

## Species Distribution Modeling of Tea (*Camellia sinensis*) in Lohit district of Arunachal Pradesh, India

RETER POTOM<sup>1</sup> AND GIBJI NIMASOW<sup>2\*</sup>

<sup>1</sup> Hills College of Teacher Education, Lekhi, Itanagar 7911109, Arunachal Pradesh, India

Email: [reter.potom@gmail.com](mailto:reter.potom@gmail.com)

<sup>2</sup> Department of Geography, Rajiv Gandhi University, Rono Hills, Doimukh, 791112, Arunachal Pradesh, India

Email: [gibji.nimasow@rgu.ac.in](mailto:gibji.nimasow@rgu.ac.in)

\* Author for correspondence

### ABSTRACT

Species distribution modeling is essential to understand the habitat suitability and ensure *in-situ* conservation of any species. We modeled the species distribution of Tea (*Camellia sinensis*) in Lohit district of Arunachal Pradesh (India) using Maximum Entropy (MaxEnt) techniques and ArcGIS software. The occurrence data of Tea was collected using Global Positioning System (GPS) by visiting the tea estates of the study area. The environmental layers include topographic, climatic and soil data. The topographic layers were generated from the Digital Elevation Model (DEM) of the Shuttle Radar Topographic Mission (SRTM) downloaded from the website (<http://seamless.usgs.gov>) of United States Geological Survey (USGS) using surface analysis in ArcGIS. The bioclimatic layers of annual mean temperature and precipitation were generated using the current global climate data (1950 to 2000) at 30 arc seconds downloaded from [www.worldclim.org](http://www.worldclim.org). The results show 22% of the total geographical areas under suitable and 14% under moderately suitable areas for tea cultivation. The study also reveals that the terrain, climatic and soil conditions of the area provides greater scope for expansion of area under tea cultivation in the study area in near future.

**Key Words:** Maximum Entropy, Niche Modeling, Bioclimate, Tea Prospects.

### INTRODUCTION

Tea is a significant perennial commercial crop in many sub-tropical and tropical areas of the world. It is a traditional beverage originally from China, the oldest, most popular, non-alcoholic caffeine containing beverage in the world, and its infusion is prepared by brewing of processed leaves of the tea plant, *Camellia sinensis* (Kumar and Shruthi 2014). The cultivated taxa of tea comprise of three main natural hybrids. They are: *Camellia sinensis* (L.) O. Kuntze or China type, *Camellia assamica* (Masters) or Assam type and *Camellia assamica* sub-sp. *Lasiocalyx* (Planchon ex Watt) or Cambod or Southern type. Two types, which are well known, are the China and Assam, less common is the Cambod (Yemane et al. 2008). India is one of the largest tea producers in the world and about 70% of tea

produced is consumed within India itself. By the turn of the century, Assam became the leading tea producing region in the world. However, due to certain specific soil and climatic requirements its cultivation was confined to only certain parts of the country (Arya 2013). Tea is grown in 16 Indian States, out of which four states viz. Assam, West Bengal, Tamil Nadu and Kerala account for about 96% of the total tea production of country whereas land utilization pattern under tea cultivation show that North East India represents 78% of total area under tea in India (Soni et al. 2015). Tea is reported to contain nearly 4000 bioactive compounds of which one third is contributed by polyphenols (Tariq et al. 2010). Other compounds are alkaloids, amino acids, carbohydrates, proteins, chlorophyll, volatile organic compounds, fluoride, aluminium, minerals and trace elements (Cabrera et al. 2003). The polyphenols, a large

group of plant chemicals that includes the catechins, are thought to be responsible for the health benefits attributed to tea, especially green tea (Cabrera et al. 2006).

The ecological niche or habitat of the species can be defined as a 'set of ecological conditions within which species are able to maintain populations without immigration' (Grinnell 1917). Species distribution patterns and ecological niche modeling are important for different plant species because the original habitats of species are changed by anthropogenic activities and natural factors (Chahouki 2011, Chahouki and Esfanjani 2015). The determination of the impact of environmental factors on the habitats of species will help in sustainable planning and management of particular plant species (Chahouki and Sahragard 2016). There are many techniques used worldwide for habitat/ecological niche modeling of both flora and fauna. Some of the GIS procedures are DOMAIN, BIOCLIM, genetic algorithm for rule set production (GARP), ecological niche modeling (ENM), maximum entropy (MaxEnt), ecological niche factor analysis (ENFA) and SMCE. The MaxEnt approach estimates a species environmental niche by finding a probability distribution that is based on a distribution of MaxEnt with reference to a set of environmental variables (Phillips et al. 2006). MaxEnt has been reportedly used in modeling of *Canacomyrica monticola* in New Caledonia (Kumar and Stohlgren 2009), *Justicia adhatoda* L. in Lesser Himalayan foothills (Yang, Kushwaha and Saran 2013), *Artemisia sieberi* and *Artemisia aucheri* in Poshtkouh area, Central Iran (Hosseini et al. 2013), *Taxus baccata* in Tawang, Arunachal Pradesh (Nimasow et al. 2016), etc. The approach could be promising in predicting the potential distribution of plant species and thus can be an effective tool in species restoration, conservation planning and proper management of existing plant species. Therefore, the study attempts to understand the habitat preferences of Tea crop and develop species distribution model to identify suitable areas of Tea cultivation in the study area.

## STUDY AREA

Lohit district of Arunachal Pradesh is located between 27° 33' N to 29° 22' N latitudes and 95° 15' E to 97° 24' E longitudes. It covers a total geographical area of 4,210.74 km<sup>2</sup> and the altitude varies from 132 to 4,317 meters above mean sea level (msl). The district consists

of eight (8) circles namely Chongkham, Lathao Lekang, Namsai, Piyong, Sunpura, Tezu and Wakro which are considered as prospective areas of tea cultivation (Figure 1). The inhabitants earn enormous profits from tea cultivation in the recent years which has revolutionized their social and economic status. At the same time they reap a good harvest of cash crops like mustard, soya bean, ginger, potatoes, etc. to derive considerable financial benefits.

