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Research article

Wild life habitat suitability and conservation hotspot mapping: Remote Sensing and GIS based decision support system

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Abstract: *Background:* The environment and habitat are the important aspects of the forest ecosystem. The continuous changes in the environment due to natural phenomenon or human actions have degraded the forest and wildlife habitat thus causing a decline in their population. Therefore it is important to study wildlife habitat in order to ensure their survival. In this regard, application of Remote Sensing and Geographic Information System has been widely accepted as a tool which has immense significance in wildlife habitat suitability modeling and mapping. Maps derived from analysis of remote sensing data and modeling in GIS are highly useful in making the strategies in wildlife management and conservation planning. *Objectives:* The objectives of the study are to identify the suitable habitat for wild life and conservation hotspot grids were delineated which require immediate attention. *Methods/Statistical analysis:* The wildlife habitat suitability parameter based on forest cover, agriculture with settlement, forest fires, roads, streams and mines were analyzed. The statistical method such as pairwise comparison was used to evaluate the weightage of each parameter which helped to determine the wildlife habitat suitability modeling and mapping. *Findings:* The study of wildlife habitat suitability mapping in Saranda forest division reveals 42% of the grid equal to 1898 has very high suitability for wild life. The conservation hotspot reserve grid based on contiguous patch was identified within the very high wildlife suitability habitat was found to be 925 (49%). *Application/Improvements:* Conservation effort can be focused based on the above study and will assist in policy related decision making.

Keywords: forest fire; GIS; DEM; wild life habitat; conservation hotspot; Saranda; Jharkhand

1. Introduction

Sustainable wildlife management (SWM) is described by FAO "An efficient management of wildlife species such that their populations are sustained and their habitats are maintained keeping in views the socio economic aspects and the needs of mankind". Anthropogenic and developmental activities in the forests such as overgrazing, deforestation, fires, mining, settlement and cultivation are the principle causes of habitat destruction [1,2].

A habitat is defined as a space in the forest ecosystem which is a home to the plant or animal species. The term typically refers to the area in which the organism lives and where it can find food, shelter, protection and mates for reproduction. Maintaining the high quality of wildlife habitats and ensuring the long-term ecological integrity and sustainability is therefore increasingly becoming an important management challenge. The Saranda forest division roughly represents 16% geographical area and retains 55% of elephant population when compared to the West Singhbhum district. The density of forest in the past was so high that even the sunrays couldn't penetrate it [3]. The forests are one of the most pristine forests of India, and retains the largest natural Sal forest ecosystem of the country [4]. These forests are rich in biodiversity are having an important elephant corridor and are recognized for mineral resources.

Rough topography, inaccessibility, dense cover and hilly terrain support less faunal population as compared to ideal wildlife habitat. However, the good forest cover and adequate water supply throughout the year in the form of perennial streams and rivers provide natural habitat for various wild life. The major important fauna found in our study area includes Indian elephant, wild boar, sloth bear, Indian hare, jackal, monkey, wild cat, flying squirrel, common krait, russell viper, cobra, python, rat snake, etc. Among the avian the red jungle fowl, grey hornbill, woodpecker, partridges, owl and night jars etc. are common. The report on Integrated Wildlife Management Plan for West Singhbhum, Jharkhand (2013) reveals that the Saranda forest division has 139 elephants [5]. This indicates that Saranda is a preferred place for wild elephants and is supposed to be a natural home for them. The whole areas of Saranda forest division area part of the core area of Singhbhum Elephant reserve.

1.1. Natural and anthropogenic disturbances in the Saranda forest division

● Mining: Open cast mines in this area and their activities such as blasting, heavy vehicles movement and washing of ores leads to noise and dust pollution. Beside this, in streams (major source drinking water for wild life and habitat for aquatic ecosystem) sedimentation and pollution occurs which leads to the deterioration of water resources which is harmful to the wildlife existence.

● Forest fire: Collection of Non Timber Forest Produce (NTFP) has been one of the causes of forest fire. The main non-wood forest product that contributes to forest fire to the area is the Mahua flower (*Madhuca indica*). Since the collection procedure of Mahua flowers is done during the summer months mostly March and April by burning the floor beneath the tree for cleaning purpose. To get a better flush for Tendu leaves- fire is ignited in forest to increase the production of Tendu leaves. Forest fires are also caused intentionally by local people to meet the need of fodder for grazing cattle. The hot dry weather due to high temperature, high wind velocity and low relative humidity accelerates the spread of forest fire.

● Roads: They facilitate easy access to people and livestock. Activities like illegal poaching, illegal felling of trees, collection of minor forest produce and grazing are thus carried out with less effort.

● Agriculture and settlement: Saranda being a home of several tribes but the most dominant ones are Munda and Ho. They have traditionally played a key role in protecting and maintaining the health of the forest [6]. Their livelihoods and spiritual practices are entirely dependent on the forest ecosystem. Mostly they belong to low income groups and have no regular jobs for sustaining. They clear the area nearer to the settlement and convert it for agriculture purpose for their livelihood [7]. Ring barking (girdling) at trees in these areas due to local tribal movement leads to the drying up of trees which has resulted in further loss of tree species affecting the wild life survival.

The advanced technology like satellite remote sensing and GIS provide an opportunity to evaluate various changes occurring on the Earth's surface at various spatial and temporal scales. In the past few decades, it has been widely used in learning the natural calamities and various phenomena affecting the natural resources. Sometimes, due to insufficient information about the changes taking place, it limits the ability to take appropriate management decisions as regards wild life by the policy makers. Application of Remote Sensing and Geographic Information System is a tool for obtaining information [8–15] and is becoming an important technology in habitat suitability modeling and monitoring for various wildlife species [16,17]. In India, the use of geospatial technology/science for wildlife species habitat suitability analysis started roughly three decades ago. Parihar *et al*. [18] utilized remotely-sensed satellite data (Landsat) for analyzing the habitat of Indian one-horned rhinoceros in Kaziranga Nation park, Assam, India.

Porwal *et al*. [19] used remote sensing data (Landsat TM) for assessing the habitat for sambar by evaluating the habitat parameters, viz., water, cover types (food and shelter values) and terrain in Kanha National Park. Kushwaha *et al*. [20] used remote sensing and GIS for evaluating suitable habitat for Rhinoceros in Kazhiranga National Park, Assam and for mountain goat an endangered species in Rajaji National Park, Uttar Pradesh. Sanare *et al.* [21] had studied wild life habitat suitability analysis at Serengeti National Park, Tanzania using AHP- Pairwise comparison and found 21.82% of the area is suitable for elephant whereas destruction and habitat fragmentation are the two biggest threats to most of the wildlife here. Dash *et al.* [17] used predictive habitat suitability modeling on prey and predator (tiger) in Palamu tiger reserve, Jharkhand, India. They have used four different types of models viz., Rank method, Analytical Hierarchical Procedure (AHP), Binomial Logistic Regression Analysis (BLRA) and Ecological Niche Factor Analysis (ENFA).

1.2. Why this study is important?

● Saranda forest being a wildlife habitat for several faunas, it is the paradise especially for elephants, but in the past few years natural and anthropogenic disturbances has altered the wildlife habitat.

● Flora uniqueness and diversity: Saranda forest represents the best Sal trees in Asia. Apart from several tree species it contains several medicinal plant species, few of these species are widely used by inhabitant tribal people as a remedy for various diseases. Still so many plant species are there whose medicinal value has not been exploited. Based on the expert panel appointed by Government of India (2011) report, it reported that 480 new species of flora and fauna have been identified in this region [22].

● Based on Hon'ble Justice M. B. Shah Commission of Enquiry reported on the illegal mining in the Saranda forest, the emphasis has been given on protection for wild life habitat and identification of hotspots for conservation reserve.

The present study aims at:

● Wildlife habitat suitability parameters such as forest cover, agriculture with settlement, forest fires, roads, streams, mines were delineated and its spatial pattern and correlation were studied.

