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Evaluating the Variables for Banana (*Musa Sp.*) Crop Intensification in Theni District, Southern India using Multi-Criteria based GIS Analysis

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ABSTRACT

Keywords

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Increasing population stresses the need for crop intensification per unit area of land to meet the demand. Over exploitation of natural resources leads to irreversible damage to crop production eco-systems. A multi-criteria decision model (MCDM) to assess the parameters contributing to intensification leads to proper utilization of resources. This manuscript presents the findings of Analytical Hierarchical Process (AHP) derived advanced decision model Technique for Order of Preference by Similarity to the Ideal Solution (TOPSIS) for evaluating the contributing intensification parameters comprising slope, soil, precipitation and socio-economic indicators for banana plantation in Theni district, Tamil Nadu, India. The location of production areas has direct relation with crop collection centers, cold storage units and market access indicating that intensification is influenced by these parameters. TOPSIS derived crop suitability map is in cohesion with crop cover map of the study area. The analysis reveals that banana area in 2016-17 was 307 hectares and in 412 hectares in 2017 – 2018 & Banana intensified area was about 49 hectares for 2016, 2017 and 2018. Topsis analysis has revealed that an area of 43732 ha is suitable for banana wherein average 14575 hectares is under banana cultivation hence an area of 29200 is available for intensification with suitable interventions.

Introduction

Agricultural intensification is defined as improving per-acre output using hybrids/advanced cultivation methods without increasing production area (United Nations, 2010). Over exploitation of natural resources for developmental activity may affect their availability and regeneration capacity. Ever increasing population has affected the carrying capacity of land and hence, optimal utilization and quantification of natural resources are pre-requisite for management of resources. Production fluctuations occur within short time periods due to variations in weather/climate conditions call for timely and accurate monitoring systems (Campbell *et al.*, 2014).

Cropping intensity is focused in areas where suitable land, climate, capital, labour and connectivity to markets are enabled, to facilitate higher yields and returns (Van Ittersum *et al.*, 2013). Socio-environmental factors and inclusive community participation ensure success of crop intensification. The future is largely dependent on land-use changes in different scenarios and assessment of social, economic and environmental consequences under these scenarios (Kunwar, 2010).

Land suitability analysis (LSA) is a technique to deduce natural and interventional capacities to assess extent suitability to specific crops (Bandyopadhyay *et al.*, 2009). Assessment of land for different activities provides capability of land to support the requirements for potential use (Malczewski 2004). GIS based Multi-criteria decision model (MCDM) is widely employed for land suitability studies. Multi-criteria evaluation of land suitability for crop production involves different criteria like geological and biophysical elements (i.e., geology, soil characteristics, relief,

atmospheric conditions, vegetation etc.), as well as economic and socio-cultural conditions in decision making process (Joerin *et al.*, 2001). Geographical information system (GIS) provides ample scope for integration of multiple spatial variables accurately and possible permutations in analyzing land suitability (Malczewski, 2006; Vittala, *et al.*, 2010). Hence, multi-criteria decision making (MCDM) methodology has been combined with spatial analytics for evaluating the land use potentials and deciphering complexities of resource allocation/utilization (Ennaji *et al.*, 2018; Heller *et al.*, 2012). These techniques extensively used for suitability analysis to identify the potential lands for agriculture intensification. GIS based analysis has been applied for analyzing Crop intensification studies (Bera *et al.*, 2017; Ahmed *et al.*, 2016), vegetable crops intensification studies for land/site suitability analysis (Sati and Wei 2018; Mazahreh *et al.*, 2018), horticultural fruit crops (Boitt *et al.*, 2015; Boonyanuphap *et al.*, 2004).