The tea plants were first found in the foothills of Lohit district of Arunachal Pradesh and experimental tea plantation was started in the state at Deomali in Tirap district. The state especially the foothills of its eastern part are ideally suitable for tea cultivation. The temperature of study area ranges in between 25° to 34° C. Generally 18 to 30 ° C temperature is required for the growth of tea plant with an average rainfall of about 115 to 180 cm per year (Carr 1972). The required humidity with high humus and nitrogen content of the soil due to extensive forest cover added favorable conditions for the growth of the plant. The area has alluvial soil with loamy or sandy texture. Thus, the study area has good scope for tea plantation. Tea being a plantation crop and a major revenue generator plays vital role in improving the socio-economic conditions of the people of Lohit district.

## MATERIALS AND METHODS

The study was done in three phases. The first phase included the data collection for base map and the boundary of study area. The second phase included the field survey and collection of presence / absence records of tea and other habitat information like soil data. The third phase included data analysis and geospatial modeling of tea using MaxEnt and ArcGIS.

### Data Collection

The base map of the study area was delineated from the topographical maps with 1: 50, 000 scales, published by Survey of India and the location map was prepared from the administrative maps of Census, 2011. Digital Elevation Model (DEM) of the Shuttle Radar Topographic Mission (SRTM) was downloaded from the website (<http://seamless.usgs.gov>) of United States Geological Survey (USGS). It was used for deriving topographic parameters like altitudinal zones, slope and slope aspect which are important topographic elements with respect to the study of plant species. The bioclimatic

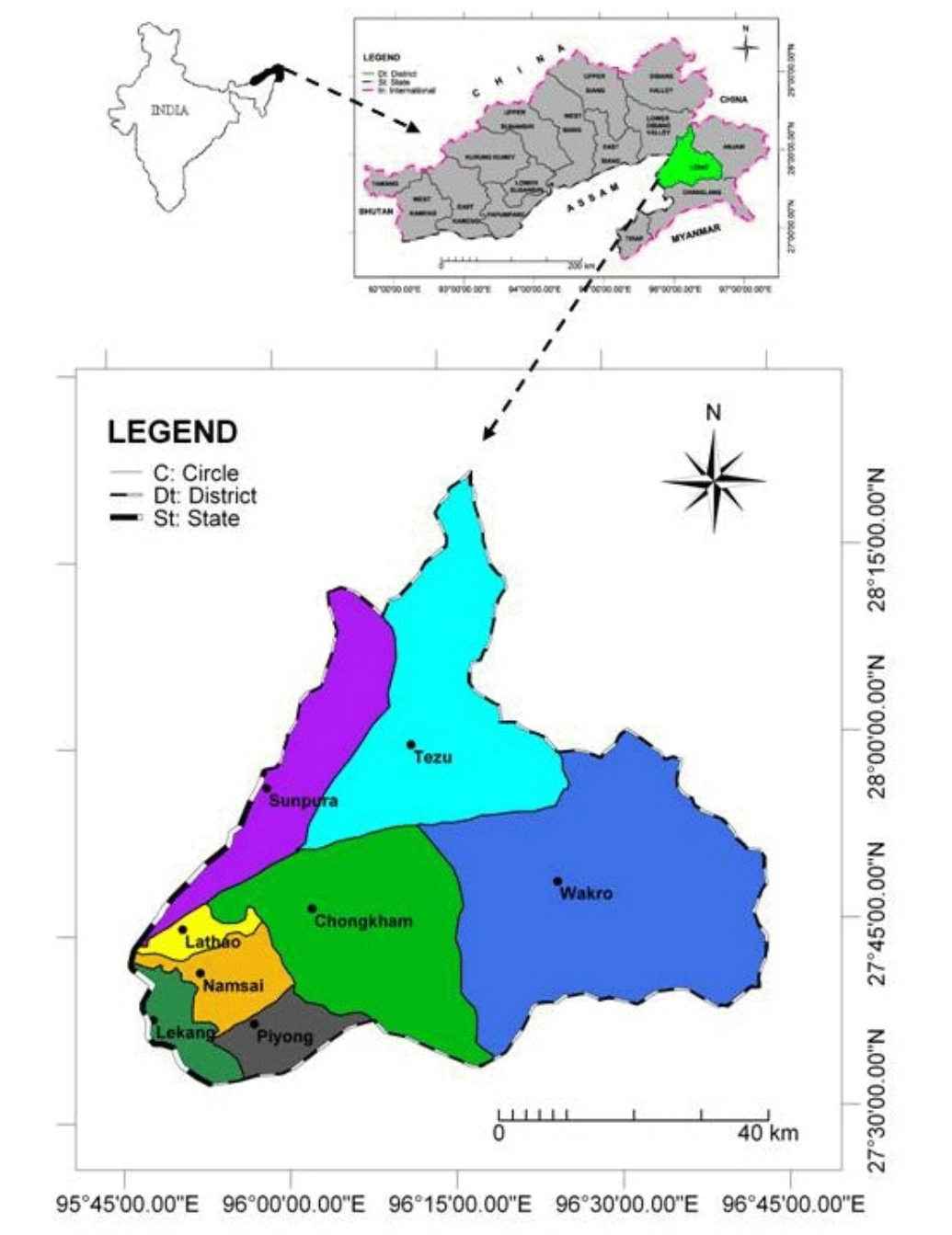


Figure 1. Location Map of Lohit District, Arunachal Pradesh, India

layers tile in .BIL format which includes the current global climate data (1950 to 2000) at 30 arc seconds was downloaded from [www.worldclim.org](http://www.worldclim.org) for deriving the Annual mean temperature, Maximum temperature of warmest month, Minimum temperature of coldest month, Annual precipitation, Precipitation of the wettest month and Precipitation of the driest month.

