevia and Vikas (2012) stated that Sundarbans face many challenges due to climate change such as rising sea level which causes the disappearing of islands. Increasing salinity in the water and soil has seriously threatened the health of mangrove forests, soil and related crop quality. In addition, there was a significant disturbance that occurred in the hydrological parameters. Changes in fishing habits, frequent cyclones and erratic patterns of monsoon rain adversely affect the environment and humanity. India has 64 Mha under forests, 72 percent of which are moist tropical deciduous, dry deciduous sand wet evergreen forest. The temperature increase and precipitation decline in Central and Northern India, would greatly stress forests in those areas (Ravindranath and Sukumar, 1998).

There are naturally occurring fires that are climate-induced in some areas, lightning in most cases, and secondly, human-induced fires in some areas. Forest fires can cause extensive damage to biodiversity, ecosystems, and landscapes and endanger human and animal life. It may also cause atmospheric pollution. A significant amount of gaseous and particulate matter pollutants will be emitted into the atmosphere during forest fires (Lazaridis *et al*., 2008).

As regards the impact on vegetation, the important aspects of climate change on forest fires are on species distribution, migration, replacement and extinction (Flannign *et al*., 2000). Forest fires not only add greatly to greenhouse gases emissions plus trigger loss of resources but also make the area more vulnerable to climate change. We must do our utmost to conserve forest resources, which is the best cover for climate change (Mukhopadhyay, 2009). In Asia, the observations in the past 20 years show an increase of forest fire spreading and its intensity, and this was largely due to temperature rises and precipitation declines (IPCC, 2007).

The interaction between climate change and forest fires is like a feedback system. Because climate change has an impact on forest fire, a forest fire can also have an impact on climate change (Joseph *et al*., 2009).

The fire is the main perturbation of the forest. Environment and climate are the most significant factors affecting fire activity and these factors are evolving as a result of human-caused climate change. In the future, we can expect more extreme fire conditions, burning of more area, more ignitions and a longer fire season under a warmer climate (Flannigan *et al*., 2006). Boreal forest fires are one of the most important sources of aerosol in the Arctic (Kondo et al., 2011). Large amounts of aerosols emitted from biomass burning (BB) are mainly in the form of carbonaceous aerosols, namely black carbon (BC) and organic aerosols (OA). Such particles strongly absorb and scatter visible solar radiation (down-welling and up-welling), which affects the radiation budget in the Artic.

Climate change in protected areas, added among other stresses, notably those caused by humans like over-consumption and pollution or urbanization (Mansourian *et al.*, 2009). The consequences of climate change negatively affect the ecosystem processes, food web structure, biodiversity, species distribution and interactions (Hunter *et al.*, 2010). Monitoring local to regional scales of the protected areas and their surroundings is important for their resilience to anthropogenic pressures (Nagendra *et al.*, 2013).

2.3 Forest Fire Mapping

Evaluation of forest fire risk is a vital part of fire prevention, as pre-fire preparation services require analytical tools to track when and where a fire is more likely to occur or would have more negative effects (Chuvieco *et al.*, 2010; Vinod *et al.*, 2016). Therefore it is important to create a forest fire hazard zone map and minimize fire frequency, damage, etc. Forest fire hazard zones are places where a fire is likely to start, and from where it can spread easily to other areas. Variable awareness affecting the occurrence of fire and comprehension of the fire's unpredictable actions are essential aspects of fire safety (Jaiswal *et al.*, 2002).

A forest fire can create ecosystem loss, wildlife depletion, deforestation, global warming and adverse impacts on health. Deforestation triggers soil erosion and flooding. In this regard, mapping of forest fire risk zones is important for decision-making processes, effective and sound forest management (Ajin *et al.*, 2015). Forest fire risk assessment is a vital part of fire prevention, as pre-fire preparation services include analytical tools to determine when and where a fire is more likely to occur with more adverse effects (Malik *et al.*, 2013).

Remote sensing can play a key role in developing baselines for the extent and condition of ecosystems and related species diversity and in quantifying declines or recovery associated with particular events or processes (Nagendra et *al.*, 2013). Satellite data and GIS have played a vital role in identifying and mapping forest fires and in recording the frequency at which various types/zones of vegetation are affected. Color composite image from the Indian Remote Sensing Satellite (IRS) LISS IV was used for the mapping of vegetation. Slope, aspect and elevation were derived from the digital elevation model (ASTER DEM), topographic maps and field information along with other information such as roads and settlements. Forest fire hazard zones were delineated by assigning subjective weights to the classes of all layers according to their fire sensitivity or fire-inducing capacity (Verma *et al*., 2013).

Forest fires are causing major forest cover losses and disrupting the ecological balance in our country. Temperature rise during the summer season is causing increased dryness. The forms of forest cover in the Garhwal Himalayas are some of the factors that lead to forest fires. Therefore, it is important to produce forest fire risk maps because they help to take preventive steps in the proper time. Such danger maps will help to showcase areas as very high, medium and low-risk areas in respect of the region's susceptibility to forest fire (Chandra and Arora, 2006).

For developing a strong communication network between monitoring station and fire suppression teams, efficient transportation, watchtowers, construction and maintenance of fire lines, establishment of water harvesting systems, fire management plans, any other technical advancement, support to Joint Forest Management Committees (JFM), education, training and research, remote sensing and GIS technology could be used effectively in fire hazard zoning (Chandra, 2005).The effect of treatments on the impacts of wildfire should be considered at different scales. The method is complicated by the lack of data integration between fire behaviour models and poor links to geographic information systems, corporate data and applications for remote offices (Ager *et al*., 2011).

Forest fires have been a significant hazard in many countries, around the world in recent years, because of their effect on biodiversity, landscape, health, environment, ecology and economy. Many researchers (Ajin *et al*., 2015; Singh, 2014; Thakur and Singh, 2014; Veeraanarayanaa and Ravikumar, 2014; Chavan *et al*., 2012; Ghobadi *et al*., 2012; Mahdavi *et al*., 2012; Sowmya and Somashekar, 2010) delineated forest fire risk zones using RS and GIS techniques. The factors chosen for the study include land use/land cover, distance from the village, from the road, from the slope and from the elevations (Ajin *et al*., 2016).

The rate of forest fire is increasing day by day and the losses that have suffered are huge. There are many ways to detect the fire flames. Benjamin *et al*., (2016) proposed a novel and robust method that segments fire flame regions from an image. The proposed method combines the unique colour and texture features of the fire flames. The RGB images obtained from digital cameras are used as inputs. The RGB images obtained are used as inputs from digital cameras. In order to assume the presence of fire flames in an image, the mean value estimate is used. By conducting background exclusion, its existence is confirmed. Colour rules defined for RGB, HSV and YCbCr colour spaces are used to segment the fire regions.

Remote sensing by satellite is the only way to map and gather information on the spatial distribution of fire scars and fire events. Understanding the behavior of forest fires, the factors leading to a vulnerable climate for fire and the factors affecting fire behavior are important for the mapping of forest fire danger zones (Chuvieco *et al.*, 1989; Sowmya and Somashekar, 2010).

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

The present study was conducted in the Peechi-Vazhani Wildlife sanctuary, Chimmony Wildlife sanctuary, Choolannur Pea Fowl Sanctuary, Idukki Wildlife sanctuary, and Thattekkad Bird sanctuary of Kerala state, India.

3.1 LOCATION OF STUDY AREAS

Peechi-Vazhani Wildlife Sanctuary lies within the geographical extremes of latitudes 10^{0}26’ N and 10^{0} 40’ N longitudes 76^{0} 15’ E and 76^{0} 28’ N. The Chimmony Wildlife Sanctuary lies between 76º 31’ and 76º 37’ East Longitude and 10º 22’ and 10º 26’ North Latitude and is a part of Peechi Wildlife division, while the Choolannur Pea Fowl Sanctuary is located between 76.45°– 76.48°E Longitude and 10.70°–10.73°N latitude and is also a part of the same division. Idukki Wildlife Sanctuary is positioned between 76º 55’ and 77º 4’ 5’ East Longitude and 9º 45’ 30’ and 9º 53’ 30’ North latitude. Thattekkad Bird Sanctuary lies between 76º40’ and 76º 45’ East longitude and 10º 7’ and 11º North latitude. Both Thattekkad Bird Sanctuary and Idukki Wildlife Sanctuary are part of the Idukki Wildlife Division.

Peechi-Vazhani Wildlife Sanctuary, in Thrissur District, was established in 1958 in the taluk of Thrissur and Thalappilly and is under the administrative jurisdiction of Peechi Wild Life Division of Northern Wild Life Circle, Palakkad. The sanctuary comprises parts of Paravattanimala, Machadmala and Bahrani pachamala. The total area of the sanctuary is 125 Sq.km. The terrain of the sanctuary is undulating, hilly and the altitude range varies between 100 m to 1000 m above MSL (Mean Sea Level). There are numerous small and big streams flowing over the entire sanctuary, most of which confluences to three main rivers Kurumali, Manali, and Vadakkanchery. Almost all the streams are seasonal. There are two reservoirs in the sanctuary, Peechi and Vazhani formed by the construction of two dams across Manalipuzha and Vadakkancherry puzha. The water spread of the two reservoirs is 14.793 sq. km. The dominant vegetation is moist deciduous and semi-evergreen species confined to the higher reaches. The Peechi-Vazhani Wildlife Sanctuary is administratively divided into one forest station and 5 sections, which includes Olakara forest station, Vazhani, Vellani, Vaniampara, Mannamangalam and Peechi (Fig. 1)

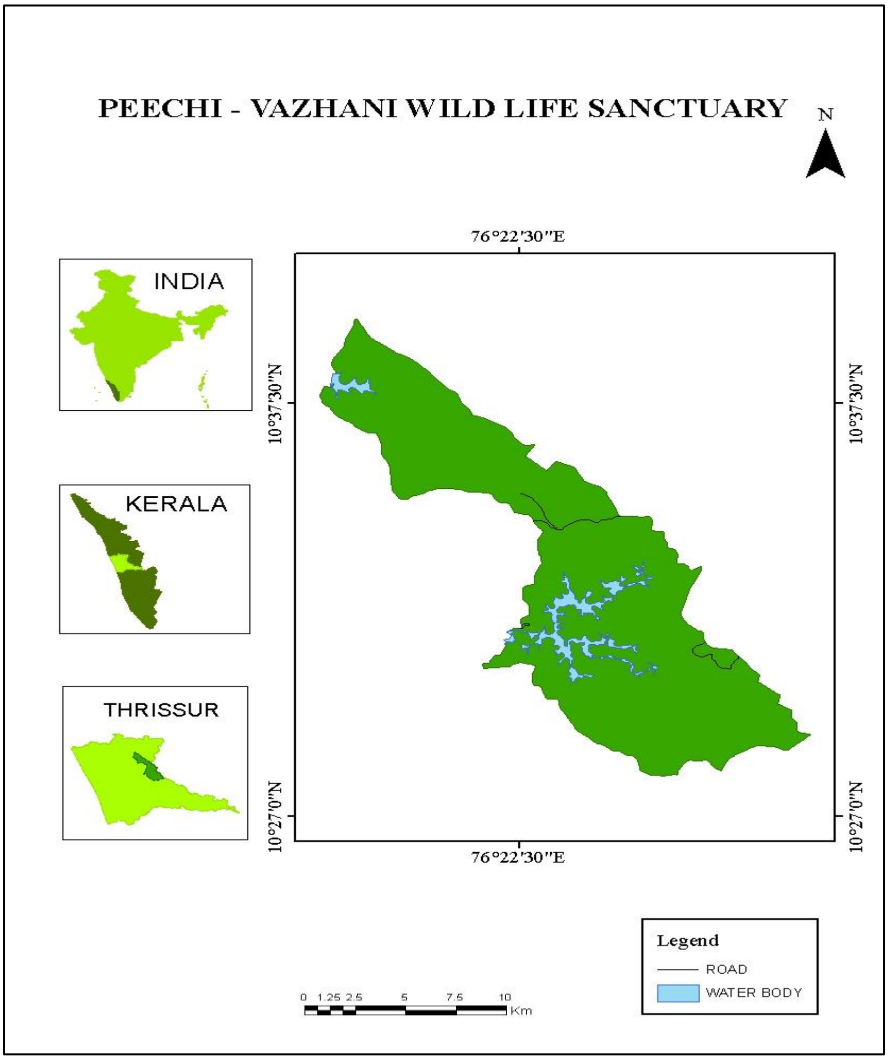

Figure 1. Peechi Vazhani Wild Life Sanctuary

Chimmony Wildlife Sanctuary (Fig. 2) has an area of 85.067 sq.km and has altitudes ranging from 40 m to 1110 m. The highest peak is Punda (1116 m). Forest types include tropical evergreen forests, Tropical semi-evergreen forests, and moist deciduous forests. Common tree species are *Palaquium ellipticum, Mesua ferrea, Cullenia exarillata, Dipterocarpus indicus, Hopea parviflora, Dysoxylum, malabaricum, Cedrela toona, Bombax ceiba, Syzygium cumini, Lagerstroemia lanceolata, Adina cordifolia, Albizia procera, Alstonia scholaris, Dalbergia latifolia,* and *Xylia xylocarpa.*

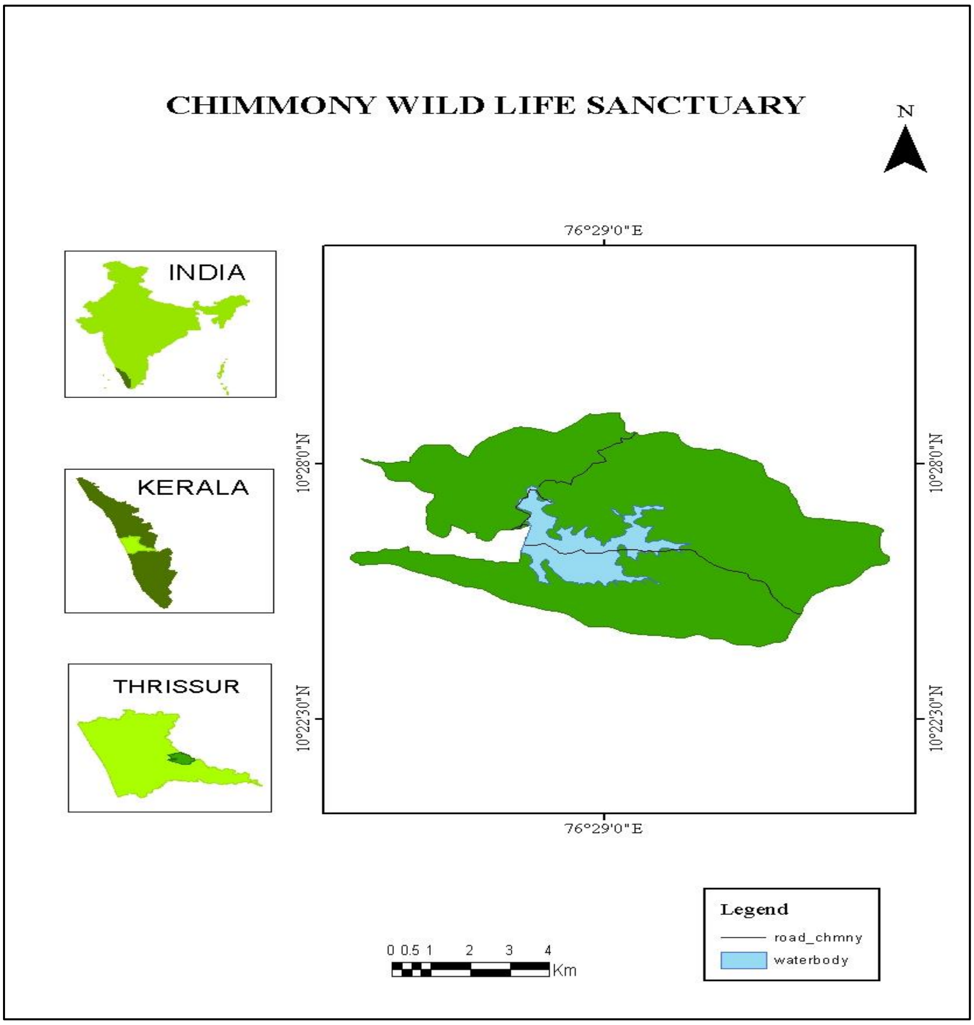

Figure 2. Chimmony Wild Life Sanctuary

Thirty nine species of mammals, 160 species of birds, 25 species of reptiles, 14 species of amphibians and 31 species of fishes are reported from the sanctuary. The common mammals found are Tiger, Leopard, Sloth bear, Elephant, Sambar, barking deer, bonnet macaque, Nilgiri langur, slender loris and porcupine.

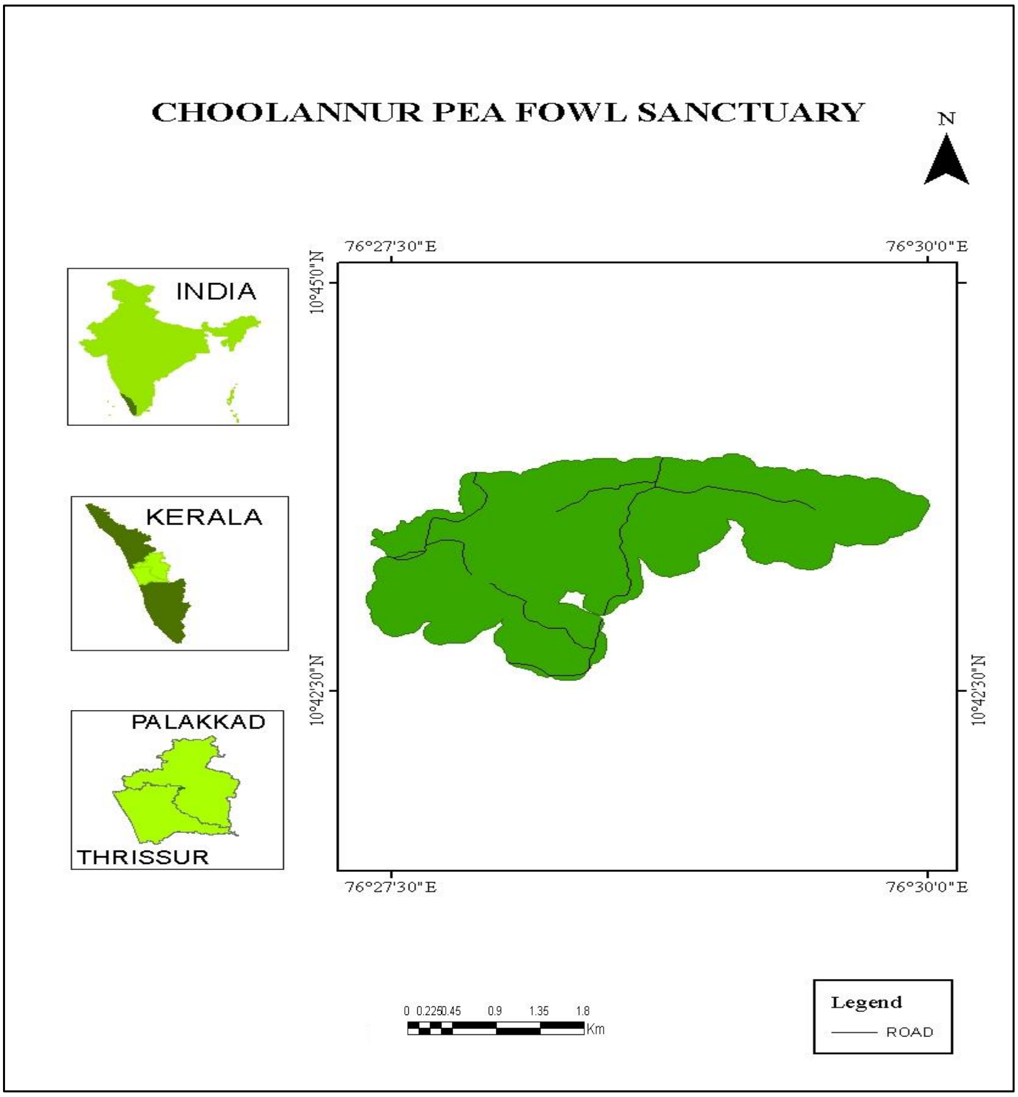

Fig 3. Choolannur Pea Fowl Sanctuary

Chulanur Pea Fowl Sanctuary (Fig. 3) consists of 342 hectares of vested forests spread over in the districts of Thrissur and Palakkad. It was declared as Sanctuary in 2007 for ensuring the long-term protection of the Pea Fowl (*Pavo cristatus*). In 2008, it was renamed as Chulanur Pea Fowl Sanctuary dedicated to the memory of Sri. K.K.

Neelakantan, famous ornithologist of Kerala and the author of the book titled 'Keralathile Pakshikal', who hailed from Kavassery near to the Sanctuary area. The forests of the sanctuary, predominantly of deciduous type with open patches and rocky areas, offer an ideal habitat for peafowl and support a good population of peafowl. It is the place in Kerala having such a sizable population of peafowls in natural forests offering scope for effective long term conservation of the species. The terrain of the Sanctuary is undulating with small hillocks and the altitude range varies between 100 m to 141 m above MSL.

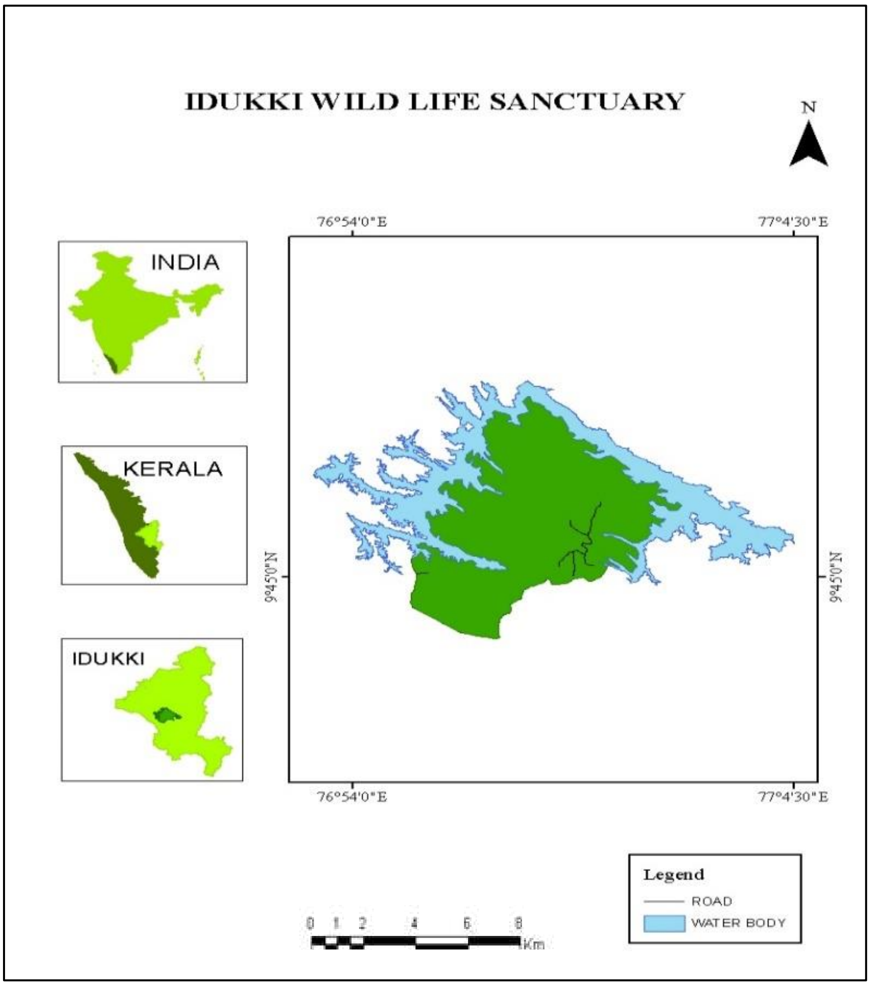

Fig. 4. Idukki Wild Life Sanctuary

Idukki Wildlife Sanctuary (Fig. 4), which came into existence in 1976, spans 105.364sq.km, and is located in the Thodupuzha and Udumbanchola taluks in Idukki district. It has an altitude ranging from 450 to 1272 m. The highest peak is Vanjur Medu (1272m). Temperature varies from 13ºC to 29ºC, whereas the hottest period is March-April. The major rivers flowing through the areas are Periyar and Cheruthoniar. The sanctuary consists of 33 sq.km of waterbody of Idukki reservoir. Forest types include West Coast Tropical Evergreen Forests, Semi-Evergreen Forests, Moist Deciduous Forests, Hill sholas and Grasslands. Major tree species are *Dipterocarpus indicus, Palaquium ellipticum, Calophyllum polyanthum, Vernonia arborea, Mesua ferrea, Hopea parviflora, Persea macrantha, Artocarpus hirsutus, Lagerstroemia microcarpa, Cinnamomum zeylanicum, Tectona grandis, Dalbergia latifolia, Terminalia paniculata, T. bellerica, Grewia tiliaefolia, Pterocarpus marsupium* etc. The common animals found are Elephant, Sambar, Barking Deer, Mouse deer, Bonnet macaque, Nilgiri Langur, Malabar giant squirrel, Wild dog, Wild boar, porcupine, Jackal, Indian Giant Squirrel etc.