Banana is a major tropical fruit crop being cultivated in Indian subcontinent. The area and output per unit of land has increased over the years owing to availability of disease-free tissue cultured planting material. Indian bananas have gained wider acceptance in Middle East and European markets leading to intensification of cropped area in traditional cultivation regions (NHB, 2016). Increasing population is posing pressure for optimizing of production factors like land, water and energy. Though food production has doubled in last five decades arable land has increased only by ~ 9% (Godfray *et al.*, 2010). In this context of banana crop intensification, there is need to adopt sustainable agricultural practices to contain the depletion of natural resources (Ochola *et al.*, 2013; Tilman *et al.*, 2011). The current study examines multi-criteria decision approach (MCDA) using TOPSIS model to

achieve the objectives: (i) to determine banana crop intensification parameters based on land accessibility, slope, soil, distance from drainage and rainfall (ii) analyze the extent of intensification for 2016 to 2018 time series period.

Materials and Methods

Study area

Theni district, Tamil Nadu, India lies between 9° 53' 0"N to 10° 22' 0" N latitudes and 77°17' 0" E to 77° 67' 0" E longitudes, covering an area of 2889 km² (Fig. 1). Theni District is gifted with moderate climate suitable for cultivation of major tropical and subtropical crops.

The temperature ranges between 20° - 40° C and average annual rainfall is about 951 mm. Precipitation is the lowest in January, with an average of 16 mm reaches its peak in October with an average of 203 mm.

The soils range from clay loam to sandy loam suitable for most of agriculture and horticulture crops. Theni is ranked 2nd in Asia for Banana trading and known for the large-scale trading of agricultural cash crops. The major crops in the region are Rice (Paddy), Banana, Mango, Coconut and other crops (Theni profile, 2018).

Data

Remote sensing data

Sentinel-2 satellite images (Level 1C), for the study area were accessed from European Space Agency (ESA) SciHub-Copernicus (ESA, 2018). We selected multi-spectral images with less than 10% or near zero (<1 %) cloud coverage for three data sets of 10 January 2016, 23 February 2017 and 28 February 2018

Secondary data

CartoDEM, a product of Cartosat-1 stereo images of 2.5m resolution was accessed from Bhuvan data portal of Indian Space research Organization (ISRO) (Bhuvan, 2018). Digital Elevation Model data was used for extracting slope and distance from drainage network. Other data used in the study are detailed in Table 1.

Socio-economic data like population, Government and financial institutions, agriculture input suppliers, regulated markets, crop collection centers and cold storage facilities data was collated from open source data of Theni district. (Theni District profile, 2018)

The work flow consists of (i) data preparation which involve land use land cover mapping using remote sensing data and generation of thematic maps of the criteria for banana suitability and (ii) suitability mapping for banana crop which involves MCDM with the weights of criteria layers determined using AHP and TOPSIS (Fig. 2).

Data preparation

Remote sensing data analysis for land use classification

Three datasets of Sentinel2 time series data (< 10% cloud free) for 2016, 2017 and 2018 were used for land use land cover analysis. A subset of the study area was extracted for image analysis. Random forest algorithm was implemented in Python script for land use classification (Manjunath *et al.*, submitted).

Extraction of banana intensified area

Crop intensification is an increase in agricultural production per unit of inputs (FAO, 2019). The increase in banana area

from 2016 through 2017 to 2018 was identified as intensified banana cultivation of the study region with appropriate inputs by local farmers. So we found the changes occurring between subsequent years and overlaid to delineate the intensified banana cultivated area. Intensification for the time series period was categorized as banana intensification as

I (C): Total area cultivated in all three years

I1 : Common cultivated area in 2016 and 2017

I2 : Common cultivated area in 2017 and 2018

I3 : Common cultivated area in 2016 and 2018

I4 : Common cultivated area in 2016 and 2017 and 2018

Multi-criterion data layers

The base map of Theni district was prepared based on Survey of India topographic maps (58F/4, 8, 12; 58 G/1, 2, 5, 6, 9, 10) on a 1:50,000 scale. Erosion and deposition of soil sediments are highly dependent on soil characteristics viz., slope, and aspect and drainage flow which were also included as topographical layers for the study area were derived from CartoDEM Version-3 R1 in ArcGIS 10.1 platform using Spatial Analyst Tool.