● Wildlife habitat suitability map grids were generated.

● Conservation hotspot area was identified based on GRID analysis.

2. Materials and methods

2.1. The study area

The geographical coordinate of the study area (Figure 1) of Saranda forest division, falling in West Singhbhum district of Jharkhand are of latitude 22 °00' 26"N to 22 °22' 34"N and longitude 84 °26' 05"E to 84 °59' 08"E, whereas the total geographical area is 858.82 km^2. The elevation varies from 185 m to 938 m from the mean sea level. Jharkhand has tropical climate of an average rainfall which varies from 945 mm to 1297 mm and temperatures vary from 6 ℃ to 47 ℃. Various ethnic groups (tribes) such as Munda, Oraon, Ho, Santhal, Paharia, Chero, Birjea, Asura and other lives in the forest. Their life revolved around agro based culture over the years. Traditionally, indigenous people have symbiotic relations to nature and forests. Local festivals like Sarhul and Karma are generally related with worshipping of the trees. The study area is a complete forest division is an administrative unit for location of fund, management and planning therefore these techniques (RS and GIS) as mapping tools.

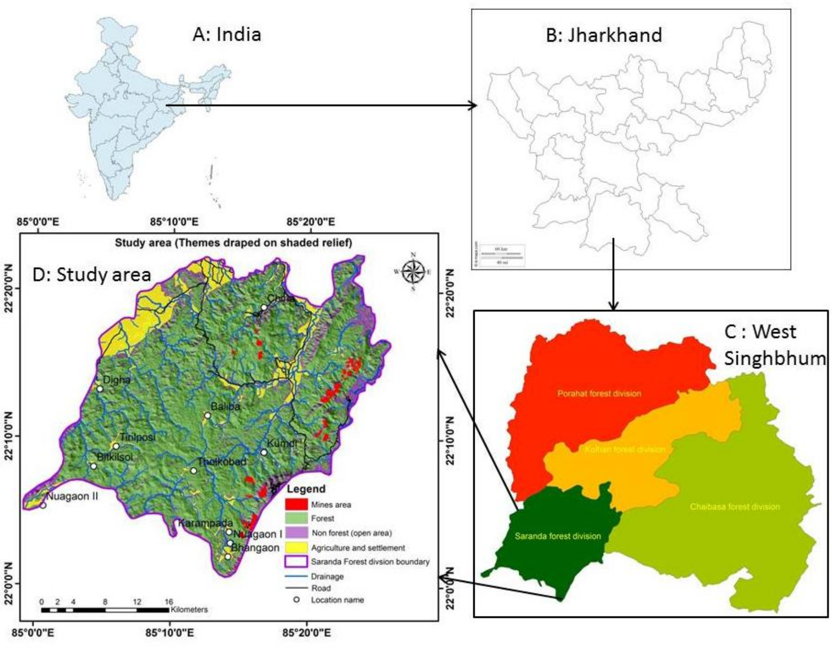

Figure 1. The location of the study area.

2.2. Data preprocessing and analysis

Six factors were identified which are important for the wildlife habitat suitability in the study area. The four prevailing disturbance factors are mining, forest fire, roads and agriculture & settlement. Other two parameters such as forest cover and streams are important factor of wildlife suitability as it provides food, shelter and water which are significant for the wildlife survival. Buffer of various layers were created based on literatures such as Bera [23] and field knowledge including local people feedback and old *in situ* experience. The mapping processes of these factors were subsequently done.

2.2.1. Forest fire risk mapping

To analyze the forest fire trend within Saranda forest division, the data were downloaded from Forest Survey of India (http://fsi.nic.in/forest-fire.php) from 2005 to 2016. It was an excel file with latitude and longitude. It was converted into point shape file using ArsGIS. There are several methods of surface generation such as inverse distance weighting, Kriging, Ripley's K, Moran's I, but "Point Density" sub-module of "Spatial Analyst" tool of ArcGIS was used as it has certain advantages over others methods. It generates density raster values and calculates a magnitude-per-unit area from point features which falls within a neighbourhood around each cell by utilizing all fire points. Furthermore, these raster values provides continuous raster surface over the study area which was grouped into three categories based on their values which significantly fulfilling the wildlife habitat suitability mapping objectives.

2.2.2. Vegetation classification and density

The Landsat images (Table 1) of the time December 2015 was downloaded from USGS website for classifying the Saranda forest division and to obtain forest cover classes. The image was mosaicked and a subset of the image was taken as per our study area requirement. To separate the vegetation from non-vegetation classes we utilized the Normalized Difference Vegetation Index (NDVI). A non-forest mask was created. It was used to delineate forest area from false color composite by masking the non-forest area. Within the forest area, the supervised classification technique (maximum likelihood) was performed over the satellite images by providing 15–20 training sets (signature) for each class distributed uniformly over the image. Image alarm technique was used to recognize, approve and finalize the various training sets. Finally four classes of namely dense forest (where canopy cover is greater than 70%), medium forest (canopy cover 40–70%), open forest (where canopy cover is 10–40%) and non-forest (0–10%) were delineated. A filter 3×3 window was executed to smoothen the classified image and to remove the noise.

Table 1. Satellite data details.

Satellite	Sensor	Path/Row	Dates
Landsat 8	OLI_TIRS	140/45	19-12-2015
Landsat 8	OLI_TIRS	140/45	09-05-2015

Accuracy assessment is an important mandatory step which was executed over the classified map. It determines the quality of the classified image. The accuracy assessment was executed by generating random points in each class of the classified dataset. The points were assigned to the respective classes based on ground knowledge. The error matrix was generated and the overall classification accuracy and kappa statistics were calculated.

2.2.3. Map preparation using Google earth

The class agriculture with settlement area and mines area were digitized based on visual interpretation of high resolution images of Google earth. The vector file (polygon) as .kmz files was converted to shape file using ArcGIS software.

2.2.4. Road and its buffer map

Roads within the forest are one of the important parameter and cause disturbance in the forest. The road vector (shape file) file was downloaded (http://download.geofabrik.de/asia/india.html) and extracted from the study area shape file and buffer are generated.

2.2.5. Stream map and its buffer

ASTER DEM which was downloaded from the USGS portal was of 30 m spatial resolution. The stream layer was derived from DEM using Spatial Analyst tool of Arc GIS using Hydrology sub tool. All different stream orders have been generated and a buffer of the stream was created. Stream is an important factor for existence of wild life since they prefer to stay nearer to buffer of stream for their daily consumption of water.

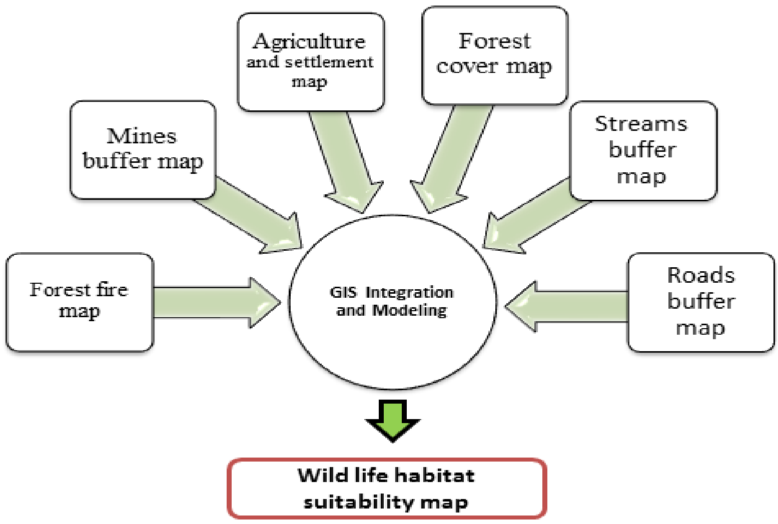

Figure 2. Flowchart for wild life habitat suitability mapping.

