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Remote Sensing and GIS Based Suitability Modeling of *Rubia Cordifolia* L. in West Kameng District of Arunachal Pradesh [India]

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Abstract *Rubia cordifolia* L. also known as Indian madder in English and Manjista in Hindi is a tonic, antidysentric, antiseptic and the roots are used internally in the treatment of abnormal uterine bleeding, internal and external haemorrhage, bronchitis, rheumatism and stones in the kidney, bladder and gall. A transact survey was carried out mainly in the secondary forests along the roads and in the vicinity of the settlements. A total of 97 GPS points of the *Rubia cordifolia* were recorded in the study area. Digital Elevation Model [DEM] of the Shuttle Radar Topographic Mission [SRTM] was downloaded from the seamless server of United States Department of Agriculture [USDA]. It was used for deriving topographic parameters like altitudinal zones, slope angle, slope aspect, generic landforms and Topographic Wetness Index [TWI] which are important for the modeling of plant. Linear Image Scanning Sensor [LISS] III was used for deriving land use / land cover, Normalized Difference Vegetation Index [NDVI], Normalized Differential Water Index NDWI], Soil Brightness Index [SBI], etc. Besides, the climatic parameters like annual average rainfall, annual average temperature and annual average humidity and others like road and settlement distance were used. The whole raster data cube was submitted to Spatial Multi-Criteria Evaluation [SMCE] module of ILWIS 3.4 [GIS software developed by ITC, Enschede, and The Netherlands] for suitability modeling of targeted species. The GPS points of the plant recorded in the field were used for verifying the results. The result was satisfactory as about 89% of GPS points fall under the moderately suitable and highly suitable categories together that constitutes about 29% of the total area. This zone is the potential area of the occurrences and regeneration of *Rubia cordifolia* in the natural habitat.
Keywords *Rubia Cordifolia L.; Remote Sensing; Global Positioning System; Suitability Modeling*

1. Introduction

Rubia cordifolia L. is commonly known as Indian Madder Manjistha [1; 2]. It is a 5–10 m long perennial climber with four leaves at each node belongs to Rubiaceae family. The flowers are orange red/yellow and fruits are black in colour that yields orange/red dye. It is a tonic, antidysentric, antiseptic and extract from a constituent of drug Septilin used for rhinonasal infection. The roots are used internally in the treatment of abnormal uterine bleeding, internal and external haemorrhage, bronchitis, rheumatism, stones in the kidney, bladder and gall, dysentery, etc. It is a high demand species in the plant medicinal market. It is also considered to be one of the most valuable herbs in Ayurvedic medicine and has been largely used by physicians since ancient times. *R. corifolia* is found in Southern Europe through African continent to Asia. The possible habitats are amongst the scrub in Himalaya, 2400 m in Dehradun and damp wet upland forests in China. In India it is found throughout the hilly districts from North-West Himalayas eastwards and southwards to Ceylon. It is in flower from July to September. The flowers are hermaphrodite [have both male and female organs]. The plant prefers light [sandy], medium [loamy] and heavy [clay] soils and chemically acid, neutral and basic [alkaline] soils. It can grow in semi-shade [light woodland]. *Rubia* has high demand in dye and pharmaceutical industries due to its anti-inflammatory, anthelminthic and antioxidant properties [3]. It has an antibacterial action, inhibiting the growth of *Staphylococcus aureus*, *S. epidermidis*, *Pneumococci*, etc. and also used to lower the blood pressure [4]. It is also used in the treatment of blood disorders and spreading fever of kidneys and intestines [5]. The whole plant of *Rubia cordifolia* is used with an approximate cost of Rs. 30 per kg and the suitable period of extraction is during the months of October to November [6]. The roots are harvested in autumn from plants that are at least 3 years old. They are peeled and then dried [7]. *Rubia* is categorized under the alpine zone medicinal plant of which the roots and rhizome are used in medicine preparation [8]. In Arunachal Pradesh, the plant mostly grows in temperate and secondary forest between 1500 and 3500 m elevations along the road side, scrublands, forest margins fencings and partially open places of almost all districts of Arunachal Pradesh except Papumpare [9].