**Field Survey**

The field survey was carried out from February, 2014 to February, 2015. A total of 94 tea estates were visited and the data on presence / absence of tea has been collected. The study area is divided in to eight circles but the intensity of tea cultivation is more in Chongkham,

Wakro, Lathao and Piyong circles. Hence, the field visits were carried out time to time to cover all the tea cultivated areas. On each site, the soil pH, temperature and moisture were measured and soil samples were collected for texture analysis.

**Data Analysis**

The species distribution modeling of tea has been carried out using Maximum Entropy (MaxEnt). The presence data (GPS points of tea) was converted into .CSV format using MS Excel. Out of the many environmental parameters affecting distribution of tea the altitude, slope, aspect and bioclimatic factors (like mean annual temperature, maximum temperature of the hottest month, minimum temperature of the coldest month, annual precipitation, precipitation of wettest month and precipitation of driest month) have been taken into account for the species distribution modeling. The altitude map was generated from the DEM of SRTM and the slope and aspect were generated from the altitude

map using surface analysis in ESRI ArcGIS 10.3 software. The 5 bioclimatic variables viz. Bio\_1 (Annual mean temperature), Bio\_5 Maximum temperature of warmest month), Bio\_6 (Minimum temperature of coldest month), Bio\_12 (Annual precipitation), Bio\_13 (Precipitation of the wettest month) and Bio\_14 (Precipitation of the driest month) in .BIL format were converted into .ASC format and clipped to match with other environmental layers. All the environmental layers were clipped to match the area of interest and submitted to MaxEnt software 3.3.3k for suitability modeling of the species. The output in .ASC format was imported into ArcMap and the value domain of 0–1 has been converted to different suitable categories of tea in the study area.

**RESULTS**

**Parametric Characteristics**

The altitude of the study area ranges in between 132 m to 4,317 m with an average height of 996 m (Figure 2A)

Table 1. Parameters characteristics of the study area

Parameters	Category	Area (km <sup>2</sup> )	Area (%)	Statistical Variable	Value	Source
Altitude (m)	0–500	2173.74	51.62	Minimum	132	A
	500–1,000	440.15	10.45	Maximum	4317	
	1,000–1,500	392.63	9.32	Average	996.02	
	1,500–2,500	735.30	17.46	STDEV	991.41	
	2,500–3,500	404.11	9.6			
	3,500–4,317	64.81	1.55			
	<b>Total</b>		<b>4210.74</b>	<b>100</b>		
Slope (degree)	Level (0–5)	2112.14	50.16	Minimum	0	B
	Gentle (5–10)	504.19	11.97	Maximum	32.93	
	Moderate (10–15)	443.57	10.53	Average	7.49	
	(Steep) 15–30	1044.14	24.80	STDEV	8.17	
	Very Steep (30 & Above)	106.69	2.53			
	<b>Total</b>		<b>4210.74</b>	<b>100.00</b>		
Slope Aspect	Flat (-1–0)	16.73	0.40	Minimum	(-) 1	B
	North (0–22.5)	290.96	6.91	Maximum	360	
	Northeast (22.5–67.5)	365.71	8.69	Average	209.42	
	East (67.5–112.5)	165.24	3.92	STDEV	101.13	
	Southeast (112.5–157.5)	206.98	4.92			
	South (157.5–202.5)	582.95	13.84			
	Southwest (202.5–247.5)	795.85	18.90			
	West (247.5–292.5)	727.11	17.27			
	Northwest (292.5–337.5)	782.21	18.58			
	North (337.5–359.9)	277.01	6.58			
<b>Total</b>		<b>4210.74</b>	<b>100.00</b>			

Table 1. (Continued)

Parameters	Category	Area (km <sup>2</sup> )	Area (%)	Statistical Variable	Value	Source
Bio_1 : Mean Annual Temperature (° C)	2.5–9.6	242.25	5.75	Minimum	2.5	C
	9.6–13.5	482.63	11.46	Maximum	22.9	
	13.5–17.0	614.19	14.59	Average	18.7	
	17.0–20.4	567.05	13.47	STDEV	4.65	
	20.4–22.9	2304.62	54.73			
	<b>Total</b>	<b>4210.74</b>	<b>100.00</b>			
Bio_5: Temperature of hottest month (° C)	13.8– 19.9	301.14	7.15	Minimum	13.8	C
	19.9–23.4	366.16	8.70	Maximum	31.4	
	23.4–26.5	654.64	15.55	Average	27.76	
	26.5–29.4	625.97	14.87	STDEV	4.07	
	29.4–31.4	2262.83	53.74			
	<b>Total</b>	<b>4210.74</b>	<b>100.00</b>			
Bio_6: Temperature of coldest month (° C)	(-) 12.2–(-) 4.4	242.34	5.76	Minimum	(-) 12.2	C
	(-) 4.3–(-) 4	32.57	0.77	Maximum	9.3	
	(-) 4–3.2	1060.72	25.19	Average	4.90	
	3.2–6.7	591.97	14.06	STDEV	4.72	
	6.7–9.3	2283.14	54.22			
	<b>Total</b>	<b>4210.74</b>	<b>100.00</b>			
Bio_12: Annual Precipitation (mm)	781– 1,519	329.31	7.82	Minimum	781	C
	1,519–2,029	411.18	9.77	Maximum	3,142	
	2,029– 2,521	435.46	10.34	Average	2617.44	
	2,521–2887	1062.93	25.24	STDEV	560.68	
	2887–3142	1971.86	46.83			
	<b>Total</b>	<b>4210.74</b>	<b>100.00</b>			
Bio_13: Precipitation of wettest month (mm)	168–336	370.31	8.79	Minimum	168	C
	336–462	437.75	10.40	Maximum	710	
	462–564	697.02	16.55	Average	565.35	
	564–634	1028.49	24.43	STDEV	124.83	
	634–710	1677.18	39.83			
	<b>Total</b>	<b>4210.74</b>	<b>100.00</b>			
Bio_14: Precipitation of driest month (mm)	4–8	214.30	5.09	Minimum	4	C
	8–11	570.87	13.56	Maximum	20	
	11–14	786.86	18.69	Average	15.26	
	14–17	1115.41	26.49	STDEV	3.55	
	17–20	1523.30	36.18			
	<b>Total</b>	<b>4210.74</b>	<b>100.00</b>			