2.2.6. Wild life habitat suitability mapping

The above geospatial model was executed to obtain wild life habitat suitability using weighted overlay technique. Wild life habitat suitability mapping flow diagram is illustrated in Figure 2, Wild life habitat suitability surface was obtained by integrating the various parameter given in the Eq 1.

$$W_S = \sum_{1}^{n} n = [(P_{FF} * W_{FF}) + (P_M * W_M) + (p_{AS} * W_{AS}) + (P_S * W_S) + (P_R * W_R) + P_{FC} * W_{FC}]$$

Where P_{FF} is the fire risk map, P_M is the mines area buffer map, P_{AS} is the agriculture and settlement map, P_S is streams buffer, P_R is the road buffer, and P_{FC} forest cover map. The W_{FF}, W_M, W_{AS}, W_S, W_R and W_{FC} are weightage values of each thematic layer used in the study are given in Table 4. The AHP process is established on judgments based upon the knowledge and experience and utilized suitably in decision-making problems [24]. The AHP statistical analysis is the best suitable in our analysis because of the advantage of the AHP over other multi-criteria decision support methods is that it takes into account the decision maker's intuitive knowledge into the analytical decision [25] whereas criteria should be chosen by an expert on the subject, representing reliably the real affecting factors of the decision [26]. Dash *et al*. [17] also utilized the similar methods for modeling habitat suitability for tiger in the adjacent forest of Palamu Tiger Reserve, India. The weight has been calculated based on pairwise comparison (Table 2 & Table 3) introduced by Saaty [27]. A pairwise comparison is a process of comparing entities in pairs to judge which of each entity is preferred. This has been chosen scientifically based on ground information and by consulting the local people. These weights are not same in all area because of disturbance and suitability parameters of wildlife are area specific. Similar pairwise comparison based weightage has been thoroughly followed by many researchers for thematic layers towards suitability analysis [28,29].

Table 2. Pairwise comparison matrix.

Criteria	Pairwise comparison matrix					
	Forest cover	Mines buffer	Streams buffer	Forest fire risk	Agriculture and settlement	Road buffer
Forest cover	1	2	2	3	2	3
Mines buffer	1/2	1	1	3	4	5
Streams buffer	1/2	1	1	1	3	4
Forest fire risk	1/3	1/3	1	1	2	3
Agriculture and settlement	1/2	1/4	1/3	1/2	1	1
Road buffer	1/3	1/5	1/4	1/3	1	1

Table 3. Normalized matrix of various thematic layer with weight.

Criteria	Normalized pairwise comparison matrix							
	Forest cover	Mines buffer	Streams buffer	Forest fire risk	Agriculture & settlement	Road buffer	Priority vector	Weight (%)
Forest cover	0.3158	0.4181	0.3582	0.3396	0.1538	0.1765	0.2937	29
Mines buffer	0.1579	0.2091	0.1791	0.3396	0.3077	0.2941	0.2479	25
Streams buffer	0.1579	0.2091	0.1791	0.1132	0.2308	0.2353	0.1876	19
Forest fire risk	0.1053	0.0697	0.1791	0.1132	0.1538	0.1765	0.1329	13
Agriculture & settlement	0.1579	0.0523	0.0597	0.0566	0.0769	0.0588	0.0770	8
Road buffer	0.1052	0.0418	0.0448	0.0377	0.0769	0.0588	0.0609	6
Consistency Ratio (CR) = 5.1%			Principal Eigen Value = 6.318					$\sum = \mathbf{100}$

Table 4. Weightage for thematic layers used for wildlife habitat suitability mapping.

Weightageof thematic layer	Weight (%)	Value/Description	Ranking	Category/Zone /Intensity
Forest fire risk map weightage ($\boldsymbol{W_{FF}}$)	13	High to medium forest fire risk	2	Low
		Medium to low forest fire risk	3	Medium
		Low to no forest risk	4	High
Mines area buffer weightage ($\boldsymbol{W_{M}}$)	25	< 1.5 Km	1	Very low
		1.5–3 Km	2	Low
		3–4.5 Km	3	Medium
		4.5–6 Km	4	High
		> 6 Km	5	Very high
Agriculture and settlement map weightage ($\boldsymbol{W_{AS}}$)	8	Other than agriculture and settlement	4	High
				Low
		Agriculture and settlement	2	
Streams buffer weightage ($\boldsymbol{W_{S}}$)	19	< 300 meter	5	Very high
		300–600 meter	4	High
		600–900 meter	3	Medium
		> 900 meter	2	Low
Road buffer weightage ($\boldsymbol{W_{R}}$)	6	< 300 meter	2	Low
		300–600 meter	3	Medium
		600–900 meter	4	High
		> 900 meter	5	Very high
Forest cover map weightage ($\boldsymbol{W_{FC}}$)	29	Dense forest	5	Very high
		Medium forest	4	High
		Open forest	3	Medium
		Non forest	2	Low

2.2.7. GRID analysis

The objective of the study was to generate a grid map with scale 1:50,000 and it is suitable for management and planning. At this scale, 1 cm on the map represents 500 m on ground. Therefore, grid spacing 500 m was chosen. If it is reduced or increased, it will significantly impact the result. A grid of 500 × 500 m was generated in the form of shape file over the study area i.e. Saranda forest division. Based on the evaluation of each grid, the wildlife habitat suitability and hotspot conservation areas were generated and respective tables were obtained.

2.2.8. Proposed hotspot conservation area

The objective here is to identify contiguous patch within the very high wild life habitat suitable area as conservation hotspot which will represent a large number of floral and faunal diversity. The number of forest patch per unit grid was evaluated based on forest cover map prepared for the year 2015, it was converted to vector which was used for spatial grid wise analysis. The criteria for identification of hotspot conservation area in very high wildlife suitability grid of Saranda forest division were based on number of forest fragmented patch. The number of fragments < 5 as high, 5–9 as medium, and > 9 as low.

3. Results

3.1. Forest fire risk mapping

Several studies have been done for the adverse impact of forest fire viz., Roy [30] reported loss of natural vegetation and reduction of forest cover, Engstrom [31] reported on loss of wild life, Rodriguez y Silva *et al*. [32] reported loss of valuable timber resources, Chen [33] reported degradation of the ecosystem, Tropical [34] reported loss of biological diversity. To analyze the forest fire risk over the study area, the whole forest fire data was evaluated. Finally by this process we generated forest fire maps (Figure 3) that have the category medium to high risk, low to medium risk and no to low risk and ranked to 2, 3 and 4 based on wild life habitat suitability. Ahmad and Goparaju [11] also reported forest fire in this areas whereas frequent fire deteriorate wild life habitat including suitable habitat for elephant [35].