The greatest advantage of the satellite image is the synoptic view it provides, which gives a regional and integrated perspective of and interrelations between various land features such as vegetation cover, drainage pattern, etc. which can be better perceived on the image than on the ground [10]. This is of greater relevance in the inaccessible and difficult terrains of the Himalayas [11]. Forest structure and composition are strongly correlated with environment factors, such as climate and topography [12; 13; 14]. Studying the composition and diversity of species and its habitat types, perhaps becomes the yardstick to judge the level of adaptation to the environment and the ecological significance [15]. There are several Remote Sensing and GIS based techniques in use worldwide for habitat modeling and ecological niche modeling of both flora and fauna. Some of the GIS procedures are DOMAIN, BIOCLIM, and Genetic Algorithm for Rule Set Production [GARP], Ecological Niche Modeling [ENM], Maximum Entropy [MAENT], Ecological Niche Factor Analysis [ENFA], etc. DOMAIN and BIOCLIM are run in DIVA-GIS and ENFA in BIOMAPPER GIS software. The ecological niche or habitat of the species can be defined as 'set of ecological conditions within which species are able to maintain populations without immigration' [16]. Carpenter et al. [17] describes DOMAIN procedure and modeling approach for plant and animal distribution modeling. Vargas [18] and Saqib et al. [19] uses DOMAIN for modeling potential distribution of *Anthurium and Taxus wallichiana*, respectively. Anderson et al. [20], Peterson [21], Meyer et al. [22], Papes [23] and Ortega-Huerta and Peterson [24] apply ENM for species distribution modeling and conservation while Adhikari et al. [25] models distribution of avian influenza through ENM. Similarly, Menon et al. [26] predicts the population of critically endangered species through ENM. Benito et al. [27] on the other hand calculates extinction risk through species distribution model for an endangered plant while Singh et al. [28] uses multi-criteria model in GIS for tiger habitat suitability and distribution evaluation in Corbett Tiger Reserve. Therefore, the study attempts to derive a land suitability model of the plant for regeneration and suggest measures to conserve it through awareness education and community participation in the area.

2. Study Area

West Kameng district is a part of Eastern Himalayan Biodiversity Hotspot that is rich in both floral and faunal diversity but its ecosystem has been considered fragile and ranked 200 ecologically important region of the world. It lies approximately between 91° 30' to 92° 40' East longitudes and 26° 54' to 28° 01' North latitudes (Figure 1). The district shares an international border with Tibet and Bhutan. The topography of the district is mostly mountainous and its greater part falls within the higher mountain zone, consisting of tangled peaks and valleys. Tenga, Bichom and Dirang Chu are the main rivers flowing through the district. All these rivers are tributaries of the river Kameng which joins the river Brahmaputra in plains of Assam. The forest types West Kameng ranges from tropical semi-evergreen to alpine forest which is a storehouse of more than 500 species of plants of medicinal and pharmacological significance. On an average the area receives 1743 mm annual rainfall and mean maximum and minimum monthly temperature 21.44˚C and -1.24˚C. West Kameng district has a total population of 74,599 (census 2001). The inhabitants of the district comprise mainly of Monpa, Miji (Sajalong), Sherdukpen, Aka (Hrusso), and Bugun (Khawa) tribes who belongs to Tibeto-Mongoloid stock.