A. www.worldclim.org; B. Surface analysis from altitude (ArcGIS); C. Clipped from worldclim data using ArcGIS

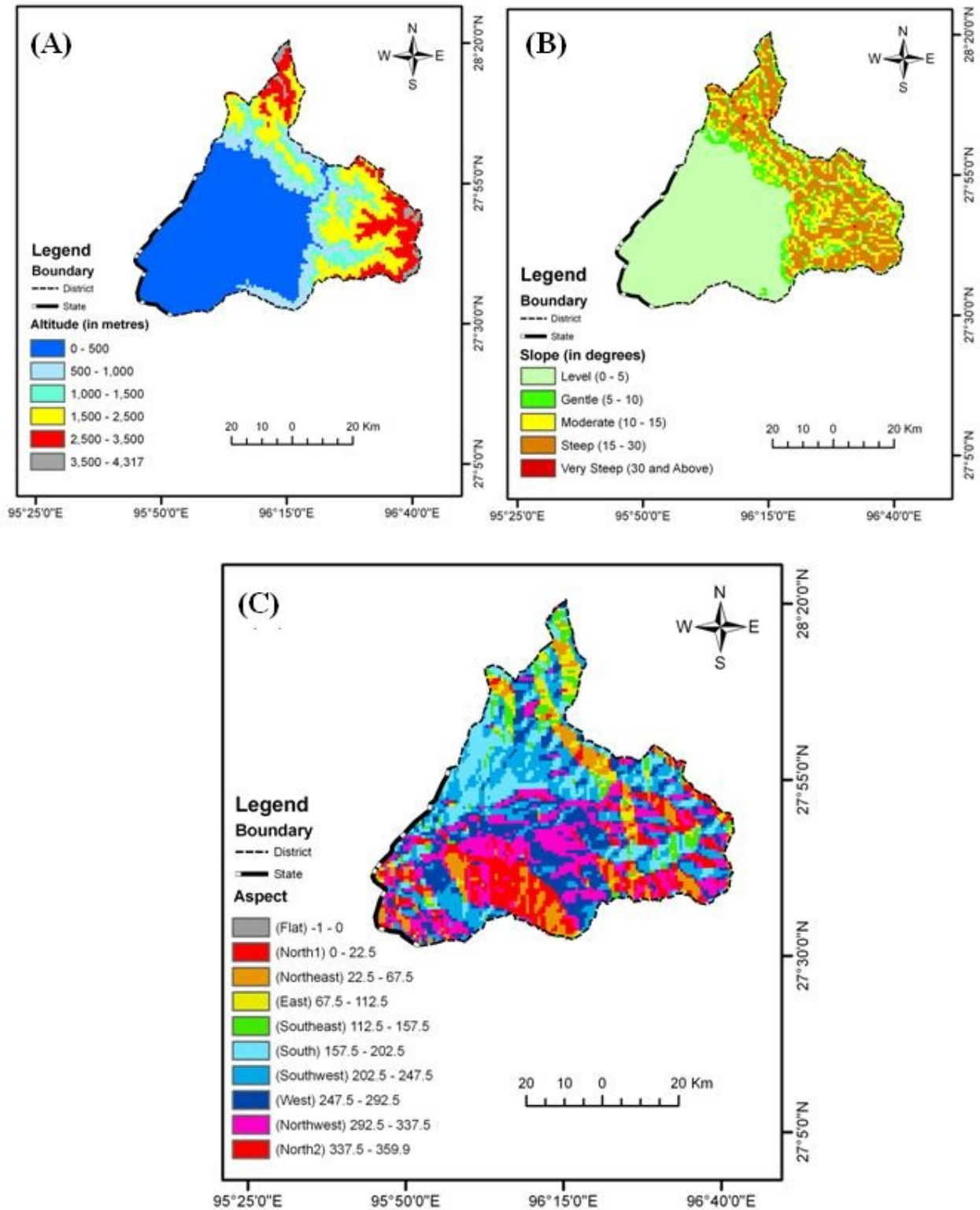


Figure 2. (A) Altitude, (B) Slope, (C) Aspect