Thattekkad Bird Sanctuary constituted during 1983 (Fig. 5), is located in Kothamangalam Taluk of Ernakulam District in Kerala. The total area of the sanctuary is 25.16 sq.km and altitude ranging from 35 to 488 m. Major peaks in the sanctuary are Thoppimudi and Nyayapillimudi. Forest Types include Tropical Evergreen Forests, Tropical Semi-evergreen Forests, Moist Deciduous Forests, Riparian Forests, Plantations of Teak, Rosewood, Mahogany and Fruit Orchard. Thirty four species of mammals, 270 species of birds, 30 species of reptiles, 15 species of amphibians and 47 species of fishes were reported from the sanctuary. The common animals found are leopard, sloth bear, porcupine etc. Elephants are occasional visitors. Common birds are Indian roller, cuckoo, common snipe, crow pheasant, grey drongo, malabar trogon, woodpeckers, large pied wagtail, Indian hill myna etc. Rare birds found are Ceylon Frogmouth, Bourdillon’s long eared Indian Nightjar, Peninsular Bay owl, Crimson throated barbet, Malabar hornbill, Malabar hornbill, Malabar shama, Greyheaded fishing eagle.

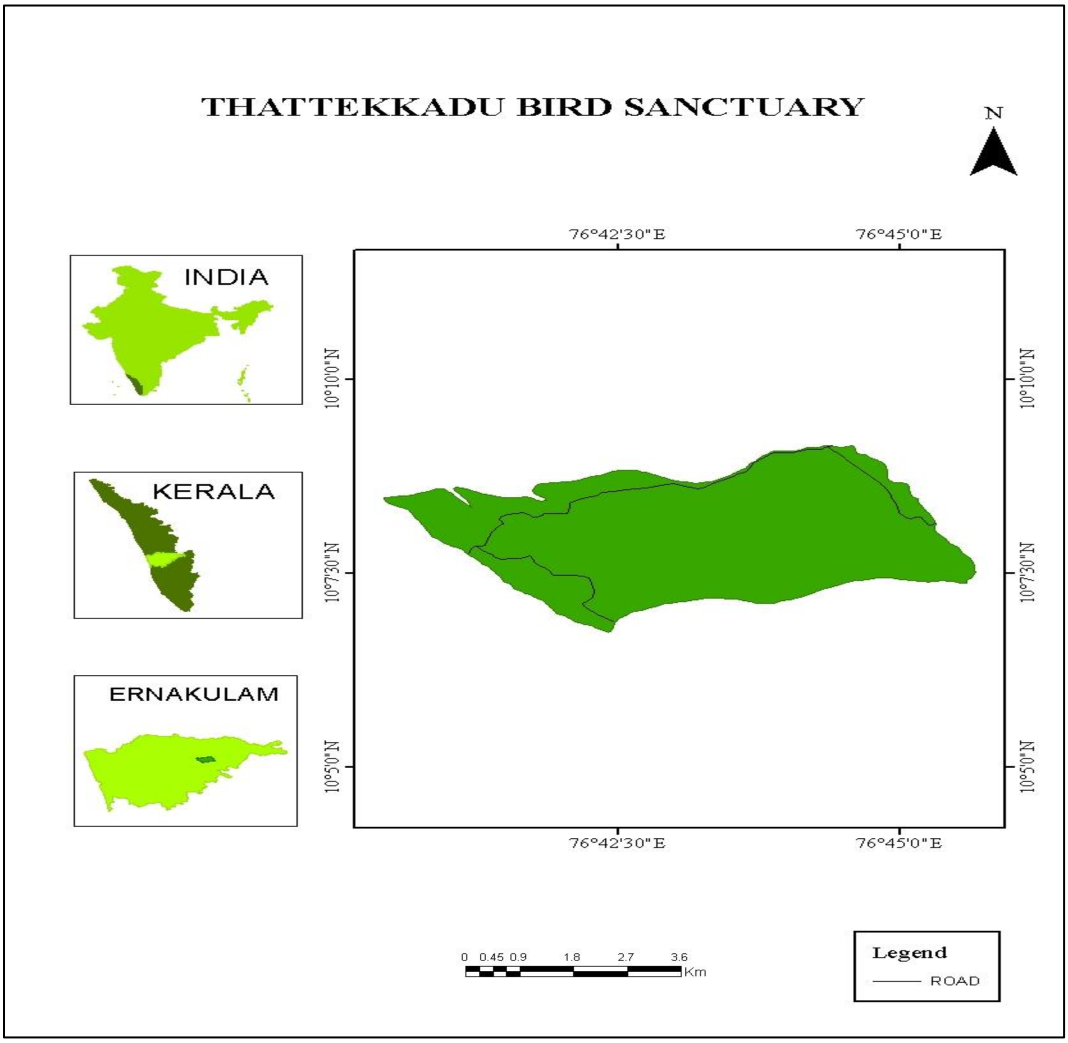

Fig. 5. Thattekkadu Bird Sanctuary

3.2. DATA COLLECTION

3.2.1. Forest fire data

Forest fire data for the six year (2014-2019) period collected from Kerala FD records. The forest fire data collected included date of fire occurrence, GPS location of fire incident, number of fire incidences and approximate area affected by forest fires. These secondary data were analysed using appropriate statistical tools and GIS software.

3.2.2. Weather data

Weather data were collected from the nearest recognized meteorological stations such as, Cardamom Research Station, Pampadumpara that was near to Idukki Wildlife Sanctuary. In the case of Thattekkadu Bird Sanctuary, weather data sourced from the nearest station, viz., Aromatic and Medicinal Plant Research Station, Odakkali was used. For Chulannur Peafowl Sanctuary, Peechi-Vazhani Wildlife Sanctuary and Chimmony Wildlife Sanctuary, the weather data of Peechi dam collected by Irrigation Design and Research Board (IDRB) was utilised.

3.2.3. Satellite data

Base maps and Satellite Images were collected for GIS analysis. Base maps were collected from respective Wild Life Sanctuaries. Satellite images (LANSAT 8) and ASTER DEM data were downloaded from Earth Explorer (USGS).

3.3. STATISTICAL ANALYSIS

The statistical analysis was carried out using Microsoft Excel 2013.

3.3.1 Graphical method

The number of forest fire incidence occurred during each months from 2014 to 2019 was calculated and plotted. Similarly in order to determine the affected area, the sum of monthly data was plotted against forest fire incidents.

The graphical analysis for the study areas was done and the bar diagrams were plotted by using these data sets. In the bar diagrams, individual graphs of the number of forest fire incidence against years, number of forest fire incidents against years and affected areas, number of forest fire incidence against months (January to May), forest fire affected areas against months (January to May) and forest fire-affected areas/fire incidence against months (January to May) were plotted for each study areas such as Peechi-Vazhani Wildlife Sanctuary, Chimmony Wildlife Sanctuary and Idukki Wildlife Sanctuary. On the other hand, individual graphs of forest fire incidence against years (2014-2019) were plotted for Chulannoor Pea Fowl Sanctuary and Thattekkadu Bird Sanctuary.

3.3.2. Correlation

Correlation between the number of fire incidences and rainfall were developed in Microsoft Excel.

3.3.3. Regression

Non-linear and linear regression was done by taking number of forest fire incidence as the dependent variable and rainfall as independent variables.

3.4 GEOGRAPHICAL INFORMATION SYSTEM (GIS) AND REMOTE SENSING (RS)

3.4.1. Delineation of study areas

The study utilized the software's platforms, ArcGIS 9.3 and ERDAS IMAGINE 2015 for the analysis of the RS images. The location maps were collected from the Forest department. The study areas were delineated from the Survey of India topographic maps (58C/15, 58G/2, 58G/3, 58G/6, and 58G/7) of 1:50,000 scale. The collected maps were geo-referenced with the help of topographic maps.

This study used coordinate system as WGS 1984 in Geographic coordinate system to create the shape files for boundary, road and settlement. Drew the boundary of the study area, road network and settlements.

3.4.2. Downloading satellite image

Downloaded LANSAT- 8 Level-1 (22/02/2018), and ASTER DEM of 30 m resolution from the USGS Earth explorer.

3.4.3. Pre-processing of LANSAT-8 OLI imagery

As the LANSAT- 8 products are delivered in 16-bit unsigned integer format, the pre-processing of the data was essential. It was then rescaled to the Top Of Atmosphere (TOA) reflectance and/or radiance using radiometric re-scaling coefficients provided in the product metadata file (MTL file) using the formula

$$\rho\lambda' = M \rho Q cal + A \rho$$

($\rho\lambda'$ = TOA planetary reflectance, without correction for solar angle. Note that $\rho\lambda'$ does not contain a correction for the sun angle, M ρ = Band-specific multiplicative rescaling factor from the metadata, A ρ = Band-specific additive rescaling factor from the metadata, Q cal = Quantized and calibrated standard product pixel values).

3.4.3.1. Correcting the reflectance value with sun angle

Correcting reflectance value with sun angle was done, using the raster calculator in Arc map.

$$\rho\lambda = \rho\lambda' / \cos \theta SZ = \rho\lambda' / \sin \theta SE$$

($\rho\lambda$ = TOA planetary reflectance, θSE = Local sun elevation angle, θSZ = Local solar zenith angle; $\theta SZ = 90° - \theta SE$.)

3.4.4. Post- Processing

Layer stack done with ERDAS imagine 2015. Each boundary shape files were mask extracted by boundary clip layer stalked satellite data. And each boundary shape files were masked with the ASTER DEM data. From the 20 m interval contour data the slope and elevation map were prepared, using spatial analyst tool.

The signature file creation was done for the supervised classification. Signature of each study area were done. Maximum likelihood classification technique in supervised classification technique was followed in the study area.

The buffer was created for settlements and roads. The buffers were in polygon form and were later converted to raster form.

Reclassification was used to assign ranks for classes. The supervised classification images, road buffer, settlement buffer, slope, and elevation were reclassified.

Rank and weight were assigned to each class of thematic map layer according to their capacity and on fire ignition and spreading. The weight and rank was used to develop an index (Index = Weight × Rank) (Tab. 1 to Tab. 5). In ArcGIS, raster calculator in spatial analyst tool was used to prepare the forest fire risk zone maps. This following equation was used to create forest fire risk zonation maps.

("rc_vegetation"*35 + "rc_slope"*25 + "rc_elevation"*20 + "rc_road"*12 + "rc_settlement"*8) / 5. Finally, the fire risk zone map was validated with six-year (2014 – 2019) fire incidents obtained from Forest Department reports. Fig. 6 show the flow chart of methodology used for this.

Table 1. Rank, weight and index assigned for different factors in Peechi – Vazhani Wildlife Sanctuary.

Factor	Class	Rank	Weight	Index
Vegetation type	Water body	1	35	35
	Barren land	2		70
	Evergreen	3		105
	Semi evergreen	4		140
	Moist deciduous	5		175
Slope (degree)	0 – 6.37	1	25	25
	6.37 – 12.74	2		50
	12.74 – 19.12	3		75
	19.12 – 26.34	4		100
	26.34 – 54.18	5		125
Elevation (m)	- 42 – 121.8	1	20	20
	121.8 – 285.6	2		40
	285.6 – 449.4	3		60
	449.4 – 613.2	4		80
	613.2 – 777	5		100
Distance from road (km)	0 – 2	1	12	12
	2 - 4	2		24
	4 – 6	3		36
	6 – 8	4		48
	8 – 10	5		60
	0 – 2	1		8
	2 – 4	2		16

Distance from settlement (km)	4 – 6	3	8	24
	6 – 8	4		32
	8 – 10	5		40

Table 2. Rank, weight and index assigned for different factors in Chimmony Wildlife Sanctuary.

Factor	Class	Rank	Weight	Index
Vegetation type	Water body	1	35	35
	Barren land	2		70
	Evergreen	3		105
	Semi evergreen	4		140
	Moist deciduous	5		175
Slope (degree)	0 – 7.32	1	25	25
	7.32 – 16.76	2		50
	16.76 – 24.32	3		75
	24.32 – 32.35	4		100
	32.35 – 60.21	5		125
Elevation (m)	-68 – 138.6	1	20	20
	138.6 – 345.2	2		40
	345.2 – 551.8	3		60
	551.8 – 758.4	4		80
	758.4 – 965	5		100
Distance from road (km)	0 – 1	1	12	12
	1 – 2	2		24
	2 – 3	3		36
	3 – 4	4		48
	4 – 5	5		60
Distance from settlement (km)	0 – 1	1	8	8
	1 – 2	2		16
	2 – 3	3		24
	3 – 4	4		32

	4 – 5	5		40

Table 3. Rank, weight and index assigned for different factors of Choolannur Pea Fowl Sanctuary.

Factor	Class	Rank	Weight	Index
Vegetation type	Water body	1	35	35
	Rocks	2		70
	Dry deciduous	3		105
	Paddy field	4		140
	Plantations	5		175
Slope (degree)	0 – 4.01	1	25	25
	4.01 – 7.05	2		50
	7.05 – 10.20	3		75
	10.20 – 14.22	4		100
	14.22 – 27.68	5		125
Elevation (m)	-40 - -23.4	1	20	20
	-23.4 - -6.8	2		40
	-6.8 – 9.8	3		60
	9.8 – 26.4	4		80
	26.4 – 43	5		100
Distance from road (m)	0 – 200	1	12	12
	200 – 400	2		24
	400 – 600	3		36
	600 – 800	4		48
	800 – 1000	5		60
Distance from settlement (m)	0 – 200	1	8	8
	200 – 400	2		16
	400 – 600	3		24
	600 – 800	4		32

	800 – 1000	5		40

Table 4. Rank, weight and index assigned for different factors in Idukki Wildlife Sanctuary

Factor	Class	Rank	Weight	Index
Vegetation type	Water body	1	35	35
	Barren land	2		70
	Evergreen	3		105
	Semi evergreen	4		140
	Moist deciduous	5		175
	Grass land	6		210
Slope (degree)	0 – 4.80	1	25	25
	4.80 – 13.08	2		50
	13.08 – 20.56	3		75
	20.56– 28.85	4		100
	28.85 – 68.11	5		125
Elevation (m)	570 – 689.2	1	20	20
	689.2 – 808.4	2		40
	808.4 – 927.6	3		60
	927.4 – 1046.8	4		80
	1046.8 - 1166	5		100
Distance from road (km)	0 – 2	1	12	12
	2 – 4	2		24
	4 – 6	3		36
	6 – 8	4		48
	8 – 10	5		60
Distance from settlement (km)	0 – 1	1	8	8
	1 – 2	2		16
	2 – 3	3		24
	3 – 4	4		32

	4 – 5	5		40

Table 5. Rank, weight and index assigned for different factors in Thattekkadu Bird Sanctuary

Factor	Class	Rank	Weight	Index
Vegetation type	Water body	1	35	35
	Barren land	2		70
	Evergreen	3		105
	Semi evergreen	4		140
	Moist deciduous	5		175
Slope (degree)	0 – 7.45	1	25	25
	7.45 – 13.60	2		50
	13.60 – 20.31	3		75
	20.31 – 27.95	4		100
	27.95 – 47.52	5		125
Elevation (m)	-85 – 21	1	20	20
	21 – 127	2		40
	127 – 233	3		60
	233 – 339	4		80
	339 – 445	5		100
Distance from road (km)	0 – 1	1	12	12
	1 – 2	2		24
	2 – 3	3		36
	3 – 4	4		48
	4 – 5	5		60
Distance from settlement (km)	0 – 2	1	8	8
	2 – 4	2		16
	4 – 6	3		24
	6 – 8	4		32
	8 – 10	5		40

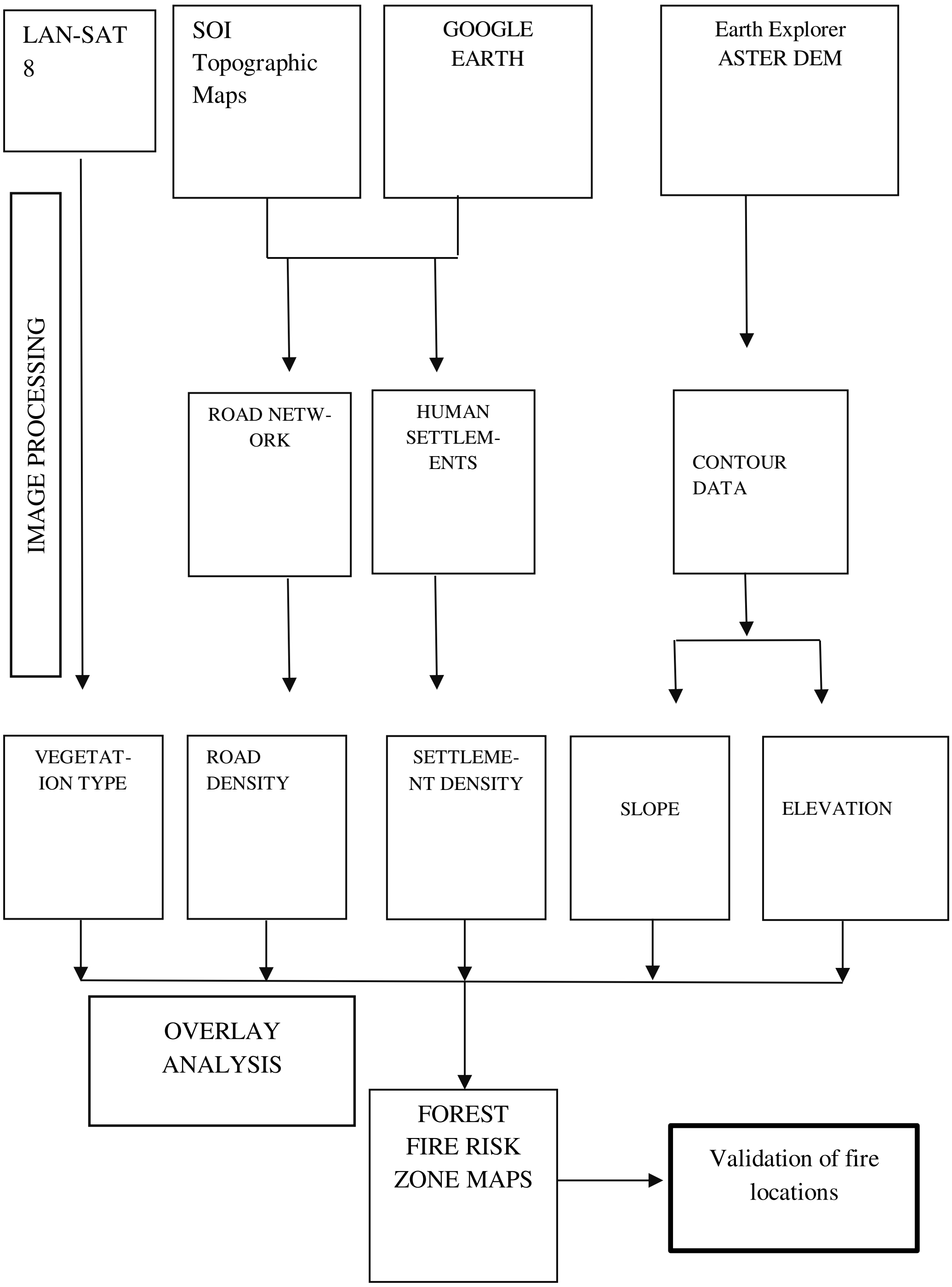

Fig. 6. Flow chart

RESULTS AND DISCUSSION

CHAPTER 4

RESULTS AND DISCUSSION

The results of the study "Climate-forest fire linkages in selected protected areas in Kerala" are explained and discussed below.

4.1. FOREST FIRES

4.1.1. Peechi-Vazhani Wildlife Sanctuary

4.1.1.1. Number of fire instances (2014-2019)

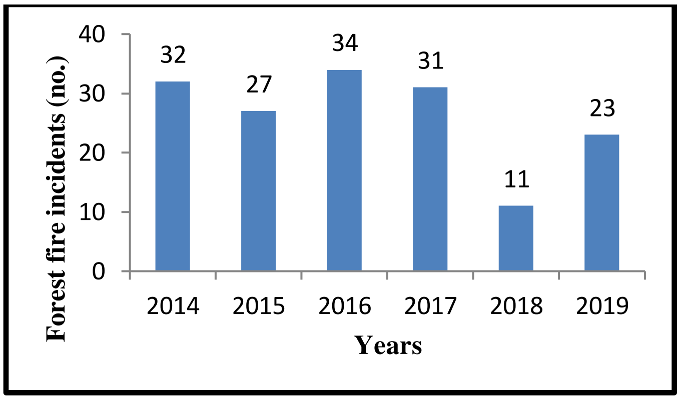

Fig. 7. Forest fire incidence in Peechi – Vazhani WLS

The number of forest fire incidence reported at Peechi-Vazhani WLS is given in Fig 7. It is evident that the highest number of fire incidents occurred during 2016 (34 fires), and fewest number of fire incidents occurred in 2018 (11 fires).

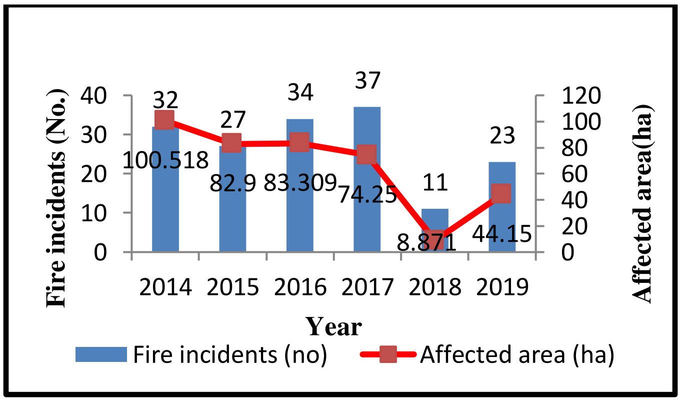

Fig. 8. Forest fire incidence (no.) and affected area (ha) during 2014 to 2019 in Peechi – Vazhani WLS.