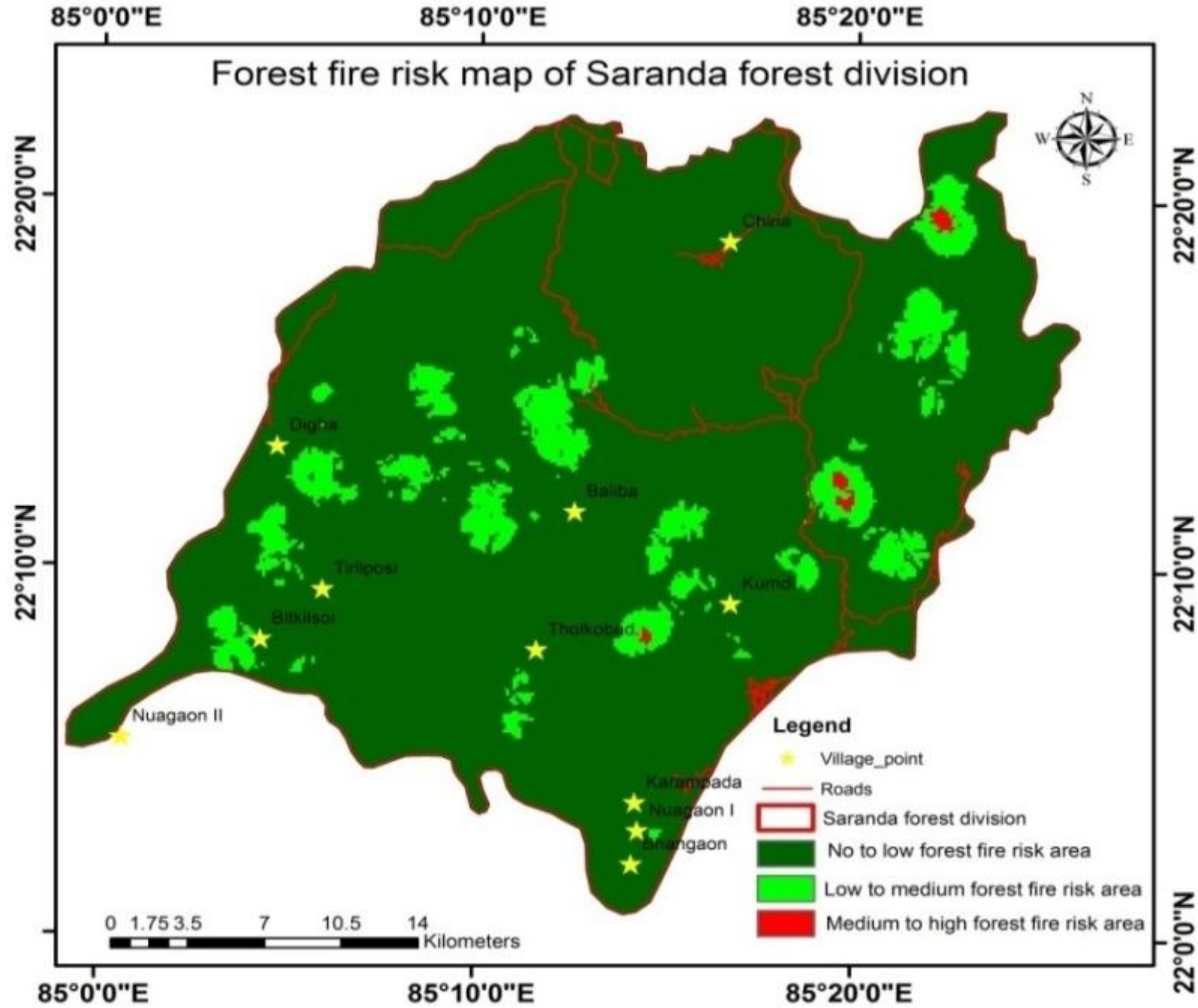

Figure 3. Forest fire risk map in Saranda forest division.

3.2. Map preparation using Google earth

Google earth images, freely available provide more clear synoptic view due to high resolution satellite data thus provide high visual interpretability of various features can be better delineated [36,37].

3.2.1. Agriculture and settlement map

The agriculture and settlement area (Figure 4) is digitized based on visual interpretation of high resolution images of Google earth. The polygon .kmz file was converted to shape file using ARC/GIS software. Agriculture and settlement is considered important parameter of disturbance leading to habitat fragmentation thus leads to change of landscape [38]. Kayet and Phathak [39] also found these parameters leading to change in Landuse/Landcover (LULC) of Saranda forest.

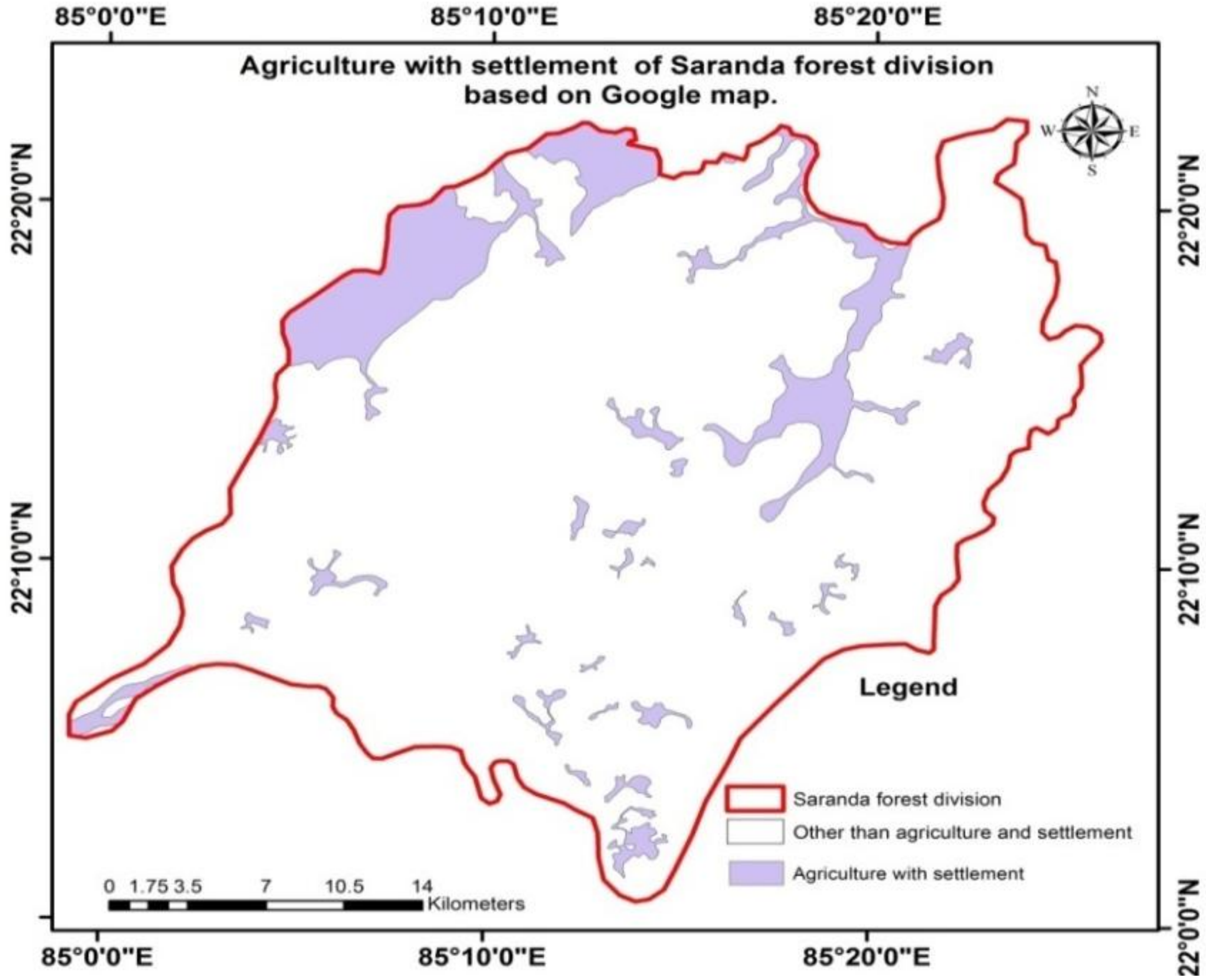

Figure 4. Agriculture and settlement map of Saranda forest division.

3.2.2. Maps of mines in the study area

Based on Google earth images the mines area is digitized as given in the Figure 5. Mining activity especially opencast mining often leads to land degradation, deforestation, forest fragmentation, atmospheric pollution, pollution of aquatic system, soil erosion finally leads to wild life habitat degradation. Mining activity in this region has resulted in the drying up of a 5 km stretch of a perennial stream reported by Bera [23]. The four buffers at 1.5 km interval from mines area were generated. Within the mining area and its vicinity the disturbance in the forest is more making it unsuitable for wildlife. Similar findings of impact on forest due to mining were observed by Kayet *et al*. [40] in Saranda. The mines buffer was generated using multi buffer option of the interval of 1.5 km from the mining site. It was classified into five classes (< 1.5 km, 1.5–3.0 km, 3.0–4.5 km, 4.5–6.0 km and > 6 km) and was ranked as 1, 2, 3, 4 and 5 with description ranging from very low, low, medium, high and very high respectively based on wild life habitat suitability.