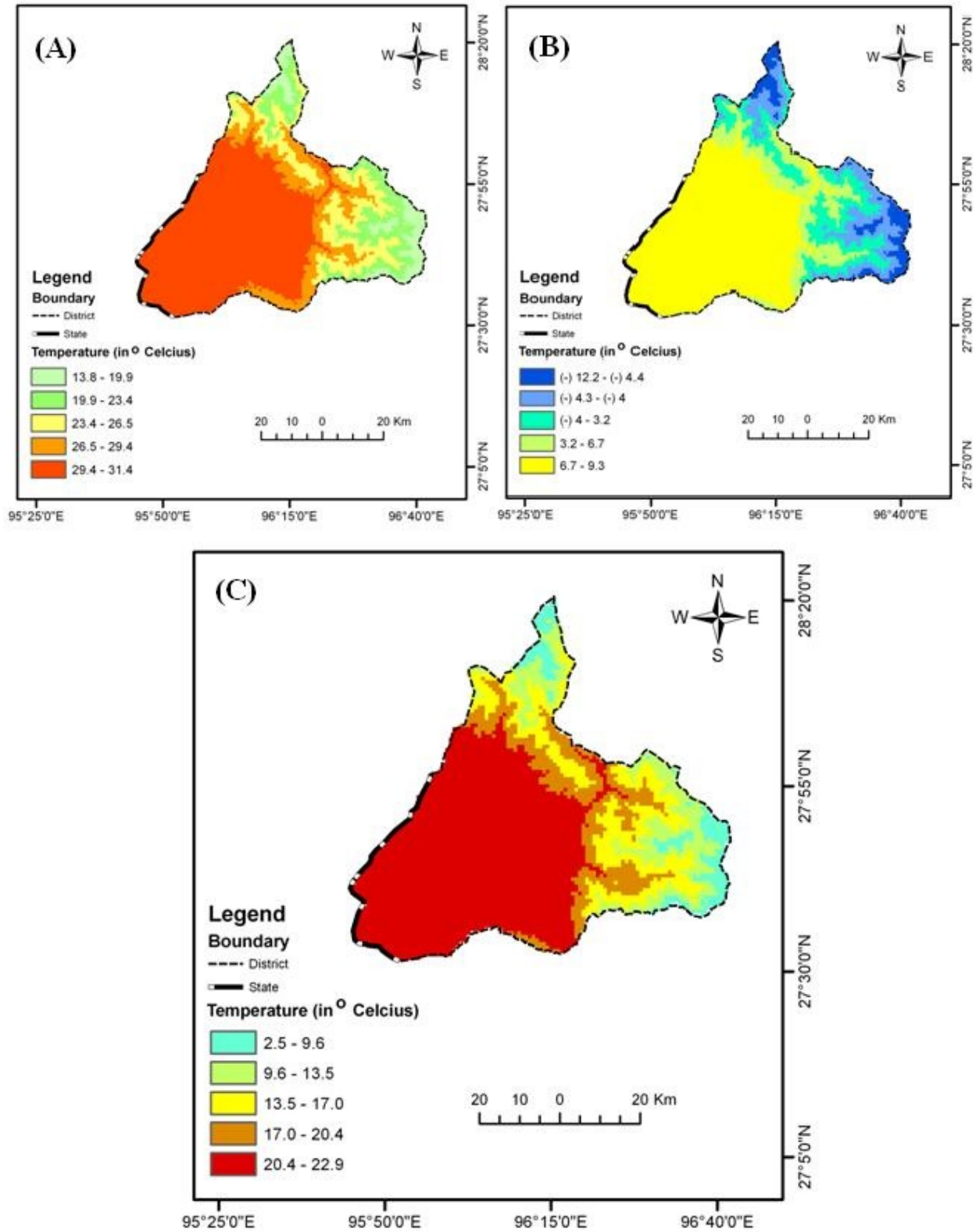


Figure 3. (A) Maximum Temperature of the Hottest Month, (B) Minimum Temperature of the Coldest Month, (C) Mean Annual Temperature