Figure 8 shows the number of forest fire incidence and area affected by forest fires during 2014 to 2019 in Peechi – Vazhani WLS. It is clear that in 2018, the fire affected area was lowest (8.871 ha) and it was also in this year, that the lowest fire incidence (11 fires) were reported. On the other hand, it was in 2017, that the highest number of fire incidents happened (37 fires). However, the maximum forest area that got affected (100.518 ha) was in 2014. The wind parameters also have an effect on fire. It helps in heat transfer and also supports pre-heating which is an important criteria for flame propagation (McGranahan and Wonkka, 2020). In 2014, the wind was blowing each month in a constant direction. This caused the fire to spread to more areas depending on the direction of the wind. But the fact that the wind did not blow in one direction in 2017 helped prevent the fire from spreading too far. Venkatesh et al (2020) had observed that the climate of a region changes with the increase in elevation. They also argue that the intensity of wind increases and the forest area will be highly exposed to sunlight with the increase in altitude, thereby causing high proneness to fire. In addition, the direction and rate of spread of fire augment also will change with the increase in slope.

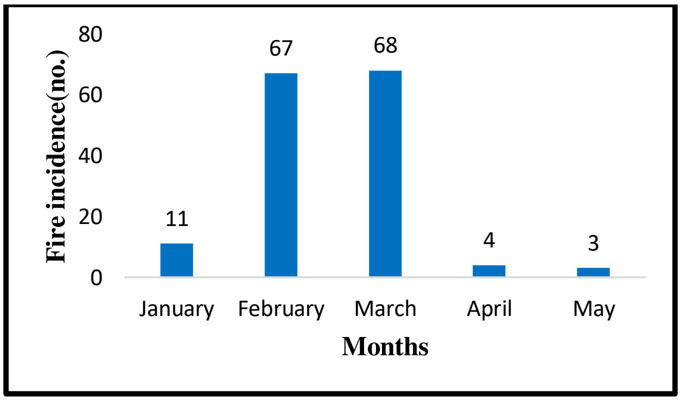

Fig. 9. Monthly wise fire incidence (2014 to 2019) in Peechi – Vazhani WLS

Fig. 9 shows that higher number of fire incidence occurred in February (67) and March (68), and least number of incidence happened in May (3).

The monthly wise fire affected area reported at Peechi – Vazhani WLS is given in the Fig 10. More forest area got affected by forest fires in the months of February (163.95 ha) and March (165.33 ha) and fewest area affected by forest fires in this sanctuary was in May (7 ha).

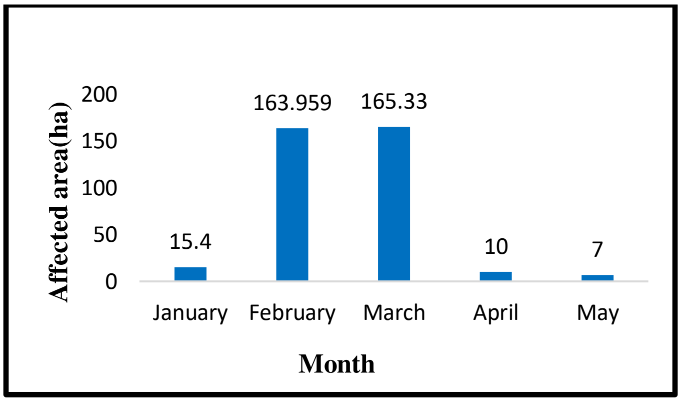

Fig. 10. Monthly wise fire affected area (2014 to 2019) in Peechi – Vazhani WLS

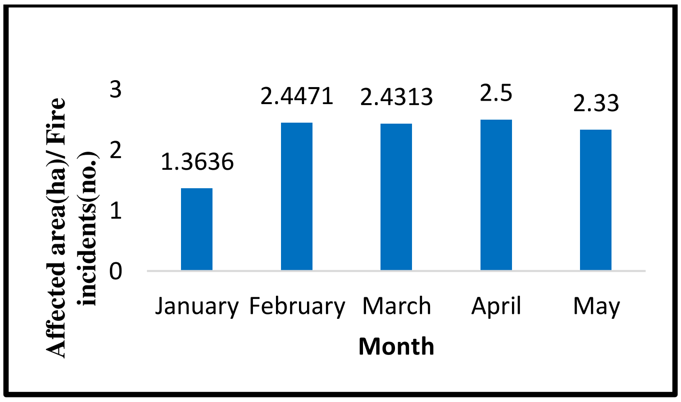

Fig. 11. Monthly wise fire affected area (ha)/ fire incidence (no.) (2014 to 2019) in Peechi – Vazhani WLS

Figure 11 shows that monthly wise affected area (ha)/ fire incidence (no.) during 2014 to 2019 at Peechi – Vazhani WLS. More forest fire affected area (ha)/ fire incidence (no.) is reported in the month of April (2.5) and least was in the month of January.

4.1.1.2. Correlation

Table 6. Relationship between number of forest fire incidence and climatic variables

Climatic variables	Peechi – Vazhani wild life sanctuary
Temperature (^{0}C)	0.66741**
Rainfall (mm)	-0.964958**

** Significant at 5% and 1%

Table 6 shows the correlation between the number of forest fire incidence with the rainfall and temperature of Peechi - Vazhani WLS. It can be seen that while the number of forest fire incidents is positively correlated with the temperature, their number had a negative correlation with rainfall. In the fire triangle, moisture and temperature play crucial roles. As temperature increases in the forest ecosystem, the moisture content in the atmosphere as well as in the biomass and fallen litter will be decreasing. In the context of the forest ecosystem, this subsequently becomes a potential fire hazard. Rainfall increases the moisture content both in the atmosphere and biomass/litter and negates all chances of a fire outbreak. Kodandapani and Parks (2019) had reported that, episodes of drought, although not the only factor influencing area burned, could be exerting an increasingly significant effect on wildfire activity in the Western Ghats.

4.2 GEOGRAPHICAL INFORMATION SYSTEM (GIS) AND REMOTE SENSING (RS) ANALYSIS

4.2.1. Peechi – Vazhani wildlife sanctuary

On the basis of GIS and RS analysis, the land cover types in Peechi - Vazhani Wild life Sanctuary (Fig.12) could be categorised as evergreen forest, semi evergreen forest, moist deciduous forest, barren land (rocks) and water body. Several studies has pointed out that deciduous forests are more vulnerable to fires (Ajin *et al*., 2017) and in the case of Peechi, the proportion of deciduous forests are more. Another important factor that has a significant influence on the spread of fire is slope, which is an indicator of steepness or the degree of inclination of the earth's surface. This natural factor has been reported to influence both the rate of fire spread and the strength of the fire (Ajin *et al*., 2016). Steep slopes in the leeward side of approaching orographic wind accelerate the upward migration of blazing forest fire (Ajin *et al*., 2016). In Peechi WLS, slope (Fig. 13) has also contributed to the damages caused by fire. The steeper slopes are more vulnerable to fire, as the convectional preheating and combustion rate are more efficient in this region. Fire travels up the slope more quickly and down the slope less quickly (Ajin *et al*., 2017).

Aspect, the direction of the slope of a terrain and the one which determine its exposure in relation to the sun's rays is significantly related to the rate of fuel drying and the movement of the fire (Ajin et al 2017). During summer, hours of sunlight significantly increase at high elevation locations. Thus lead the upward convective movement of warm air at higher elevations increases the rate of desiccation of organic matter and thus can provide potential fuel for fire escalation. Sometimes in higher elevation areas lightning strikes more frequently or higher frequency, that can cause natural forest fire (Ajin *et al*., 2016 and Ajin *et al*., 2018). Elevation too (Fig. 14) influenced fire incidences. The higher-altitude areas are more vulnerable to fires (Ajin *et al*., 2017).

Areas nearest areas to the road are always fire prone (Ajin *et al*., 2016). Careless actions by humans like cooking, camp fire by travellers, throwing cigarette butts etc can always trigger a spark which turns into a big inferno. In Peechi WLS too (Fig. 15), the road density maps indicates such clear possibilities. It is also clear that more forest fire instances occurred in areas located near to human settlements (Fig. 16). In such cases also careless human activities triggered forest fires. Possible fire triggering activities include activities associated with fodder grass production (clearing forest land), collection of Non Timber Forest Products (NTFP), burning farm residues, using fire as a potential tool to ward off wild animal attacks etc. Based on experiences in forest fires in Brazil, Ribeiro et al. (2016) had recommended the zonation of areas based on fire risks. They are of the view that such zoning helps to recognise high fire-prone areas, while extending the protective steps in these zones by perpetuating high monitoring, building roads for quicker entry, reducing access to these sites and reshaping forest fire prevention management activities that are also true for this protected area.

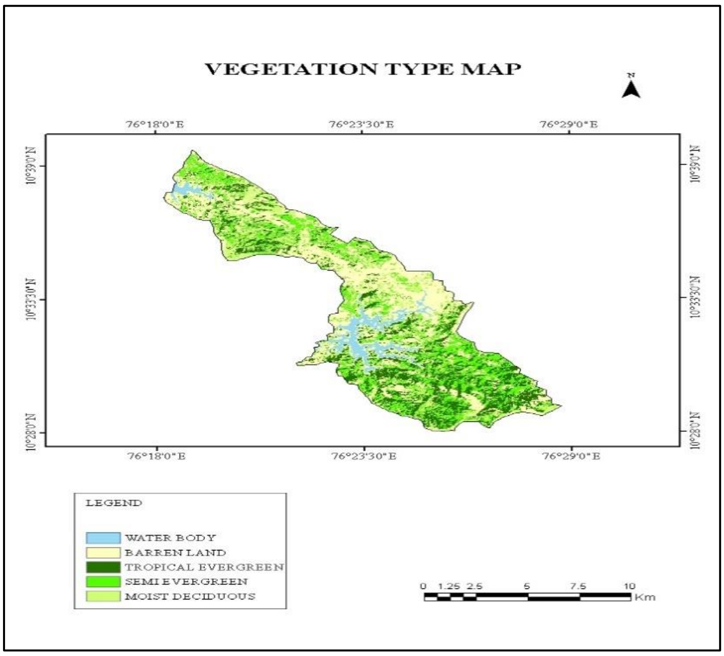

Fig. 12. Vegetation type map of Peechi – Vazhani WLS

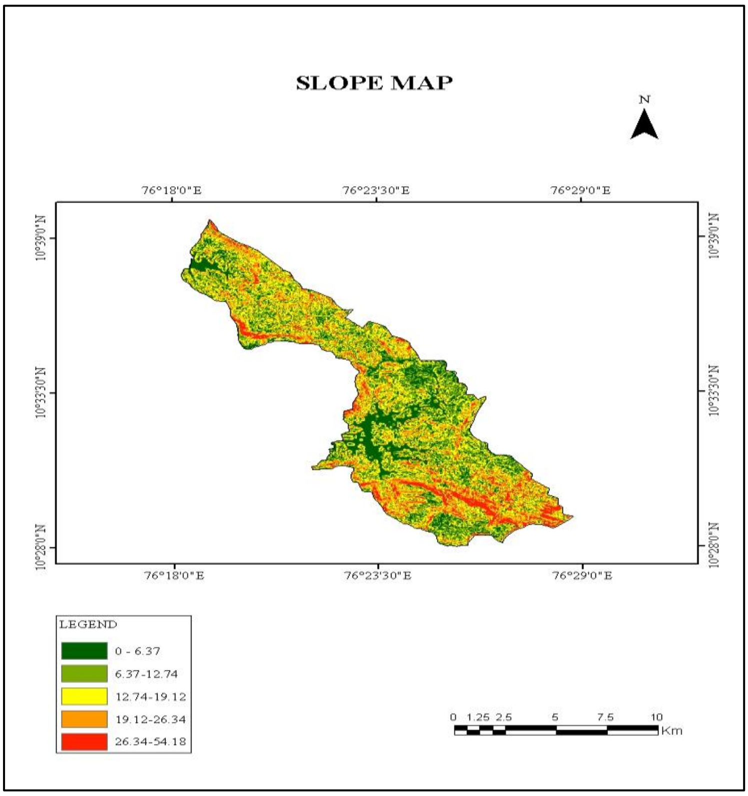

Fig. 13. Slope map of Peechi – Vazhani WLS

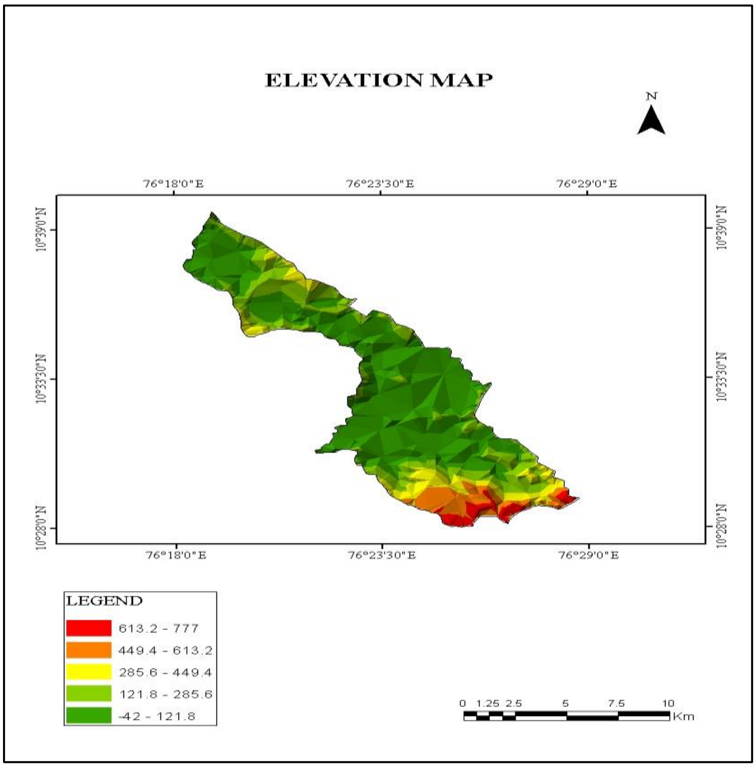

Fig. 14. Elevation map of Peechi – Vazhani WLS

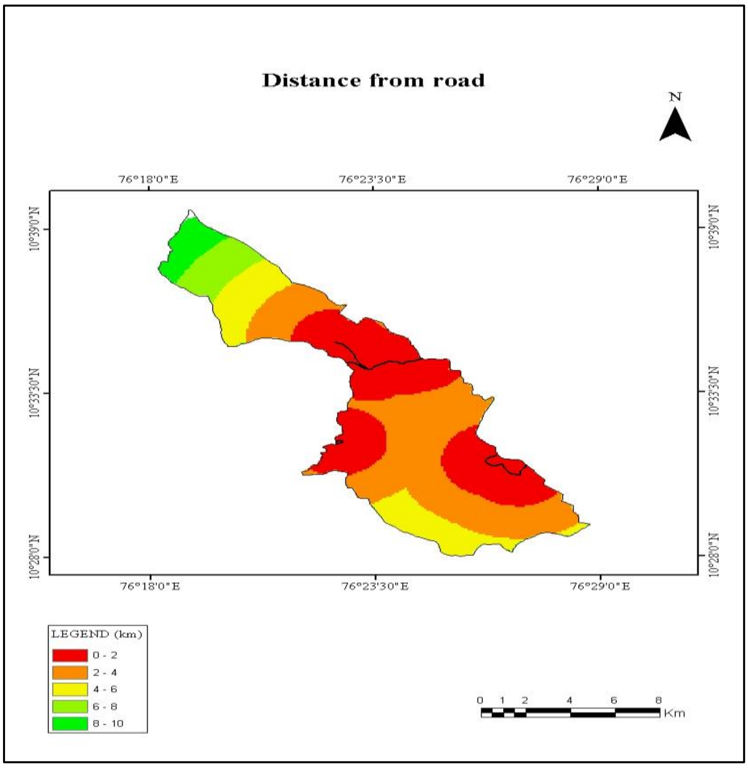

Fig. 15. Distance from road map of Peechi – Vazhani WLS

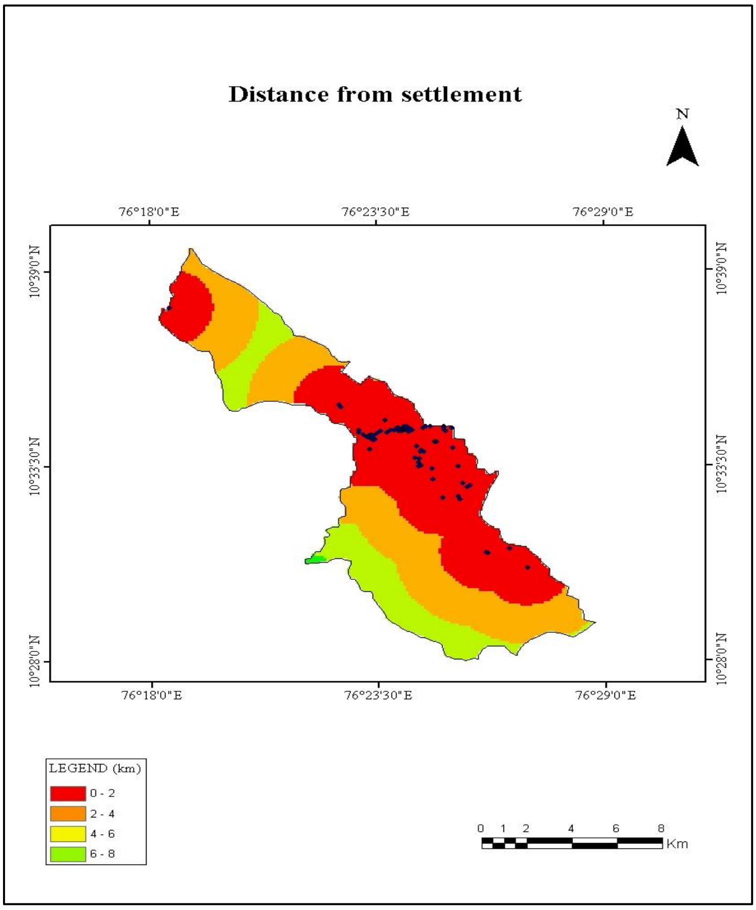

Fig. 16. Distance from settlement map of Peechi – Vazhani WLS

4.2.1.1. Forest fire risk zones

Using GIS tools, the index map layers of vegetation type, slope, elevation, distance from road, and distance from settlement were combined to prepare the fire risk zone maps for Peechi WLS. From the prepared fire risk zone maps, Peechi WLS was classified into five risk zones, namely very low fire risk zone, low fire risk zone, moderate fire risk zone, high fire risk zone, and very high fire risk zone. Fire incidents locations of past five year data were validated with the fire risk zone maps.

It is evident from Table 7 that 43.48 % area fell in low and very low fire risk zones, and 29.22 % area under high and very high risk fire zones. Under moderate fire risk zone, 27.28 % area could be attached. Based on collected data, it could be observed that the maximum number of fire events occurred in this region. The largest area fell under very low and low fire risk zones (53.23 km^2).

Fire Risk Zones category	Percentage (%)	Area (Km^2)
Very low	15.37	18.82
Low	28.11	34.41
Moderate	27.28	33.40
High	21.05	25.77
Very high	8.17	10.01

Table 7. Area and percentage of fire risk zones at Peechi - Vazhani WLS

Important topographic parameters which significantly influence the ignition of forest fire are elevation, aspect, slope, and terrain ruggedness (Jaiswal et al., 2002). From the fire risk zonation map (Fig. 17), it can be deduced that more forest fire incidents occurred near to roads, which clearly confirm an anthropogenic origin (accidental or intentional). Ajin *et al.*, (2016) noted that the most of the fire incidents points are near to roads in Chinnar wild life sanctuary, Kerala, confirming anthropogenic orogeny. One possible reason for wild fires whose trigger is clearly not known could be attributed to careless human interventions using fire as a strategy to ward off consistent instances of human – wildlife conflicts. Humans have been reported to use fire as a tool to protect himself and his belongings. In this study at Peechi WLS, it was observed that the highest number of forest fire incidence was reported in the month of February. According to Greeshma *et al.*, (2016) who did an earlier study in Peechi – Vazhani WLS, it was noted that human wild life conflicts were more in February. Many human settlements could be seen in the forest fringe areas of Peechi-Vazhani WLS. Unscientific cropping patterns encourage certain wild animals to raid crops. Ineffective conservation measures, increase of the wild animal population, cultivation of palatable, nutritious crops near the forest boundaries are some of the widely reported reasons for crop damage. So we clearly detected an anthropogenic activity behind the incidents of wild fire that occurred near the road and greater incidents of fire that occurred in February at Peechi WLS. Added to this the results of the correlation also attest to the fact that the forest fire incidents created more damage when the temperature increased.

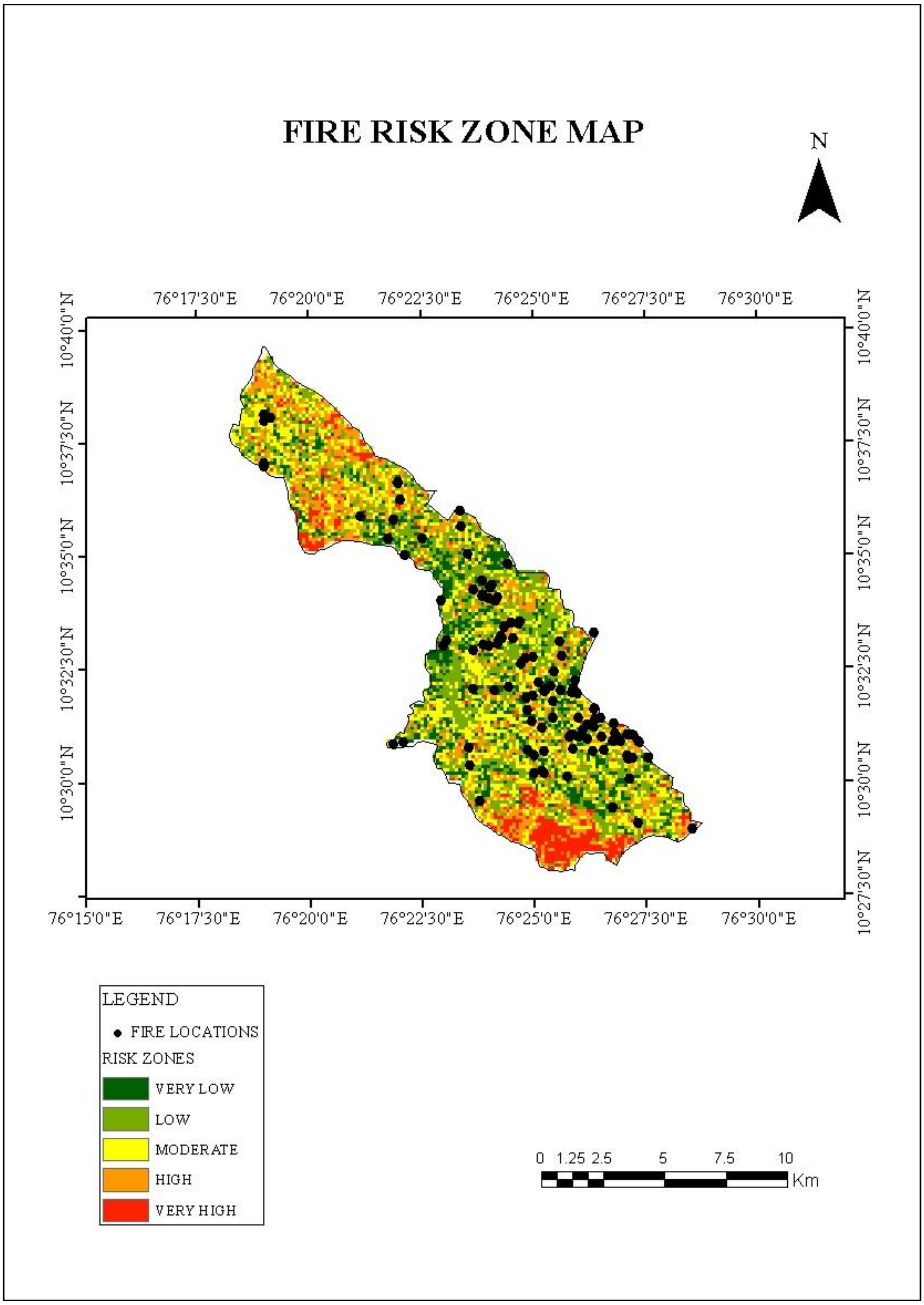

Fig. 17 Forest fire risk zone map of Peechi – Vazhani WLS.

