FOREST FIRE RISK ZONATION MAPPING AND S FOREST FIRE PREVENTIVE MEASURES IN BALANGODA AREA

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Abstract- Forest fires have become a localized hazard in some areas of Sri Lanka, especially in the study area Balangoda. But the fact is a limited numbers of efforts were taken to control the fires due to lack of risk maps. According to the Disaster Management Center (DMC) throughout the last years it has been reported almost one fire per day nationally. Most tradigical part here is most of fires occur due to anthropogenic activities. This research is focused on three aspects. First is to conduct time series analysis to extract, burn areas within last 10years, second to map the potential of forest fire risk and third to suggest suitable fire preventive measures. Remote sensing, Geographical information system, mathematical model (AHP) and time series analysis is used in this study. Due to several limitations exist, such as; the nature of fires in the study forest area and also the limited no of data, the first aspect is not revealed an appropriate result. However, the second aspect shows that 1.364Square kilometers are potential for fire. Other than using fire break this study has suggested more effective methods which are used worldwide such as; vegetation implementation, firefighting reservoirs and etc. which can be effectively applied to Sri Lanka.

Keywords- Burn areas, Risk potential map, preventive measures

I. INTRODUCTION

Forest is considered as a major natural resource and they play an important role in maintaining environmental balance. Ecological conditions of any area will be indicated true the health of the forest in that area.[8] Forest destruction due to forest fires has become serious problems in some regions in Sri Lanka as it is directly affected for natural vegetation, community livelihoods and infrastructural development of the those areas. Throughout the years fires are occurring and still there is no methodical way to prevent forest fires. Many Government and Non-government organizations trying to find the solution for this and Fundamental problem is they are not available with a risk zone map to continue their work.

In this research first part was to discriminate burn areas from a 10 years' time series of satellite images. Landsat TM and ETM+ images have used due to their 30m spatial resolution, 16 day temporal resolution and those are publicly available. Normalized Burn Ratio (NBR) (1) was used to discriminate the burn patches using Landsat images TM and ETM+ images. [10], [12]

$$NBR=\frac{\text{Near infrared}-\text{Mid infrered}}{\text{Near infrared}+\text{Mid infrared}} \quad (1)$$

NBR is sensitive to the amount of Chlorophyll content in plants, moisture and char or ash in the soil.[12]NBR was chosen over several other published methods for mapping burn severity due to the fact that it outperformed other remotely sensed indices.[11]

The DNBR (2) technique looks at the change from pre fire and post fire image and identifies how severely an area was burned by quantifying spectral change. [10]

$$DNBR=\text{pre ire NBR} - \text{post ire NBR} \quad (2)$$

Next part this study is mapping the potential forest fire risk map for forest fires in the study area. Many developed countries, Canada, Australia and U.S.A have developed sophisticated forest fire danger Rating Systems but in developing countries like Sri Lanka there is no such system to implement. Many researchers used different models to predict the forest fire risk and most of them mapped risk using remote sensing and GIS that contains topography, vegetation, land use, population and settlement information.[8],[3],[4],[5],[9]

A common practice was that forest risk zones were delineated by assigning subjective weights to the classes of all the layers according to their sensitivity to fire.[8],[5] Degree of fire sensitivity for each class is defined using AHP(Analytical Hierarchical Process).

Finally, using the forest fire risk map some preventive measures are suggested for high risk areas by considering the characteristics of those areas to prevent forest fires. There are several methods throughout the world to prevent fires like the creation of tracks, firebreaks and water reserves, Establish fire lookouts, Follow safe debris burning rules, Detection services, Greenbelt, Plant vegetation with low flammability and etc.[7],[6] Out of those methods following methods are suggested as more suitable measures in practically and economically for this study area.

- Fire/Fuel breaks
- Fire belts
- Vegetation implementation
- firefighting reservoirs

This study was made to use remote sensing matrices to discriminate burned sites from time series of satellite images and generate and evaluate a potential fire risk map using vegetation variables, topographic factors and human factors using GIS with suggesting some preventive measures.

II. DETAILS EXPERIMENTAL

2.1. Study Area

The study area is Balangoda which is a prime township in the Ratnapura District, Sabaragamuwa Province in Sri Lanka. It is located between 80^o 35’ to 80^o 55’ east longitude and 60^o 30’ to 60_o 45’ north latitude. [10] The area mainly consists with the hilly areas. A majority of hilly areas conserved as forest reservation and mainly composed of forest plantation especially in Eucalyptus and pine.
These plantations are considered as high fire hazard plantations [6] and as a result, forest fires become a localized hazard for forest destruction of forest plantation in Balangoda. Another significant reason for forest fires in Balangoda area is it displays remarkable climatic characteristics and weather pattern throughout the year and dry season is from mainly from April to August[10]. With prevailing wind, topography and forest plantation create fire season. [1] The main reason for frequent fires in the study area is people in this area believe a myth that if there is a forest fire the god will be given a rain. So people tend fire the forest and 100% of forest fires in this study year and also in Sri Lanka are due to anthropogenic activities.