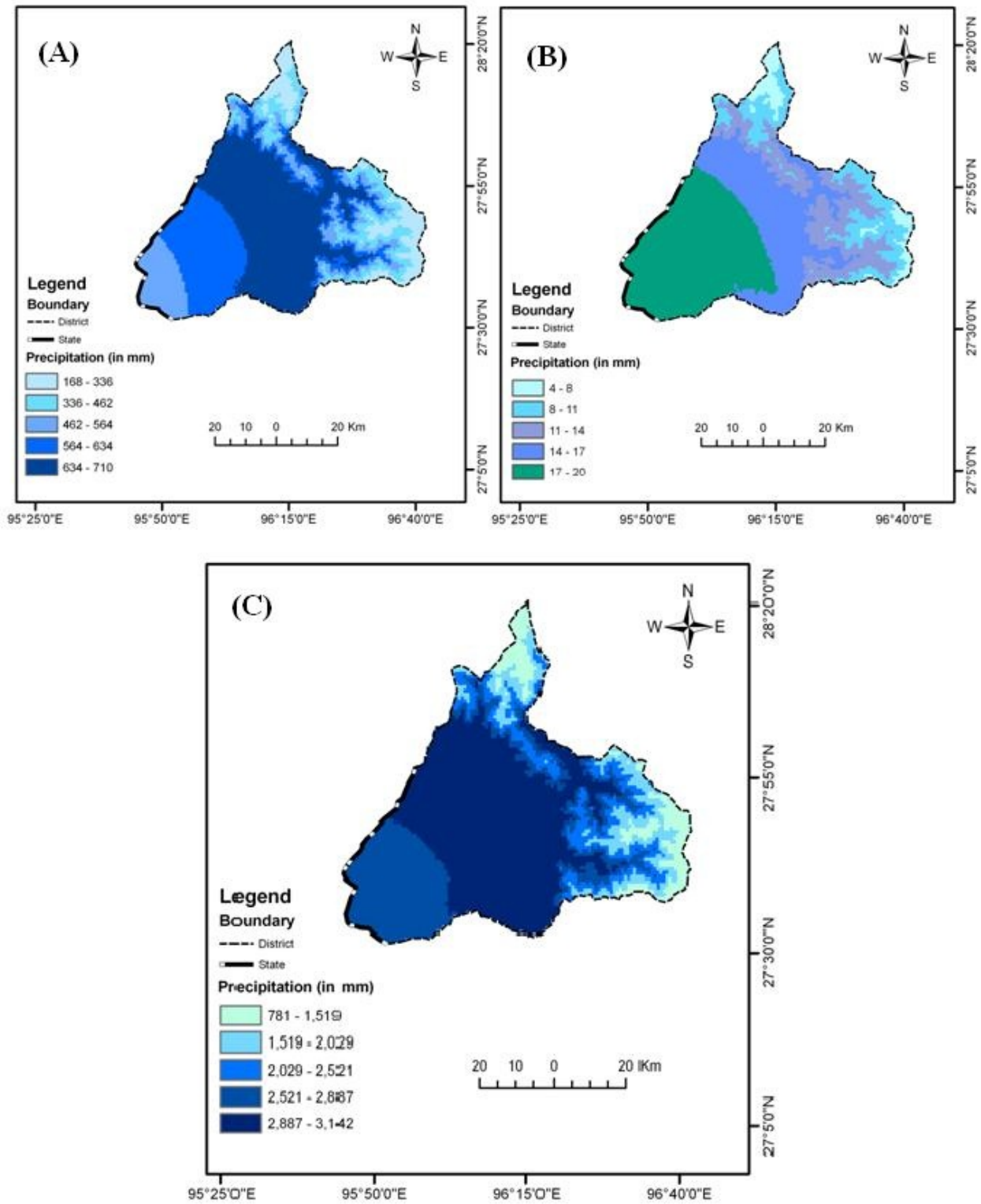


Figure 4. (A) Precipitation of the Wettest Month, (B) Precipitation of the Driest Month, (C) Annual Precipitation

Majority of the area falls under the altitude below 500 m (51.62%) and lowest area of 1.55% under 3,500 to 4,317 m. Slope in degree of the study area ranges between 0° to 32.93° (Table 1). Maximum area experiences slope of 0–5° and lowest area of 2.53% under slope of 30° and above (Figure 2B). Southwest facing slope has maximum area of about 18.90% (Figure 2C). The average annual temperature ranges in between 2.5° to 22.9° C (Figure 3A). Maximum area of 54.73% experiences average annual temperature of 20.4° to 22.9° C and lowest area of 5.75% under the average annual temperature of 2.5° to 9.6° C (Table 1). The temperature of hottest month ranges in between 13.8° to 31.4° C (Figure 3B). Maximum area of 53.74% falls under the temperature range of 29.4° to 31.4° C and lowest area of 7.15% under the temperature range of 13.8°–19.9° C. The temperature of the coldest month ranges between –12.2° to 9.3° C (Figure 3C). Maximum area of 54.22% falls under the temperature range of 6.7° to 9.3° C and lowest area of 0.77% under the temperature range of –4.3 to –4° C. The annual precipitation of the area ranges in between 781 mm to 3,142 mm with an average of 2,617.44 mm (Figure 4A). Maximum area of 46.83% falls under the precipitation range of 2,887-3,142 mm and lowest area of 7.82% under the precipitation range of 781-1,519 mm. The precipitation of wettest month ranges in between 168 mm to 710 mm (Figure 4B). The highest area of 39.83% falls under the precipitation range of 634–710 mm and lowest area of 8.79% under the precipitation range of 168-336 mm. The precipitation of driest month ranges in between 4.0 mm to 20.00 mm (Figure 4C). The highest area of 36.18% falls under the precipitation range of 17-20 mm and lowest area of 5.09% under the precipitation range of 4–8 mm.

**Species Distribution Modeling**

The occurrence records of tea and environmental layers are submitted to MaxEnt to derive the species distribution model. The 94 GPS points of *Camellia sinensis* recorded during the linear transect survey was used as geo-referenced occurrence data. The species name, latitude and longitude were entered into excel spreadsheet and converted to .CSV format as input layer. Out of 94 occurrence points 55 presence records were used for training and 10,055 points were used to determine MaxEnt distribution (background and presence points). Bio\_1 (Mean annual temperature), Bio\_5 Maximum temperature of warmest month), Bio\_6 (Minimum temperature of coldest month), Bio\_12 (Annual precipitation), Bio\_13 (Precipitation of wettest month) and Bio\_14 (Precipitation of driest month), altitude, slope and aspect (generated from altitude map through surface analysis of ArcGIS 10.3) were used as input layers of environmental variables. The regularized training gain was 3.759, unregularized training gain was 4.162 and algorithm converged after 500 iterations (20 seconds). The relative contributions of the environmental variables to the MaxEnt model shows that the highest gain when used in isolation was altitude which therefore appears to have the most useful information in the species distribution. The environmental variable that decreases the gain the most when it is omitted is Bio\_14 (Precipitation of driest month), which therefore appears to have the most information that is not present in the other variables. The final output in .ASC format was imported to ArcGIS and the value domain of 0–1 was redistributed into five suitable classes. The areas with 0–0.15 were assigned least suitable which constitute the

Table 2. Suitability categories of Tea (*Camellia sinensis*) in the study area

Suitability Index	Category	Area (km <sup>2</sup> )	Area (%)	GPS Points	
				Pixels	%
0–0.15	Least Suitable	2312.73	54.92	03	3.19
0.15–0.35	Slightly Suitable	394.91	9.38	02	2.13
0.35–0.50	Moderately Suitable	576.45	13.69	04	4.26
0.50–0.70	Suitable	740.77	17.59	09	9.57
0.70–0.80	Highly Suitable	185.87	4.41	76	80.85
Total		4210.74	100.00	94	100.00