The fire risk zone map of Peechi – Vazhani wild life sanctuary is shown in Fig 17. Fifty six forest fire incidents occurred in the low and very low risk zones, 29 occurred in the moderate risk zone, and 32 occurred in the high and very high risk zones.

4.1.2. Chimmony Wildlife Sanctuary

4.1.2.1. Number of instances in 2014-2019 period

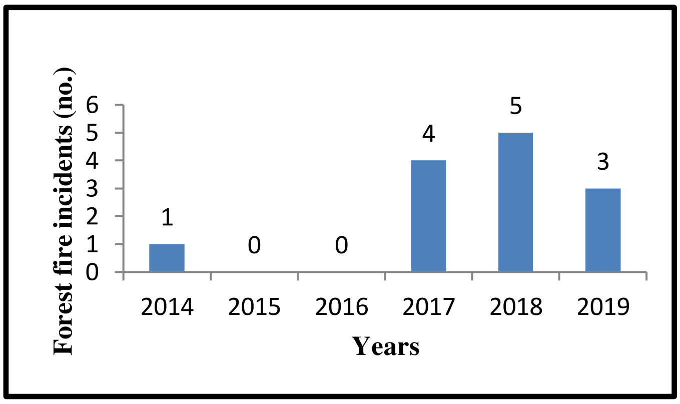

Fig. 18. Forest fire incidence in Chimmony WLS

The number of forest fire incidence reported at Chimmony WLS is given in Figure 18. It is obvious that more fire accidents happened in 2018 (5) and there was just one fire incidence in 2014.

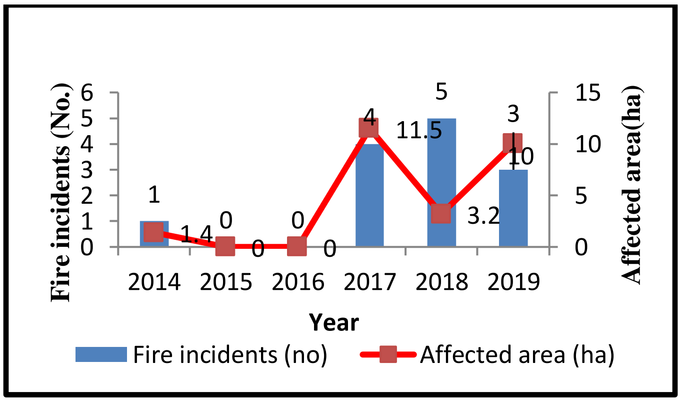

Fig. 19. Forest fire incidence (no.) and affected area (ha) during 2014 to 2019 in Chimmony WLS

It is evident from the above figure (19) that the highest number of instances (5 fires) and the largest area affected by fire incidents (11.5 ha) were recorded in 2018.

The lowest number of fire incidents (1 fire) and the lowest area affected by fire instances (1.4 ha) occurred during 2014.

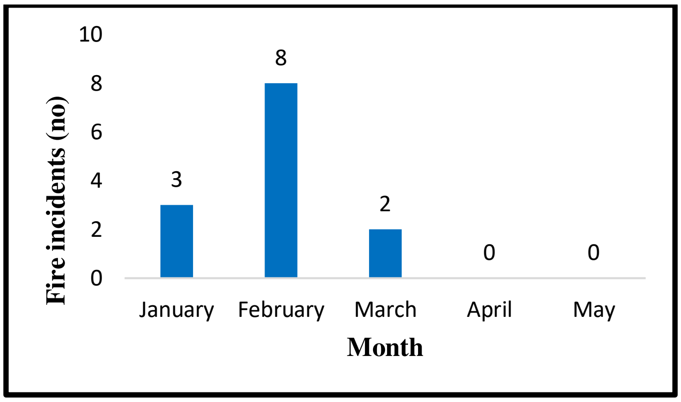

Fig. 20. Monthly wise fire incidence during 2014 to 2019 in Chimmony WLS.

A monthly wise fire incident during 2014 to 2019 at Chimmony WLS is given in the Fig. 20. More number of fire incidence happened in the month of February (8 fires) and lowest fire incidents occurred in March (2 fires).

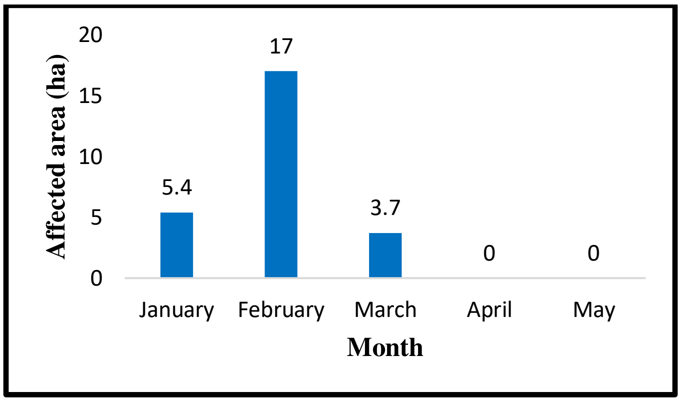

Fig. 21. Monthly wise fire affected area during 2014 to 2019 in Chimmony WLS

The monthly wise fire affected area reported at Chimmony WLS is given in the Fig 21. More forest area got affected by forest fires in the months of February (17 ha) and less area affected by forest fires in this sanctuary was in March (3.7 ha).

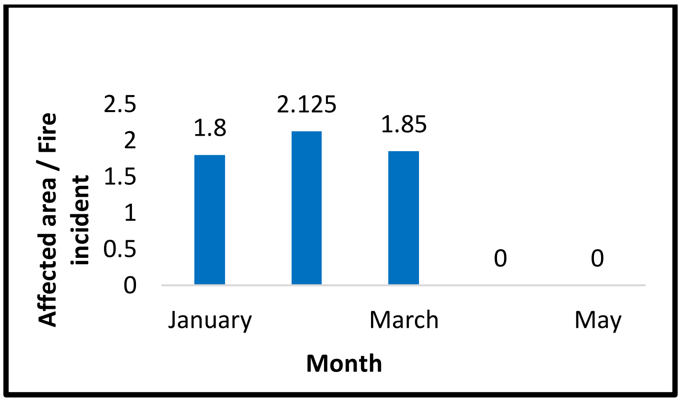

Fig. 22. Monthly wise affected area (ha)/ Fire incidence (no.) during 2014 to 2019 in Chimmony WLS

Figure 22. Shows the monthly wise affected area (ha)/ fire incidence (no.) during 2014 to 2019 at Chimmony WLS. More forest fire affected area (ha)/ fire incidence (no.) is reported in the month of February (2.125).

4.1.2.2. Correlation

Table 8. Correlation of forest fire incidence with climatic variables

Climatic variables	Chimmony wild life sanctuary
Temperature (^{0}C)	0.155656**
Rainfall (mm)	-0.19845**

** Significant at 5% and 1%

Table 8 shows the correlation between the number of forest fire incidence with the rainfall and temperature of Chimmony wildlife sanctuary. It can be seen that while the number of forest fire incidence is positively correlated with the temperature, there is a negative correlation with rainfall. The forest ecosystem is drier in higher temperature. Wettability of the surface soils layer could be greatly reduced and the grasses become drier. This situation is more favourable for wild fire. Rainfall, on the other hand, raises the moisture content of the soil, increases and cools the atmosphere, thereby decreasing the risk of forest fire. Holden *et al*., (2018) had reported that decrease in summer rainfall (soil water balance deficits increase rapidly in the absence of summer precipitation causing a rapid onset of drying and warming) leads to wildfire or increases in wildfire affected area.

4.2.2. Chimmony Wild life Sanctuary

The vegetation at Chimmony Wildlife sanctuary (Fig.23) includes evergreen forest, semi evergreen forest, moist deciduous forest, barren land (rocks) and water body. Slope map of Chimmony wildlife sanctuary is divided into five classes (Fig. 24). Forest fire has quickly spread to the steep slope areas (Ajin *et al.*, 2015).

The humidity and temperature of an area depends on the region's attitude or elevation, the higher-elevation areas are more vulnerable to wildfire (Ajin *et al.*, 2015). Fig. 25 shows the elevation map of Chimmony WLS. Distance from road map of Chimmony wildlife sanctuary is given Fig. 26. The human invasion and settlement along the forest fringes is an important explanation for the dwindling of the forested areas. Increasing human access to forests has led to many accidental forest fires caused by humans (Ajin *et al.*, 2015). Distance from settlement map of Chimmony wildlife sanctuary is divided into five groups (Fig. 27). Chances of accidental forest fire occurring near to the roads and the settlement is more. As already indicated, different factors affecting the frequency and spread of fire, such as topography, atmosphere, vegetation, and water body proximity, as well as human-induced parameters, are typically used to build fire susceptibility maps to consider the likelihood of fire threat. (Pourtaghi et al., 2016, Tripathi et al., 2017).

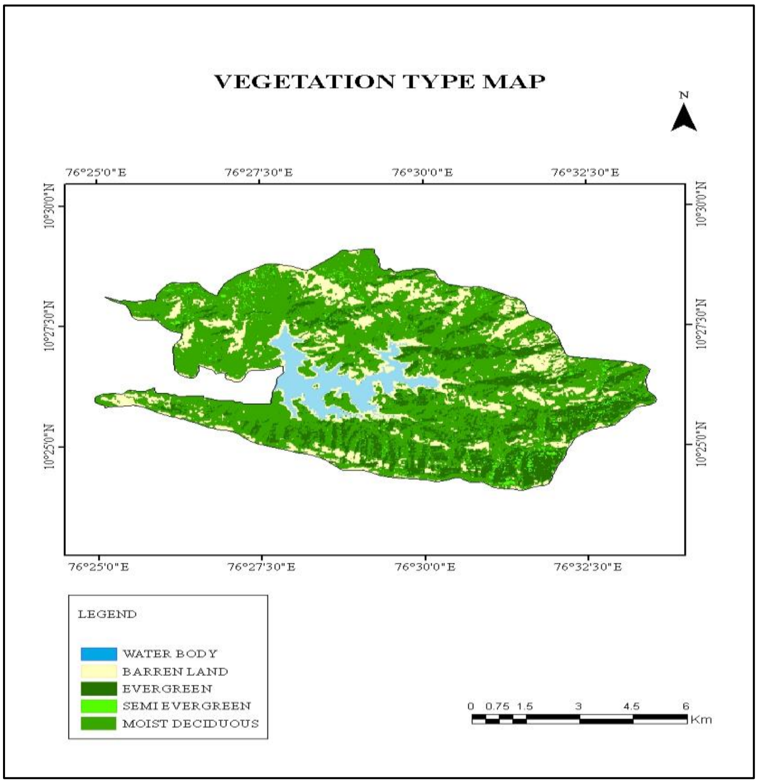

Fig. 23. Vegetation type map of Chimmony WLS.

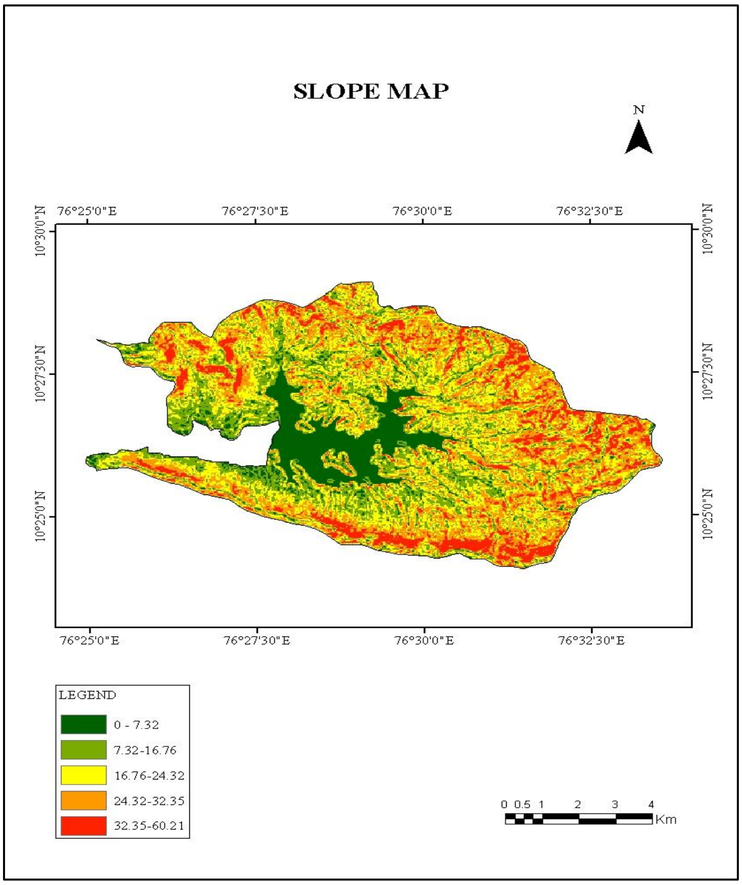

Fig. 24 Slope map of Chimmony WLS.

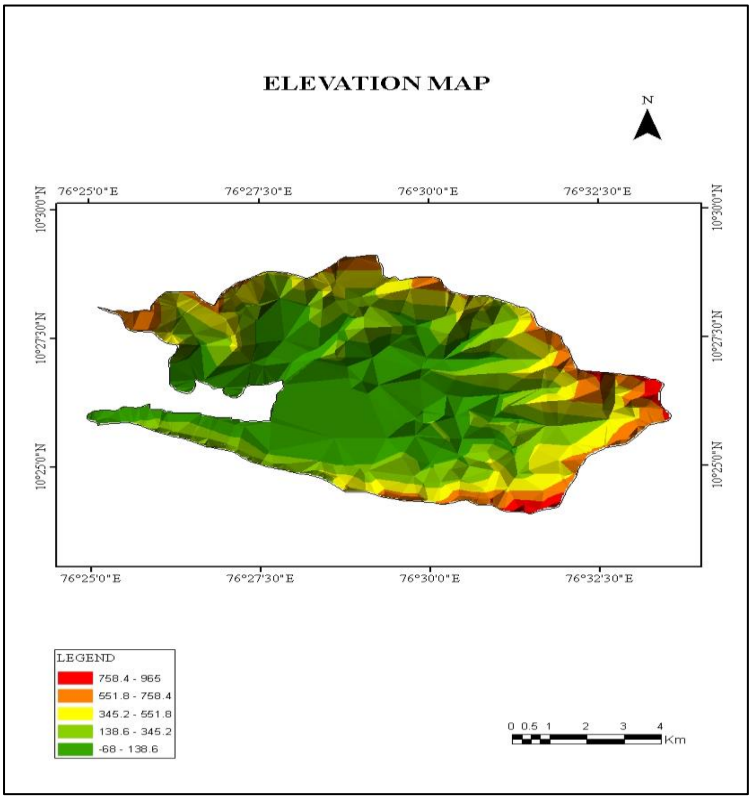

Fig. 25 Elevation map of Chimmony WLS.

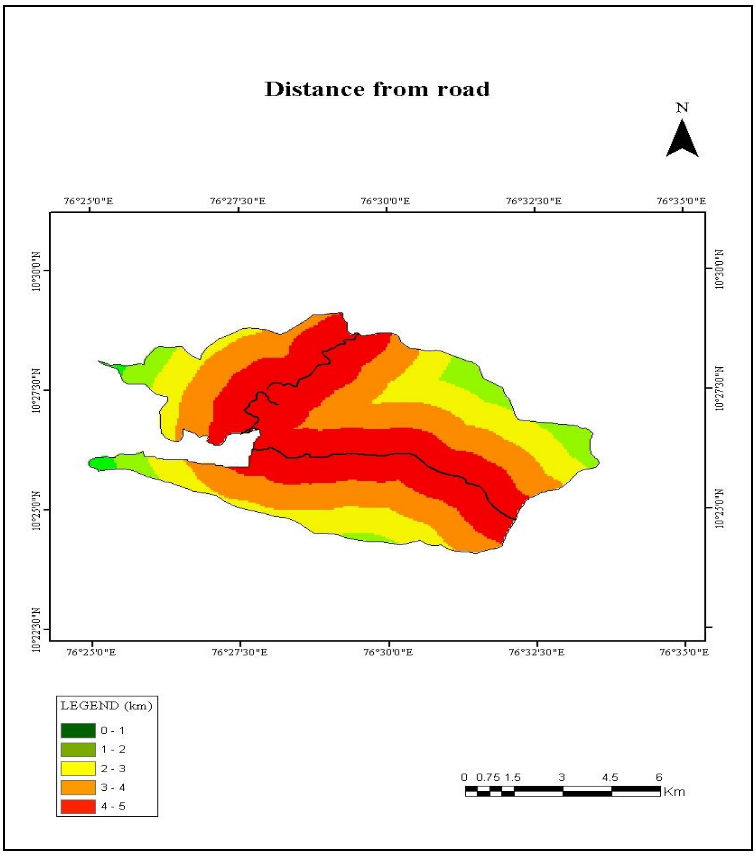

Fig. 26 Distance from road map of Chimmony WLS

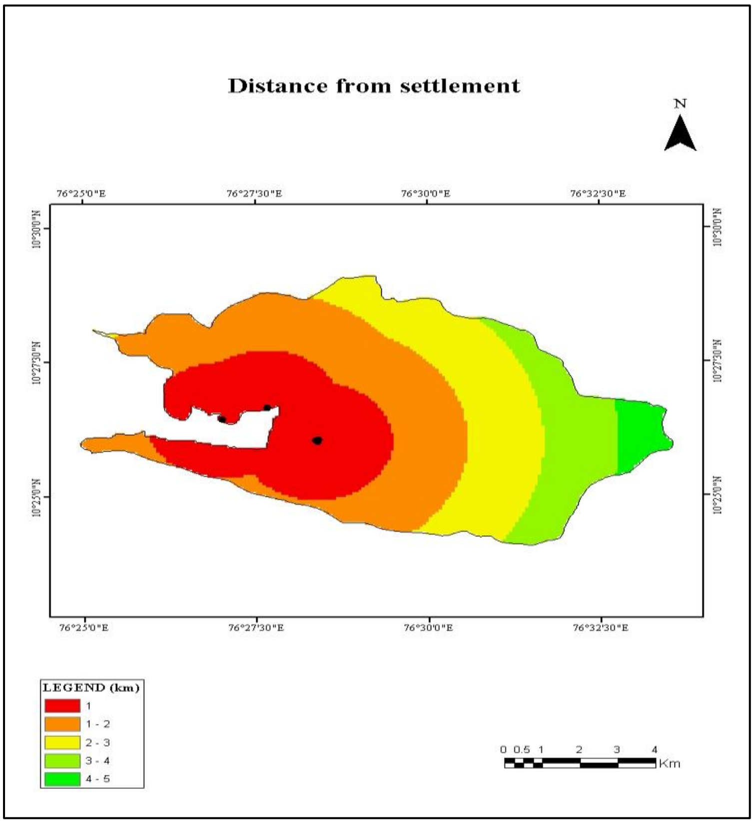

Fig. 27 Distance from settlement map of Chimmony WLS

4.2.2.1. Forest fire risk zones

Fire Risk Zones	Percentage (%)	Area (Km^2)
Very low	7.38	5.98
Low	32.15	26.04
Moderate	29.09	23.56
High	22.41	18.15
Very high	8.96	7.26

Table 9. Area and percentage of fire risk zones at Chimmony WLS

From Table 9, it is evident that 31.37 % area of Chimmony WLS is under very high and high risk zones. However, the largest area fell under very low and low fire risk zones (42.04 %) and 19.76 % area under moderate risk zone. Forest fire risk zone map of Chimmony WLS is given in the Fig. 28. From the above table it is clearly evident that largest area fell under very low and low fire risk zone, but only two fire incidents happened in this region. Higher number of fire incidents occurred in the very high and high fire risk zone (9 fires) and 3 fire incidents occurred in moderate risk zone.

In Chimmony wildlife sanctuary, it was observed that more fire incidence happened in 2018 (5 fires). Based on the forest fire risk zonation map of Chimmony WLS, the higher number of fire incidents happened in the very high and high risk zone. This clearly confirms an anthropogenic origin for the forest fire incidents. It is in the month of February large number of fire incidents happened and more area affected by fire incidents. Lowest fire incidents and fewest fire affected area was observed in March.

According to Mondal and Sukumar (2016), Climate is an overall factor that influences the type, quantity and moisture content of fuel through its effect on the type of vegetation, productivity, decomposition of biomass and the state of desiccation in a region.In Chimmony WLS, the temperature profiles during February was high during 2014 to 2017 with average temperatures being 29.7 ^{o}C, 27.8 ^{o}C, 29.1 ^{o}C, 28.5 ^{o}C, 28.8 ^{o}C and 32.0 ^{o}C respectively. There is considerable research data which shows that an increase in air temperature and reduction of precipitation greatly influence of the possibility of fire occurrence. So, this high temperature profile perhaps caused more forest fire incidents in February in Chimmony WLS. Here, the forest department undertake fire precautionary measures usually in March and they remain more alert. So, this alertness explains the reasons for lesser fire incidents in the month of March.