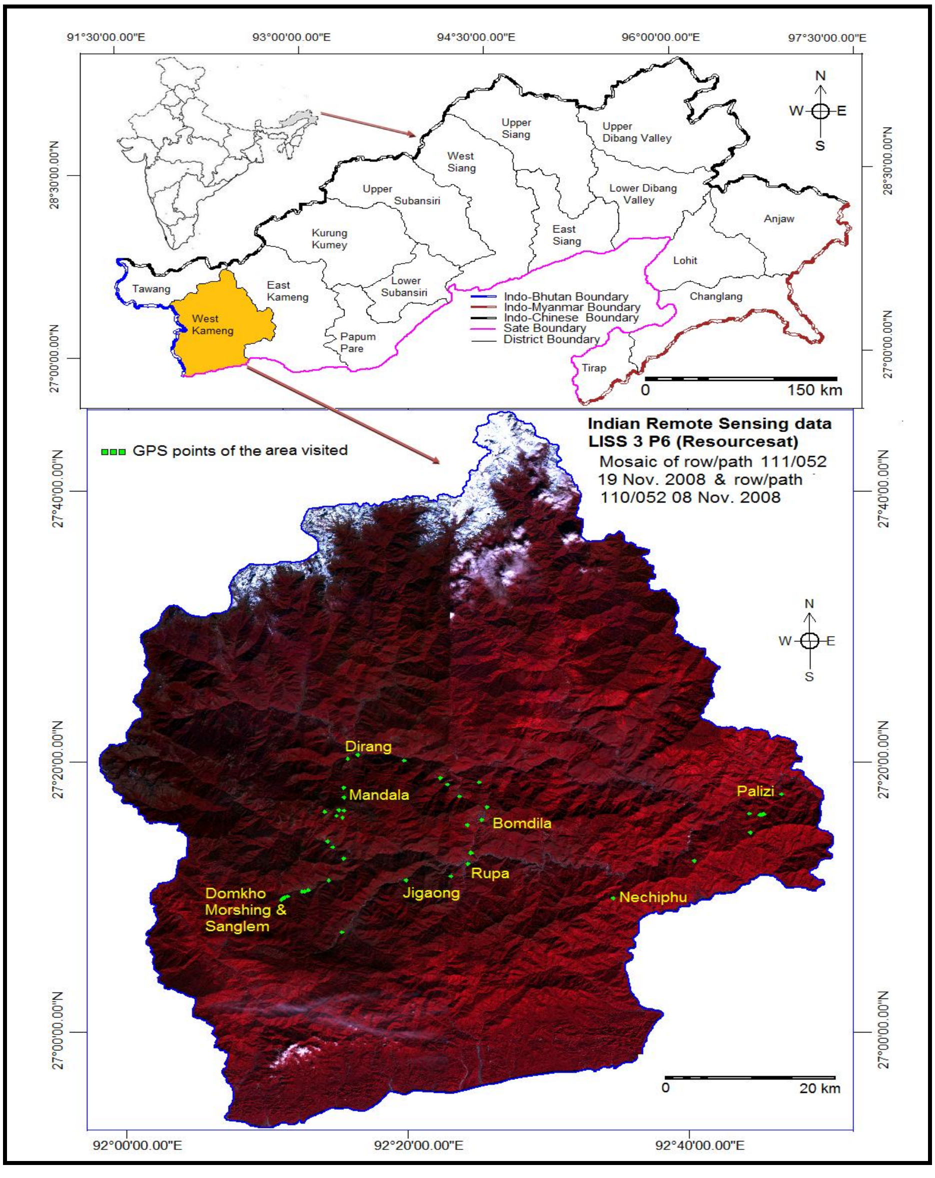

Figure 1: *West Kameng District: Location Map*

3. Methodology

3.1. Field Methods

Intensive transact surveys with the help of local experts, hunters, semi-nomadic herders, etc. were conducted in a random manner to locate *Rubia cordifolia*. Information was also collected through informal interaction with the villagers. Global Positioning System (GPS) was used to record the latitude, longitude and altitude of the targeted species. At each GPS point of location of *Rubia cordifolia* other information such as soil temperature, pH; moisture content, etc. were recorded. Soil samples are also collected for laboratory analysis. Conservation strategies through awareness campaign, workshops, poster display, pamphlets, calendar, talks, etc. are carried out in the areas where plant is located and extensive exploitation is observed. In the workshop pamphlets containing the information on targeted plant species were also distributed to the villagers. The pamphlets are also distributed in the schools, offices and to the military personnel to generate mass awareness.

