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Land Suitability Analysis for Cashew Plantation in Bastar district, Chhattisgarh, India: Multi-Criteria Evolution approach of Geospatial Technology

Akhilesh K Tripathi[1], Amit Prakash Multaniya[2], Hemant Dansena[3]
Chhattisgarh Council of Science & Technology, Raipur, CG, India [1, 3]
Chhattisgarh Swami Vivekanand Technical University, Bhilai, CG, India[2]
akhil_sci1980@rediffmail.com[1], amultaniya@gmail.com[2], hemant.dansena88@gmail.com[3]

Abstract: *Assessment of land suitability potentials is an important step to detect the environmental limit for sustainable land management (SLM) for Cashew plantation. Multi criteria Evaluation (MCE) methods are used to analyze the land suitability evaluation. Land evaluation is carried out to estimate the suitability of land for a specific use such as arable farming or irrigated agriculture. Land suitability evaluation is a prerequisite for land-use planning and development. It provides information on the constraints and opportunities for the use of the land and therefore guides decisions on optimal utilization of land resources. The aim in integrating Multi criteria Evaluation (MCE) with Geographical Information Systems (GIS) is to provide more flexible and more accurate decisions to the decision makers in order to evaluate the effective factors. Furthermore, by changing the parameters in this type of method, a wide range of decision strategies or scenarios can be generated in some procedures. The goal of this research is to take the advantage of incorporation of thematic analysis into GIS-based land suitability analysis by Multi criteria decision analysis (MCDA). The nature of the MCDA procedure depends on some parameters, which can be specified by weighted thematic factors. The MCE procedure is illustrated using land-use suitability analysis in Bastar district. Commodity development requires site selection which should be established prior to large scale development. The land suitability criteria for Cashew are not presently available. The objective of this Study is to establish the criteria of land suitability for Cashew in Bastar district, based on its production and land characteristics. In the present Study, the spatial data base of soil, surface elevation, mean annual rainfall, mean annual temperature, mean minimum temperature and mean maximum temperature at district level was prepared under GIS environment for the crop suitability studies. The investigation area factors are classified into five classes viz. Very suitable, suitable, moderately suitable, marginally suitable and not suitable. The final results showed that there are more locations for Cashew plantation for Bastar district. In the present Study there are sporadic areas identified as suitable sites for plantation. In the land suitability analysis 8.00% area found very suitable for plantation, 9.16 % area found suitable, 40.04% moderate suitable and 28.07% marginally suitable. Out of the remaining area, 14.73% area is found not suitable. It can be concluded that benefits of modern technology for identification of suitable land in cultivation of Cashew plant and it may be more beneficial for the farming community as well as agriculture society by providing better techniques of cultivation of Cashew plantation in the Study area.*

Keywords: *Author Remote sensing, GIS, Multi criteria Evaluation (MCE) and Cashew Plantation*.

1. INTRODUCTION

Cashew (Anacardium Occidentale) is one of the largest foreign exchange producing perennial horticultural crops in India. Though, it is an exotic horticultural crop brought to India by Portuguese travelers in 16th Century mainly to prevent soil erosion but now adapted well in Indian conditions[1–4]. Cashew is grown in India, Brazil, Vietnam, Tanzania, Mozambique, Sri Lanka, Indonesia and other tropical Asian countries such as the Philippines, Thailand and African countries such as Kenya and Nigeria. At present, It is grown extensively in more than 28 countries around the world [5]. India occupies first place in terms of area as well as production of Cashew nut [5,6]. Cashew cultivation in India confines mainly to the peninsular areas. It is grown in Kerala, Karnataka, Goa and Maharashtra along the West coast and Tamil Nadu, Andhra Pradesh, Orissa and West Bengal along the east coast[7]. To a limited extent Chhattisgarh, Jharkhand, Manipur, Tripura, Meghalaya and Andaman and Nicobar Islands also take part in the cultivation and production of Cashew [3,8]. It is spreading in non-traditional areas such as Bastar region of Chhattisgarh and Plain regions of Karnataka, Gujarat, Jharkhand and Highly region of NE states. Due to its high nutritional value and increasing affordability by the consumers, demand for Cashew continues to increase both in India and in foreign countries [1,3].

In Chhattisgarh, it is being cultivated in Bastar, Dantewada, Kanker, Raigarh, Sarguja and Jashpur district occupying an area of 8000 ha with a production of 3.0 thousand metric tons and productivity of 460 kg/ha (raw nut) in spite of this about 40 thousand hectare non-traditional area can be brought under Cashew cultivation[9]. Cashew nut is a tropical tree crop of much importance. Looking to the economic importance of Cashew nut in the state has been undertaken[1,5]. Chhattisgarh has a large wasteland area suitable for Cashew cultivation mostly in the districts of Bastar and Raigarh. Cashew plantation was started in Bastar around the 1960s. The majority of the Cashew plantations raised by the Forest Department and Chhattisgarh Horticulture Department were of seedling origin. Some of the plantations are as old as 20-30 years[10,11] . Therefore, there is a possibility of locating high yielding types and other diverse types suitable for growing in waste degraded lands. There are ample opportunities to develop the Cashew in the state by eliminating the socio-economic gaps of Cashew grower's farmers of the state[5,8,12].

Assessment of land suitability potentials is an important step to detect the environmental limit for sustainable land management (SLM) for Cashew plantation. Many researchers, organizations and government agencies have established the framework to monitor the Land Suitability Analysis (LSA) for sustainable land management [13–15].These methods consider environmental qualities and conflicts in formation of land use policies for precise plantation activities[16]. LSA is one of the fundamental steps in SLM[13,15] . Therefore, the objective of the present Study was to determine the areas suitable for Cashew plantation in the Bastar District of Chhattisgarh State using GIS based MIF technique. The MIF method is one of the multi-criteria Evolution (MCE) approaches which are commonly used in land suitability analysis.[14].