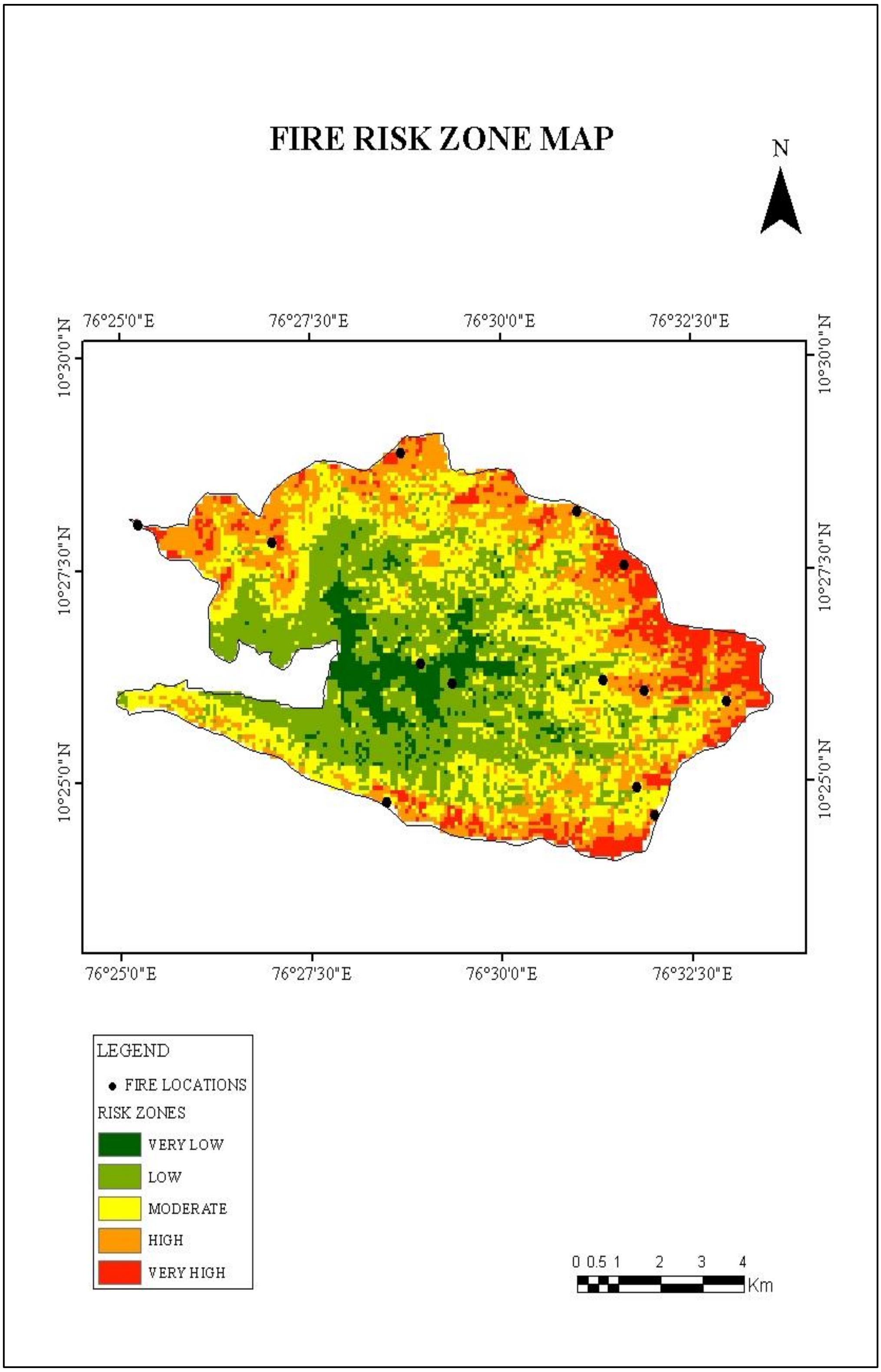

Fig. 28 Forest fire risk zon map of Chimmony WLS

4.1.3. Choolannur Peafowl Sanctuary

4.1.3.1. Number of instances in 2014-2019 period

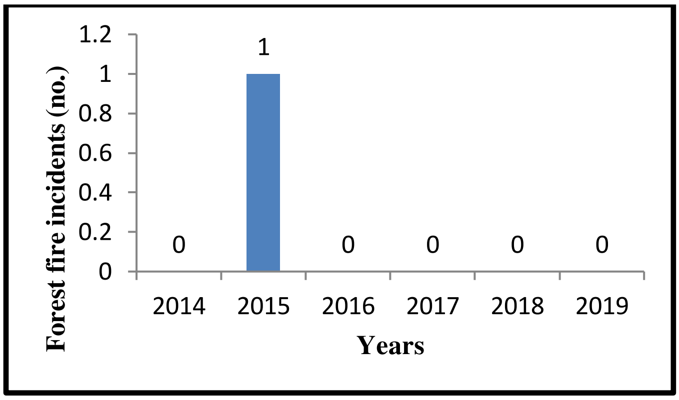

Fig. 29. Forest fire incidents in Choolannur pea fowl sanctuary.

The number of forest fire incidents reported at Choolannur peafowl sanctuary is given in Fig. 29. Only one fire incident was reported in 2015 (February) and 0.4 ha area was affected by this fire incident. In this region, fire precautionary measures are very effective, which is the reason that only one fire incident occurred in the study period (2014-2019). In Ayakkurssi Mythikkampara, where this fire incident occurred, falls under hilly regions. From field survey it was understood that the local people had resorted to fire preventive measures in order to check the attack of wild boars. However, this region where the fire occurred comes under low and very low risk zone in fire risk zonation map. So it can be reasonably concluded that this fire incident has a human connection.

4.2.3. Choolannur pea fowl sanctuary

In the vegetation type map (Fig. 30) of Choolannur Peafowl Sanctuary, the terrain consists of water body, rocks, paddy field, plantation and moist deciduous forests. The cover of moist deciduous forests is maximum area. The rocky patches and moist deciduous forest provide an ideal habitat for Indian peafowl, which is the principal species which is conserved here. As already explained, slope (Fig. 31), elevation (Fig. 32), distance from road (Fig. 33) and distance from settlement (Fig. 34) play an importance role in wild fire incidence.

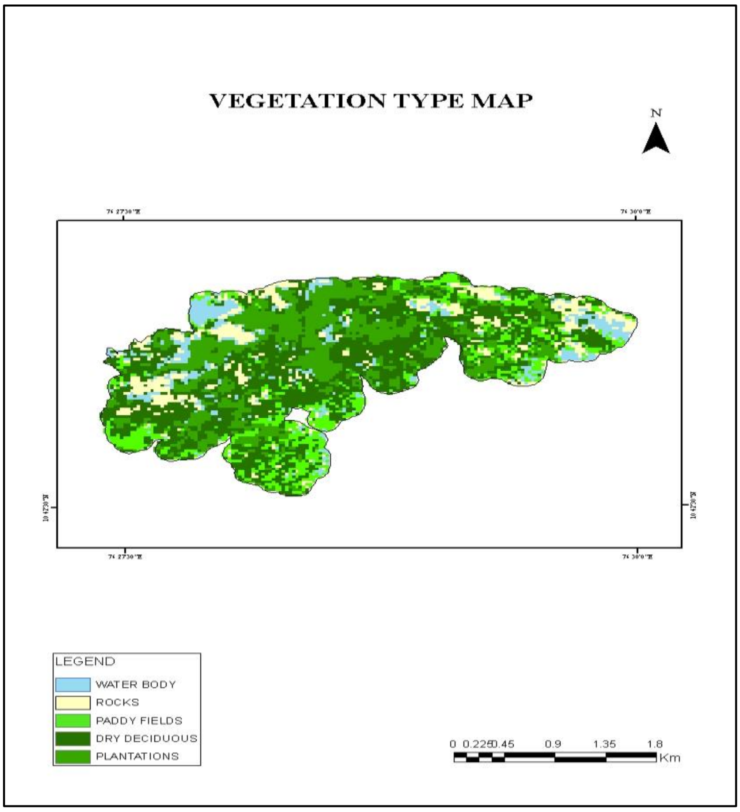

Fig. 30 Vegetation type map of Choolannur pea fowl sanctuary

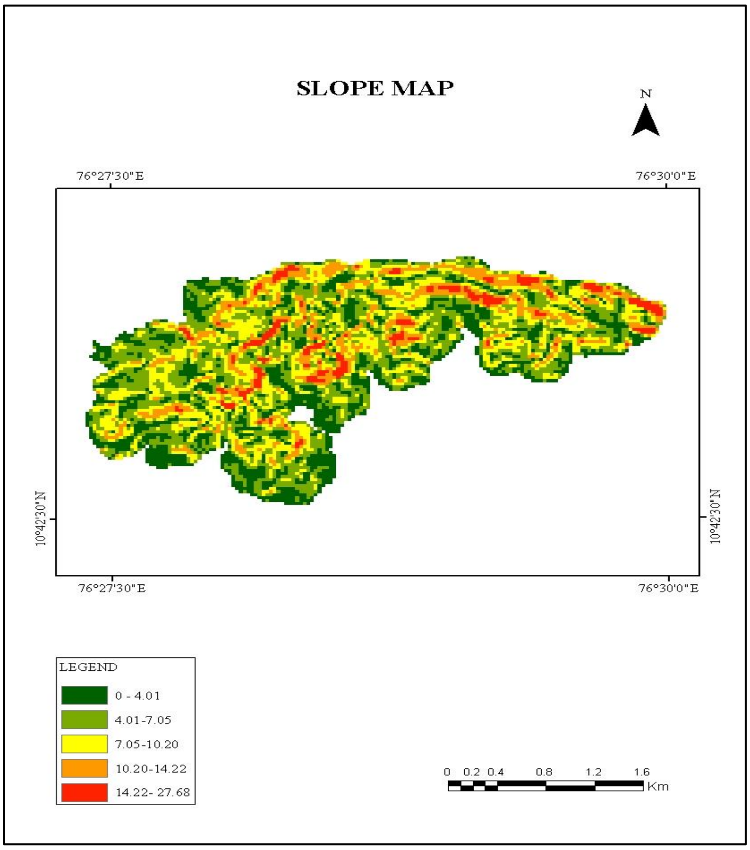

Fig. 31 Slope map of Choolannur pea fowl sanctuary.

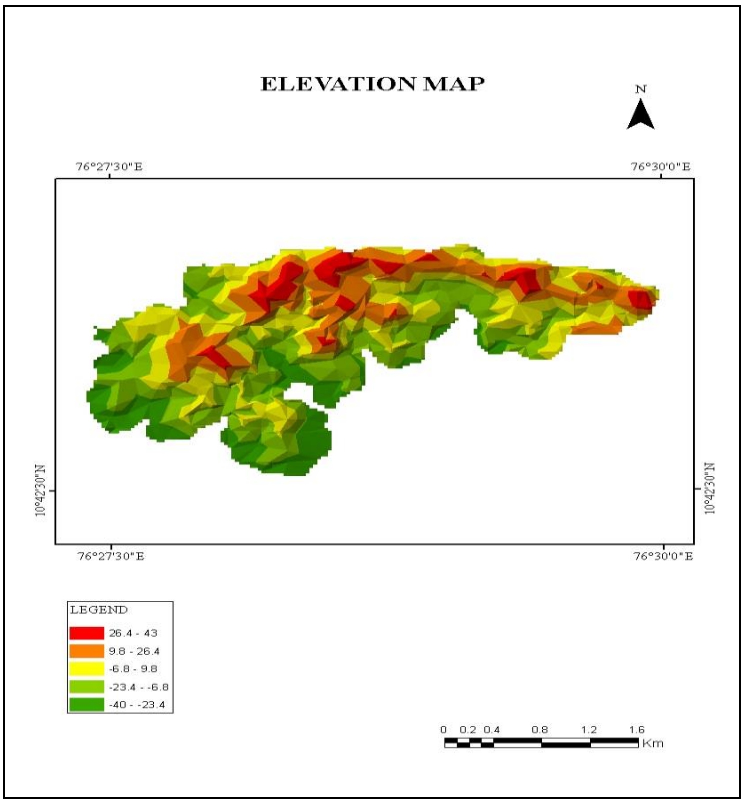

Fig. 32 Elevation map of Choolannur pea fowl sanctuary

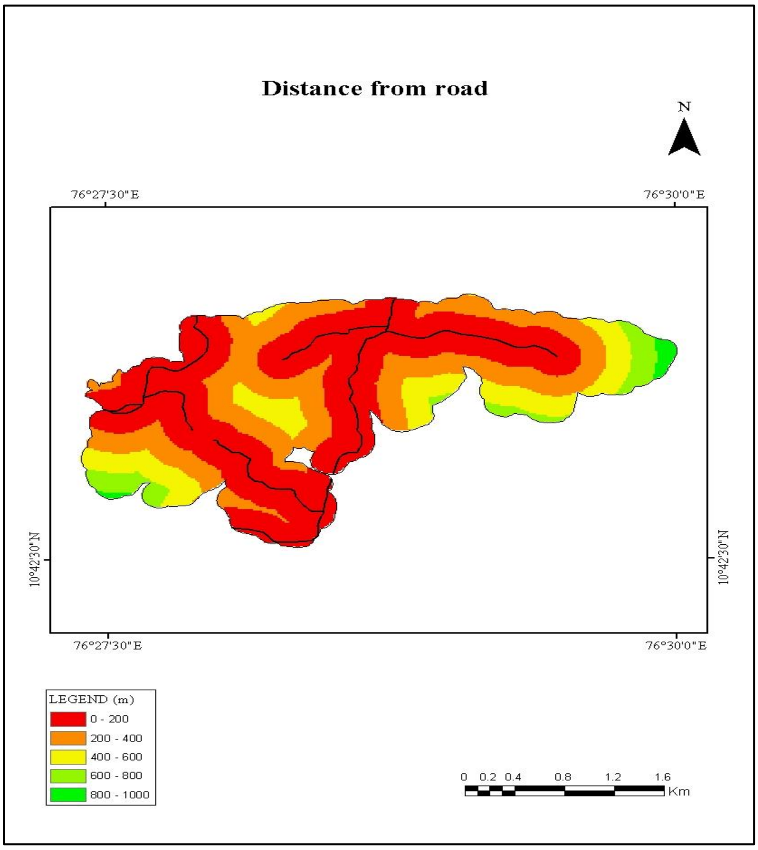

Fig. 33 Distance from road map of Choolannur pea fowl sanctuary.

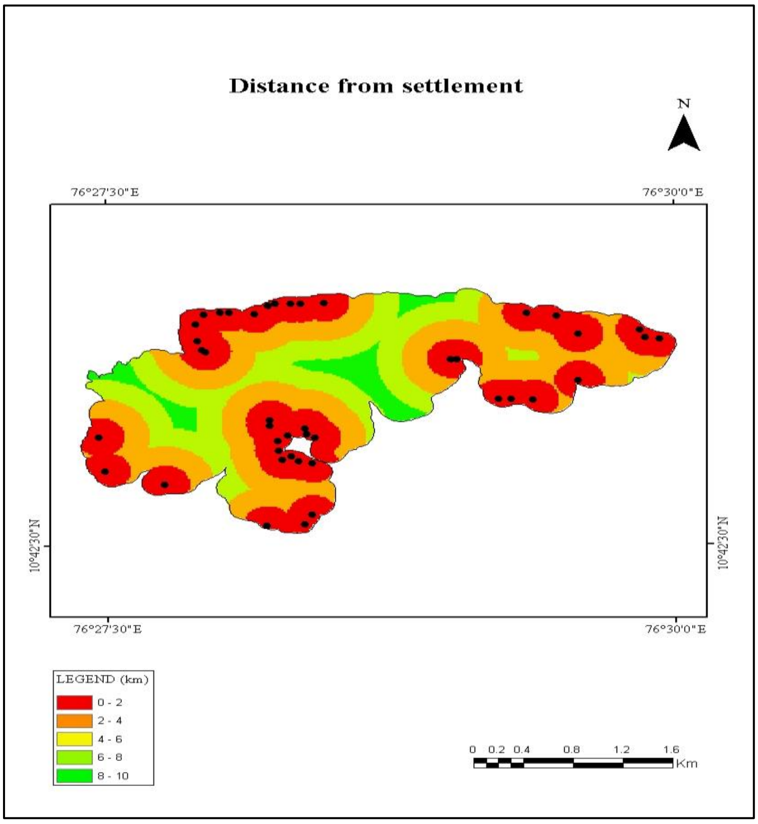

Fig. 34 Distance from settlement map of Choolannur pea fowl sanctuary.

4.2.3.1. Forest fire risk zones

Fire Risk Zones	Percentage (%)	Area (Km^2)
Very low	11.22	0.68
Low	13.36	0.81
Moderate	27.72	1.68
High	18.97	1.15
Very high	28.71	1.74

Table 10. Area and percentage of fire risk zones at Choolannur Peafowl sanctuary

Based on the above maps, it was observed that the maximum area fell under the very high and high fire risk zones (47.68 %). Area coverage under very low and low fire risk zone is 24.58%. And 27.72 % area fell under moderate fire risk zone (Table 10). One fire incident occurred in the very low risk zone at Choolannur pea fowl sanctuary (Fig. 35). The Choolannur peafowl sanctuary covers a small area and there are many human settlements near the fringes. Most of these people are in farming and the paddy fields are near to the settlements. So farmer-pea fowl conflict is a major issue here.

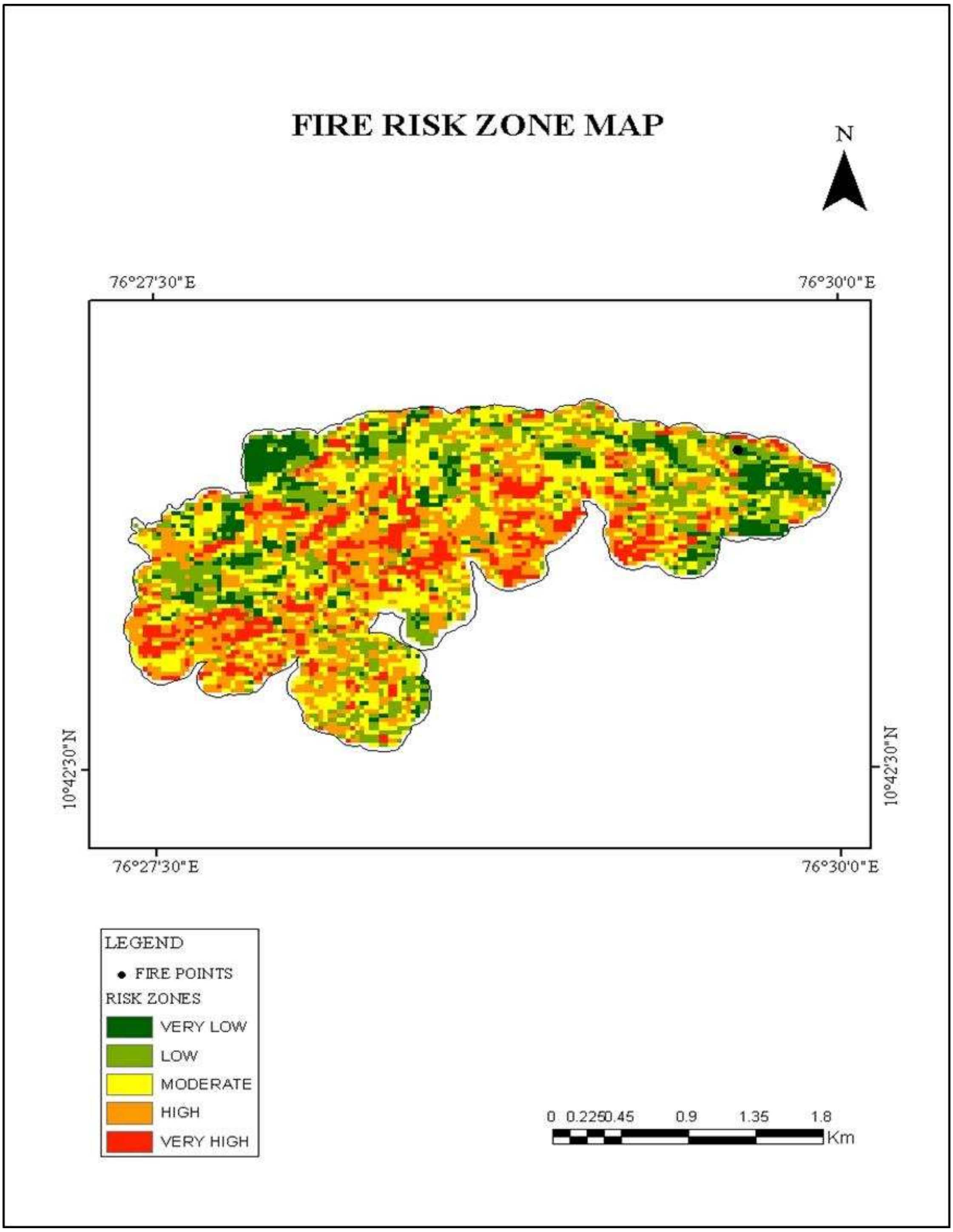

Fig. 35 Forest fire risk zone map of Choolannur pea fowl sanctuary.

4.1.4. Idukki wild life sanctuary

4.1.4.1. Number of instances in 2014-2019 period

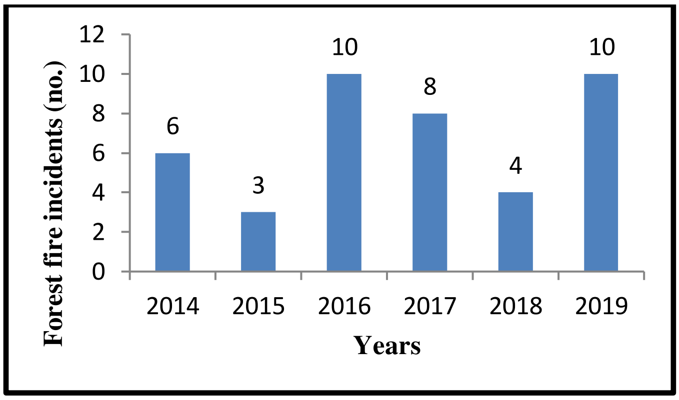

Fig. 36. Forest fire incidence in Idukki WLS.

The number of forest fire incidence reported at Idukki WLS is given in Fig 36. Highest number of fire incidence (10 fires) reported in 2016 and 2019. The year 2016 was also which experienced highest drought intensity. Lowest number of fire incidence occurred in 2015 (3 fires).

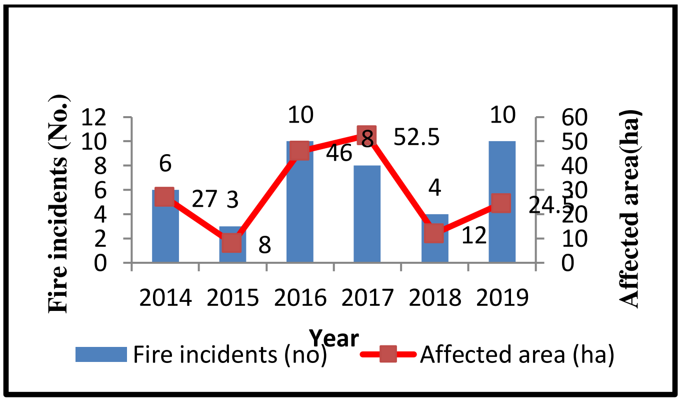

Fig. 37. Forest fire incidence (no.) and affected area (ha) during 2014 to 2019 in Idukki WLS

Figure 37 shows the number of forest fire incidence and area affected by forest fires during 2014 to 2019 in Idukki WLS. Least number of fire incidence happened in 2018 (4 fire), while the minimum area got affected by fire incidence was in 2015 (8 ha). Highest number of fire incidence (10 fires) occurred in 2016 and 2019. More area affected by fire incidence was in 2017 (52.5 ha).