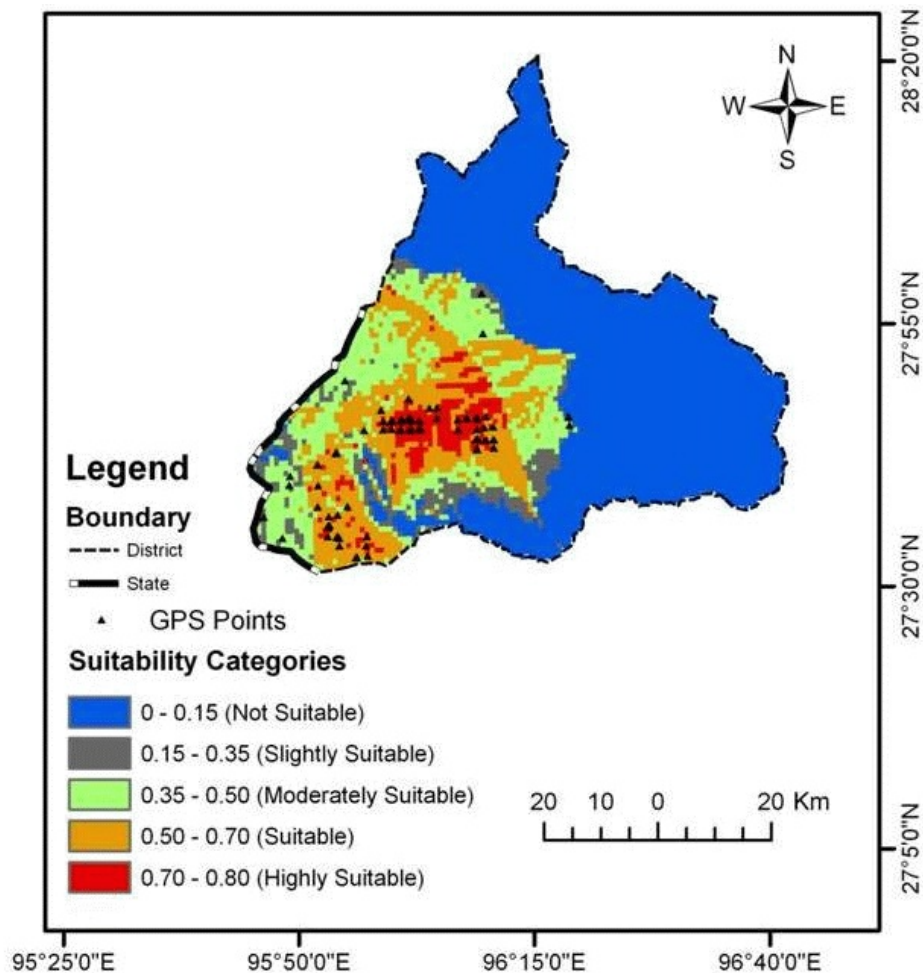


Figure 5. Suitability Modeling of Tea (*Camellia sinensis*)

highest 54.92 % of the total area. The areas with 0.15–0.35 was categorized as slightly suitable which constitutes 9.38 % of the total area. The areas with 0.35–0.50 (moderately suitable), 0.50–0.70 (suitable) and 0.70–0.80 (highly suitable) constitutes 13.69 %, 17.59 % and 4.41 % respectively (Table 2; Figure 5).

## DISCUSSION

The environmental characteristics that are considered to be most influencing on tea quality are soil, shade, slope, aspect, climate (particularly precipitation levels), elevation, nearness to a river, etc. (Reynertson and Mahmood 2015). The nature of terrain plays a significant role in tea cultivation and the quality and quantity of raw materials depend upon it. It determines the soil fertility, method of cultivation as well as mode of transportation. The tea plant is highly adaptable, and can grow in a

broad range of conditions. Altitude, slope and aspect have enormous importance to tea plants and also to soil conditions (Dutta 2010). Most of the tea plantations in India are found at elevations varying from 600 to 1,800 m (msl). It is planted in flat and slightly undulating land at elevation ranging from 20 to 250 m above sea level in major part of the plains of North East India. On hill slopes of Darjeeling and South India, it is planted up to a height of 2,000 m (msl). The steep and hilly slopes are not suitable for some specific food crops, but they are, nevertheless suitable for highland crops such as tea and coffee cultivation as well as animal grazing (Tossam and Fombe 2015). Tea, a water loving plant, tends to be grown on the windward sides of mountain ranges. Tea plants like well-drained soil which explains why tea is usually grown in the highlands where the natural drainage is good. Most of the commercially-managed tea plantations in the world are found in the highlands and on hill slopes where the natural drainage system is good.

Tea cannot tolerate stagnant water and waterlogged lowlands are thus least suited to tea cultivation. Tea bush is a tropical and sub-tropical plant and thrives well in a moderately hot and humid climate. Tea is mostly cultivated in the monsoon lands as these areas are characterized by high temperatures, long growing season and heavy rainfall which helps in the growth of the plants. The ideal climate of tea is misty at night, sunny during the day, with rain at tea-time and not too much cold weather and hail or drought. Tea is a monoculture crop with very less inter-culture operation and no crop rotation. Such conditions ultimately lead to degradation of soil environment and health of the bushes. The monoculture of tea is said to cause a condition of improper soil functioning known as soil sickness (Barua 1969). Inadequate soil water supply is a major cause of low crop productivity. So to solve low crop productivity an adequate supply of soil water is essential (Shaxson and Barber 2003).

Presently, tea cultivation is highly significant in the agrarian economy of the people. The social interaction with the neighboring state of Assam has made them realize the commercial importance of tea cultivation. The first tea plantation in Lohit district was initiated by Arunachal Pradesh Forest Corporation in the year 1980 at Medo as "Medo Tea Estate". Later, a resident of Chongkham namely Chow Meheo Namchoom was the first to undertake private tea cultivation in the year 1984. Mrs. Basamlu Krisikro, a lady hailing from Wakro, started cultivating organic tea in the year 2010. She inspired many people of her community to grow organic tea and changed the mindset of people addicted to opium. In 2012, she sold 8,500 kg of green tea made in a small mechanical factory she had set up. She found buyers from Canada, Australia, USA, Japan and Germany for her Wakro Organic Tea brand (The Hindustan Times 2013). The introduction of tea in Lohit has contributed immensely towards the socio-economic development of the people. Tea industry is a perennial industry which provides employment round the year. It creates employment opportunities in the field of manufacturing, transportation of green leaf and supply of required implements in the garden. Many of the local people are engaged as managers, supervisors, labour, etc. in the recent days (Potom and Nimasow 2016). Therefore, extensive field work, statistical approach and geospatial techniques will be helpful in suitability modeling of such important crops.

