



ASSESSMENT OF CROP SUITABILITY ANALYSIS FOR DROUGHT PRONE AREAS IN SEMI-ARID REGIONS OF MAHARASHTRA INDIA USING GEOSPATIAL TECHNOLOGY.

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Abstract: Identification of the suitable areas for cultivation of crop is very much essential to increase the productivity. The soil physicochemical properties play an important role in crop productivity improvement. The soil nutrient balance for less endowed dry land cropping systems of smallholder farms has to be maintained to build the gap between potential and actual yield. The current study focuses on assessment of suitable area for Sugarcane (*Saccharum officinarum*) and Maize (*Zea mays L*) crops based on climatic parameters such as temperature, rainfall, evapotranspiration and soil physicochemical parameters for semi-arid regions of Maharashtra, India. The study reveals that 22% of the total area is suitable for sugarcane and for maize, the study area is pH deficient. For sugarcane, soil pH and EC are sufficient as per the standard requirements but potassium, phosphorus and organic carbon are deficient for the crop which can be improved by the application of suitable fertilizer.

Keywords: Crop Suitability, semiarid regions, drought, Geographical Information System, Spatial Analysis

I. Introduction

Agriculture is a backbone of Indian Economy. It is a primary source of living for more than 58% of the population in India. As per the Advanced Estimates of National Income for the year 2012-2013, agriculture and allied sector contributed 13.7% of India's GDP, at constant 2004-2005 prices[1]. As per the 11th Five year plan for the years 2007-2012, India has incorporated the target of increasing agriculture production and improving food security [2]. The above statistical substantiation confirms that crop productivity improvement is one of the important activities in Indian agriculture management.

Soil is one of the governing factors in crop production. It is a consolidation of different micro and macro nutrients like Nitrogen (N), Phosphorous (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Zinc (Zn) and Iron (I). These nutrients play a very important role for natural growth of the crop[3][4][5]. In India there is considerable difference between the soil nutrient balances in different agro ecological regions. The more focus is given on soil nutrient balance practices for specific cropping systems in irrigated areas of the country [6]. At the same time out of total geographical area more than 50% of the geographical area is constituted by semi-arid and arid lands and there is a need to focus soil nutrient balances of these areas[7][8]. Accordingly to build the gap between potential and actual yield the soil nutrient balance for smallholder farms has to be maintained [9].

Besides soil nutrient parameters crop production also depends upon rainfall, temperature, elevation, fertilizers used and land use types. As a result for management of complex agricultural systems the modern frontier geospatial technologies such as Remote Sensing (RS), Geographical Information System (GIS) and the Information Technology (IT) are very much essential to understand, analyze and planning of agricultural data[10][11].

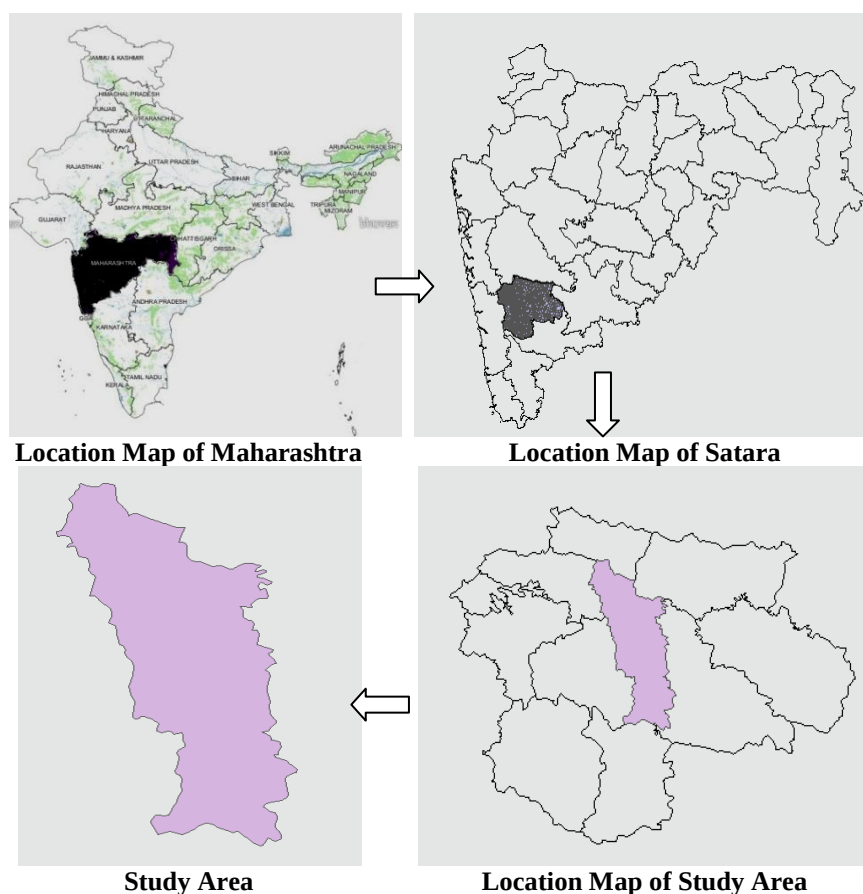
Geospatial data combined with topographic features is useful for soil nutrient analysis, crop productivity improvement and to optimize the consumption of fertilizers [12] [13] [14]. The application of GIS has proven result in soil fertility management to maintain soil nutrient balance along with recommendation for N, P, and K fertilizers [15]. The GIS based multi-criteria analysis is used for the decision making process of land suitability analysis for the crop to enhance the crop productivity [16] [17] [18] [19]. The crop productivity has been accurately assessed by the researchers with the integration of Geostatistical technique, soil knowledge classification with GIS[20][21]. It was also applied to produce nutrient maps and to provide information for site-specific fertilizer application to increase the crop productivity [22] [23]. The statistical and geo-statistical analysis techniques were applied to identify the spatial variability of Soil Total Nitrogen (STN) and Soil Total