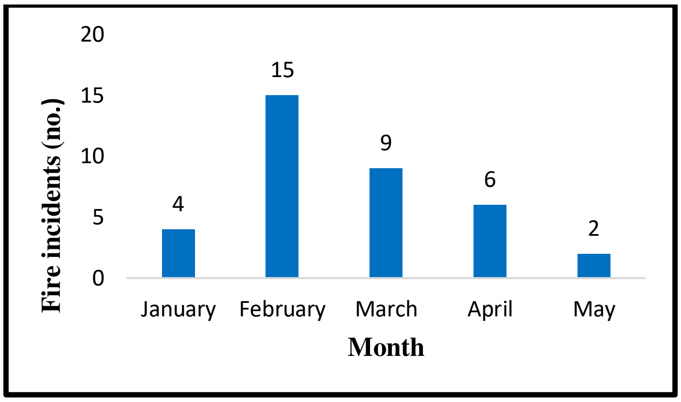

Fig. 38. Monthly wise fire incidence during 2014 to 2019 in Idukki WLS.

Fig. 38 shows that the highest number of fire incidence which was recorded in February (15 fires) and lowest in May (2 fires)

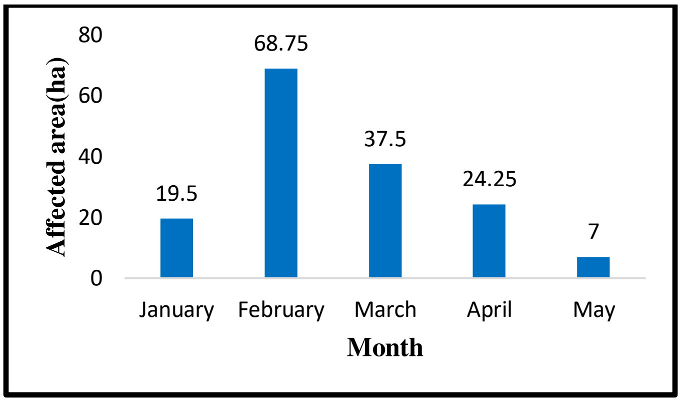

Fig. 39. Monthly wise fire affected area during 2014 to 2019 in Idukki WLS.

Monthly wise fire affected area during 2014 to 2019 in Idukki WLS is given in Fig. 39. The maximum area affected by fire was in February (68.75 ha.). The lowest area that got affected by fire was in May (7 ha).

Fig. 40 displays the monthly wise affected area (ha)/ Fire incidence (no.) during 2014 to 2019 in Idukki WLS. The highest monthly wise affected area (ha)/ Fire incidents (no.) recorded in the month of January (4.875) and lowest observed in the month of May (3.5)

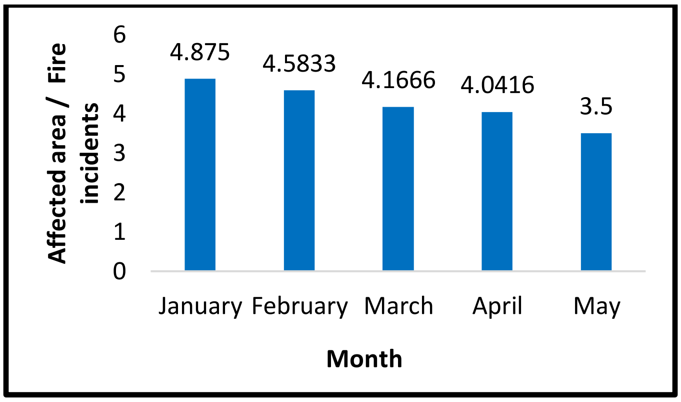

Fig. 40. Monthly wise affected area (ha)/ Fire incidence (no.) during 2014 to 2019 in Idukki WLS.

4.1.4.2. Correlation

Table 11. Correlation of forest fire incidence with climatic variables

Climatic variables	Idukki wild life sanctuary
Temperature (^{0}C)	0.26723**
Rainfall (mm)	-0.42799**

** Significant at 5% and 1%

Table 11 shows the correlation between the number of forest fire incidence with the rainfall and temperature of Idukki wild life sanctuary. It can be seen that while the number of forest fire incidence is positively correlated with the temperature, there is a negative correlation with rainfall. The higher temperature leads to rapid drying of the grass that provides fire litter. In Idukki WLS there are more grass lands on the hilly areas. Deciduous forests and grasslands are more susceptible to higher incidences of forest fires (Ajin et al., 2017). So rising temperatures can bring a greater risk of wildfire in this ecosystem. Moreover, in the higher elevation, the topography is steeper and the wind energy is more and more steady. Thus, conditions are very favorable for nurturing localized natural or triggered forest fires to disasters of disturbing proportions at higher elevations. (Ajin et al., 2017). On the other side, the precipitation is higher, the plants grow faster, and the atmosphere and soils have more moisture content. That creates an unfavourable fire scenario.

4.1.4.3. Regression analysis

In Idukki wild life sanctuary, Linear Regression Model (LRM) was found to be significant (P value <0.05). The model explains 93.11% (R2= 0.9311) of the total variance. The fitted linear regression model equation is;

No: of fire incidents (Y) = -2.85 R + 11.88

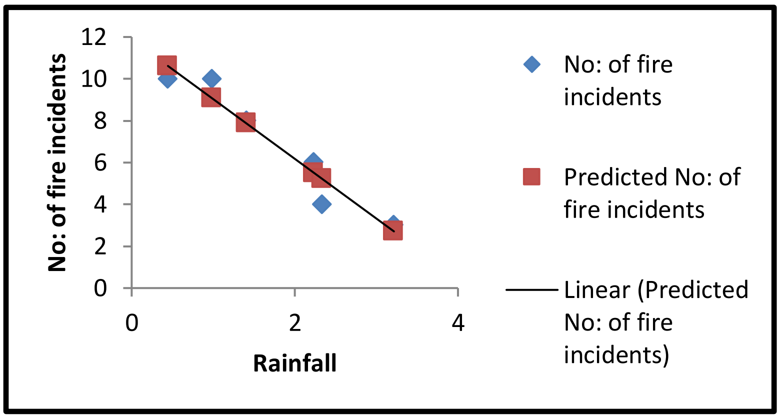

Fig. 41 Rainfall Line Fit Plot

The model shows that the rainfall negatively influenced the number of forest fire incidence. Rainfall increases the moisture content in atmosphere and biomass, which reduces the chance of fire outbreaks. However, fitting a similar linear regression model was tried in the case of number of forest fires in the other study areas but that was found to have a poor goodness of fit.

4.2.4. Idukki wild life sanctuary

In Idukki wild life sanctuary (Fig. 42), the vegetation cover includes water body, barren land, tropical evergreen forest, semi evergreen forest, and moist deciduous forest and grass lands. As already explained, grass lands are more susceptible to fire. Ajin *et al*., (2016) noted that elevation has a major role in spreading fire within a short period of time, owing to its interaction with the wind activity. Convective winds moving upslope affected areas with higher elevations. During the daytime, high temperatures caused warm air to rise, which led to uphill drying. A lightning strike is higher in higher elevations than in lower areas. Forest fire catches up much quicker in the uphill direction. Moisture from fuel and humidity from air decreases as the slope grows. If the ground slope is steeper, the mountain winds serve as a catalyst in the spread of fire. The vegetation on top of the hill is quickly heated and dried out by the fire that advances up the slope (Veena *et al*., 2017) In this sanctuary most area is occupied by grass lands. More fire incidents occurred in the grass lands and that too in summer season. The water body and barren land (rocky areas) are, naturally, not prone to fire.

.

Humans may cause forest fires in two separate ways, intentionally or accidentally. Inadvertent forest fire can be triggered through collection of non-timber forest products, carelessly discarded cigarette butts, fires used for cooking and campfires (Ajin *et al*., 2016). Based on the above concepts, distance from road map of Idukki wildlife sanctuary was divided into five classes (Fig. 45) and distance from settlement map was divided into five classes (Fig. 46).

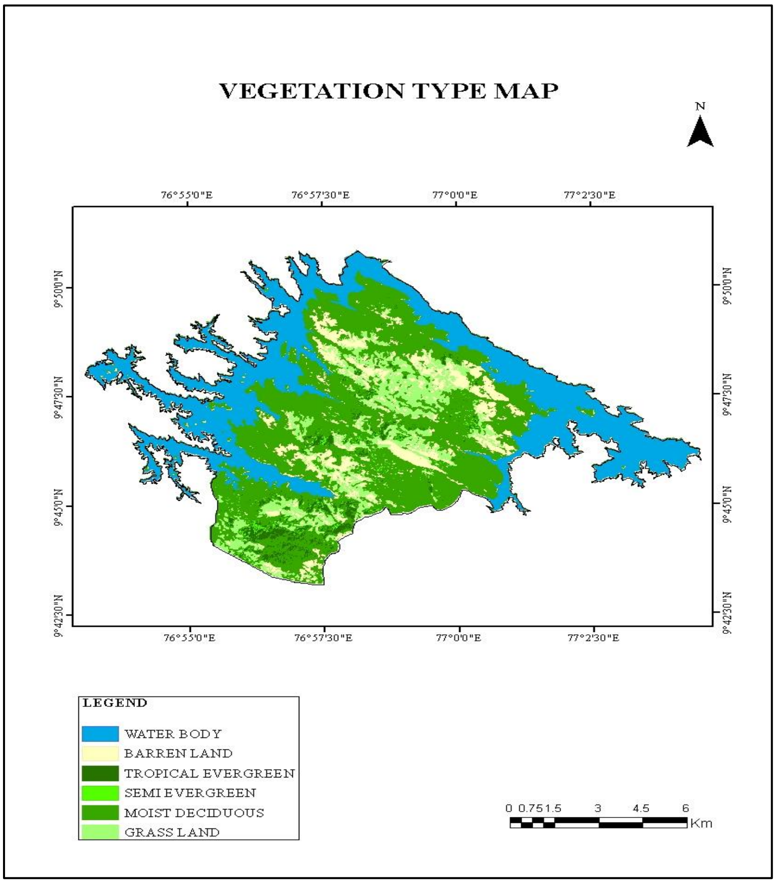

Fig. 42 Vegetation type map of Idukki WLS

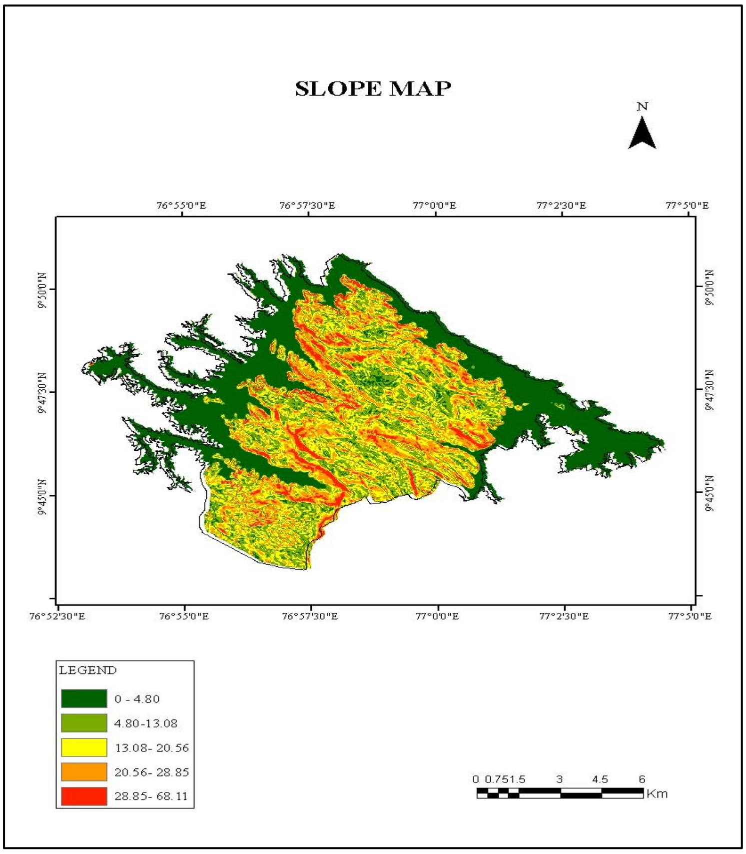

Fig. 43 Slope map of Idukki WLS

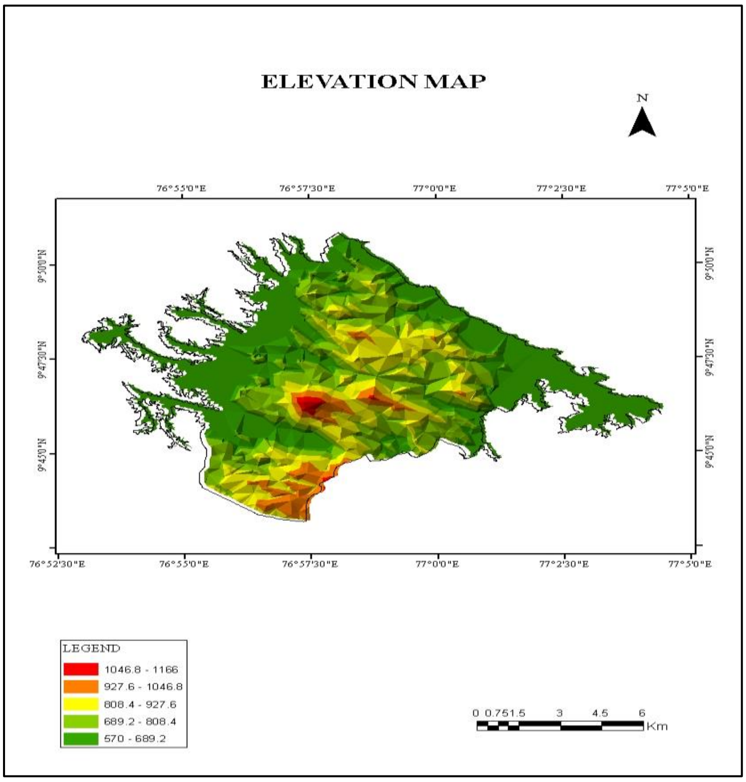

Fig. 44 Elevation map of Idukki WLS

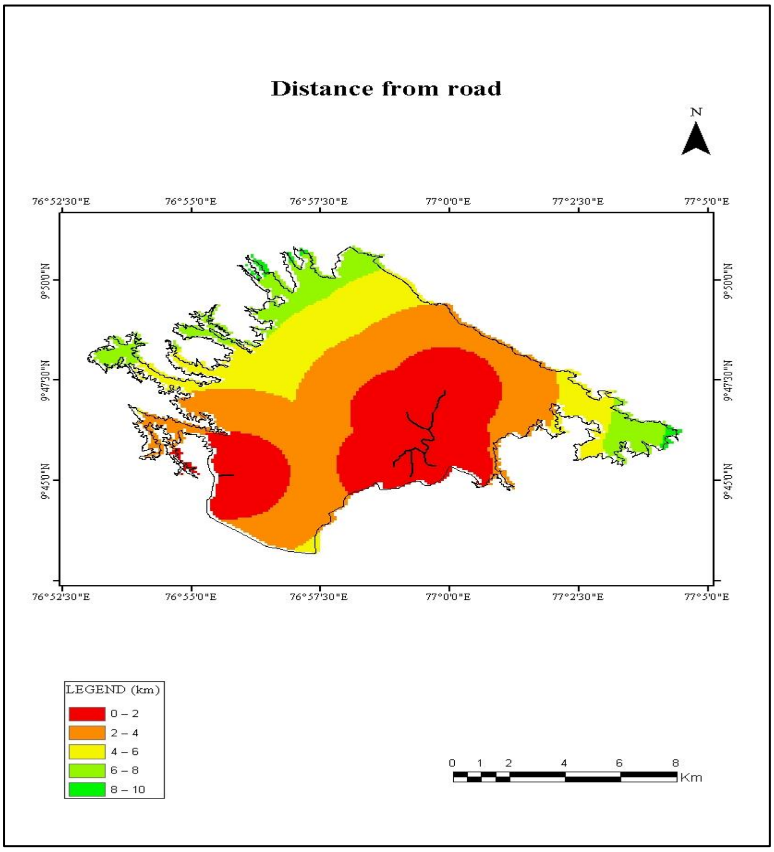

Fig. 45 Distance from road map of Idukki WLS

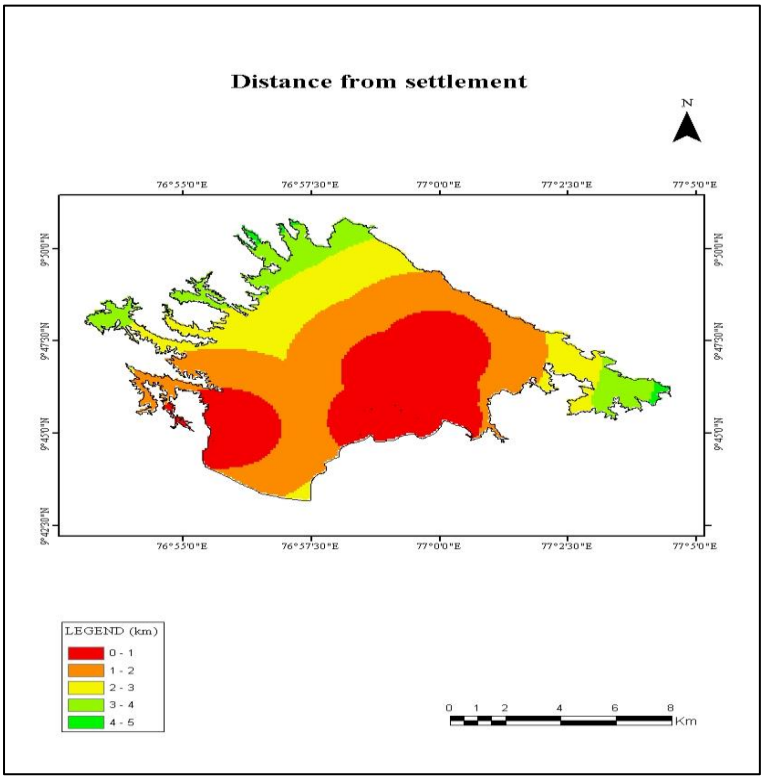

Fig. 46 Distance from settlement map of Idukki WLS

4.2.4.1. Forest fire risk zones

Table 12. Area and percentage of fire risk zones at Idukki WLS.

Fire Risk Zones	Percentage (%)	Area (Km^2)
Very low	32.98	38.28
Low	9.06	10.52
Moderate	19.76	22.94
High	24.89	28.89
Very high	13.27	15.41

It is evident from Table 12, 38.16 % area occurs in very low and low fire risk zones. Seventy six per cent areas fell under moderate fire risk zone and 42.04 % area fell in low and very low fire risk zones. In Idukki wild life sanctuary (Fig. 47), nine fire incidents occurred in very low and low fire risk zones, 10 forest fires occurred in moderate fire risk zone and 18 fires occurred in the high and very high fire risk zones. Dissing and Verbyla (2003) had noted that the relationship between lightning strike intensity and elevation was generally positive to a maximum height of 1100–1200 m. In Idukki wild life sanctuaries there are steep slopes and have higher elevation. So the chance of natural forest fires, although marginal, cannot be ruled out completely But, centered on observations from the Geographical Information System (GIS) and Remote Sensing (RS), several fire incidents were observed near to roads and settlements, which clearly indicated the possibility of man-made forest fires (Ajin *et al*., 2016).. Another possible reasons quoted by Ajin et al., (2016), the use of fire by timber traffickers to cover the stumps of unlawful felling, the small fires set by farmers to clear the forest path covered by tree branches and leaves, and the fires set for the collection of NTFP, etc.,

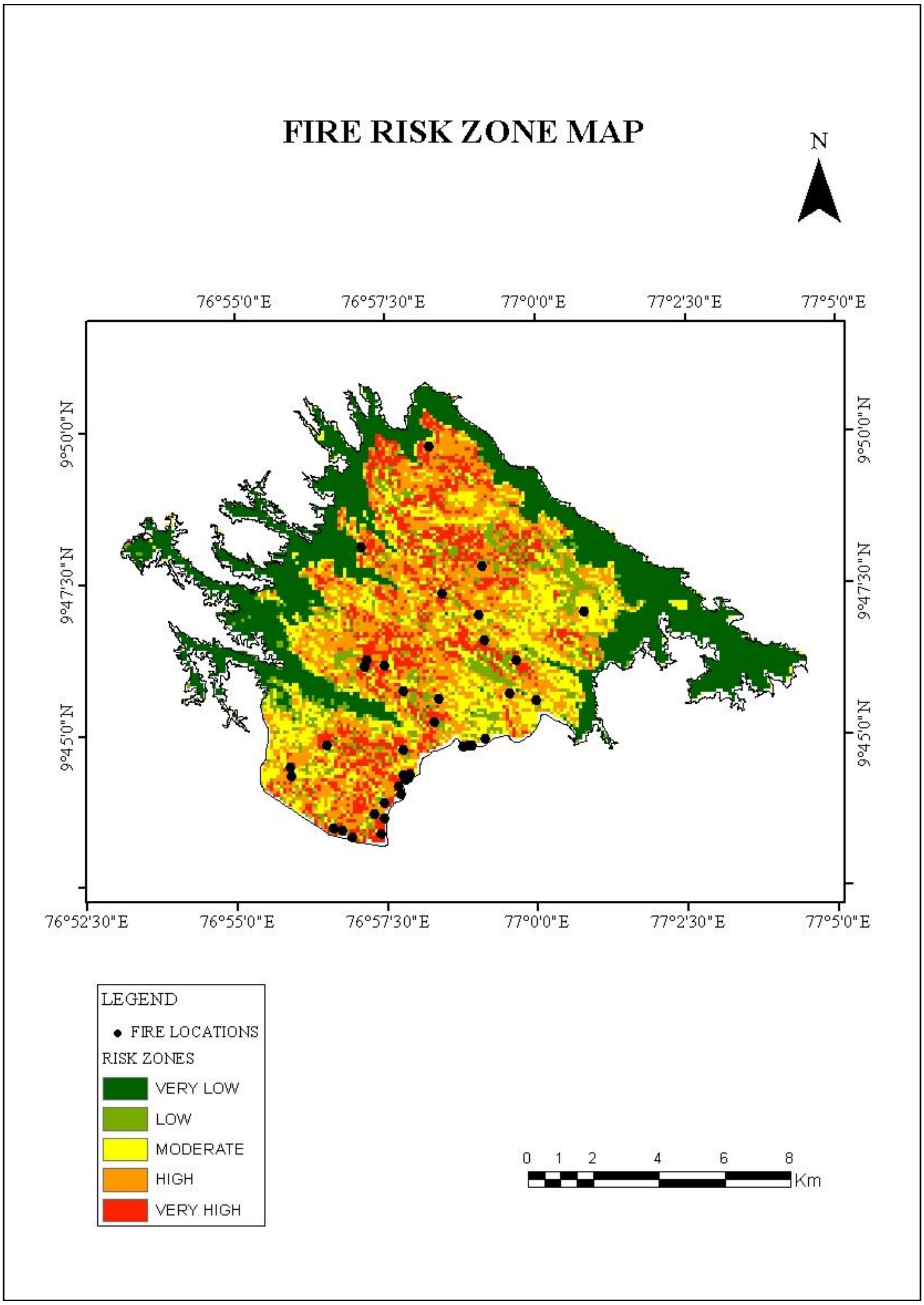

Fig. 47 Forest fire risk zone map of Idukki WLS

4.1.5. Thattekkadu Bird Sanctuary

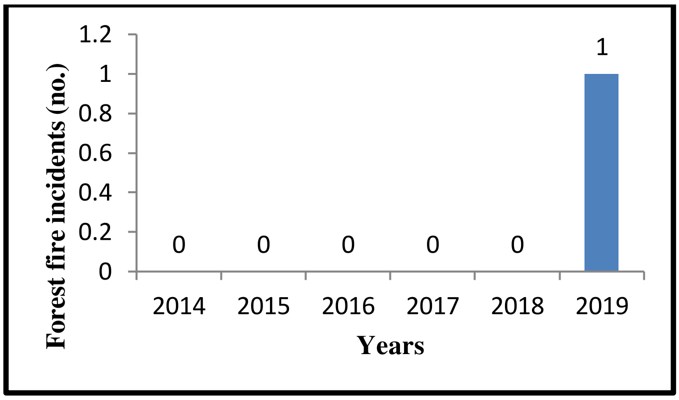

Fig. 48 Fire incidence number in Thattekkadu Bird Sanctuary

Fire incidence number (2014 – 2019) in Thattekkadu Bird Sanctuary is given the Fig. 48. Only one fire incident was reported in 2019, and 2 ha area affected by this fire incidence in the month of January. The fire was reported as originated at ' Njayappilly mudi ' top. But as this region comes under low and very low risk zone in fire risk zonation map, it can be concluded that there is a human connection behind this incident.