2.2. Materials and Procedures

2.2.1. Burn area extraction maps of last 10 years

Landsat TM and ETM+ images of last the 10 years (2005-2014) were obtained for two images for year as the beginning of the dry season and end of season. All images were processed and converted to a satellite reflectance before calculating NBR (1) and DNBR (2) values.

Detection thresholds
Identifying threshold value is becoming unable with Sri Lankan fires after applying several methods. So lastly Threshold was identified using MODIS image published in Times of India (2014, March 22) which represent the forest fire occur at Sri Venkateshwara Sanctuary & National Park.

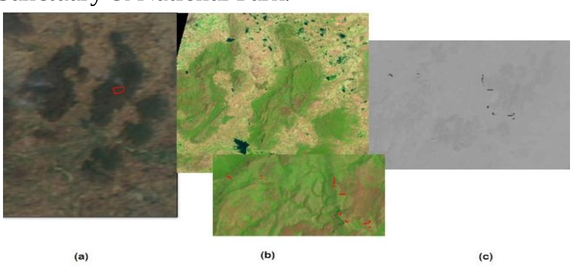

Fig.1. Threshold Identification

(a)Image published on Times of India at Venkateshwara Sanctuary and National park (b) Post fire Landsat 8 true color composite image (c) Burn area map using NBR index

2.2.2 Forest fire risk potential map

GIS Database

Distance from the road map and Distance from settlements were used as anthropogenic variables and elevation, land use and land cover, slope and aspect were used as topographical variables.
The Road map was prepared by combining road shape file from Survey Department and google earth. Vegetation type and land cover classes map were obtained from Survey department in digital format. Slope, Aspect and elevation maps were prepared using ASTER DEM. Settlement map was prepared using combining NDVI and NDBI index.

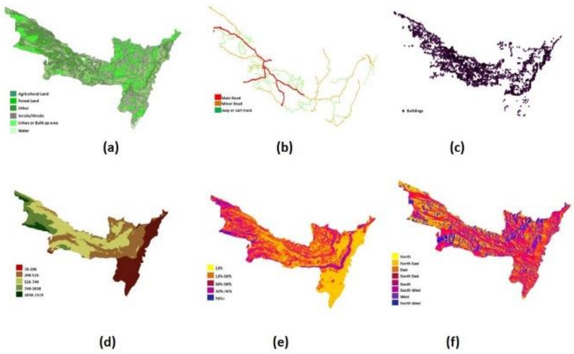

Fig.2. Thematic layers used for forest fire risk potential map (a) Vegetation and Land cover map (b) Road map (c) Settlement map (d)Elevation map (e) Slope map (f) Aspect map
Determination of fire Risk index

Degree of Forest fire risk sensitivity for each variable (Table I) is calculated from using mathematical model AHP (Analytical Process).

Table I: GIS. Weights assigned to variables

Land use and Land cover	55
Distance to roads	16
Distance to settlements	16
Slope	5
Aspect	5
Elevation	3

Forest fire risk areas can be calculated using the following formula:

$$FRI = 55Lc + 16Ro + 16Se + 5Sl + 5As + 3El$$

…where FRI is Fire Risk Index, Lc is Land cover and vegetation, Ro is Distance to Road, Se is distance to settlements, Sl is Slope, As is Aspect and El is Elevation. All thematic layers were then integrated to produce risk potential map.

Due to the limitation of data and according to previous researches. [8], [3], [4], [5], [9] climatic variables were not used for fire potential risk map but in this study those are analyzed separately for future reference.
Data were obtained from www.weatherspakle.com and then analyzed statistically using Minitab software to identify the best method to use for time series analyzing.

Autocorrelation function is applied to data to understand whether the data has seasonal variation, stationary and trend. (Fig 3)

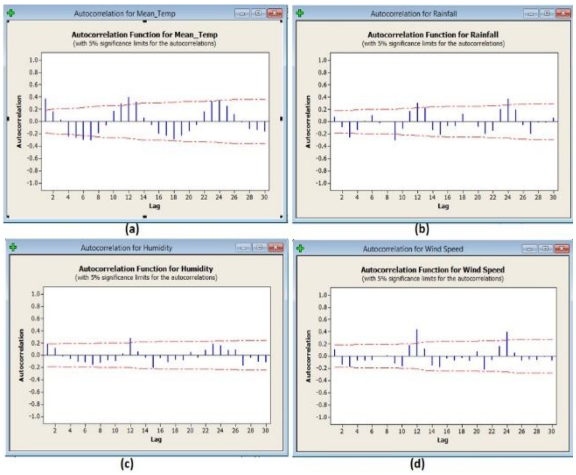

Fig.3.Autocorrelation function applied for (a) Temperature (b) Rainfall (c) Humidity (d) Wind speed in Balangoda

It results that data is stationery, has seasonal variation, but no trend so according to that deposition multiplicative model (Fig 4) is applied to forecasts the variable values which may prevail next fire potential season.