Phosphorus (STP) and to identify the relationship between precipitation and temperature and STN, STP densities[24] [25]. The literature confirms that geospatial technologies have played vital role to identify crop suitability and soil nutrient assessment and in turn to improve the crop production. The current study focuses on assessment of crop suitability under drought prone areas in semi-arid regions of Maharashtra, India .

II. 2. Study Area

Koregaon Taluka is a semi-arid region of Satara district in the Indian state of Maharashtra. It covers area between 17° 27'40 "N to 18°01'11 "N and 74°00'45"E to 74°15'46"E, which corresponds to an area of 901.14 km². The monthly average temperature varies between 20°C (Minimum) to 30°C (Maximum). The average annual rainfall varies from 602mm to 1040mm. The climate is semi arid and soil type varies from Medium to deep black, shallow red, mixed red and red loamy[26]. The major crops cultivated in the region are Sorghum (*Sorghum bicolor*), Millets (*Pennisetum glaucum*), Groundnut (*Arachis hypogaea*), Wheat (*Triticum aestivum* L.) and Sugarcane (*Saccharum officinarum*).

Figure 1: Location Map of the Study Area



III. Materials and Methods

A. Hardware/Software/Topographical Sheets Used

GIS software Arc Map 10.0 and Image processing software ERDAS 2013 has utilized for this study. For statistical analysis, Statistical Package for Social Science (SPSS) 17.0 has been used. Table1 shows the list of topographical sheets for spatial and statistical analysis.

Table 1: List of Materials Used

Sr. No	Description
1.	Survey of India (SOI) Topographic Sheets : 47 J/04,47K/01,47K/02,47K/03,47K/05,47K/06,47K/07

B. Climatic Data

For the current study climatic parameters such as rainfall and temperature are considered. The climatic data has been collected from different departments of Government of Maharashtra.

C. Soil Evapotranspiration Data

Soil evapotranspiration helps in predicting crop-water requirements. The soil evapotranspiration was calculated using the Hargreaves Potential Evapotranspiration (PET) method (Equation 1)[27].

Equation 1 Hargreaves Potential Evapotranspiration (PET)

$$\text{Potential Evapotranspiration(PET)} = 0.0075 \cdot R_a \cdot C_t \cdot \partial t^{1/2} \cdot T_{\text{avg,d}}$$

In the above equation:

1. R_a = The total incoming straterrestrial Solar radiation
2. C_t = Temperature Reduction Coefficient
3. ∂t = The difference between mean monthly maximum and mean monthly minimum temperature
4. $T_{\text{avg,d}}$ = Mean temperature in the time step

D. Crop Specific Evapotranspiration

Every crop has a different evapotranspiration rate, which determines the crop water need. The crop specific evapotranspiration for sugarcane and maize crop was calculated. To calculate this first reference crop evapotranspiration is calculated by using Blaney-Criddle Method (Equation 2) [28].