Monthly average rainfall data were collected for 7 years up to 2011 - 2017 (IMD, 2018) and annual average rainfall was computed for the study area. Precipitation data from seven weather stations was used to derive rainfall map using Universal Kriging method of spatial interpolation (Table 2). Soil is an important production factor which determines

the type of crops cultivated and their productivity. The soil texture data from TNAU was processed using spatial interpolation technique to generate soil classes and integrated with other spatial layers as reported by Widiatmaka (2016) for intensification study.

Layer ranking using MCDM

Determination of relative importance of variables was established based on the importance of each parameter in relationship with land use suitability for crop classification (Table 3). The variable ranking was achieved within the layer and also for every layer relevant to land use suitability for banana crop. The parameter with higher significance was assigned increased weight (Hackett and Carolane, 1982) and Griffiths 1994) as detailed in table 4.

Implementation phase of TOPSIS analysis

In the present study land suitability analysis was carried out using MCDM technique namely AHP – TOPSIS. Analytical hierarchy process (AHP) assigns weights to manifold and diverse criterion to determine their relative significance. AHP provides for operative method for checking the consistency of the evaluations through consistency index and ratio within stipulated limits (Saaty, 1980). AHP derived TOPSIS is developed based on selection of best elucidation from a definite set of options which have the minimum distance from the positive best solution and the maximum distance from the negative best solution in a geometrical sense TOPSIS presumes that each element (or option) has a propensity toward monotonically escalating or diminishing utility. Hence, it is simple to establish the (positive/ negative) idyllic solution (Triantaphyllou and Lin, 1996; Olson, 2004). AHP is based on evaluation parameters and its suitable alternatives to

arrive at the best decision. It assigns a rank to every criteria on basis of pairwise comparisons of criterion (Table 5). Weights are assigned in increasing order of importance and global value for each criteria leading to ranking options (Table 6) (Saaty, 1980).

AHP evaluates consistency by multiplying matrix of comparisons. Consistency index displays the extent of deviation from consistency. To determine the goodness of C.I., AHP compares it by Random Index (R.I.), and this result is Consistency Ratio (C.R.). (Saaty, 1988) AHP's theory suggests that the consistency ratio (CR) must be < 0.1 .

Consistency: Following the creation of the Eigen vector of the AHP, its consistency needs to be evaluated. The required level of consistency is evaluated using the following index:

$$CR = \frac{CI}{RI} \quad (1)$$

Where:

CR = Consistency Ratio, CI = Consistency Index and RI = Random Index

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (2)$$

where λ_{max} being the maximum Eigen value of the comparison matrix and n the number of criteria. For the values of Table 6, CI was calculated for: $\lambda_{max} = 5.23$, $n = 5$

Random Index is the Consistency Index of a randomly generated reciprocal matrix from the scale 1 to 9.

Random Index value is dependent on the number of criteria as given by Saaty (1980) (Table 6) and its 1.12 for this study with 5 criteria. Consistency ratio (CR) was calculated using equation (1) to validate the consistency of matrix (Malczewski, 1999) and in our study

CR derived was 0.053 which is within permissible range of 0.1. Since CR's value is lower than the threshold (0.1) the weights' consistency is affirmed.

Criteria comparison matrix deduced from AHP is used as input for TOPSIS which was developed by Yoon and Hwang (1981).

Geospatial analysis technique includes the following steps for land suitability of banana crop through TOPSIS method: (Malczewski, 1999; Demesouka *et al.*, 2013)

P1: The alternative layers are to be prioritized based on the importance within the sub-criterion of each layer.

P2: Calculate Normalized Matrix with condition that summation of all weights for the alternative must be equivalent to one

$$r_{ij} = \frac{V_{ij}}{\sqrt{\sum_{j=1}^n V_{ij}^2}}$$

where r_{ij} is normalized value, V_{ij} is $i = 1, \dots, m$; $j = 1, \dots, n$, where m is the number of attribute value in each criterion, n is the number of criteria

$$v_{ij} = r_{ij} \times weights_{(j)}$$

where w_j is the weight of the j^{th} criterion

P3: Negative Ideal Solution (NIS) -Determine the minimum value (v_{j-}) from normalized weight for each column vector