The suitability model predicted greater prospects of expanding the tea cultivated areas in future. The moderately suitable area of 576.45 km<sup>2</sup> can be utilized by

the farmers for future expansion of tea cultivation with suitable inputs to boost their economy. Further, the suitable and highly suitable areas which together constitute about 22 % of the total area and presently under tea cultivation should be properly maintained to get maximum output for their economic betterment. Concerted efforts with the local community participation and the state government in expanding the tea plantation areas could help in raising the living standard of the people. Tea plantation is one time huge investment and if scientifically and properly managed then it has more than 100 years of economic life.

#### ACKNOWLEDGEMENTS

We are thankful to the owners, managers, labourers and the public in general for providing relevant information of tea plantation in the area. We extend our thanks also to the Department of Geography, Rajiv Gandhi University, Rono Hills, Doimukh (Itanagar) for providing necessary help for carrying out Ph.D. related work. Both the authors conceptualized and designed the research. The first author collected data from the field, tabulated and drafted the paper while the second author analysed the data and derived logical interpretation of the results.

#### REFERENCES

- Barua, D.N. 1969. Seasonal dormancy in tea (*Camellia sinensis* L.). *Nature* 224: 514.
- Cabrera, C.; Artacho, R. and Gimenez, R. 2006. Beneficial effects of green tea-a review. *Journal of the American College of Nutrition* 25(2): 79-99.
- Cabrera, C.; Gimenez, R. and Lopez, M.C. 2003. Determination of tea components with antioxidant activity. *Journal of Agricultural and Food Chemistry* 51(15): 4427-35.
- Carr, M.K.V. 1972. The climatic requirements of the Tea plant: A review. *Experimental Agriculture* 8(1): 1-14.
- Chahouki M.A.Z. and Sahragard, H.P. 2016. MaxEnt Modelling for Distribution of Plant Species Habitats of Rangelands (Iran). *Polish Journal of Ecology* 64(4): 453-467.
- Chahouki, M.A.Z and Esfanjani, J. 2015. Predicting potential distribution of plant species by modeling techniques in southern rangelands of Golestan, Iran. *Journal of Range Management and Agroforestry* 36(1): 66-71.
- Chahouki, M.A.Z. 2011. Multivariate analysis techniques in environmental science. *Earth and Environment Sciences* 1: 539-564.
- Dutta, R. 2010. An integrated approach for monitoring tea plantations. <http://geospatialworld.net/Paper/Application/ArticleView.aspx?aid=170>. (Retrieved on 26 March 2016).

- Grinnell, J. 1917. Field tests of theories concerning distributional control. *American Naturalist* 51: 115–128.
- Kumar, S. and Stohlgren T.J. 2009. MaxEnt modeling for predicting suitable habitat for threatened and endangered tree *Canacomyrica monticola* in New Caledonia. *Journal of Ecology and the Natural Environment* 1: 94–98.
- Kumar, V.P. and Shruthi, B.S. 2014. Tea: An Oral Elixir. *Scholars Academic Journal of Pharmacy* 3(1): 9–18.
- Nimasow, G.; Nimasow, O.D.; Rawat, J.S.; Tsering, G. and Litin, T. 2016. Remote sensing and GIS-based suitability modeling of medicinal plant (*Taxus baccata* Linn.) in Tawang district, Arunachal Pradesh, India. *Current Science* 110(2): 219–227.
- Nizara, A. 2013. Indian Tea Scenario. *International Journal of Scientific and Research Publications* 3(7): 1–10.
- Phillips, S.J.; Anderson, R.P. and Schapire, R.E. 2006. Maximum entropy modeling of species geographic distributions. *Ecological Modelling* 190: 231–259.
- Potom, R. and Nimasow, G. 2016. Status and constraints of tea cultivation in Lohit District of Arunachal Pradesh, India. *International Journal of Current Science* 19(1): E 156–155.
- Reynertson, K.A. and Mahmood, K. 2015. *Botanicals: Methods and Techniques for Quality & Authenticity*. CRC Press, Taylor & Francis Group, New York, USA. 332 pages.
- Shaxson, F. and Barber, R. 2003. Optimizing Soil Moisture for Plant Production. The Significance of Soil Porosity. *FAO Soils Bulletin* 79, Rome, Italy. 107 pages
- Soni, R.P.; Katoch, M.; Kumar, A.; Ladohiya, R. and Verma, P. 2015. Tea: Production, Composition, Consumption and its Potential an Antioxidant and Antimicrobial Agent. *International Journal of Food and Fermentation Technology* 5(2): 95–106.
- Tariq, M.; Naveed A. and Ali, K.B. 2010. The morphology, characteristics and medicinal properties of '*Camellia sinensis*' tea. *Journal of Medicinal Plants Research* 4(19): 2028–2033.
- The Hindustan Times. 2013. 'Tea Lady' inspires drug addicts to shun habit, do tea farming, 4th March (Retrieved on 29 February 2016).
- Tossam, H.N. and Fombe, L.F. 2015. Slope Morphology and Impacts on Agricultural Productivity in the Kom Highlands of Cameroon. *Advances in Social Sciences Research Journal* 2(9): 92–103.
- Worldclim – Global Climate Data. Free climate data for ecological modelling and GIS. [www.worldclim.org](http://www.worldclim.org).
- Yang, X.Q.; Kushwaha S.P.S. and Saran, S. 2013. Maxent modeling for predicting the potential distribution of medicinal plant, *Justicia adhatoda* L. in Lesser Himalayan foothills. *Ecological Engineering* 51: 83–87.
- Yemane, M.; Chandravanshi, B.S. and Wondimu, T. 2008. Levels of essential and non-essential metals in leaves of the tea plant (*Camellia sinensis* L.) and soil of Wushwush farms, Ethiopia. *Food Chemistry* 107: 1236–1243.

Received 16 July 2019  
Accepted 8 October 2019