Geographical Information System (GIS) based multi-criteria evolution (MCE) approach can help researchers and planners in the field of LSA to improve decision making processes [17,18]. However, MCE techniques can undertake multiple criterions in the decision making process [14,19] to find solutions with multiple alternatives [20]. GIS can provide the facility of multiple geo-spatial data analyses and more flexibility with higher precision in decisions in order to LSA[21]. Therefore, MCE based MIF method has been integrated with GIS techniques in the present Study[14].

2. MATERIALS AND METHODS

STUDY AREA

Bastar district lies approximately 19°35'06'' to 18°35'00'' north latitude and 81°20'09'' to 82°15'10'' east longitude, location map is shown in Figure 1. Bastar is at an altitude of around 600 meters above sea level and covers an area of approximately 6,597 km² with population of 834375 in census 2011, of which male and female were 413706 and 420669 respectively.

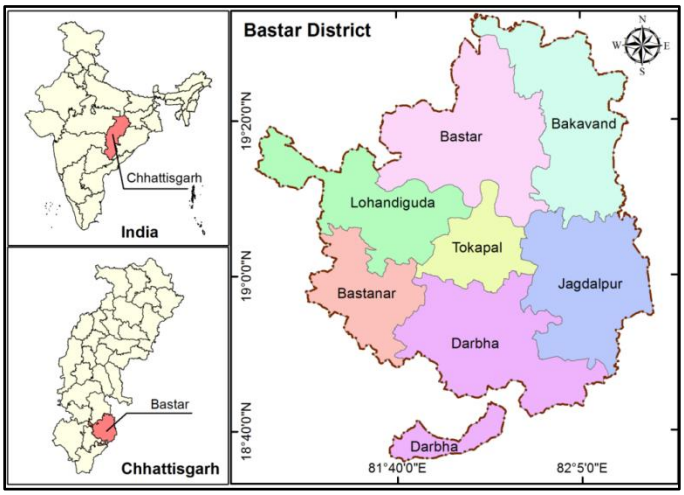


Figure 1: Location Map of the Study Area.

More than 70 percent are tribal people like Gond Tribe, Maria, Muria ,Dhruva, Bhatra, Halba Tribe, etc. Bastar is bounded on the northwest by Narayanpur District, on the north by Kondagaon District, on the east by Nabarangpur and Koraput Districts of Odisha State, on the south and southwest by Dantewada and Sukma.

DATA USE

Table 1: Geospatial data used in this Study

Factor	Description	Format	Source
Drainage network and water source	Refers to the drainage system of the Study	Vector, Shape file	Interpretation of Santinal-2 Satellite Data
Agrometrological data	Rainfall, Temperature and Relative Humidity	Raster	IMD and https://data.isric.org/
Soil	Agronomic aspects, Soil depth and textures	Vector, Shape file	https://data.isric.org/ National Bureau of Soil Survey and Land Use planning
LULC	Land utilized by human and natural	Vector, Shape file	Interpretation of Santinal-2 Satellite Data
Slope	Stability of Land surface	Raster	CartoDEM (CCoST)

Land use and land cover were delineated using Santinal-2 imagery from 2020, with an accuracy of 20 m. Image interpretation and classification was performed by supervised classification using ERDAS Imagine software, followed by field checking. Field checking was performed for each type of land use and land cover. The technique of field checking involves the observation of land use and land cover characteristics in the field, which were then matched with their appearance in the image.

Spatial data of the areas with different forest status was obtained from a LULC Map at a scale of 1:50000 and was provided by the LULC Division, Chhattisgarh Council of Science and Technology. The Agro meteorological spatial data (Rainfall, Temperature, Relative Humidity was obtained from IMD and https://data.isric.org/, and prepared at a scale of 1:100,000. Soil Units Data were obtained from National Bureau of Soil Survey and Land Use planning (NBSS&LUP) & https://data.isric.org/ and Elevation data were obtained under SIS-DP project conducted in 2011-12 on the initiative of the National Remote Sensing Centre, Hyderabad.

METHODOLOGY

In the present Study, the spatial data base of soil, surface elevation, mean annual rainfall, mean annual temperature, mean minimum temperature and mean maximum temperature at district level was prepared under GIS environment for the crop suitability studies [3,22]. The activity of Cashew nut plantation in Chhattisgarh state is provided by the Directorate Horticulture and Farm Forestry, Chhattisgarh [23] (Figure 6). Cashew area and Land suitability area map was prepared by digitization, rasterization and reclassification of the selected creations for Cashew growing locations obtained from different sources.

Multi-criteria evolution (MCE) methods have used for spatial analysis for land suitability for Cashew plantation. Land suitability analysis in the present Study can be discussed in four steps i.e. 1) selection of criterion; 2) preparation of thematic layers and data base; 3) Multi criteria decision analysis; 4) Geospatial calculation by assigned ranks to prepare land suitability map for Cashew Plantation. The final suitability map was arrived by applying the suitability criteria derived for all the selected parameters after intercepting the different layers in GIS [3]. In this Study, an attempt was also made to Study the suitability of Cashew crop with change in weather condition, which can arise due to climate change. The analysis procedure used in this research is described in Figure 2.