P4: Positive Ideal Solution (PIS) - Determine the maximum value (v_{j+}) from normalized weight for each column vector

P5: To calculate the Separation measure from ideal point where s is separation measure from Positive ideal point

$$S_{i+} = \sqrt{\sum_{j=1}^n (v_{ij} - v_{j+})^2}$$

from negative ideal point

$$S_{i-} = \sqrt{\sum_{j=1}^n (v_{ij} - v_{j-})^2}$$

P6: Deduce the comparative closeness to idyllic point

$$C_{i+} = \frac{S_{i-}}{S_{i+} + S_{i-}}$$

where $0 \leq C_{i+} \leq 1$, $i = 1, 2, \dots, m$.

P7: Rank the alternatives according to the descending order of relative closeness to ideal point. The best sites are those that have higher values of C_{i+} and they are closer to positive ideal situation, they are chosen.

Land use suitability for banana crop

According to MCDM initially we assigned 40 and 20 % importance for land use and slope respectively however TOPSIS analysis transformed land use and slope importance. Weighted overlay method was used in GIS tool to integrate the thematic layers to generate land suitability index (LSI), through equation where n is the total number of LS criteria, w_i is the normalized weight index of main criteria and x_i is the normalized weight index of sub-criterion. Higher LSI values indicate areas more suitable for sustainable agriculture (Cengiz and Akbulak, 2009).

$$LSI = \sum_{i=1}^n w_i * x_i$$

The thematic map on spatial pattern of each variable provides information on the current geo-physical aspects of Theni District. Each variable on present land suitability was

analyzed into 4 intensity of suitability viz., not suitable (NS), Marginally suitable (MRS), Moderately suitable (MOS) and Highly suitable (HS).

Socio-Economic Indicators

The production of banana crop solely depends on the overall socio-economic status of a geographical region. Important indicators comprise of population, road network, location of markets, crop collection centers, institutional support and financial institutions.

The location data was collated from Theni district profile (2018) and point data was interpolated for thematic outputs generated:

Population map

Institutional support – research institutions and department of horticulture

Proximity map for crop collection centers, godowns and cold storage units

Proximity map for market accessibility

Results and Discussion

The thematic maps of variables considered for analysis like slope, soil, drainage, rainfall, population, socio-economic indicators such as banks, institutions (extension departments), agri-input suppliers, proximity of market to major towns and crop collection centers/cold storage units/regulated markets were generated.

In our study crop intensification factors based on MCDA approach with AHP derived method TOPSIS were implemented to identify the influence of variable contributing towards intensification. The influence of the socio-economic indicators on banana production is discussed.

Land suitability analysis map- generate through thematic maps of slope, soil, distance from drainage and rainfall intensity.

Banana intensification map- Land use landcover data for 2016, 2017 and 2018.

Socio-economic variables- Proximity map of institutional support and infrastructure facilities with banana intensification.

Proximity map of market access with district, block headquarters towns and banana production

Crop intensification parameters

Land use map with banana intensification

Banana crop duration ranges between 10 -12 months, may extend up to 18 months in ratoon crop (Second crop) hence overlapped area between two analyzed years is anticipated. The analysis banana intensified during time series of 2016 to 2018 reveals that an area under banana in all the years 49 ha (Banana i4). The common banana area in 2016-17 is 307 ha (Banana i1), 2017-18 is 412 ha (Banana i2) and 2016-18 is 225 ha (Banana i3) [Fig. 3 (i)].

Slope

Slope is derived for each cell as “the maximum rate of change in value from the cell to its neighbours” (Burrough, 1986). Based on the slope, the study area can be divided into five classes [Fig. 3 (ii)]. The areas having $< 3^\circ$ slope falls into the category of nearly flat terrain and are highly suitable for agriculture. The banana crop cultivation regions in Theni are observed in slope class $< 3^\circ$ which are suitable for crop production. The areas with $6-13^\circ$ slope are considered as moderately to strongly sloping (undulating topography) with some runoff and are suitable for bench

terracing or terrace farming. Areas having slope $>22^\circ$ are considered strongly slope to very steep with higher runoff. These areas are suitable only for permanent tree crops such as trees, fruit trees, forest or agro-forestry.