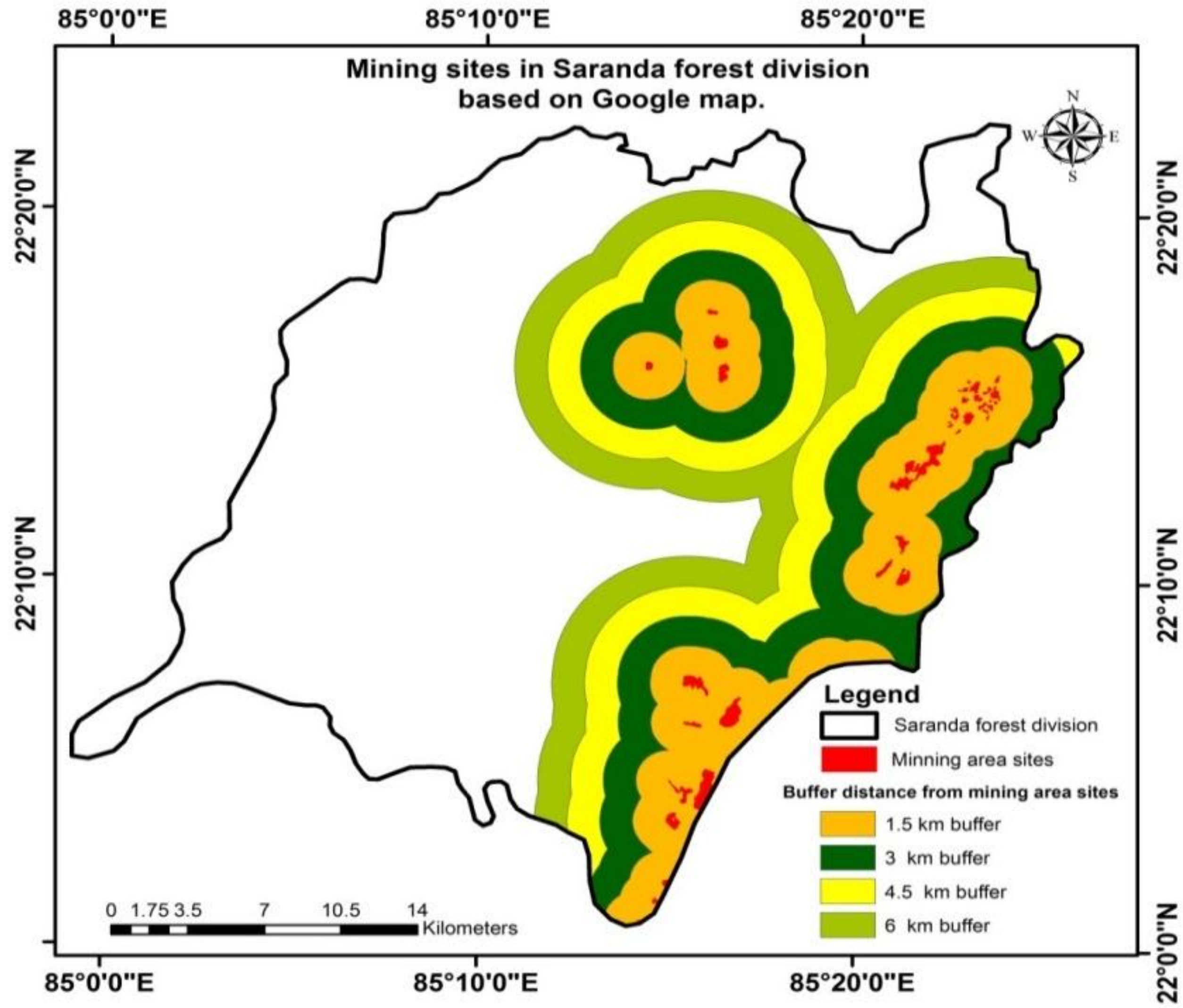

Figure 5. Mines sites with buffer map of Saranda forest division.

3.3. Road and its buffer map

Road is an important factor for habitat degradation [41]. The four buffers from road at the 300 meter interval were generated as given in the Figure 6. Buffer nearer to the road within the forest area is a disturbing factor to the wildlife. Heavy vehicle movement, its sound and frequency of movement of people is more in this area. The road buffer was classified into four classes (< 300 meter, 300–600 meter, 600–900 meter, and > 900 meter) and was ranked as 2, 3, 4 and 5 with description ranging from low, medium, high and very high respectively based on wild life habitat suitability. The roads in these forest area are doing major damage to wildlife and its habitat [5].

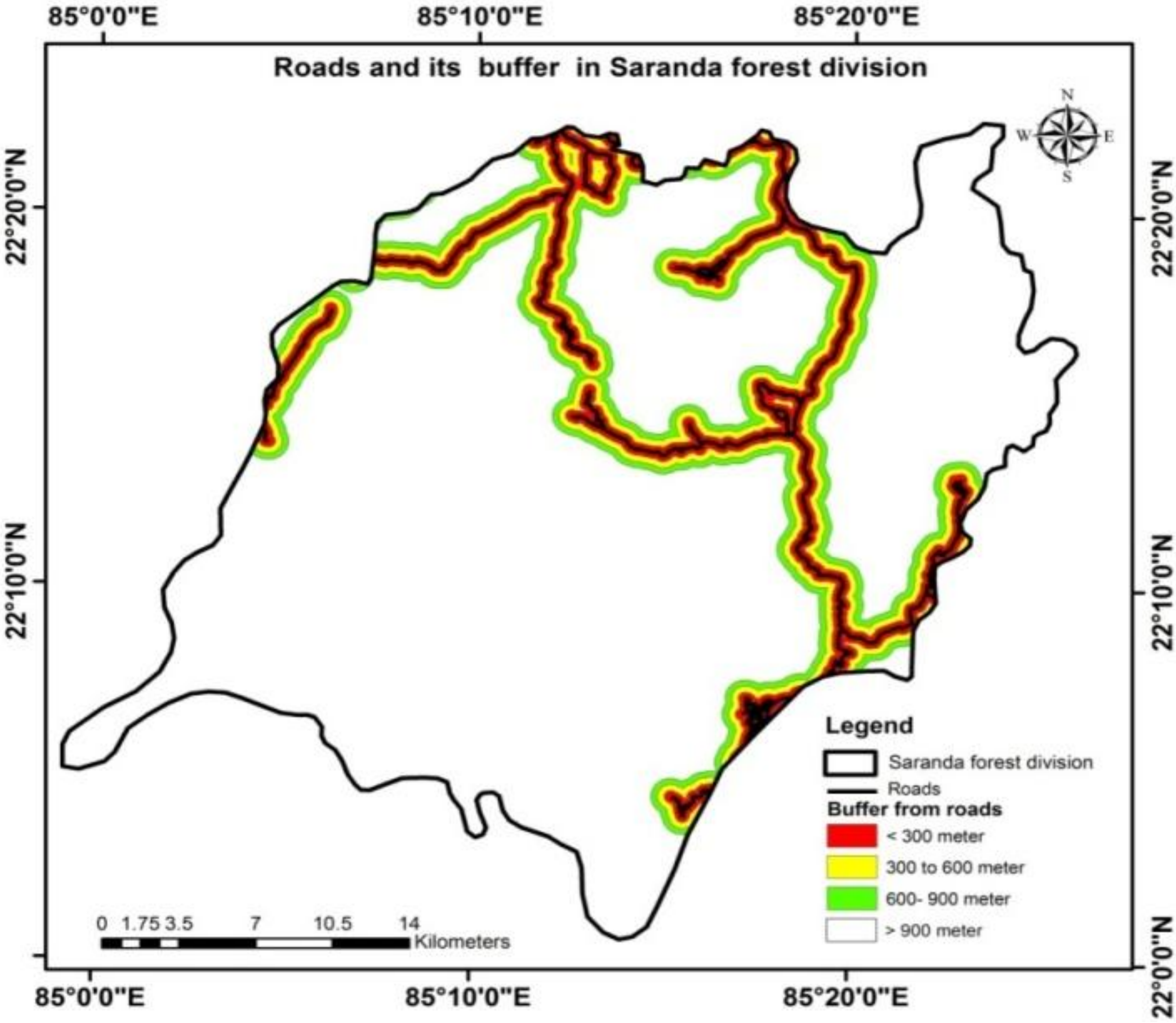

Figure 6. Roads and its buffermap of Saranda forest division.