4.2.5. Fire risk Zonation map of Thattekkadu bird sanctuary

In this sanctuary, the vegetation types (Fig. 49) included water body, barren land, evergreen forest semi evergreen forest and moist deciduous forests. The semi evergreen forest and moist deciduous forest are comparatively more liable to fire. This sanctuary though has a thick canopy cover and they show a variety of migratory birds. Slope (Fig. 50), elevation (Fig. 51), distance from roads (Fig. 52) and distance from settlement (Fig. 53), as indicated earlier, were the parameters used to create the fire zone maps as these also influence the spread of a forest fire.

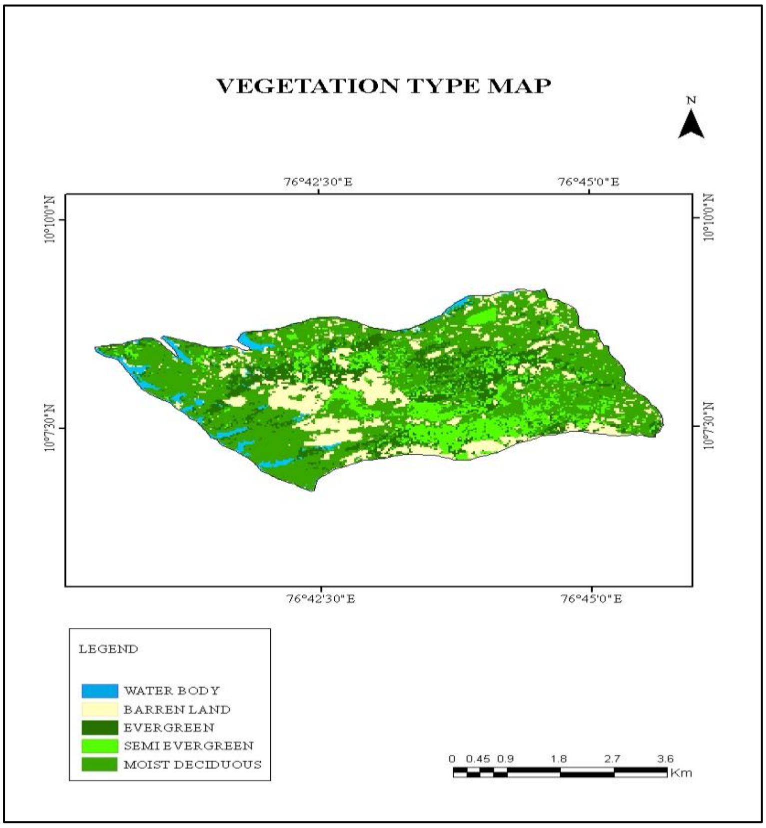

Fig. 49 vegetation type map of Thattekkadu bird sanctuary

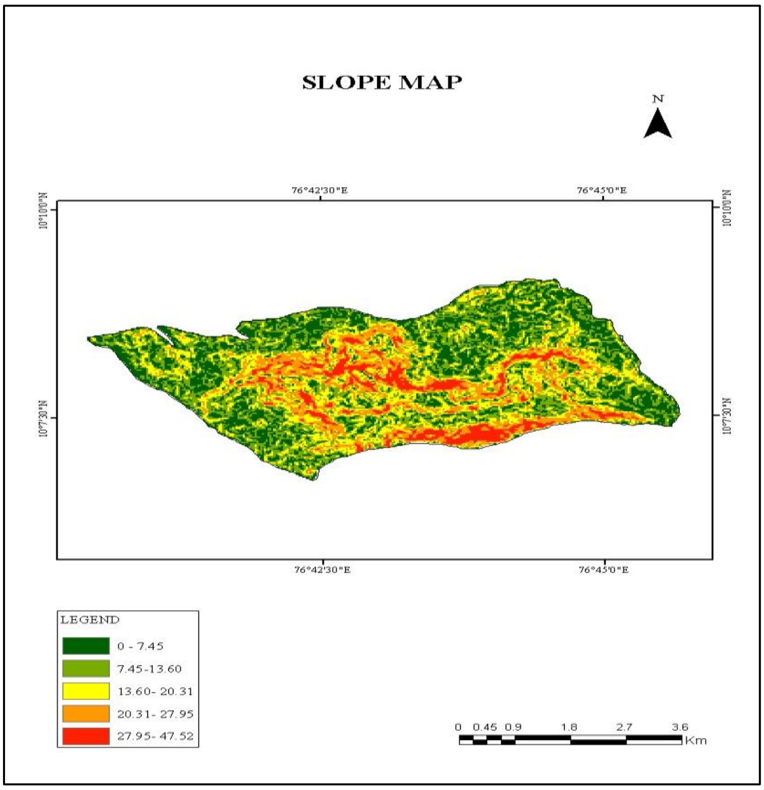

Fig. 50 Slope map of Thattekkadu bird sanctuary

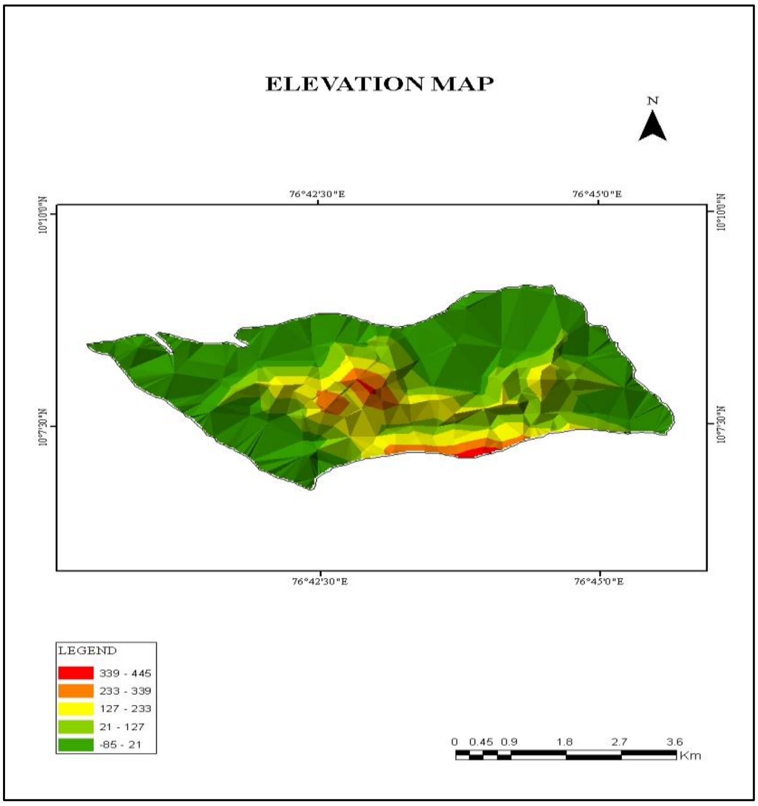

Fig. 51 Elevation map of Thattekkadu bird sanctuary

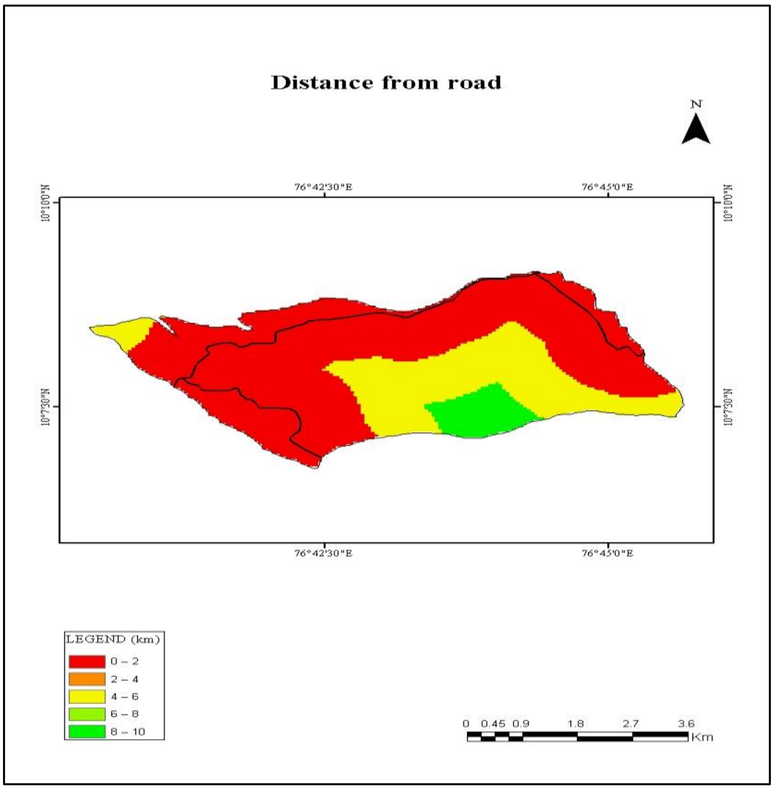

Fig. 52 Distance from road map of Thattekkadu bird sanctuary

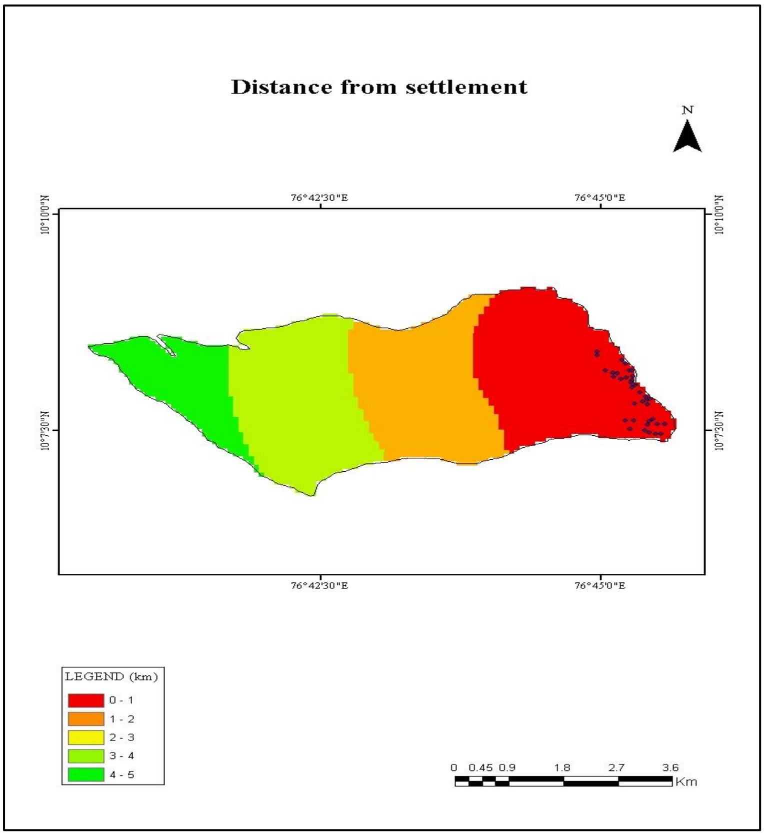

Fig. 53 Distance from settlement map of Thattekkadu bird sanctuary

4.2.5.6. Forest fire risk zones

Fire Risk Zones	Percentage(%)	Area (km^2)
Very low	5.44	1.23
Low	33.01	7.46
Moderate	33.14	7.49
High	18.67	4.22
Very high	9.73	2.19

Table 13. Area and percentage of fire risk zones at Thattekkadu bird sanctuary

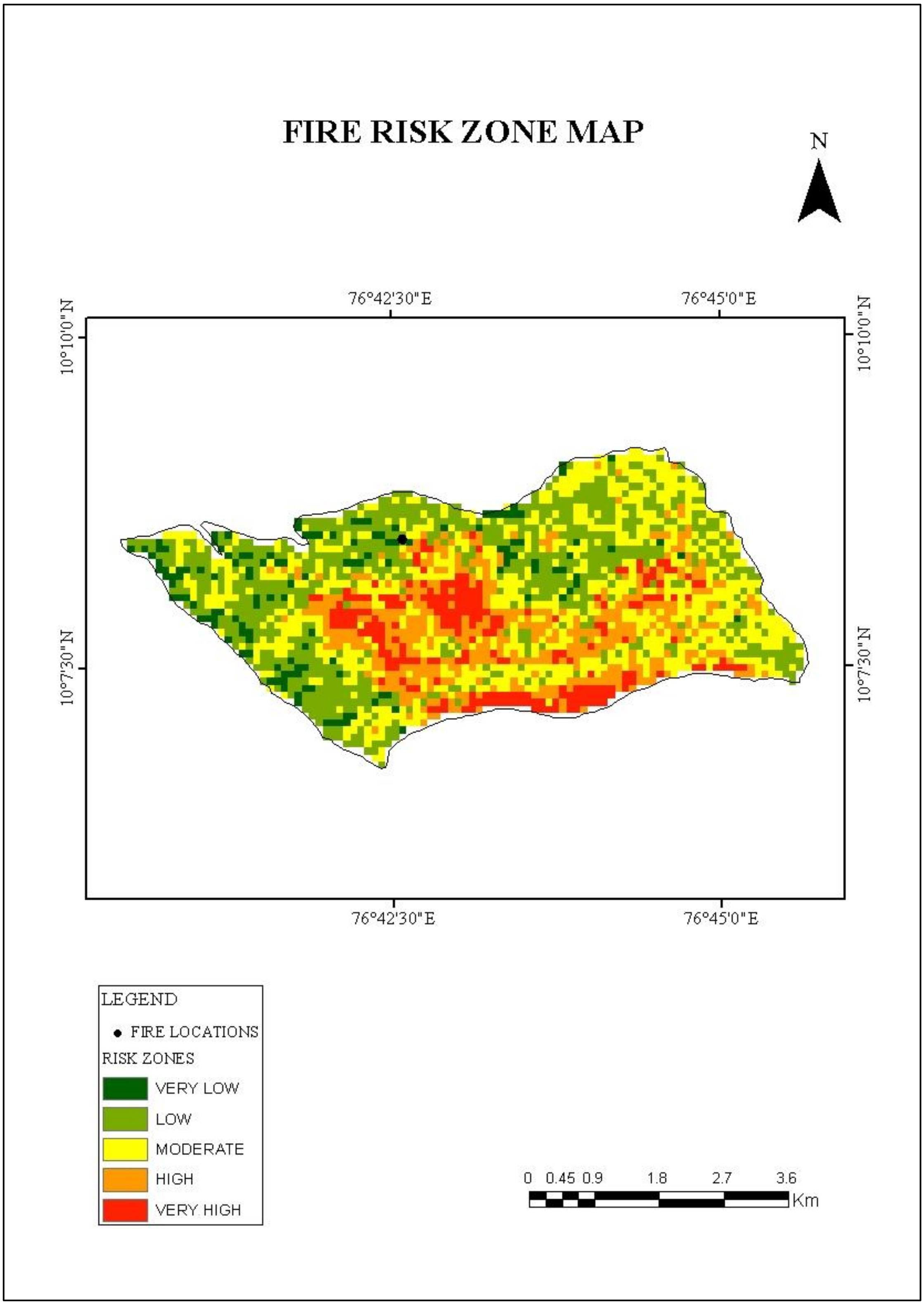

Fig. 54 Forest fire risk zone map of Thattekkadu bird sanctuary

It is evident from Table 13, 28.4 % areas in this sanctuary are located in very high and high fire risk zone and 33.14 % occur in moderate fire risk zone. 38.45 % area fell under very low and low fire risk zones. However, in Thattekkadu bird sanctuary one fire incident occurred in low risk zone (Fig.54).

From the present study it can be concluded that more fire incidence was reported in Peechi – Vazhani wildlife sanctuary (158 fires) and Idukki wildlife sanctuary (41 fires) followed by Chimmony wildlife sanctuary (13 fires) during the study periods (2014 – 2015). Chulannoor Peafowl Sanctuary and Thattekadu Bird Sanctuary suffered only one fire incident case during this period. The major reason for fire incidents are anthropogenic in nature which could be proved by the fire risk zonation maps. Along with that there are also slim chances of natural fire incidents at Idukki wildlife sanctuary because of its topographical features (steep slope areas and has higher elevation) the incidents of direct solar radiation and thunderstorm may trigger a natural forest fire.

All forest fire analysis concluded that, more fire incidence happened in February in Peechi - Vazhani WLS, Chimmony WLS, Idukki WLS and Choolannur pea fowl sanctuary. In Kerala, temperatures range from 28 ° C to 32 ° C (82 ° F to 90 ° F) on the plains but drop to around 20 ° C (68 ° F) in the highlands (Sajna *et al.*, 2015). Since the climate is only dry in the summer they dry the soil, produce more litter (dried vegetation parts), these encourage the strength of the fire or this may trigger a fire.

From the correlation analysis, it is also evident that forest fire increases as temperature increases. It can also be observed that the increase in rainfall also lead to decreases in instance of forest fire. However, these two observations are not new and is indeed a typical feature of tropical deciduous forest ecosystems. Unscientific collection of NTFPs is another major reason for manmade forest fire in Chimmony wildlife sanctuary. Being of smaller geographical area, Chulannoor pea fowl sanctuary is comparatively safe from forest fires as regular observations and fire mitigation measures are easy to carry out. Awareness programs among locals have also helped in controlling the fire here. In Chulannoor, the human-peafowl conflicts are an issue. Since peafowl is protected under Section 51 (1-A) of the Wildlife Protection Act, 1972, farmers are left with no option but to use various deterring techniques, including perhaps in some cases, fire as a tool. The sole fire incident which got reported in Thattakkadu Bird Sanctuary, originated in ' Njayappilly mudi ' top, was due to anthropogenic activity. But considering the forest fire records obtained from Kerala forest department, the loss of forest resources in these protected areas is not that much severe.

India is one of the world's mega-biodiversity nations, where forests occupy over a fifth of the geographical area. There are nearly 173,000 villages identified as forest villages in India largely inhabited tribal people who depend entirely on forest resources and generate government revenue by collecting Non-Timber Forest Products (Kishwan *et al.*, 2009). Ramesh *et al.*, (2003) had reported that forest fire poses a direct danger in 97 % of Kerala forest divisions. More than 95% of forest fires in Kerala are believed to be man-made, either intentional or accidental. According to our fire risk zonation map, many fire incidence happened near to the roads and settlements, it's clearly confirmed that the wildfires are triggered by human activity, and it may deliberately or unintentionally. Forest fires apart from reducing the commercial worth of trees and forest ecosystems *per se*, also produces abundant quantity of green-house gases (CH_4 and CO_2) and alters the carbon cycle and atmospheric composition. Hence to prevent such catastrophizes and to protect our remaining forests, forest fire risk regions must be demarcated and preventive actions taken. This study is a contribution in that direction.

SUMMARY

CHAPTER 5

SUMMARY

On the basis of this study, it could be observed that the highest number of forest fire incidents was reported in February in all the study sites. More number of forest fire incidences happened at Peechi – Vazhani WLS (158 fires), followed by Idukki WLS (41 fires) and Chimmony WLS (13 fires). Only one fire incident each was reported from Thattekkadu bird sanctuary and Choolannur peafowl sanctuary respectively during the same period. Temperature and rainfall were observed to significantly correlate with fire incidents in all the study sites.

From the fire risk zonation maps, it can be deduced that majority of the forest fire incidents occurred near to the roads, which confirms an anthropogenic connection. In Peechi – Vazhani WLS, fifty six forest fire incidences occurred in the low and very low risk zones, while 29 fires occurred in the moderate risk zone, and 32 occurred in the high and very high risk zones. At Chimmony WLS, higher number of fire incidents occurred in the very high and high fire risk zone (9 fires) and 3 fire incidents occurred in moderate risk zone. Only two fire incidents happened in very low and low fire risk zones. At Idukki WLS, nine fire incidents occurred in very low and low fire risk zones, 10 forest fires occurred in moderate fire risk zone and 18 fires occurred in the high and very high fire risk zones. One fire incident occurred in the very low risk zone at Choolannur pea fowl sanctuary. In Thattekkadu bird sanctuary one fire incident occurred in low risk zone.

As 99% of all forest fires are manmade, one possible trigger for all these fire incidents could be careless human interventions arising out of using fire as a strategy to ward off consistent instances of human – wildlife conflicts. Many human settlements were observed in the forest fringe areas. Cultivation of palatable, nutritious crops near the forest boundaries is one main reason for increased human-wildlife interactions. Earlier researchers had reported that human wild life conflicts were more in February at Peechi – Vazhani WLS. All these conclusively point to anthropogenic activities behind the incidence of wild fires that occurred near the road and greater incidents of fire that occurred in February in the PAs.

REFERENCES

REFERENCES

Ager, A. A., Vaillant, N. M. and Finney, M. A. 2011. Integrating fire behavior models and geospatial analysis for wildland fire risk assessment and fuel management planning. *J. Combustion*. 2011 :1-19.

Ahmad, F., Goparaju, L. and Qayum, A. 2018. Himalayan forest fire characterization in relation to topography, socio-economy and meteorology parameters in Arunachal Pradesh, India. *Spatial Information Research* 26(3): 305-315.

Ajin, R. S., Ciobotaru, A., Vinod, P. G. and Jacob, M. K. 2015. Forest and Wildland fire risk assessment using geospatial techniques: A case study of Nenmmara forest division, Kerala, India. *J. Wetlands Biodiversity*. 5: 29-37.

Ajin, R. S., Loghin, A. M., Jacob, M. K., Vinod, P. G. and Krishnamurthy, R. R. 2016. The risk assessment study of potential forest fire in Idukki Wildlife Sanctuary using RS and GIS techniques. *Int. J. Advanced Earth Sci. and Eng.* 5(1): 308-318.

Ajin, R. S., Loghin, A. M., Vinod, P. G. and Jacob, M. K. 2016. Forest fire risk zone mapping using RS and GIS techniques: a study in Achankovil Forest Division, Kerala, India. *J. Earth, Environ. and Health Sci*. 2(3): 109.