Equation 2 Blaney-Criddle Formula

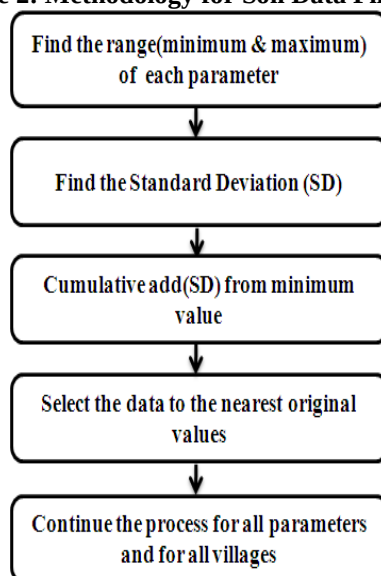
$$ET_0 = \rho(0.46 * T_{\text{avg}} + 8)$$

This method gives the reference evapotranspiration with the reference crop as "grass". The crop specific evapotranspiration is then calculated by using Equation3. In the equation the crop factor (K_c) is the factor which distinguishes the field crop from grass and which dependent upon various stages of growth [29].

E. Soil Data

The soil data was collected from 88 villages with 2065 soil samples from District Soil Survey and Soil Testing Laboratory, Satara, Maharashtra. Each sample included the details of soil pH, soil electrical conductivity (EC), soil organic carbon (OC), soil macronutrients like Phosphorus (P) and Potassium (K).The entire sample collected showed redundancy and repetition. As the number of samples were more to remove biasness the village wise soil data was filtered using ratio and range method (Figure 2). The soil data filtration method reduced the sample points from 2065 to 290 samples. The process of filtering the samples was validated by conducting the Principal Component Analysis (PCA) in SPSS and selecting the Kaiser-Meyer-Olkin (KMO)-Bartlett's Test. The KMO and Bartlett's test consider the samples are adequate for the analysis when the result of the test is 0.5 or above[30]. The KMO and Bartlett's test, showed the value of sampling adequacy as 0.525 and 0.556 respectively for new and old samples respectively.

Figure 2: Methodology for Soil Data Filtration



F. Standard Requirements for Climatic & Soil Parameters

The standard requirements of climate and soil parameters were collected for two major crops Sugarcane (*Saccharum officinarum*) and Maize (*Zea mays L*) [31][32][33][34][35][36] (Table 2).

Table 2: Standard Requirements for different parameters for Sugarcane and Maize

Sr. No	Name of the Parameter	Standard Values Required	
		Sugarcane (<i>Saccharum Officinarum</i>)	Maize (<i>Zea Mays</i>)
1.	Rainfall	750 to 1500 mm	250 to 5000 mm
2	Temperature	21°C to 27°C	25°C to 30°C
3.	Soil pH	7.3 to 7.9	7.41 to 8.5
4.	Electrical Conductivity (EC)	0.07 and 0.68	0.03 and 1
5.	Organic Carbon (OC)	0.54 and 0.61	--
6.	Phosphorous (P)	2.7 to 29	11.5 to 23.5
7.	Potassium (K)	206 and 276	350 – 534

G. Geo-statistical Analysis

Geostatistical methods are useful in modelling spatial variability through prediction and simulation[37][38]. These methods involve fitting a mathematical function to a specified number of points, or all points within a specified radius, to determine the output value. Ordinary Kriging with Gaussian model was used for rainfall data and a Stable model was used for temperature data as temperature data did not show the remarkable trends. For soil nutrients and chemical properties ordinary kriging was used. (Equation 4).