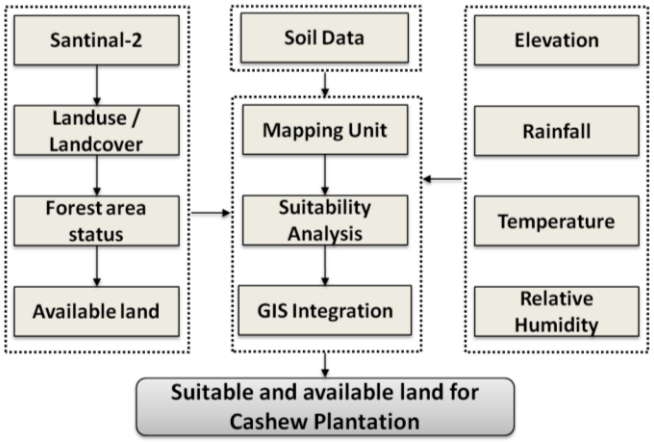


Figure 2: Research steps followed to define suitable and available land for Cashew plants

Rational for Selection of suitable land for Cashew Plantation

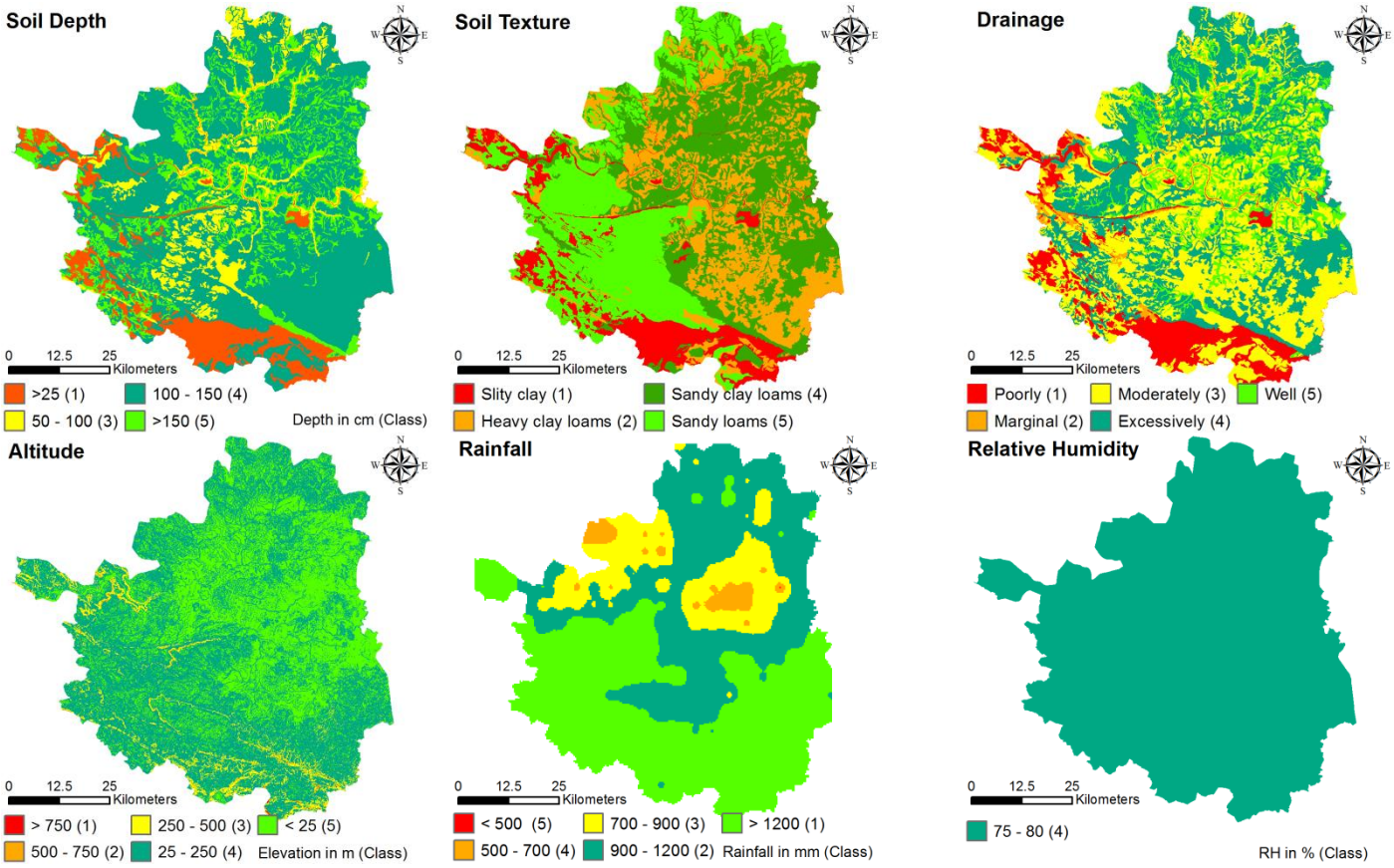
Land availability analysis was done by overlaying land use and land cover maps resulting from the Santinal-2 imagery interpretation, a map of Forest area Status and a map of Drainage network and water source then spatially overlaid to obtain spatial data for the suitability of the available land. The land suitability analysis for Cashews was conducted using Available land, Soil, Climate and Environmental factors data[24]. In GIS environment these creations was overlayed and derived the suitability criteria pertaining to each parameter for Very Suitable, Suitable, Moderately Suitable, Marginally Suitable, Not Suitable productivity regions.

Table 2: The Land suitability criteria for selection of site for Cashew growth

Sl	Land Quality/ Land Characteristics	Land suitability class				
		Very Suitable	**Suitable**	**Moderately Suitable**	**Marginally Suitable**	**Not Suitable**
I	**Soil physical characteristics**					
	Soil depth	>150	100-150	50-100	25-50	<25
	Soil texture	Sandy loams and loams sands, Slity loams	Coastal sands, loamy silty clay loams, Heavy sandy clay loams	Light clay loams, light silty loams, heavy sandy clay loams	Heavy clay loams,	Clay, sandy clay, Slity Clay
	Drainage	Well	Excessively	Moderately	Marginal	Poorly
II	**Climate and Environment factors**					
	Altitude	< 25	25-250	250-500	500-750	> 750
	Rainfall	> 1200	900-1200	700-900	500-700	< 500
	Relative humidity	70-75	75-80	80-85	85-90	> 90
	Mean annual temperature	< 24	24-25	25-26	26-27.5	> 27.5
	Max temperature (summer)	33-37	37-39	39-41	41-43	> 43
	Min temperature (Winter)	16-18	13-16 18-20	10-13	8-10	< 10
III	**Agronomic aspect**					
	Organic Carbon (%)	> 0.78	0.59-0.78	0.39-0.59	0.11-0.39	<0.11

	pH	5.4-6.4	5.1-5.4	4.8-5.1	4.6-4.8	< 4.6
IV	**Land Utility**					
	Land Use / Land Cover	Agriculture land	Waste land	Tree Clad Area	Forest	Built up, Water body