Rainfall and distance to drainage

The distribution of rainfall over the study area was computed for 2011-2017 [Fig. 3(iii)] and spatial extent shows that average annual rainfall varies from 577 - 951 mm. Annual precipitation is spread over the entire district leading to multiple cropping systems. The total water requirement of banana is about 900-1000 mm for its entire life cycle and rainfall of Theni is within the required range.

Drainage density of a basin is the total length of the stream network divided by basin area. A high density may indicate one or more of the following: a “mature”, well developed channel system exists, surface runoff moves rapidly from hill slopes (overland flow) to channels, thin/deforested vegetation cover, basin rocks/soils/surface has generally low infiltration rate.

It also describes the texture of a stream network. Drainage is related to runoff erosivity and vegetation resistivity, which vary with climate. Figure 4 (i) depicts the distance to drainage of the study area. Banana performs well in well drained regions and banana cultivation regions are located in well drained regions

Soil

Declining soil productivity is posing a great threat to sustainability of agricultural production (Ennaji *et al.*, 2018). Spatial database of soil and their inherent characteristics are important for optimal exploitation for crop production. Based on morphological features soils are categorized

into seven soil types [Fig. 4 (ii)]. It was found the sandy loam constitutes nearly 35%, loamy sand and sandy clay comprises nearly 20% of the study area. The recommended soil types for banana are deep rich loamy soils and major soil types of Theni district are clay loam, loamy sand, sandy clay loam and sandy loam. The recommended soil parameters for cultivation of banana are synchronized with analysis results (TNAU, 2018).

Land suitability for banana crop

Crop intensification is composite interaction of the factors analyzed above. MCDM based AHP model has been extensively used for land/site suitability studies given its advantages and ease of integrating number of parameters in to unified result. TOPSIS is sparsely applied for such studies considering its complexity and generalist approach to calculate the ideal points for deducing suitability.

The outputs indicates that banana cultivated areas are located in optimum recommended conditions. An area of around 3127 ha of banana is under highly suitable region (Fig. 5). Soils for banana should be well drained with adequate moisture, the distance from drainage shows banana crop is produced in areas with good drainage and good rainfall intensity.

The slope map shows slope $< 3^\circ$ are highly suitable for agriculture and land use maps reveals that banana production areas in this region. Banana crop performs well in Sandy loam / loamy sand is evident from soil map that banana cropped regions are located in these situations (NHB, 2016).

In our study we attempted to methodologically apply TOPSIS technique to analyze the factors influencing banana crop intensification. When AHP derived pairwise comparison matrix

(Table 5 and 7) was analyzed to derive normalized weights (Table 8) which in turn analyzed in TOPSIS, to get the transformed relative importance by estimating positive ideal solution and negative ideal solution of each criterion (Table 9) resulting transformed relative importance of land use and slope as shown in Table 10. The outputs of TOPSIS analysis was applied for ranking of layers in the order of importance slope, land use, soil, drainage distance, rainfall to derive land suitability map. The thematic map of land suitability for banana crop matches with the region of intensified banana cultivation identified in the composite of classified outputs. About 3127 ha of banana crop is observed in 'Highly suitable (HS)' area and around 5548 ha is available for banana cultivation in this category. Similarly 4540 ha of banana is found in 'Moderately suitable (MOS)' area and 14887 ha is available for banana cultivation. The areas under forest, built up, water bodies and wasteland categories are represented as 'Not suitable' (NS) [Fig. 4 (iii)].

Socio-economic indicators

The indicators such as population for labor availability, infrastructure facilities etc. were visually analyzed by integrating with suitability and intensified banana extent.

Population

The population of major towns and villages varies between 4800 and 94000. The cultivated area is directly related to the population in terms of resources availability like labour, suitable land, water, roads, and markets. District headquarters Theni has highest population followed by block headquarters Uthamapalyam, Chinnamanur, Bodinayakanur, Periyakulam and Andipatti. [Fig. 6 (i)].