3.2 Data Analysis

The SRTM tile srtm_55_06.zip in GeoTIFF format is downloaded from USGS seamless server and sub-mapped for study area. The voids and abnormal values in the SRTM DEM are removed following Castellanos (29). The abnormal values (negative value and values above maximum height) are converted into undefined values and removed using iterative average filter. The 1 arc-second DEM with 30 m spatial resolution is generated from the 3 arc-second SRTM DEM through bicubic polynomial interpolation method Keeratikasikorn and Trisirisatayawong (2008). The final DEM is used for deriving topographic parameters like altitudinal zones, slope angle, aspect, shape and Topographic Wetness Index (TWI) which are important topographic elements for the study of plant species. The 8 bit digital data of Indian Remote Sensing (IRS) LISS III in 4 spectral bands with spatial resolution of 23.5 m of November 2011 was used to derive the important indices like Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index and Soil Brightness Index (SBI). The first component (PCA1) derived through Principal Component Analysis which stores maximum variation in the 4 spectral bands of LISS III is also used as a digital parameter. The land use map of the study area for 2011 is prepared using LISS III data along with NDVI, NDWI, SBI, PCA1, DEM and Band ratio of different bands converted into 8 bit data. Supervised classification technique is used for image classification. The point layer of the rainfall, temperature and humidity are created using annual average rainfall, temperature and humidity data respectively for the study area. Each point layer is interpolated separately through moving average method into raster layers of climatic parameters. These climatic parameters and others derived from DEM processing are resampled into the spatial resolution of satellite imagery in order to facilitate raster analysis.

The whole raster data cube is submitted to Spatial Multi-Criteria Evaluation (SMCE) module of ILWIS for ecological niche modeling of the targeted species. Each parameter is standardized into SMCE criteria tree separately for the species as per the ecological requirements of the species on the selected parameters. While standardizing, the parameters with value domains are grouped as cost, benefit and combination. Those parameters whose values have positive correlation with the goal i.e. occurrences of the selected species is standardized as benefit and those which are negatively related with the goal is standardized as cost factors. Further, those parameters of which extreme values are negatively related and intermediate values are positively related with occurrences of species are standardized as combination u-shaped up and vice-versa. Parameters with class domain are standardized through ranking method. While standardizing, the original pixel values are redistributed from 0 to 1. Finally, the parameters are also weighed through ranking method from 0 to 1 as per their relative importance to the goal. Then, running the SMCE module results into a composite map which also contains values from 0 to 1. Slicing the composite maps into desired layers produces ecological niche of different degree.

4. Results

4.1. Field Results

The availability of *Rubia cordifilia* is recorded through random transacts using GPS. The transact survey is carried out mainly in the secondary forest areas along the roads or in the vicinity of the settlements. *Rubia* was found growing abundantly in Tenzinggaon area of Kalaktang, Shergaon, Dirang, in between Bomdila and Rupa, Palizi and Bhalukpong. In some places it has been found bearing ripened black fruits resembling cherry. *Rubia* proliferate vigorously in the places where forests or undergrowth are recently cleared, however, in some places it is associated with dense and moderately dense forest. A total of 97 GPS points of *Rubia cordifolia* was recorded in the above mentioned areas. A workshop was conducted at Domkho village to educate the villagers about the importance, vulnerability and present condition at global, national and local levels. They were also encouraged to protect and regenerate the plant**.**

Figure 2: A. *Rubia Cordifolia Near Bomdila,* ***B.*** *Rubia Cordifolia Near Dirang,* ***C.*** *Rubia Cordifolia Bearing Fruits,* ***D.*** *Rubia Germinating In Recently Cleared Forest*