Source: (2;3)



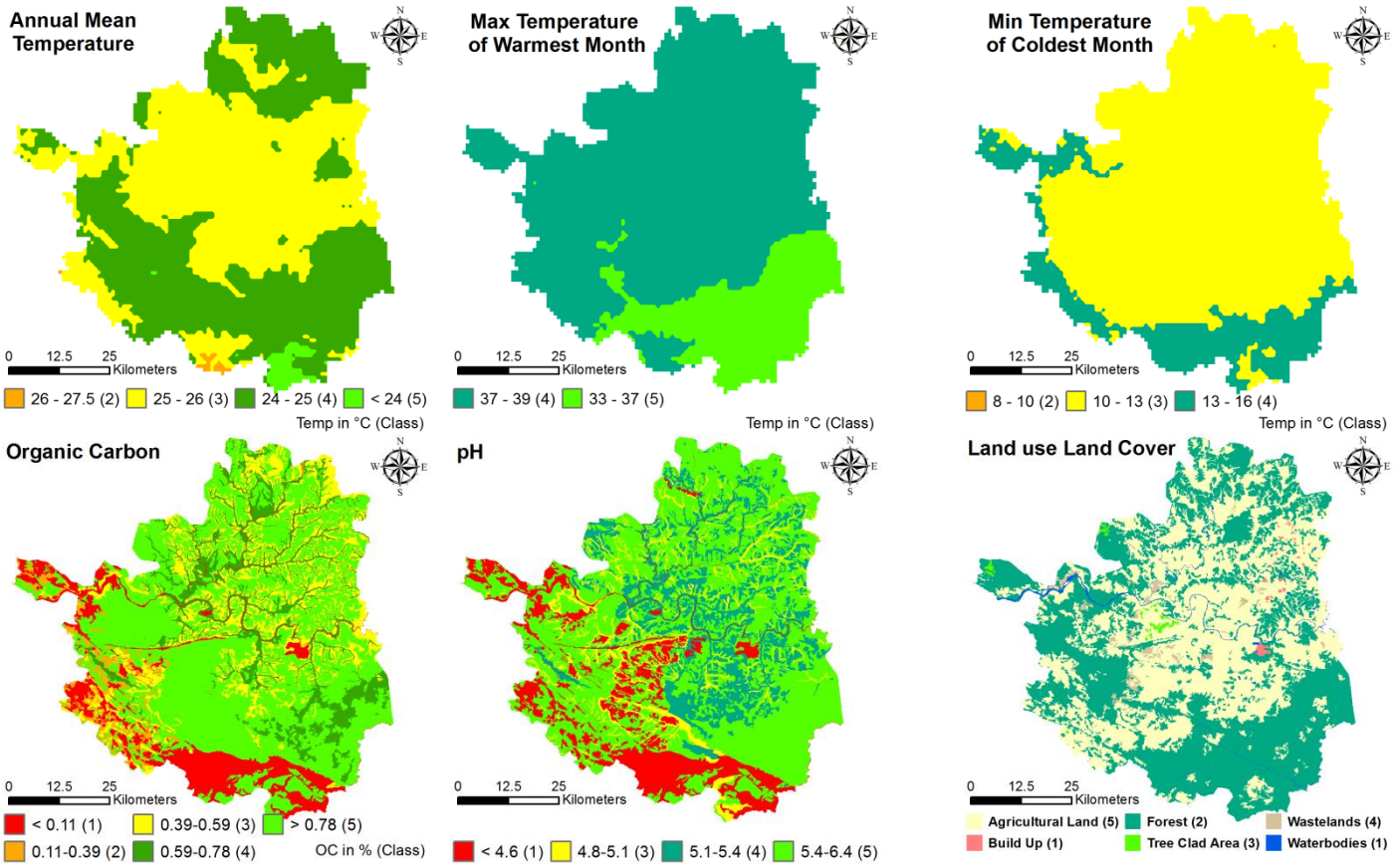


Figure 3: The Thematic maps for selection of site for Cashew growth

3. RESULTS AND DISCUSSION

Soil is the most important criterion for determining an area's suitability. The general notion is that "Cashew is very modest in its soil requirements and can adapt itself to varying soil conditions without impairing productivity"[25]. While Cashew can be grown in poor soils, its performance would be much better on good soils. The best soils for Cashew are deep and well-drained sandy loams without a hard pan. Cashew also thrives on pure sandy soils, although mineral deficiencies are more likely to occur. Water stagnation and flooding are not congenial for Cashew. Heavy clay soils with poor drainage and soils with pH more than 8.0 are not suitable for Cashew cultivation. Excessive alkaline and saline soils also do not support its growth. Red sandy loam, lateritic soils and coastal sands with slightly acidic pH are best for Cashew[22].