3.4. Stream buffer map

Proximity to water is one of the determinant features of habitat selection [42]. The four buffers of streams are made at an interval 300 meter. Streams and rivers provide drinking water to inhabitant wild animals as the distance increases its suitability decreases. The streams buffer (Figure 7) was classified into four classes (< 300 m, 300–600 m, 600–900 m, and > 900 m) and was ranked as 5, 4, 3 and 2 with description ranging from very high, high, medium and low respectively based on wild life habitat suitability. Similar streams drying phenomenon was observed in this area reported by Bera [23] which affect the wildlife suitability significantly.

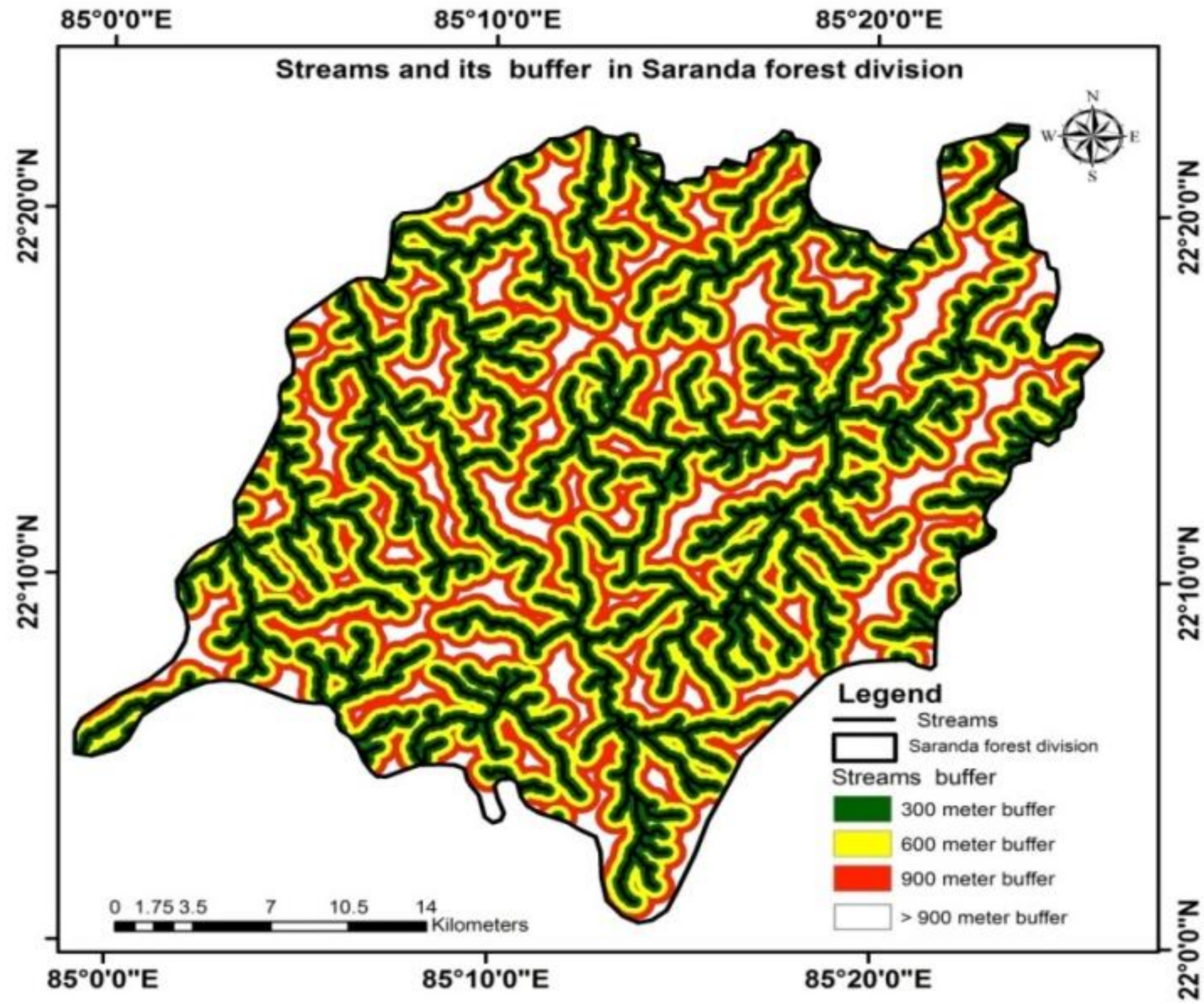

Figure 7. Streams and its buffer map of Saranda forest division.

3.5. Forest cover map

Forest covers is an important parameter considered by various wild life studies [17] which retains wildlife food and provides shelter. The forest cover was classified into four classes (dense forest, medium forest, open forest and non-forest) and was ranked as 5, 4, 3 and 2 with description ranging from very high, high, medium and low respectively based on wild life habitat suitability (Figure 8). Overall accuracy and Kappa statistics of mosaicked classified forest cover map were 95% and 0.9180 respectively. Our classified forest cover was validated with MoEFCC [43] and found similarity to large extent. Our classification also shows the agreement with the forest covers classification done by Kayet *et al*. [40] in the same area.