4.2. Parameter Characteristics

The derivates of DEM such as altitude, slope angle, slope aspect, generic landforms, TWI, etc. exercise dominant influence on vegetation type and vegetation distribution. These elements also affect the climatic condition and soil type of the area thereby indirectly modifies the distribution of plant species. Altitude on the one hand defines the climatic condition of a locality, on the other hand directly influences the vegetation distribution and adaptation. The altitude in the study area ranges from 133 m in the southern margin to 5600 m towards the northern extremity. With an average height of 2804 m and maximum height of 2446 m, the area between 1800–2400 m and 2400–3000 m constitute 22.84% and 20.21% respectively. The heights ranging between 4800–5400 m and above 5400 m constitutes only 0.86% and 0.03% respectively. Slope angle also defines vegetation distribution and soil depth thereby soil moisture content. Slope angle in the study area ranges between 0º to 79º with an average slope angle of 39º and predominantly occurring slope value of 24.91º. The maximum area experiences slope values ranging from 20–30º followed by 30–40º constituting 36% and 30% respectively. The area experiencing slope of 40–50º and above 50º slope forms 7.76% and only 1.12% respectively.

Slope aspect defines the duration of the sunshine, moisture availability and thereby the vegetation adaptation. The equator facing slope has longer sunshine and is water deficient whereas the pole facing slope has shorter duration of sunshine. The slope aspect in West Kameng ranges from 0º to 360º which have been divided into 8 directions. Maximum slope in the study area is declining towards South-East followed by South direction. About 35% area in the district constitutes convex slope, 32% area has concave slope and 27% area experiences straight slope. Channel forms only 2.78%, ridges constitutes 2.35%, plain forms 1.15% and pit and peak constitutes only 0.09% and 0.06% of the total area. Topographic Wetness Index is the relation between topography and moisture distribution, more specifically the topographic control on moisture distribution on the basis of flow direction and flow lines. The higher value of TWI indicates high concentration of moisture and vice-versa. The TWI of the area ranges from 5.36 to 21.65 with an average of 11.68 and standard deviation of 3.17 which is 27.16% from its mean. The highest values occur in the rivers and lowest values occur along the ridges and peaks. About 62% area experiences TWI between 8 to 10 and TWI 13 to 16 and above 16 is found in 2.55% and 0.19% areas respectively.

The land use/landcover categories based on the IRS LISS III data of 2008 shows 22.48% area under the temperate forest followed by deciduous forest constituting 20.87%, sub-tropical forest 8.41%, alpine forest 7.05%, and tropical forest 6.29%. The degraded forest spreads over 13% of the area which also includes jhum cultivated areas and abandoned jhum. The alpine grassland locally known as Brok forms 3.41%, agriculture and built-up area covers 6.51% and 0.65% area respectively. Snow covers 2.45% area and cloud obscure 0.77% area while another 7.42% was under the shadow due to the sun declination. The NDVI is an important index which reveals the health of vegetation cover. The value of NDVI ranges between -1 to 1. Value below 0 indicates no vegetation and value close to 1 indicates thick vegetation. In the study area NDVI ranges between -0.7 to 1 with an average value of 1 and predominantly occurring value of 0.5 which accounts for 22.08% followed by 0.6 and 0.4 constituting 18.75% and 18.51% respectively. The extreme values constitute very low percentage. Similarly, the NDWI, a measure of moisture or water content by the objects of earth surface, varies from -0.7 to 0.9 with an average of 0.1 and maximum occurring value of 0.3 which covers about 31% of the study area followed by 0.2 and 0.4 which forms 23% and 16% area respectively. Alike NDVI, the extreme values of NDWI forms least parts of the study area. The soil brightness index (SBI), a measure of the surface cover condition, varies from 7.7 to 305.2 with an average of 160.8, predominately occurring value of 39.1 and standard deviation of 83.1. About 73% of the study area experiences SBI value in between 30 to 60.

The average annual rainfall in the study area fluctuates between minimum of 1973 mm and maximum of 2689 mm with an average of 2273 mm. The most frequently occurring rainfall value is 1974 mm and standard deviation of 181.66 mm which is 7.99% from its mean. Similarly, the average mean temperature ranges from 11.30º C to 19.33º C with mode of 11.32º C. About 65% of the area experiences average annual temperature of 14º C to 16º C. The average annual relative humidity ranges from 70.47% to 76.35% and in most of the cases it is 70.54%.