Ajin, R. S., Loghin, A. M., Vinod, P. G. and Jacob, M. K. 2017. The risk analysis of potential forest fires in a wildlife sanctuary in the Western Ghats (Southwest Indian Peninsula) using geospatial techniques. *Int. J. Health System and Disaster Manag*. 5(1): 18.

Alexander, M. E. and Cruz, M. G. 2011. What are the safety implications of crown fires?. In: Proceedings of 11th International Wildland Fire Safety Summit; 4-8, April, 2011, Missoula. International Association of Wildland Fire, Missoula, pp. 4-8.

Balagopalan, M. 1987. Effects of fire on soil properties in different forest ecosystems of Kulamav, Kerala, India. *Malaysian Forester*. 50(1-2): 99-106.

Benjamin, S. G., Radhakrishnan, B., Nidhin, T. G. and Suresh, L. P. 2016. October. Extraction of fire region from forest fire images using color rules and texture analysis. In: *Int. Conf. Emerging Technological Trends (ICETT), Institute of Electrical and Electronics Engineers (*IEEE): 1-7).

Biju, V. 2014. Chemical modifications and bioconjugate reactions of nanomaterials for sensing, imaging, drug delivery and therapy. *Chemical Society Reviews*. 43(3): 744-764.

Chandra, K. K. and Bhardwaj, A. K. 2015. Incidence of forest fire in India and its effect on terrestrial ecosystem dynamics, nutrient and microbial status of soil. *Int. J. Agric. and For*. 5(2): 69-78.

Chandra, S. and Arora, M. K. 2006, December. Forest fire risk zonation mapping using remote sensing technology. In: *Disaster Forewarning Diagnostic Methods and Management*. International Society for Optics and Photonics. 6412, p.10.

Chandra, S., 2005. Application of remote sensing and gis technology in forest fire risk modeling and management of forest fires: A case study in the garhwal himalayan region. In: *Geo-information for Disaster management.* Springer, Berlin, Heidelberg. pp. 1239-1254.

Chandrashekara, S. 2014. C-reactive protein: An inflammatory marker with specific role in physiology, pathology, and diagnosis. *Int. J. Rheumatology and Clin. Immunol*. 2(S1). p.23.

Chandrashekara, U. M., Muraleedharan, P. K. and Sibichan, V. 2006. Anthropogenic pressure on structure and composition of a shola forest in Kerala, India. *J. Mountain Sci*. 3(1): 58-70.

Chavan, M. E., Das, K. K., and Suryawanshi, R. S. 2012. Forest Fire Risk Zonation using Remote Sensing and GIS in Huynial watershed, Tehri Garhwal District, UA. *Int. J. Basic and Appl. Res.* 2: 6-12.

Chopra, K. 1998. The Valuation of biodiversity within protected areas: Alternative approaches and a case study. *Institute of Economic Growth. University Enclave Delhi, India.*

Chowdhury, A. N., Brahma, A., Mondal, R. and Biswas, M. K. 2016. Stigma of tiger attack: Study of tiger-widows from Sundarban Delta, India. *Indian. psychiatry*. 58(1): 12 .

Chuvieco, E. and Congalton, R. G. 1989. Application of remote sensing and geographic information systems to forest fire hazard mapping. *Remote sensing of Environment*. 29(2): 147-159.

Chuvieco, E., Aguado, I., Yebra, M., Nieto, H., Salas, J., Martín, M. P., Vilar, L., Martínez, J., Martín, S., Ibarra, P. and De La Riva, J. 2010. Development of a framework for fire risk assessment using remote sensing and geographic information system technologies. *Ecological Modelling.* 221(1): 46-58.

DeFries, R., Hansen, A., Newton, A. C. and Hansen, M. C. 2005. Increasing isolation of protected areas in tropical forests over the past twenty years. *Ecological applications*. *15*(1): 19-26.

Dissing, D. and Verbyla, D.L., 2003. Spatial patterns of lightning strikes in interior Alaska and their relations to elevation and vegetation. Canadian Journal of Forest Research, 33(5), pp.770-782.

Eugenio, F. C., dos Santos, A. R., Fiedler, N. C., Ribeiro, G. A., da Silva, A. G., dos Santos, Á. B., Paneto, G. G. and Schettino, V. R. 2016. Applying GIS to develop a model for forest fire risk: a case study in Espírito Santo, Brazil. J. Environ. Manage, 173:65-71.

FSI. 2019. An Assessment Report on Forest Cover Status of India. Government of India: Ministry of Environment and Forest (MoEF); Forest Survey of India

Flannigan, M., Cantin, A. S., De Groot, W. J., Wotton, M., Newbery, A. and Gowman, L. M. 2013. Global wildland fire season severity in the 21st century. *Forest Ecology and Management*, *294*: 54-61.

Flannigan, M. D., Amiro, B. D., Logan, K. A., Stocks, B. J. and Wotton, B. M. 2006. Forest fires and climate change in the 21st century. *Mitigation and adaptation strategies for global change*. *11*(4): 847-859.

Flannigan, M. D., Stocks, B. J. and Wotton, B. M. 2000. Climate change and forest fires. *Science of the total environment*. *262*(3): 221-229.

Ghobadi, G. J., Gholizadeh, B. and Dashliburun, O. M. 2012. Forest Fire Risk Zone Mapping From Geographic Information System in Northern Forests of Iran (Case study, Golestan province). *Int. J. Agric. and Crop Sci*. 4 (12): 818-824.

Giri, K., Pandey, R., Jayaraj, R. S. C., Nainamalai, R. and Ashutosh, S. 2019. Regression equations for estimating tree volume and biomass of important timber species in Meghalaya, India. *Curr. Sci*. *116*(1): 75-81.

Govind, S. K. and Jayson, E. A. 2018. Crop Damage by Wild Animals in Thrissur District, Kerala, India. In: *Indian Hotspots.* Springer, Singapore, pp. 309-323.

Greeshma, P., Jayson, E. A. and Govind, S. K. 2016. The impact of human-wildlife conflict in Peechi-Vazhani wildlife sanctuary, Thrissur, Kerala. *Int. Res. J. Nat. and appl. Sci*. *3*: 32-45.

Guhathakurta, P., Sreejith, O. P. and Menon, P. A. 2011. Impact of climate change on extreme rainfall events and flood risk in India. *J. Earth Syst. Sci*. *120*(3): 359 p.

Hao, W. M., Liu, M. H. and Crutzen, P. J. 1990. Estimates of annual and regional releases of CO 2 and other trace gases to the atmosphere from fires in the tropics, based on the FAO statistics for the period 1975–1980. In *Fire in the tropical biota*. Springer, Berlin, Heidelberg, pp. 440-462.

Holden, Z. A., Swanson, A., Luce, C. H., Jolly, W. M., Maneta, M., Oyler, J. W., Warren, D. A., Parsons, R. and Affleck, D. 2018. Decreasing fire season precipitation increased recent western US forest wildfire activity. *Proceedings of the National Academy of Sciences*, *115*(36): 8349-8357.

Hunter, C. M., Caswell, H., Runge, M. C., Regehr, E. V., Amstrup, S. C. and Stirling, I. 2010. Climate change threatens polar bear populations: a stochastic demographic analysis. *Ecology*. *91*(10): 2883-2897.

IPCC. 2007. Fourth Assessment Report Intergovernmental Panel on Climate Change Secretariat. Geneva, Switzerland. http://www.ipcc.ch/

IPCC. 2014. Summary for policymakers. In: Field, C.B., Barros, V . R., and Dokken. D, J. (eds.). *Climate change 2014: impacts, adaptations, and vulnerability. Part A: global and sectoral aspects. Contribution of working*

International Union for Conservation of Nature (IUCN).2008.Protected Areas.[online].Available: https://www.iucn.org/theme/protected-areas/about.[2 May 2020].

Jaiswal, R. K., Saumitra, M., Kumaran, D. R. and Rajesh, S. 2002. Forest fire risk zone mapping from satellite imagery and GIS. Int. J. Appl. Earth Obs. Geoinf., 4 (1):1-10.

Jayanarayanan, T. 2001. Forest Degradation in Kerala: Causes and Consequences: A Case Study of Peechi-Vazhani Area. Centre for Development Studies. p.116.

Jayson, E. A. and Padmanabhan, P. 2002. Evaluation of the problems of captive/natural population of crocodiles in Neyyar Wildlife Sanctuary and suggestions for their management with special emphasis on reduction of human-animal conflict. *KFRI Research Report* No.237. Kerala Forest Research Institute. Peechi. p.95.

Jinzhu, Y., Zhongke, F., Wei, J. and Xiaoqin, Y. 2007. Risk management: A probe and study on forest fires, Frontiers of Forestry in China. 2(3): 335-339.

Jose, S. K., Kumar, S., Jesnamol, M. M., Sreeraj, N. K., Madhu, G. and Ambat, B. Forest Fire Risk Analysis and Management System Using Geoinformation Technology. *AGSE 2010*, p.57.

Joseph, S., Anitha, K. and Murthy, M. S. R. 2009. Forest fire in India: a review of the knowledge base. *J. Ror. Res. 14*(3): 127-134.

Kanga, S., Sharma, L. K., Pandey, P. C., Nathawat, M. S. and Sharma, S. K. 2013. Forest fire modeling to evaluate potential hazard to tourism sites using geospatial approach. *J. Geomatics. 7*(1): 93-99.

Kerala Forests and Wildlife Department 2018. [online]. Available: http://www.forest.kerala.gov.in/. [11 Nov 2018].

Kishwan, J., Pandey, R. and Dadhwal, V. K. 2009. India's Forest and Tree Cover: Contribution as a Carbon Sink. 130. ICFRE Bl–23. ICFRE, Dehradun.

Kittur, B. H., Swamy, S. L., Bargali, S. S. and Jhariya, M. K. 2014. Wildland fires and moist deciduous forests of Chhattisgarh, India: divergent component assessment. . *For. Res*. *25*(4): 857-866.

Kodandapani, N., Cochrane, M. A. and Sukumar, R. 2004. Conservation threat of increasing fire frequencies in the Western Ghats, India. *Conservation Biology*. *18*(6): 1553-1561.

Kodandapani, N. and Parks, S. A. 2019. Effects of Drought on Wildfires in Forest Landscapes of the Western Ghats, India. *Int. J. Wildland Fire*, 28(6):431-444.

Kondo, Y., Matsui, H., Moteki, N., Sahu, L., Takegawa, N., Kajino, M., Zhao, Y., Cubison, M. J., Jimenez, J. L., Vay, S. and Diskin, G. S. 2011. Emissions of black carbon, organic, and inorganic aerosols from biomass burning in North America and Asia in 2008. *J. Geophys. Res: Atmospheres*. *116*(D8): 1-25.

Kulkarni, A. M. and Manikiam, B. 2018. Fire risk zoning of Bandipur National park using Remote Sensing and GIS Techniques. In *19th Esri India User Conference 2018*.

Lal, P., Prakash, A., Kumar, A., Srivastava, P.K., Saikia, P., Pandey, A.C., Srivastava, P. and Khan, M.L., 2020. Evaluating the 2018 extreme flood hazard events in Kerala, India. *Remote Sensing Letters*, *11*(5):436-445.

Lazaridis, M., Dzumbova, L., Kopanakis, I., Ondracek, J., Glytsos, T., Aleksandropoulou, V., Voulgarakis, A., Katsivela, E., Mihalopoulos, N. and Eleftheriadis, K. 2008. PM 10 and PM 2.5 levels in the Eastern Mediterranean (Akrotiri research station, Crete, Greece). *Water Air Soil Pollut. 189*(1-4): 85-101.

Lazaridis, M., Latos, M., Aleksandropoulou, V., Hov, Ø., Papayannis, A. and Tørseth, K. 2008. Contribution of forest fire emissions to atmospheric pollution in Greece. *Air quality, atmosphere health*. *1*(3): 143-158.

Mahadevia, G. K. and Vikas, M. 2012. Climate Change–Impact on the Sundarbans, a Case Study. *Int. Sci. J. : Environ. Sci. 2*(1): 7-15.

Mahdavi, A., Shamsi, S. R. F. and Nazari, R. 2012. Forests and Rangelands' Wildfire Risk Zoning Using GIS and AHP Techniques. *Caspian J. Environ. Sci*. 10(1): 43-52.

Malik, T., Rabbani, G. and Farooq, M. 2013. Forest fire risk zonation using remote sensing and GIS technology in Kansrao Forest Range of Rajaji National Park, Uttarakhand, India. *India. Int. J. of advanced RS and GIS*. *2*(1): 86-95.

Mansourian, S., Belokurov, A. and Stephenson, P. J. 2009. The role of forest protected areas in adaptation to climate change. *Unasylva* 60(231-232): 63-69.

Mawdsley, J. R., O'Malley, R. O. B. I. N. and Ojima, D. S., 2009. A review of climate-change adaptation strategies for wildlife management and biodiversity conservation. *Conserv. Biology*. *23*(5): 1080-1089.

McGranahan, D.A. and Wonkka, C.L., 2020. *Ecology of Fire-Dependent Ecosystems* (1st Ed.), Wildland Fire Science, Policy, and Management. CRC Press. p.26.

Mondal, N. and Sukumar, R. 2016. Fires in seasonally dry tropical forest: testing the varying constraints hypothesis across a regional rainfall gradient. PLoS One, 11(7), p.e0159691.

Morancho, A. B. 2003. A hedonic valuation of urban green areas. *Landscape and urban planning*. *66*(1): 35-41.

Mukhopadhyay, D. 2009. Impact of climate change on forest ecosystem and forest fire in India. In: *IOP Conference Series: Earth and Environmental Science*. IOP Publishing, Vol. 6, No. 38, p. 382027.

Nagendra, H., Lucas, R., Honrado, J. P., Jongman, R. H., Tarantino, C., Adamo, M. and Mairota, P. 2013. Remote sensing for conservation monitoring: Assessing protected areas, habitat extent, habitat condition, species diversity, and threats. *Ecological Indicators.* 33: 45-59.

Nair, R. P. and Jayson, E. A. 2016. Effectiveness of beehive fences to deter crop raiding elephants in Kerala, India. *Int. Res. J. Nat. Appl. Sci*. 3: 14-19.

Nanda, K. P. and Sutar, C. P. 2003. Management of Forest through Local Communities: A Study in the Bolangir, Deogarh and Sundergarh Districts of Orissa, India. *RAP Publication*. 8 p.

Nigel Dudley and Sue Stolton (eds) (2008). *Defining protected areas: an international conference in Almerica, Spain*. Gland, Switzerland: IUCN. 220 pp

Pourtaghi, Z. S., Pourghasemi, H. R., Aretano, R. and Semeraro, T. 2016. Investigation of general indicators influencing on forest fire and its susceptibility modeling using different data mining techniques. Ecol. Ind., 64:72-84.

Raghavan Sathyan, A., Aenis, T. and Breuer, L. 2016. Participatory vulnerability analysis of watershed development programmes as a basis for climate change adaptation strategies in Kerala, India. J. Environ. Res. Dev., 11(1):196-209.

Ramanathan, V. and Carmichael, G. 2008. Global and regional climate changes due to black carbon. *Nature geoscience*. *1*(4): 221-227.

Ramesh, B. R., Karunakaran, P. V., Balasubramanian, M., Seen, D. L. and Kaler, O. P. 2003. A brief outline of Biodiversity Conservation Strategy and Action Plan for Kerala. French Institute of Pondicherry. 171 p.

Raneesh, K.Y. and Thampi Santosh, G. 2011. A study on the impact of climate change on streamflow at the watershed scale in the humid tropics. *Hydrological Sci. J. 56*(6): 946-965.

Rautela, P. and Karki, B. 2015. Impact of climate change on life and livelihood of indigenous people of higher Himalaya in Uttarakhand, India. *American J. Environ. Prot. 3*(4): 112-124.

Ravindranath, N. H. and Sukumar, R. 1998. Climate change and tropical forests in India. In: *Potential Impacts of Climate Change on Tropical Forest Ecosystems*. Springer, Dordrecht. pp. 423-441.

Rawat, G. S. 2003. November. Fire Risk Assessment for Forest Fire Control Management in Chilla Forest Range of Rajaji National Park, Uttaranchal, India. ITC.

Reddy, C. S., Alekhya, V. P., Saranya, K. R. L., Athira, K., Jha, C. S., Diwakar, P. G. and Dadhwal, V. K. 2017. Monitoring of fire incidences in vegetation types and Protected Areas of India: Implications on carbon emissions. *J. Earth System Science*. *126*(1): 11 p.

Rohini, P., Rajeevan, M. and Srivastava, A. K. 2016. On the variability and increasing trends of heat waves over India. *Scientific reports. 6*(1): 1-9.

Sajna, M. V., Raphael, L. and Jose, P. 2015. Epidemiological trend of malaria from 2007 to 2012 in a tertiary care centre of Kerala-a cross sectional study. *Int. J. Multidisciplinary Res. and Dev. 2*(2): 91-5.

Saklani, A. and Kutty, S. K. 2008. Plant-derived compounds in clinical trials. *Drug discovery today.* 13(3-4): 161-171.

Schindler, D. W. and Lee, P. G. 2010. Comprehensive conservation planning to protect biodiversity and ecosystem services in Canadian boreal regions under a warming climate and increasing exploitation. *Biol. Conserv.* 143(7): 1571-1586.

Shafizadeh, F. 1968. Pyrolysis and combustion of cellulosic materials. In: *Advances in carbohydrate chemistry.* Academic Press. 23:419-474.

Shanmuganathan, K. and Chacko, K. C. 1988. Forest fire, its prevention and suppression. Standard India. 2(3), KFRI Scientific Paper No. 467. pp.115-119

Singh, D. 2014. Historical Fire Frequency based Forest Fire Risk Zonation Relating Role of Topographical and Forest Biophysical Factors with Geospatial Technology in Raipur and Chilla Range. SSARSC. *Int. J. Geo Sci. and Geo Informatics*. 1(1): 1-9.

Singh, R. D., Gumber, S., Tewari, P. and Singh, S. P. 2016. Nature of forest fires in Uttarakhand: frequency, size and seasonal patterns in relation to pre-monsoonal environment. *Curr. Sci.* 398-403.

Somashekar, R. K., Ravikumar, P., Kumar, C. M., Prakash, K. L. and Nagaraja, B. C. 2009. Burnt area mapping of Bandipur National Park, India using IRS 1C/1D LISS III data. *J. the Indian Soc. of R S.* 37(1): 37-50.

Sowmya, S. V. and Somashekar, R. K., 2010. Application of remote sensing and geographical information system in mapping forest fire risk zone at Bhadra wildlife sanctuary, India. *J. Environ. Biol*. 31(6): 969-974.

Thakur, A. K. and Singh, D. 2014. Forest Fire Risk Zonation Using Geospatial Techniques and Analytic Hierarchy Process in Dehradun District, Uttarakhand, India. *Universal. Environ. Res. and Technol*. 4(2): 82-89.

Tripathi, D. K., Sahdev, S. and Kumar, M. 2017. Forest fire risk zone mapping using geographic information system: a case study. IPASJ Int. J. Comput. Sci., 5(7):9-15.

UNFCC [United Nations Framework Convention on Climate Change]. 2011. *Fact sheet: Climate change science – the status of climate change science today*. United Nations Framework Convention on Climate Change, Germany, 7p.

Veena, H. S., Ajin, R. S., Loghin, A. M., Sipai, R., Adarsh, P., Viswam, A., Vinod, P. G., Jacob, M. K. and Jayaprakash, M. 2017. Wildfire risk zonation in a tropical forest division in Kerala, India: a study using geospatial techniques. International Journal of Conservation Science, 8(3):475-484.

Veeraanarayanaa, B. and Ravikumar, S. K. 2014. Assessing fire risk in forest ranges of Guntur district, Andhra Pradesh: Using integrated remote sensing and GIS. *Int. J. Sci. Res.* 3: 1328-32.

Venkatesh, K., Preethi, K. and Ramesh, H. 2020. Evaluating the Effects of Forest Fire on Water Balance Using Fire Susceptibility Maps. Ecological Indicators, 110.

Verma, A. M., Singh, D., Dev Sharma, S. and Kamlesh, K. 2013. Forest fire risk zonation in Raipur Range, Mussoorie Forest Division using: GIS and remote sensing technology. *Int. J. Advanced Sci. and Tech. Res. 6*: 141-150.

Vinod, P. G., Ajin, R. S. and Jacob, M. K. 2016. RS and GIS based spatial mapping of forest fires in Wayanad Wildlife Sanctuary, Wayanad, North Kerala, India. *Int. J. Earth Sci. Eng*. 9: 498-502.

Weladji, R. B. and Tchamba, M. N. 2003. Conflict between people and protected areas within the Bénoué Wildlife Conservation Area, North Cameroon. *Oryx*, 37(1): 72-79.

CLIMATE-FOREST FIRE LINKAGES IN SELECTED PROTECTED AREAS IN KERALA

by

SREEDEVI K

(2014-20-132)

THESIS ABSTRACT

Submitted in partial fulfillment of the requirements for the degree of

B.Sc.-M.Sc. (Integrated) CLIMATE CHANGE ADAPTATION

FACULTY OF AGRICULTURE

Kerala Agricultural University

ACADEMY OF CLIMATE CHANGE EDUCATION AND RESEARCH

VELLANIKKARA, THRISSUR-680 656

KERALA, INDIA

2020

ABSTRACT

India is one of the world's mega-biodiversity nations, where forests occupy over a fifth of the geographical area. Forests are called earth's lungs because they absorb considerable amount of carbon dioxide from the atmosphere. More than 95 % of forest fires in Kerala are believed to be man-made, either intentional or accidental.

The present study "Climate-forest fire linkages in selected protected areas in Kerala." was conducted in the Peechi-Vazhani Wildlife sanctuary, Chimmony Wildlife sanctuary, Choolannur Pea Fowl Sanctuary, Idukki Wildlife sanctuary and Thattekkad Bird sanctuary with the objective to characterize and compare the nature of the forest fire that had occurred during last five years in these protected areas. The study also aimed to understand the size, frequency and severity of these fires and to establish possible linkages with various recorded climatic variables. The data collected included forest fire data, weather data and satellite data. Forest fire data for the six year (2014-2019) period were collected from Kerala FD records. Weather data were collected from the nearest recognized meteorological stations. Base maps and satellite images were sourced for GIS analysis. Base maps were collected from respective Wild Life Sanctuaries. Satellite images (LANSAT 8) and ASTER DEM data were downloaded from Earth Explorer (USGS). Correlation between the number of fire incidences and climatic variables, namely temperature and rainfall was done for Peechi-Vazhani Wildlife sanctuary, Chimmony Wildlife sanctuary and Idukki Wildlife sanctuary. A linear regression was done for Idukki Wildlife sanctuary. Forest fire risk zonation maps were prepared for Peechi-Vazhani Wildlife sanctuary, Chimmony Wildlife sanctuary, Choolannur Pea Fowl Sanctuary, Idukki Wildlife sanctuary, and Thattekkad Bird sanctuary.

Forest fire incidences positively correlated with the temperature, while there was a negative correlation with rainfall. The highest number of fire incidences was recorded in February for all study areas. The major reasons for fire incidence in all PAs are anthropogenic which is evident from the fire risk zonation maps that were created. Most of the forest fires occurred near to roads and settlements. The results point out the need for forest managers of all the study sites to take adequate fire prevention measures well before the announcement of fire season, especially in areas closer to settlements and in forest boundaries.