Table.1 Details of data sources

Data type	Year	Source
Sentinel 2 satellite images	2016 - 2018	https://scihub.copernicus.eu/
CartoDEM Version-3 R1	2005	http://bhuvan.nrsc.gov.in/data/download/index.php
Rainfall data	2011-2017	Indian Meteorological Department (IMD), Chennai
Theni district database	2018	Theni district profile. www.theni.nic.in
Topo-sheet	2010	www.soinakshe.uk.gov.in
Soil data	2015	Remote Sensing and GIS Department, TNAU

Table.2 Relative importance of main criterion layers

Main criteria		Importance
C1	Landuse	40%
C2	Slope	20%
C3	Soil	18%
C4	Drainage distance	12%
C5	Rainfall	10%

Table.3 MCDM layer ranking for sub-criteria of each layer

Main Criteria	Sub-criteria	Rank
Landuse	Agriculture /Cultivable land	5
	Fallow	4
	Pastures, Plantation	3
	Wasteland, Forest	2
	Built-up, Water body	1
Slope	< 3 %	5
	4 – 7 %	4
	8 – 15 %	3
	16 - 25 %	2
	>25 %	1
Soil	Clay Loam	5
	Sandy Clay Loam	4
	Sandy Loam	3
	Loamy Sand/Sandy Loam	2
	Rock Sand	1
Drainage distance (Meters)	< 200 m	5
	200-500 m	4
	500 – 1000 m	3
	1000 – 2000 m	2
	>2000 m	1
Rainfall	887 – 952 mm	5
	766 – 887 mm	4
	706 – 766 mm	3
	646 – 706 mm	2
	577 – 646 mm	1

Table.4 Rating of pairwise comparison matrix between alternatives and criterion

Parameters	Land use	Slope	Soil	Distance to drainage	Rainfall
Land use	1	3	5	7	9
Slope	1/3	1	3	5	7
Soil	1/5	1/3	1	3	3
Drainage distance	1/7	1/5	1/5	1	3
Rainfall	1/9	1/7	1/5	1/3	1

Table.5 Area of banana and other crops in suitability class

Suitability Class	Banana	Fallow	Mango	Coconut	Other crops	Non-crop classes
Highly suitable	3127	5548	508	11254	5812	2367
Moderately suitable	4540	14887	490	14004	12001	12009
Marginally suitable	4205	29187	1423	6499	12469	12349
Not suitable	2660	9711	645	12838	21487	86546

Table.6 Area under land suitability categories

Land suitability Class	Area in Ha
Highly suitable	27050.00
Marginally suitable	55034.00
Moderately suitable	61078.00
Not suitable	128086.00
Total	271252.00

Table.7 Normalized matrix of the parameters of Table 5 and their mean each variable

Parameters	Land use	Slope	Soil	Drainage distance	Rainfall	Normalized weight (V_{ij})
Land use	0.559	0.641	0.524	0.428	0.36	0.260
Slope	0.186	0.213	0.314	0.306	0.28	0.502
Soil	0.111	0.0712	0.104	0.183	0.20	0.134
Drainage distance	0.079	0.042	0.034	0.061	0.12	0.067
Rainfall	0.062	0.030	0.020	0.020	0.04	0.034

Table.8 Positive ideal solution and negative ideal solution for each criterion

	Positive ideal solution S_{i+}	Negative ideal solution S_{i-}
C1 - Landuse	0.076	0.077
C2 - Slope	0.033	0.040
C3 - Soil	0.036	0.035
C4 - Drainage distance	0.027	0.020
C5 - Rainfall	0.014	0.009

Table.9 Transformed relative importance of main criterion layers after TOPSIS

	C_{i+}	Importance
C2 – Slope	0.545	40%
C1 - Landuse	0.504	20%
C3 - Soil	0.493	18%
C4 - Drainage	0.425	12%
C5 - Rainfall	0.402	10%

Fig.1 Study area map of Theni district

Fig.2 Flowchart of TOPSIS land suitability and crop intensification analysis

Fig.3 (i) and (ii) Banana intensification 2016, 2017 and 2018, (ii) Slope map, (iii) Rainfall map of 2017