Suitable area for Cashew grown lies along Sandy loams and loams sands, Slity loam, Coastal sands, loamy silty clay loams and Heavy sandy clay loams (Table 2). Soil and climatic conditions of different Cashew growing area in Chhattisgarh with respect to production and productivity revealed that the well drained Sandy loams and loams sands soil with high organic matter content is ideal for growing Cashew. Land suitability in Chhattisgarh for Cashew was found to be medium in eroded Light clay loams, light silty loams, heavy sandy clay loams and waterlogged soils. Heavy clay loams, Clay, sandy clay, Slity Clay soils was found to be unsuitable for the growth of Cashew. The depth of soil should be more than 90 cm and the soil can be neutral to medium acidic (5.4 to 6.4 pH) [2,3]. Various research papers reported that brown soil or a deep well drained Laterite soil with high water holding capacity and rich in organic matter content appears to be an ideal soil type for better growth and higher productivity of Cashew. Almost all type of soils from

sandy to Laterite, deep, fertile and well drained soils in the transitional zones are the most suitable areas for Cashew cultivation. Heavy clay soils with poor drainage condition and also excessive alkalinity and salinity soils as well as areas prone to water logging and hard pan are not suitable for Cashew growing. The soil depth in Baster district, 18 % area is most suitable and 60.4 % area is suitable and only 11 % lands are not suitable. The soil texture in the Study area 29.6% is very suitable and 34.9% is suitable, which is very good for Cashew cultivation. The soil depth in the district, 13 % area is most suitable and 37 % area is suitable and only 11 % lands are not suitable for Cashew plantation.

In India, Cashew experiences severe moisture stress from January to May, adversely affects its flowering and fruit set. The elevation of the Cashew growing areas ranged from 0 to 750 m above mean sea level (MSL) and the productivity of Cashew was higher in regions upto 250 m above MSL [2–4,7,22]. Cashew is a tropical plant and can thrive even at high temperatures. Young plants are sensitive to frost. The distribution of Cashew is restricted to altitudes upto 750 m above mean sea level where the temperature does not fall below 20°C for prolonged period [25]. Areas where the temperatures range from 20 to 30°C with an annual precipitation of 1000 - 2000 mm are ideal for Cashew growing. However, temperatures above 35°C between the flowering and fruiting period could adversely affect the fruit setting and retention. Heavy rainfall, evenly distributed throughout the year is not favorable though the trees may grow and sometimes set fruit. Cashew needs a climate with a well-defined dry season of at least four months to produce the best yields. Coincidence of excessive rainfall and high relative humidity with flowering may result in flower/fruit drop and heavy incidence of fungal diseases[22].

Cashew yield increases with few light rains during January to March. But the yield will get severely affected with heavy rains resulting in immature nut drop and inferior kernel quality. The overlay maps showed that the mean annual temperature in Cashew area ranged from 20 to even more than 27.5°C whereas, the productivity was higher in regions with 26 to 30°C. The minimum and maximum temperatures in suitable area ranged from 10 to 20 °C and 33 to 40°C respectively. The productivity of Cashew was lower in regions where the minimum temperature drops below 10°C [3]. Similar results were reported by Cashew, along steep slopes of hills or on neglected land unsuitable for any other crop[26].

The altitudes elucidate that the 37% area is very suitable, 58% area is suitable and less than 1% land are not suitable for plantation activity. The rainfall condition in Baster district, 47% area is most suitable and 36% area is suitable with distributed rainfall. Relative humidity of entire Bastar is very suitable for Cashew growth. The Study shows more than 50% area has most suitable annual temperature for Cashew plantations in Baster district.

Agronomic aspects associated with nutrient retention in soil include soil pH, C-organic content and base saturation. Nutrient availabilities which affect the productivity of Cashew nuts include pH and organic carbon. The role of these elements is essential for the growth associated with vegetative performance and crop productivity[27]. As a comparison, research has reported that more than 75% area is most suitable for the best growth is obtained between Cashews grow well in Bastar within a pH range of 4.6–4.8. The Organic Carbon in Bastar soil represents more than 65% area is suitable for Cashew plantation.

Information on land use and land cover (LULC) including forest cover is important for the development of strategies for land planning and management of Cashew plantation. The overall area of Bastar District is divided into 6 Land use land cover classes. The components of LULC used in this Study include the Built-up, Agriculture land, Waste land, Forest, Tree clad area and Water body. A LULC class map of Bastar is presented in Fig. 6. LULC maps were used as input layers and additional knowledge-based information was used for land suitability. The Land use land cover map illustrate that more than 47 % land comes under sailable and 52% are not or marginally suitable for Cashew plantation in the Study area.

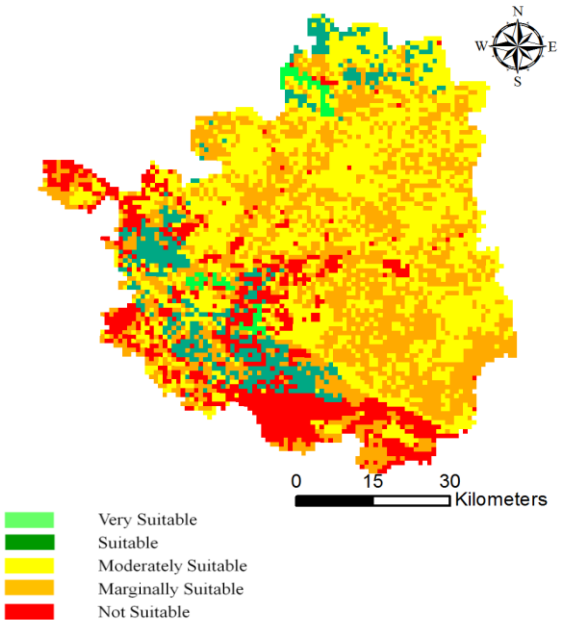


Figure 4: The Land suitability map for selection of site for Cashew growth

Table 3: Statistical analysis for the Landfill site suitability map

Class	Area (ha)	Area (%)
Not Suitable	79379.99	14.73
Marginally Suitable	151269.3	28.07
Moderate Suitable	215775.6	40.04
Suitable	49363.25	9.16
Highly Suitable	43112.01	8.00
Total	538900.1	100