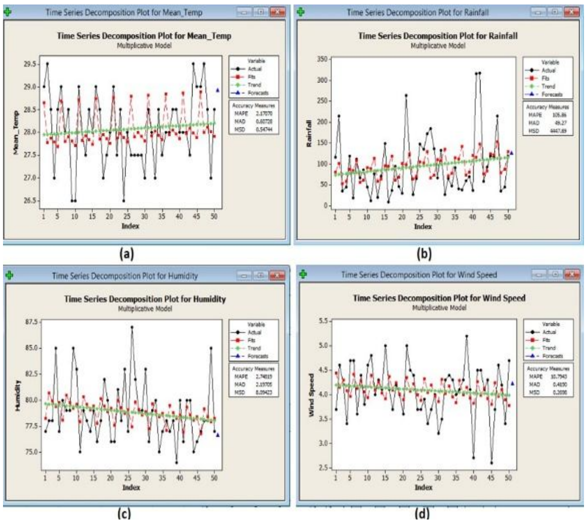

Fig.4. Applying deposition method for (a) Temperature (b) Rainfall (c) Humidity (d) Wind speed of Balangoda

2.3 Suggesting Forest fire preventive measures

There are several methods throughout the world to prevent fires and some can be listed as below.

1) Creation of tracks, firebreaks and water reserves
2) Establish fire lookouts
3) Follow safe debris burning rules
4) Detection services
5) Greenbelt
6) Plant vegetation with low flammability
7) Grazing
8) Spray the brushes with herbicides
9) Thinning
10) Pruning

All measures were studied with the nature of risk areas.

III. RESULTS AND DISCUSSION

3.1. Burn area extraction maps of last 10 years

Classified burn area extraction maps of 10 years (2005-2014) were obtained applying threshold values. (Fig 6)

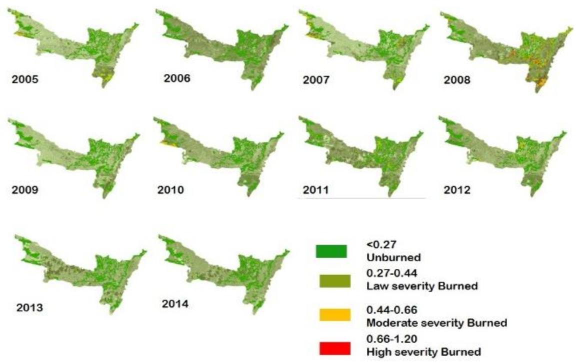

Fig.5. 2005-2014 Burn area extraction map

Predetermined Burn patches were unable to identify using selected method and following facts are affected for that.
1. Unavailability of cloud free daily Landsat images
2. As forest in Balangoda is consisted with pine plantations and Eucalyptus plantations Type of forest fires is ground fire. (Fig. 7) So it is difficult to observe through selected method

Fig.6.Forest plantation in Balangoda

3.2. Forest fire risk potential map

The final weighted integrated map was then classified based on level of no risk, very low, low, medium, high and very high risk. (Fig 8)

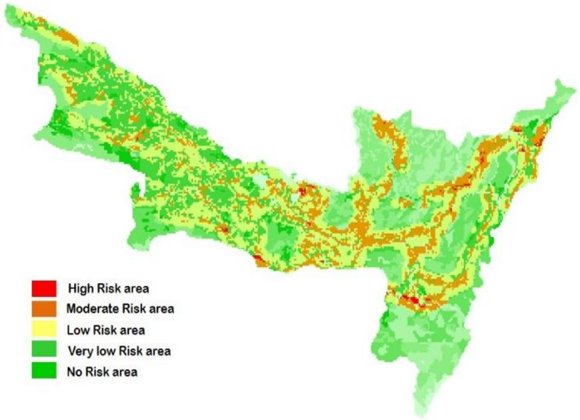

Fig.7.Potential Risk map in Balangoda

It was resulted that out of total land area 5% area is potential for forest fires very high and it is 14% which is potentially highly. (Table II)

Table II: Description of the forest fire risk areas

Fire Sensitivity	Area (Km^2)	%
Very High	1.364	5.457
High	3.508	14.035
Medium	7.605	30.426
Low	4.484	17.939
Very low	3.034	12.138
No Risk	5	20

The potential risk map was then validated by integrated with experts' knowledge of this area. Highly risk areas were identified as patches of past fires by forest experts using google earth. Circle of red indicates the previously burn patches marked on KML of high risk areas on risk potential map. (Fig.8)