All these mentioned parameters have been submitted to Spatial Multi-Criteria Evaluation (SMCE) model to analyze the suitable areas of *Rubia cordifolia* in the light of ecological niche modeling. The composite index ranging from 0 to 1 is divided into four suitability categories of occurrences for *Rubia cordifolia* (Figure 3). The highly suitable area for distribution of *Rubia* comprises 48.05 km^2 which is 0.96% of the total and about 1443 km^2 (28.82%) falls under moderately suitable class (Table 1). The area under not suitable and slightly suitable categories comprises of 539 km^2 (10.77%) and 2978 km^2 (59.45%). Out of the total 97 GPS points located during random transact survey, 35 points (36%) falls under highly suitable category while 52 points (53.61%) falls under moderately suitable category.

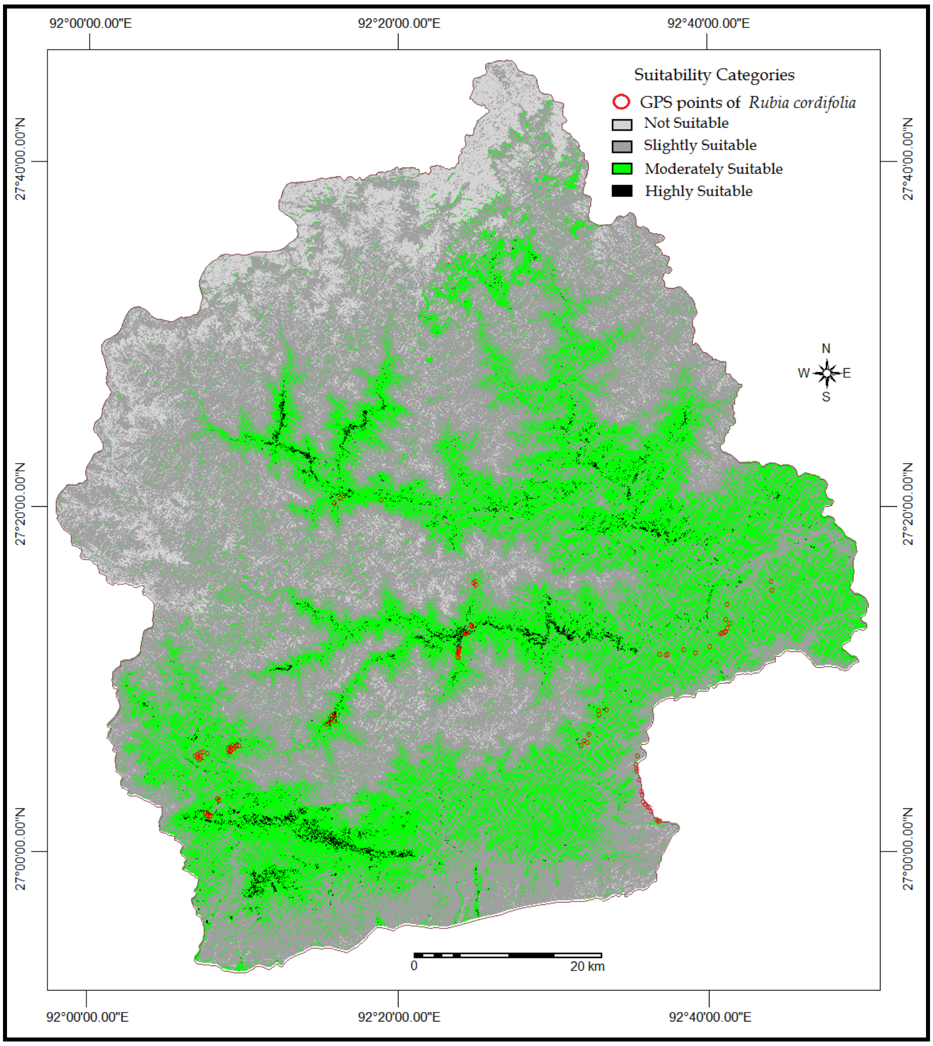

Figure 3: *Suitability Modeling of Rubia cordifolia L. in West Kameng District*

Table 1: *Habitat Suitability Categories of Rubia Cordifolia*

Suitability Index	Category	Area (km^2)	%	GPS points	
				Pixels	%
0.05-0.23	Not Suitable	539.75	10.77	1	1.03
0.23-0.42	Slightly Suitable	2978.62	59.45	9	9.28
0.42-0.60	Moderately Suitable	1443.90	28.82	52	53.61
0.60-0.79	Highly Suitable	48.05	0.96	35	36.08
	Total	**5010.31**	**100.00**	**97**	**100.00**