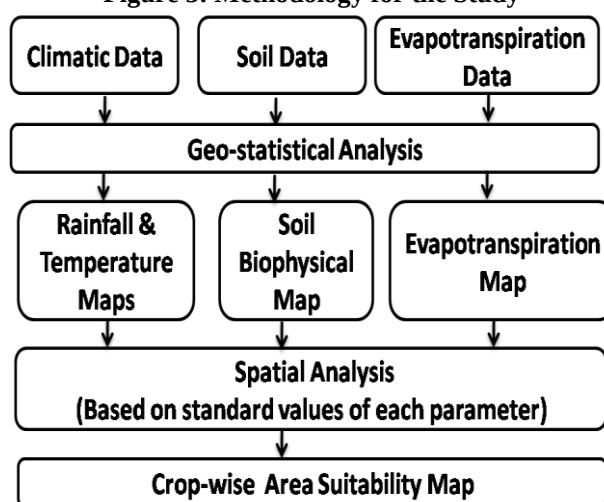
Equation 3 Ordinary Kriging

$$F(X, Y) = \sum_{i=1}^n W_i F_i$$

H. Soil Suitability Analysis

To assess the soil suitability for Sugarcane and Maize the spatial analysis of thematic maps of all the parameters was performed. For this raster calculator from Spatial Analyst tools of ArcMap 10.1.3 was used. The raster layer of each of the soil and climatic parameters was provided as an input to the raster calculator. The condition expression in python script was written for each of the input parameters as per the standard requirements (Table 2)(Figure 3).

Figure 3: Methodology for the Study



IV. Results

The Study shows that rainfall for sugarcane and maize is inadequate in this region and for cultivation of these crops sufficient irrigation infrastructure is required to increase the crop productivity. The monthly crop specific evapotranspiration for maize varies from 0.2378 mmd⁻¹ to 4.95378 mmd⁻¹. As rainfall is inadequate evapotranspiration is more and which is within range of the standard required rainfall amount. The study reveals for evapotranspiration parameter that entire study area is suitable for sugarcane and maize. Similarly soil parameter wise the area suitability for sugarcane and maize have been identified (Table 3).

Table 3: Parameter wise percentages of suitable area

Sr.No	Parameter Name	Suitable Area (in %)	
		Sugarcane	Maize
1.	pH	68.14	14.15
2.	EC	89.13	98.23
3.	Oc	4.4	--
4.	P	13.27	71.68
5	K	3.53	52.33

For sugarcane, soil pH and EC are sufficient as per the standard requirements but potassium, phosphorus and organic carbon is deficient for the crop which can be improved by the application of suitable fertilizer. The study reveals that 22% of the total area is suitable for sugarcane and for maize, the study area is pH deficient. With suitable application of pH rich fertilizer the maize productivity can be increased.

Depending upon the soil and climate data collected for Koregaon, the areas showing suitable soil for the cultivation of sugarcane are actually the areas, which have all the optimum conditions required for the cultivation of sugarcane and which do not require the application of any fertilizers but requires irrigation infrastructure. The Table 4 also shows the villages which come under the suitable area have adequate number of samples or farmers, which currently cultivate sugarcane to prove the validity of the analysis done (Figure 5, Figure 6).

In Jarewadi, no samples were available for sugarcane but as per the result of the analysis, the soil is highly suitable. The sugarcane is not cultivated there and we required to educate the farmers about the prospect of sugarcane cultivation in Jarewadi and would not require fertilizers for normal yield. In case of Maize, the study concludes that entire Koregaon requires application of one or other fertilizers as the soil do not have all the required parameters in right proportion.

Table 4: Villages having soil suitability

Sr.No	Village Name	Number of Samples available
1.	Dudhi	28
2.	Lhasurne	27
3.	Kinhai	11
4.	Chimangaon	14
5.	Bhatamwadi	17
6.	Koregaon	18
7.	Shirambe	09
8.	Dhamner	56
9.	Velu	51
10.	Jarewadi	NA

(Source: Soil Survey and Soil Testing Laboratory, Satara, Maharashtra)

V. Conclusion

The current study reveals that geospatial and its kindred technologies provides accurate and near to accurate information for crop suitability analysis for semiarid regions. Geospatial technologies have potential to identify the agriculture suitable area, which can lead to the crop productivity. However collection of sample point format is an important factor to predict the agriculture suitability area. Study shows that instead of high density of sample point of area the proper format of soil sample is more important to predict using geostastical techniques. The results of the predictive model using geostastical techniques will help to optimize the crop types. This method can be implemented using GIS and was tested in regions with the semi-arid climatology. It has understood during study that the productivity of the semiarid area can increase with the proper identification of soil potential of the area according to the crop type.

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Acknowledgements

The authors acknowledge Symbiosis Institute of Research and Innovation (SIRI), Symbiosis International University (SIU), Pune, Maharashtra, India for providing financial support for this project. We also acknowledge District Soil Survey and Soil Testing Laboratory, Satara, Maharashtra, India for providing support for collection of soil data required for the project.