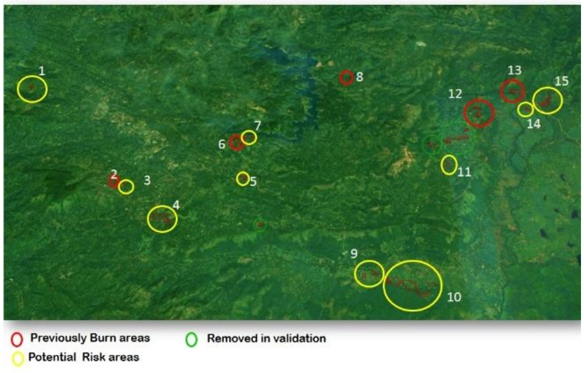

Fig.8. Validated Potential High risk areas marked in Balangoda

This study was an attempt to integrate GIS and remote sensing concepts to determine risky places and to plan forestry management. This model can be used as precautionary measures for protection of the forest.

This model can be further improved by using data such as evaporation, soil moisture and etc. As this model is developed for Balangoda divisional secretarial division same approach can be applied for other regions with frequent fires with some alternatives.

When analyzing climatic variables it is understood Balangoda area displays different weather characteristics and weather patterns at different times of the year. (Fig.2) Dry season, which is potential for forest fires is from May to September.

Forecasting values for climatic variables which is potential for forest fires as follows:

Mean Temperature of Dry Season	28.9201
Rainfall of Dry Season	125.724
Wind speed of Dry Season	4.21872
Humidity of Dry Season	76.6041

3.3. Suggesting Forest fire preventive measures for high risk areas

Very high risk areas were used to identify preventive measures as those areas need an immediate step to protect forests. After analyzing characteristics of high risk areas and studying about preventive measures following four methods were identified as most suitable and economic methods which can be applied for Balangoda easily.

- Fire/Fuel breaks (Fig.10.a)
- Fire belts (Fig.10.b)
- Vegetation implementation (Fig.10.c)
- Firefighting reservoirs (Fig.10.d)

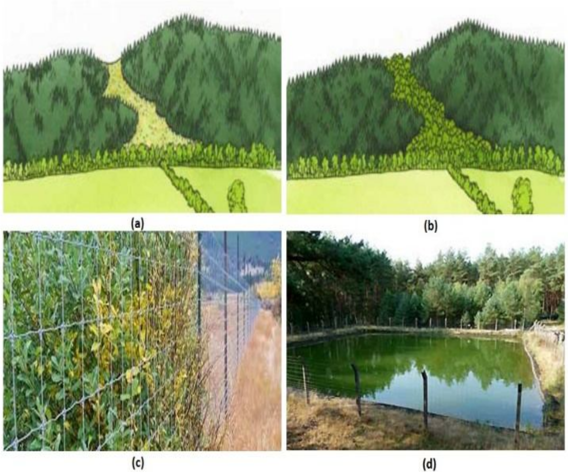

Fig.9. Forest fire preventive measures (a) Fire/Fuel breaks (b) Fire belts (c) Vegetation implementation (d) Firefighting reservoirs

According to the characteristics of very high risk area forest fire preventive measures are suggested. Fire belts or fuel breaks are suggested for the areas numbered as 1, 4, 3,5,13 in fig.9 and etc. (Table III)

Table III: Suggested preventive measures for risk area

Area	Description of the area	Suggested method
1,4,3,5,13	Forest is spread at the edges of roads and residential areas are between forest areas.	Fire/Fuel breaks
2,7	No breaks between forest covers and near to the paddy lands	Fire belts and commercial vegetation implementation
8,	No breaks between forest covers no near water source	vegetation implementation and firefighting reservoirs
6,10,11,14	near to the paddy lands	vegetation implementation, fire belts
12,15	No breaks between forest covers	vegetation implementation, fire belts

CONCLUSIONS

Due to a lack of past records of forest fires it was unable to understand past forest fires. In future studies burn patches can be analyzed by a combination of data from other sensors like MODIS, SAR and etc.

The study was an attempt to integrate environmental factors, GIS concept and remote sensing to determine risky places and to plan forest management. As results shown GIS is a useful tool for mapping forest fire risk future studies can implement more variables to make forest fire risk maps and can have a more accurate result.

To protect forests and to preparing fire management plans, fire risk map and preventive measures should evaluate together.

ACKNOWLEDGMENTS

H.P.U Fonseka thanks senior forest officers of the Ratnapura regional forest department for giving his full support for the validation of forest fire risk potential map and mean time thanks to Dr. Udaya Kumar, Dr. Chandramali, Dr.Ranmalee Bandara, Dr. Jayawardana and Mrs.Samanthi Munasighe of Sabaragamuwa University of Sri Lanka for providing me with skills to complete this project.

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