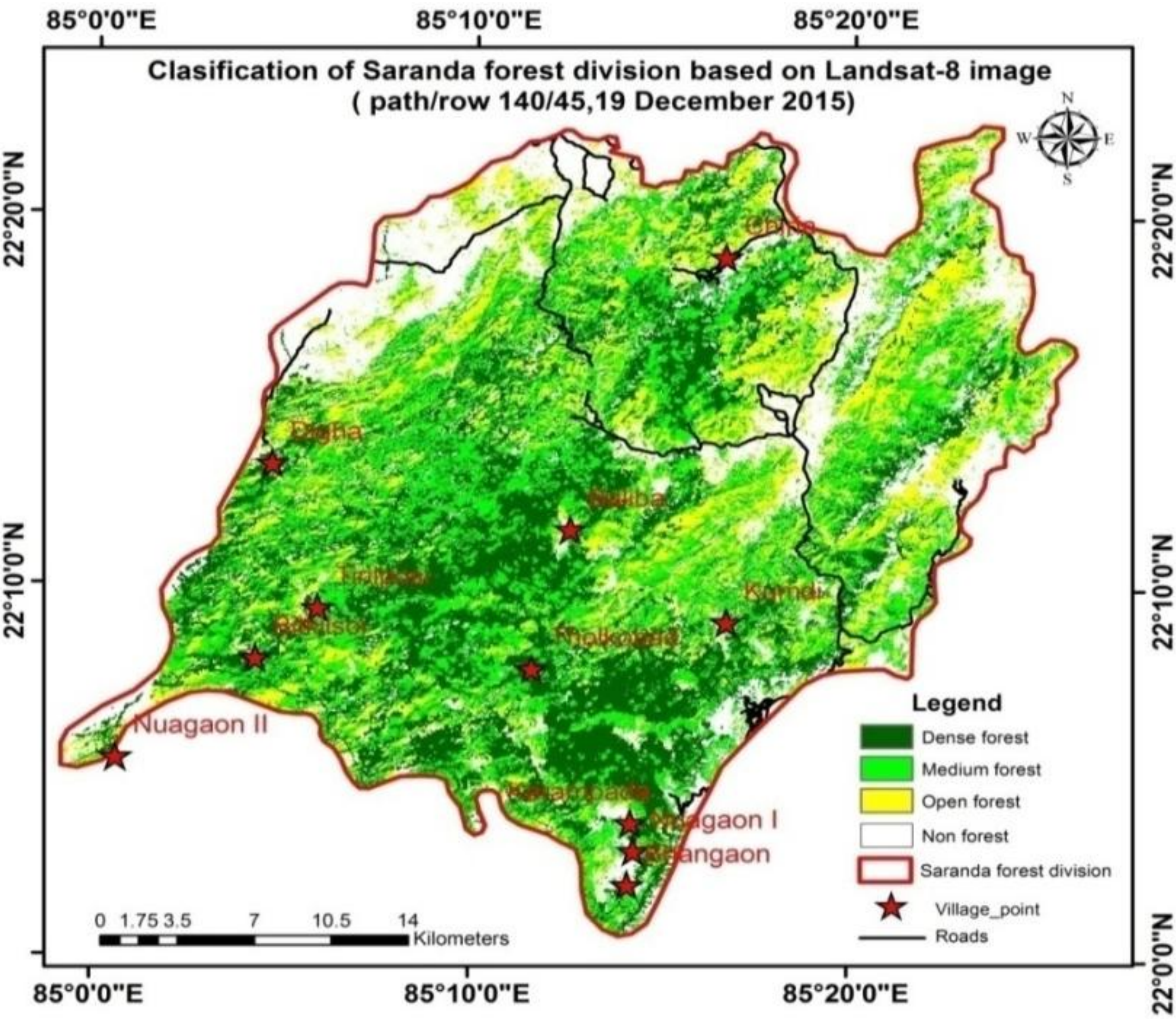

Figure 8. Forest cover map of Saranda forest division.

3.6. GRID analysis

Grid-based map analysis is often used in natural resources management and land use planning and mapping and widely used for statistical analysis. Grid as a unit is more convenient for conservation [44]. It was also be advocated by Rodriguez *et al.* [45] and a prioritization/hotspot/conservation based on grid was successfully studied in forest ecosystem by Reddy *et al*. [46]. The result of such analysis is highly beneficial for decision makers for future planning. Ceausu *et al*. [47] also used the grid based approach for conservation planning for biodiversity.

3.7. Wildlife suitability mapping

This analysis complements an assessment of Wildlife habitat suitability in a threatened ecosystem (undergoing various threats) as given in the Figure 9. Of the total grids (Table 5), 1898 (42%) found very highly suitable, whereas 1033 (23%) is highly suitable, 320 (7%) is medium suitable, 181 (4%) is low suitable and 1076 (24%) is found non forest. Very high suitable grids are favorite habitat for elephants. Similar result of elephant presence was also being reported by MoEFCC [43]. The similar grid based modeling approach was adopted by Reddy *et al*. [44] in their study for prioritization.

Table 5. Wildlife suitability grid of study area.

Wildlife suitability	Number of grids	% of grids
Very high suitable area	1898	42
High suitable area	1033	23
Medium suitable area	320	7
Low suitable area	181	4
Non forest	1076	24
Total	4508	100

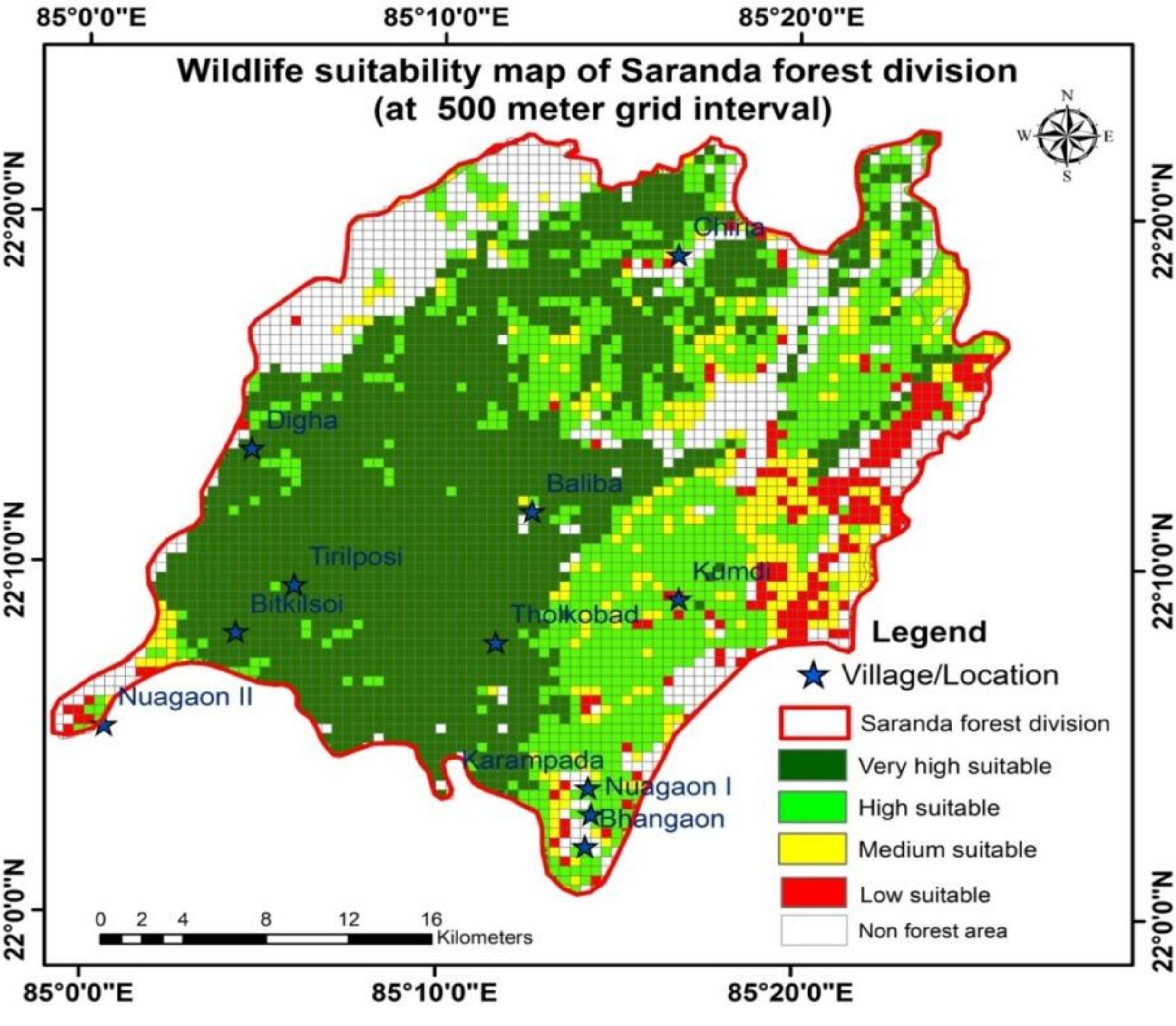

Figure 9. Wild life habitat suitability map of Saranda forest division.

Description: The study reveals very high wild life suitability area was found south-west part of study area where there was less anthropogenic disturbance and was far away from the mining sites, ample dense forest, high regeneration capacity, undulating and tough terrain, exhibit ample soil moisture, fall on less to no fire risk areas with sufficient clean perennial streams retained forest ecosystem with rich flora and fauna. The conditions for germination, establishment and development of Sal are favorable such that optimum conditions suitable for Sal growth can be found in this region. Bamboo (*Dendrocalamus strictus*) is confined to the north of the area, in and around Tirilposi area which is a favorite food for the wild elephant which is one of the reasons for their presence in this area. High and medium wild life suitable area was found in northern and eastern part away from mining area whereas low wildlife suitable area was found near to mining area mostly north-eastern part of the study area. The streams in low wild life suitability area are highly polluted water appears to red due to continuous waste materials from iron ore washeries are drained to the streams [23]. The continuous loading and unloading of the iron ores by heavy vehicle inside the forest due to mining activity further degrade the wildlife habitat. Similar finding has been reported by Integrated Wildlife Management Plan for West Singhbhum, Jharkhand [5].