5. Discussion

Large scale exploitation of *Rubia cordifolia* has taken place in the study area. The interaction with villagers reported that *Rubia* was found abundantly in nearby forest surrounding the villages. But, after the large scale supply, it is now not found within 10 to 15 km radius from the villages. It is reported as rare in Arunachal and Darjeeling Himalayan ranges. During the period of 1997-98 about 1.5 tonne of *R. cordifolia* has been extracted for various dye and medicinal purposes from West Kameng district (Forest Department, Itanagar, 1998). There is no standard method of extraction and no any regulatory mechanisms for sustainable harvest. The villagers expressed their ignorance about the importance and vulnerability of the tree. In the context of rapid changes owing to forest losses, vegetation cover and species population is expected to decrease over small spatial scale [31] the excessive species loss could also lead to collapse of the ecosystem [32]. Further, shortening of *jhum* cycle from the traditional 10 years or more to 4–5 years on an average now is indeed a matter of concern [33] The awareness campaign on *Rubia* has received good response from the villagers. The distribution of pamphlets containing basic information, importance and conservation slogans of the plant has been largely appreciated by the people.

In order to carry out habitat suitability modeling i.e. niche modeling topographic parameters like altitudinal zone, slope aspect, slope gradient, generic landforms and topographic wetness index, as well as the climatic parameters like annual average rainfall, annual average temperature, annual average humidity are taken into consideration. Besides, other parameters like land use/land cover, NDVI, NDWI, soil brightness index, principle component, settlement distance and road distance are also used for overall suitability analysis. The composite index of SMEC which ranges from 0 to 1 is sliced into five categories of habitat suitability – not suitable, less suitable, moderately suitable, suitable and highly suitable. The GPS points recorded during the field survey were used for verifying the results. The result of the habitat suitability is highly satisfactory as 89% of the GPS points fall under the highly suitable and moderately suitable categories together. These categories together constitute about 29% of the total area of West Kameng District of Arunachal Pradesh. This zone is the potential area of the occurrences of *Rubia cordifolia* in the natural habitat. In other words, the highly suitable and suitable zones are the best areas for the regeneration of this species.

6. Conclusion

The rampant exploitation of *Rubia* has occurred in many areas of West Kameng District of Arunachal Pradesh. Since no regulatory mechanism and standardized harvesting techniques were adopted, the plants dried up once it is harvested. There are no systematic approaches made in order to regenerate this species through the active participation of the communities and the people themselves are also not coming up to take up such challenges. Thus, the findings show adverse effects of exploitation on *Rubia* plant. Besides, there is need of special care and additional financial involvement in providing proper fencing to protect the plant against browsing animals. Therefore, there is an urgent need of developing concrete steps for conservation and regeneration of this valuable resource. This can be achieved by systematic strategies through larger community awareness, community participation, suitable propagation techniques*, in-situ and ex-situ* trials, demonstration, financial and infrastructural assistance, adequate remuneration, etc. More focus is needed on the front of financial assistance and remuneration to the growers to ensure large scale participation. There is also a need of regulatory mechanism and standardized harvesting techniques for the sustainable use of this resource. The result of the habitat suitability indicates that about 29% of the total area falls under moderately suitable and highly suitable habitat categories of *Rubia cordifolia*. About 89% of the GPS points of the *Rubia cordifolia* collected during the field survey fall under the moderately suitable and highly suitable categories which is indicative of the level of accuracy and success of the suitability analysis carried out for the targeted species.

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