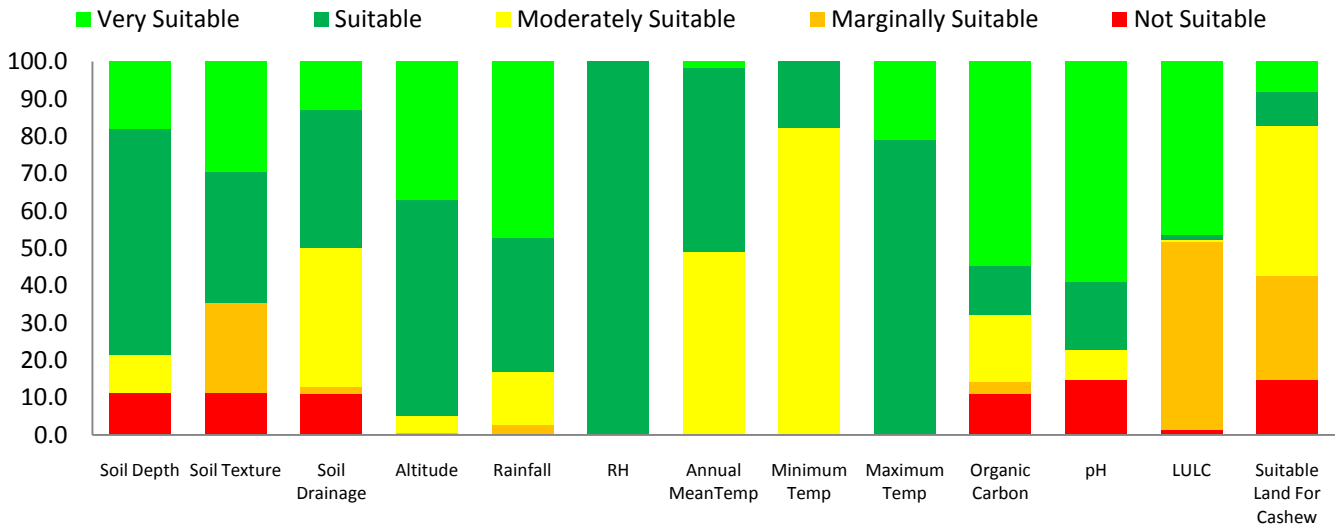


Figure 5: The Land suitability graph for Cashew plantation

4. CASHEW GROWING STATUS IN CHHATTISGARH

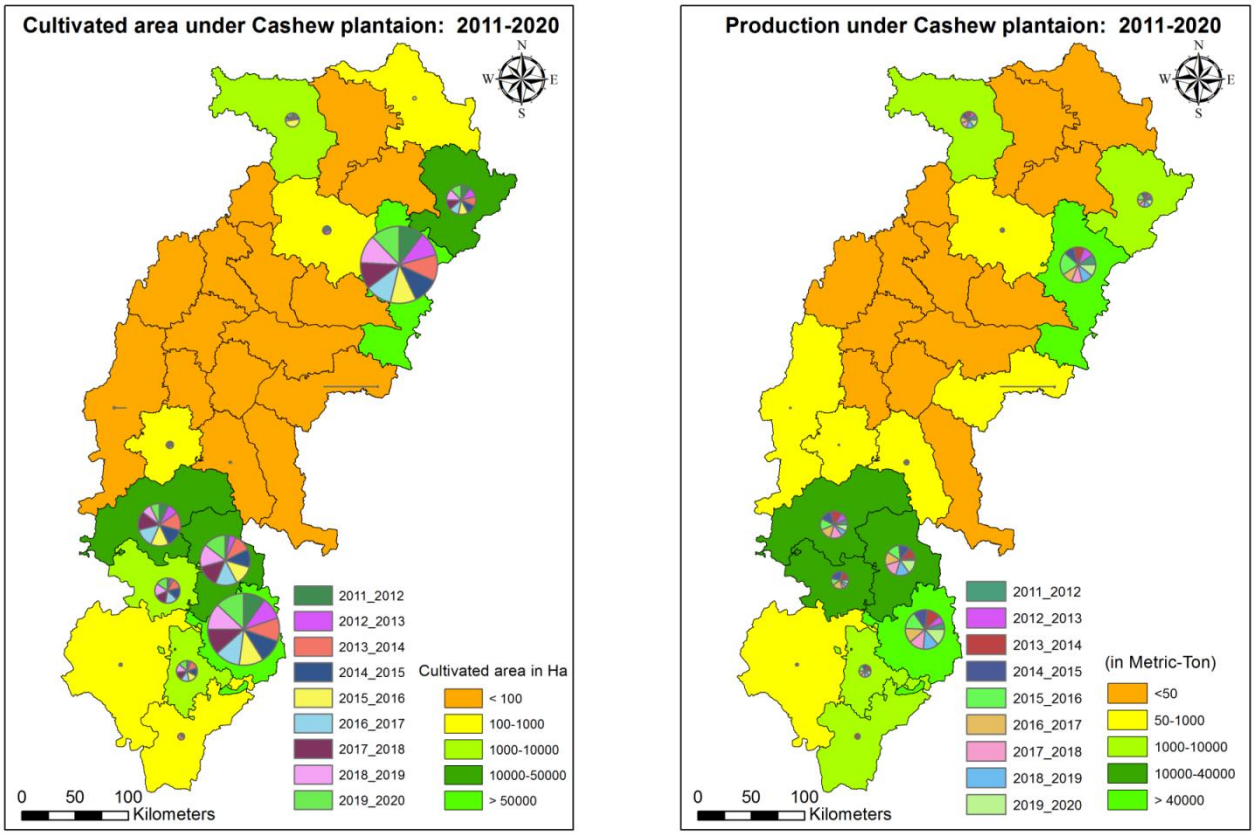


Figure 6: Production against cultivated area for Cashew plantation in Chhattisgarh