Fig.4 (i) Distance from drainage, (ii) Soil map, (iii) Land Suitability map for banana

Fig.5 Banana intensification for all three years (2016-2017-2018) and overlay on land suitability output

Fig.6 (i) Population of Theni district
(ii) Proximity map of crop collection centers, cold storage units and regulated markets
(iii) Proximity map of district, block head quarters and towns

Fig.7 (i) Banana intensification areas for time series 2016-2017-2018

(ii) Integration of proximity map of institutional support and financial institutions with banana intensification

(iii) Integration of proximity map of district, block headquarters, towns and infrastructure facilities with banana intensification

Proximity to institutions, crop collection centers, markets and storage facilities

The district has five block headquarters viz., Andipatti, Bodinayakanur, Theni, Periyakulam and Uthamapalayam. Majority of the banana growing region are located around towns of Theni, Uthamapalayam, Cumbum, Gudalur, Chinnamanur and Bodinayakanur.

Village / regulated markets at block/district headquarters are the point of sale for the crops produced. Most of the habituated settlements are connected with metaled roads. The terrestrial transport network was digitized with SOI toposheets and validated with real time open street maps. The proximity maps (radial distance) of village block and district headquarters shows the connectivity of major banana production centers to crop collection centers, cold storage units and open/regulated markets [Fig. 6 (ii and iii)]. Each headquarters has access to technical support from department of Horticulture/agriculture. Crop production is equally influenced by

parameters that lead to adoption improved methods for cultivation. Support from extension agencies like agri-horticulture Departments, research institutions and colleges add value for farmers in crop intensification. Agriculture input suppliers are located in towns/villages leads to timely availability of crop production inputs. All the towns are well connected by road network leading to ease of market access.

Crop collection centers/Warehouses/Cold storage units are accessible in Theni, Chinnamanur, Cumbum and Bodinayakanur. Major commercial banks are located in towns of Theni, Uthamapalayam, Cumbum, Gudalur, Chinnamanur and Bodinayakanur. Ease of access to banks and markets completes the basic requirements for farming community. The LULC map for the time series data 2016-2017-2018 indicates banana intensification. Visual comparison of the map demonstrates that intensification is in regions influenced by location of socio-economic indicators [Fig. 7(i)].

The interaction of secondary factors indicates the positive co-relation with banana production areas. Congregated location of agri-input suppliers, banks, extension institutions, collection centers, cold storage units and markets to major banana production hubs are contributing towards the intensification. The overlay of the banana land suitability map shows that the socio-economic indicators are located close to the banana suitable areas [Fig. 7(ii) and (iii)].

Crop intensification is a confluence of multiple criteria of natural and anthropogenic factors. The interplay between the factors decides the cropping pattern in a geographical area. Banana has emerged one of the dominant crops in Theni district in recent years. The study aimed to analyze the impact of the factors contributing towards the intensification of Banana in the district. The spatial analysis of the factors of intensification derived through remote sensing, GIS and assignment of weights of the factors using TOPSIS had resulted ranking of factors in order of importance for banana intensification. Also the availability of banking system, institutional, storage and marketing support is contributing towards the cultivation of banana extensively. Out of the total suitable area 43732 hectares for banana average 14575 hectares (Table 6) is under banana cultivation during the study period hence an area of 29200 is available for intensification with suitable interventions. This data can be utilized farmers at large to gain insight about the expected production in the district. Policy makers, public institutions and private enterprises can leverage the outputs of the study for capacity building for establishing cold storage units, processing centers and technology interventions to manage natural resources. Further research on cadastral level mapping of varietal specific banana database of Theni district can be initiated as region has diverse range of horticultural crops under

cultivation. The need however, is to gain in-depth knowledge about production factors that affect crop intensification. This paper approaches a methodology for factoring societal, economical and environment variables in analyzing capability for crop intensification at the regional scale. The technique includes a spatially implicit multi-criteria based data analysis which is applicable to any geographical region. The results show interaction of variables is expressed explicitly according to land suitability and capability for crop intensification.

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