3.8. Hotspot conservation grid

Forest fragmentation is one of the greatest threats to biodiversity in forests [48]. The hotspot conservation grid identified in very high wildlife habitat suitability area based on least forest fragmented patch represent unique ecosystem should be protected from anthropogenic activity. The result of analysis of various hotspot conservation grids are given in (Table 6 and Figure 10). The high, medium and low hotspot conservation grids were 925,779 and 194 respectively. The high hotspot conservation grids concentration mostly falls in and around of the triangle village Thalkobad, Baliba and Trilposi have rich plant diversity with excellent regeneration, represent unique diversified ecosystem. This was also validated based on field experience and literature cited by MoEFCC [43]. One of the unique ecosystems are also found here such as Ligarda swamp ecosystem (a narrow marshy land) and called botanical paradise with rich biodiversity.

Table 6. Conservation priority grid within high wildlife habitat suitability area.

Conservation priority	Number of grids	% of grids
High	925	49
Medium	779	41
Low	194	10
Total	1898	100

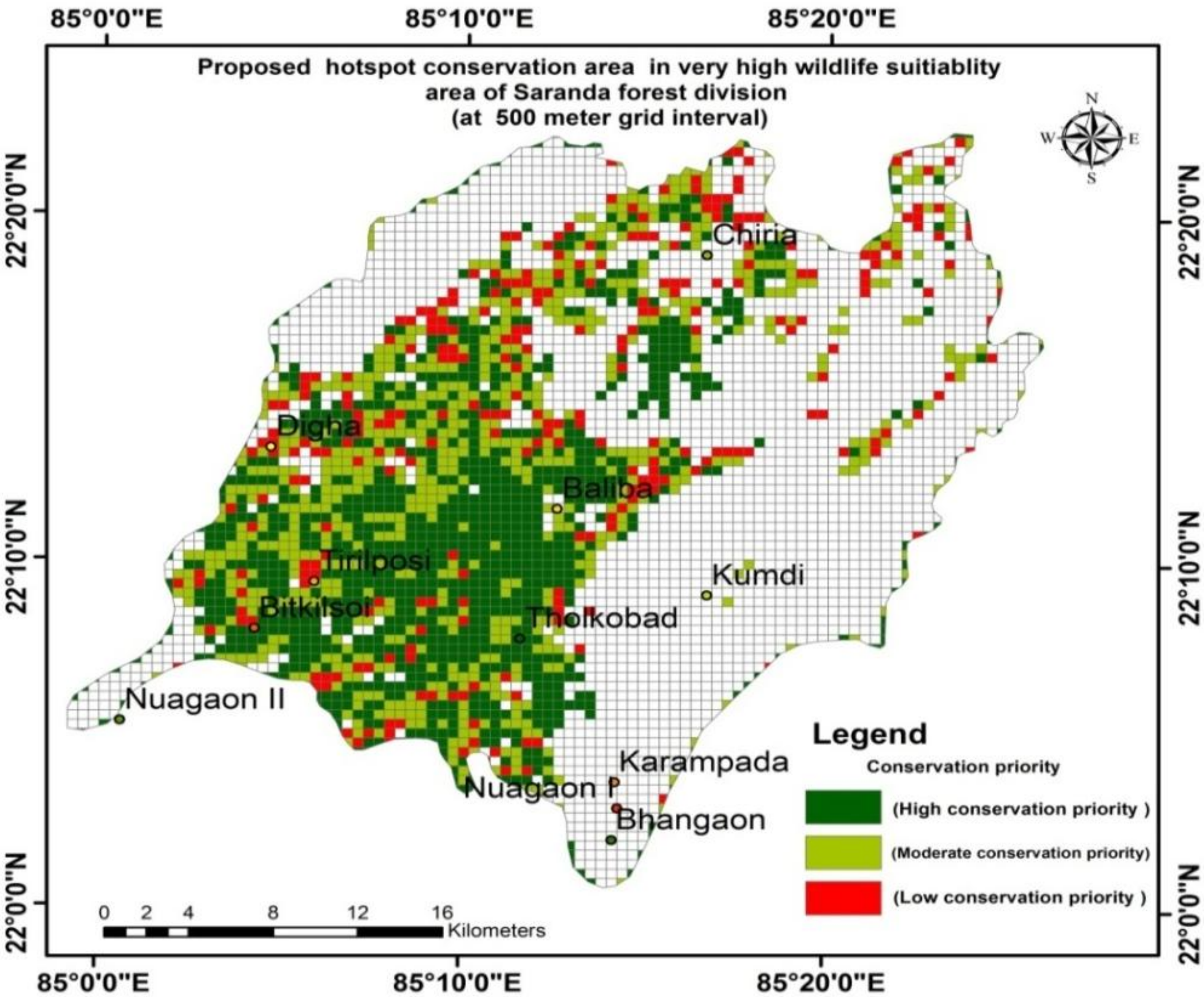

Figure 10. Conservation area map of Saranda forest division.

As in the study in Saranda forest by Ministry of Environment and Forest it was mentioned there is a need for multi-disciplinary research to identify crucial wild life habitat and identifying inviolate forest for conservation Reserve/Corridors or Ecologically Sensitive Areas for posterity. Thus, the present study give insight as it has identified wild life habitat suitability area taking almost all disturbance parameters (natural, anthropogenic) which exist on the Saranda forest and conservation hotspot area has been identified which retain contiguous virgin forest with rich biodiversity and represent unique ecosystem using an advance technology such as Remote sensing satellite data, digital image processing, GIS application, GRID analysis and Google earth map interface.

4. Conclusion

The present study highlights the integration of decadal forest fire point data, coarse resolution satellite images, Aster DEM and Google earth map and their visualization towards analyzing high wild life habitat suitability mapping and identifying less fragmented hotspot conservation grid. The geospatial technique has facilitated for systematic approach to classify and map the Saranda forest division which is facing various anthropogenic activity. Class like mines, agriculture with settlement are clearly delineated using Google map have advantage over Landsat images because of their resolution. The wild life habitat suitability map was delineated based on composite value which was obtained by integrating various delineated influential spatial data sets using the weightage derived from pair wise comparison of the study area.

From the wildlife suitability map it is clear that mining activity has deteriorated the wildlife habitat at large scale. Mining lease should not be permitted in very high wildlife suitability area. The ecological sensitivity of this area demands an urgent need to formulate a high level multi-disciplinary team that will monitor all the sensitive activity including mining and companies should strictly follow the existing act (Water pollution act 1974, Air pollution act 1971, Forest conservation act 1980 and Wildlife Protection Act 1972). Illegal mining should be controlled. The team should also assess the post mining restoration and regeneration process on abandoned mines and surrounding areas in due course of time. The watersheds with polluted stream from the mining activity should be treated and clean water be restored. The mines waste from mines washeries should restrain from draining to the streams. In hot summer, alternative drinking water resource should be developed specially on those areas where the streams are not perennial will satisfy the water demand of small animals and reptiles. Before the start of the summer season forest fire preventive measures should be adequately taken by forest department which must include local inhabitant tribal people (community). Alternate livelihood program should be generated by Govt. agency/NGO/local bodies for inhabitant tribes for their upliftment which will reduce the dependency on cultivation in forest land. The high hotspot conservation grid should be strictly protected because it represents the unique ecosystem with high floral and faunal diversity and has also been strongly advocated in the report of Honorable Justice M. B. Shah Commission of Enquiry reports on illegal mining. Finally we recommend that the whole Saranda forest should be temporally monitored using remote sensing and GIS for identifying vegetation health and disturbance (also be adopted by MoEFCC, 2016) so that appropriate conservation related policy/decision should be taken on time.

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Conflict of interest

The authors declare that they have no competing interests.

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