Table 4: Area under Cashew Year 2011-2020

Year	Raipur	Baloda Bazar	Gariyaband	Mahasamund	Dhamtari	Durg	Balod	Bemetara	Rajnandgaon	Kabirdham	Bastar	Kondagaon	Uttar Bastar Kanker	Dakshin Bastar Dantewada	Sukma	Bilaspur	Mungeli	Janjgir - Champa	Korba	Raigarh	Jashpur	Surguja	Surajpur	Balrampur	Koriya	Narayanpur	Bijapur	Gaurela Pendra Marwahi	Total
2011-2012	0	0	0	0	0	0	55	0	4	0	6830	920	1783	172	82	0	0	0	260	8468	1260	0	0	0	150	302	33		20319
2012-2013	0	0	0	0	0	0	57	0	7	0	7125	1445	2070	221	80	0	0	0	300	8468	1260	0	0	0	150	385	35		21603
2013-2014	0	0	0	0	12	0	70	0	7	0	7560	3716	3440	779	415	0	0	0	52	8976	1260	0	0	0	154	1210	0		27651
2014-2015	0	0	0	0	12	0	74	0	7	0	7560	4088	3448	788	4	0	0	0	55	8976	1260	0	0	0	160	1360	7		27799
2015-2016	0	0	0	0	11	0	81	0	7	0	7770	4459	3468	788	4	0	0	0	56	8976	1260	0	0	165	1374	10			28429
2016-2017	0	0	0	0	11	0	81	0	8	0	8159	4905	3570	788	5	0	0	0	57	8976	1280	0	0	0	170	1374	15		29399
2017-2018	0	0	0	0	10	0	83	0	8	0	8241	5003	3572	788	5	0	0	0	57	9096	1280	0	0	0	177	1374	17		29711
2018-2019	0	0	0	0	10	0	84	0	8	0	8405	5028	1830	788	5	0	0	0	57	9809	1460	0	0	0	194	1443	18		29139
2019-2020	0	0	0	29	10	0	84	0	8	0	9246	5053	1840	788	5	0	0	0	58	9889	1530	0	0	0	204	1374	20		30138

Table 5: Productions under Cashew Year 2011-2020

Year	Raipur	Baloda Bazar	Gariyaband	Mahasamund	Dhamtari	Durg	Balod	Bemetara	Rajnandgaon	Kabirdham	Bastar	Kondagaon	Uttar Bastar Kanker	Dakshin Bastar Dantewada	Sukma	Bilaspur	Mungeli	Janjgir - Champa	Korba	Raigarh	Jashpur	Surguja	Surajpur	Balrampur	Koriya	Narayanpur	Bijapur	Gaurela Pendra Marwahi	Total
2011-2012	0	0	0	0	0	0	0	0	4.4	0	2936	395	1783	71	34	0	0	0	80	4234	630	0	0	0	975	177	44		11362
2012-2013	0	0	0	0	0	0	0	0	8	0	3562	621	2111	93	160	0	0	0	120	4234	630	0	0	0	975	203	50		12767
2013-2014	0	0	0	0	132	0	0	0	8	0	6048	3530	3578	779	830	0	0	0	42	4234	630	0	0	0	975	1815	0		22601
2014-2015	0	0	0	0	132	0	0	0	8	0	6048	3883	3517	788	8	0	0	0	62	4237	630	0	0	0	992	2720	14		23039
2015-2016	0	0	0	0	11	0	81	0	7	0	7770	4459	3468	788	4	0	0	0	56	8976	1260	0	0	0	165	1374	10		28429
2016-2017	0	0	0	0	121	0	0	0	9	0	6589	4660	3677	638	1	0	0	0	60	4237	768	0	0	0	1206	2061	30		24057
2017-2018	0	0	0	0	121	0	0	0	9	0	6655	4753	3679	638	0	0	0	0	61	4294	896	0	0	0	1255	724	33		23118
2018-2019	0	0	0	0	125	0	0	0	10	0	6790	4777	1885	638	0	0	0	0	61	4630	1035	0	0	0	1380	761	35		22127
2019-2020	0	0	0	116	125	0	0	0	10	0	7396	4801	1932	637	0	0	0	0	61	4668	1036	0	0	0	1449	724	50		23005

(Source: http://agriportal.cg.nic.in/horticulture/HortiEn/Default.aspx)

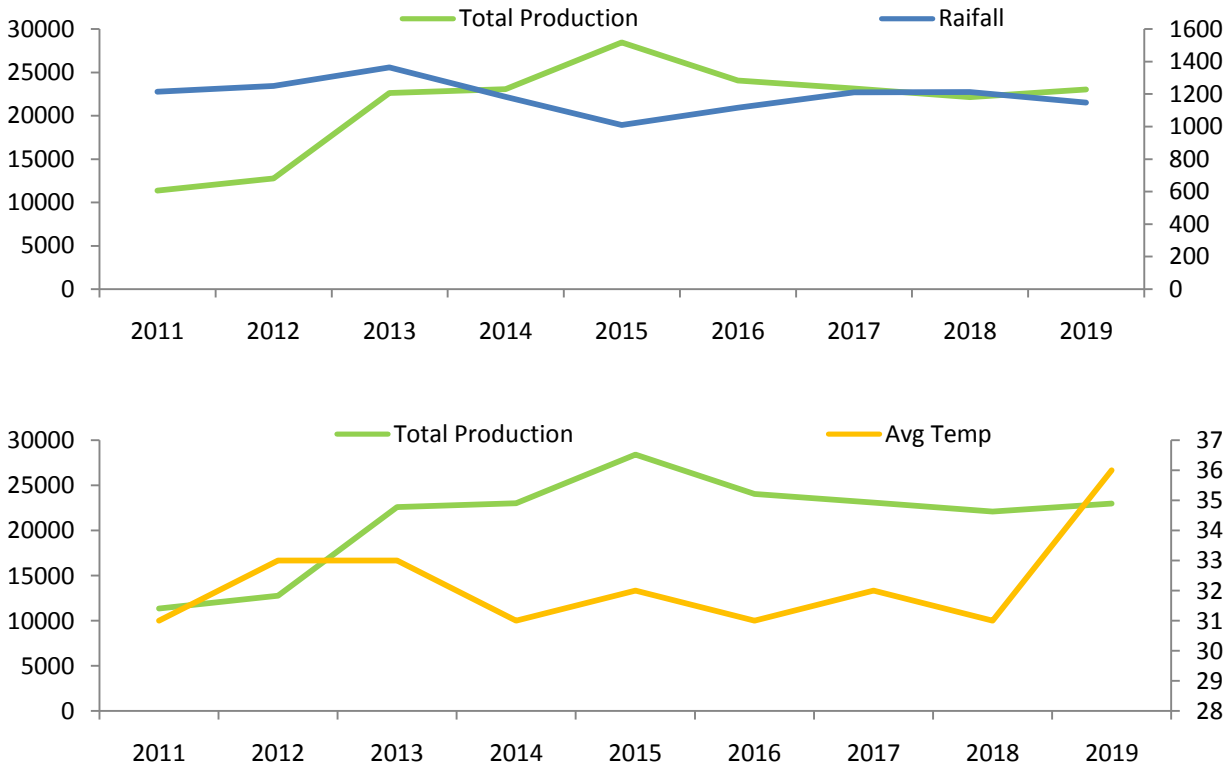


Figure 7: Production against climate condition for Cashew plantation in Chhattisgarh

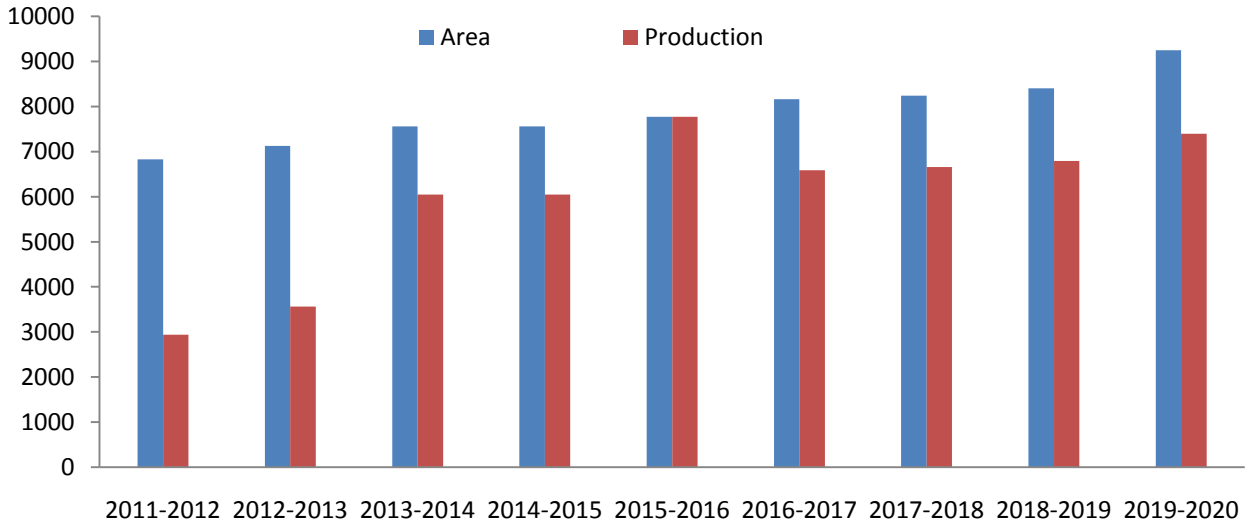


Figure 8: Area vs. Production of Cashew nut in Bastar

The effect of climate change poses many threats; one of the important consequences is bringing about changes in the quality and quantity water resources and crop productivity[28]. Based on some research paper, change in climate will impact on growth of Cashew plant. Cashew plantation is not only sensitive change in climate but also one of the major drivers for weather changes. Understanding the weather changes over a period of time and adjusting the management practices towards achieving better harvest are challenges to the growth of agricultural sector as a whole. The last 10 year weather data and Cashew production analysis illustrate as per Bastar concern, climate sensitivity of Cashew is uncertain, as there is regional variation in rainfall, temperature, Relative Humidity, cropping systems, soils and management practices. It can be concluded that less effect of change in climatic condition in the Bastar region as compare to globe in cultivation activity.

5. CONCLUSION

The optimal use of reserved land resources for Cashew plantation is a complex problem that involves subjective assessments with multiple criteria. This research established the utility of geospatial technology will provide greatest facility to achieved Land suitability for agriculture. Land suitability is a critical versatile process which can considerably affect the benefits that can be derived from the land. In the context of application, this case Study identified the land with high suitability land for agriculture use. The area estimates and spatial distributions of the land suitability from the current Study will assist local authorities, managers, and other stakeholders in decision-making and planning regarding Cashew plantation. Land suitability is a critical versatile process which can considerably affect the benefits that can be derived from the land. In the context of application, this case Study identified the land with high suitability land for Cashew plantation. It is more expensive to use land that is categorized as moderately suitable. This Study demonstrates that GIS based methods can be used in Cashew plantation planning. The current work assessed sustainable utilization of agriculture in the Bastar district by using sustainable GIS based agricultural model.

The properties of the soil, topography, climate, and agronomic condition were determined as the main criteria for determining the suitability with regard to the expert opinion and the previous literature. This map was then compared with the existing land use map of the Study region. The investigation area is classified into five classes viz. Very suitable, suitable, moderately suitable, marginally suitable and not suitable. The results show that the regions entitled suitable have already largely been under cultivation.

In conclusion, geospatial technology derived thematic layers is very useful data for assessment of suitable land in areas with substantial fragmentation, especially for climatic condition that have been effect at different levels of Cashew cultivation. It can be concluded that benefits of modern technology for identification of suitable land in cultivation of Cashew plant and it may be more beneficial for the farming community as well as governing body by providing better techniques of cultivation of Cashew plantation in the Study area. Consequently, the approach facilitates a better understanding of the alternative land-use suitability patterns. The methods developed for this Study are applicable worldwide for agriculture support. However, the model parameters always need to be re-estimated for each application.

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