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Assessment of Soil Productivity based on Storie Index Rating using GIS in Daund Tahsil, Pune District, Maharashtra

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Abstract

The Storie index rating based on soil characteristics is a useful method for estimating potential productive capacity of soils. In the present research paper, soil productivity based on Storie index rating in Daund Tahsil of Pune District in Maharashtra has been assessed using GIS (Geographical Information System). The entire study area has been divided into 523 grid cells of 1 minute by 1 minute (1' x 1') dimension. The Storie index rating has been estimated for each map unit (grid cell) by multiplying separate ratings for soil profile morphology (A), surface soil texture (B), slope (C) and modifying conditions such as soil alkalinity (X). The factor ratings for factors A, B, C for every grid cell were determined according to the criteria mentioned in the Storie soil rating chart. The Storie index values ranged from 15.3 % to 45 % with an average value of 31.4 % in the study area. The three classes of soil productivity or soil grades based on Storie index in the study area are fair grade soils, poor grade soils and very poor grade soils. The maximum part of Daund Tahsil has comparatively lower Storie index values (between 20% and 40%) which indicates poor grade of soils having a narrow range in their agricultural possibilities. There are few patches of land in the north-western, northern and south-eastern parts of the study area having very low Storie index values (less than 20% rating) indicating very poor grade of soils that are not suitable for agriculture. The area having fair grade soils is confined along Mula-Mutha river banks in the northern part, a small area in the central part and along banks of Bhima River in the eastern part.

Key Words: *GIS, soil productivity, Storie index, factor ratings, soil grade.*

Introduction:

The Storie index is a widely used and accepted method of soil rating based on soil characteristics for estimating potential productive capacity of soils. It is a soil-based system of classification of land productivity, which is independent of other physical and economic factors. The method of Storie index was mainly used for irrigated soils in California, U.S.A. in North America. The Storie index was originally applied to semi-arid and arid regions. It included soil profile characteristics that influenced the root zone, subsurface properties (permeability, available water capacity, drainage, etc.) and landscape properties such as slope, and the degree of erosion. R. Storie was the first scientist to determine specific criteria for rating soil productivity in the year 1933. The original Storie index rating was estimated by multiplying separate ratings for soil profile morphology (A), surface soil texture (B), slope (C), and dynamic or modifying conditions such as soil drainage or soil alkalinity (X).

Study Area:

The study area is Daund Tahsil which has a total geographical area of 1360 square kilometers. Daund Tahsil is situated in the eastern part of Pune District in Maharashtra. Daund Tahsil extends from 18 17' to 18 40' North latitudes and 74 08' to 74 50' East longitudes (Figure 1). The study area is geologically a part of the Deccan Basalt Province (DBP). The maximum part of Daund tahsil has plain physiography. The region under study has tropical type of climate highly influenced by the southwest monsoon rainfall. The climate of Daund tahsil is semi-arid type of climate. Daund tahsil is situated on the southern bank of Bhima River which is the biggest river in Pune District. The Bhima River and its tributaries, namely, Mula-Mutha are the major rivers in the study area.

The soils of Daund tahsil are basically grouped into the following categories: moderately shallow to deep (> 50 cm), shallow soils (25-50 cm) confined to hill ranges, very shallow soils (10-25 cm) in the

between hill ranges and plains and extremely shallow soils (less than 10 cm). The soils are mostly fine textured and well drained black soils and medium textured in some patches. Moderately shallow to deep soil covers the maximum portion of the study region. Deep black soil is found along the low-lying areas of Bhima and Mula-Mutha rivers. This soil is clayey, well drained and it is dark brown to greyish black in colour. The soil can support crops such as sugarcane, jowar, bajra, groundnut and onion. This soil is suitable for cultivation of crops when supplemented by irrigation. In Daund Tahsil, the type of natural vegetation is tropical dry deciduous, except along river Bhima which is mixed deciduous vegetation.

The urban town of Daund is the headquarters of Daund Tahsil and it is the main market place and one of the two major urban areas in this predominantly rural area. Agriculture is the dominant activity practiced by the people living in the Daund Tahsil. Crops such as sugarcane and wheat are grown on deep black soil along the low lying areas of Bhima and Mula-Mutha rivers in the study region. The principal cash crop in the study region is sugarcane. A significant area of Daund Tahsil is irrigated land which is mainly used for sugarcane cultivation. There are many sugar-based industries in the study area.

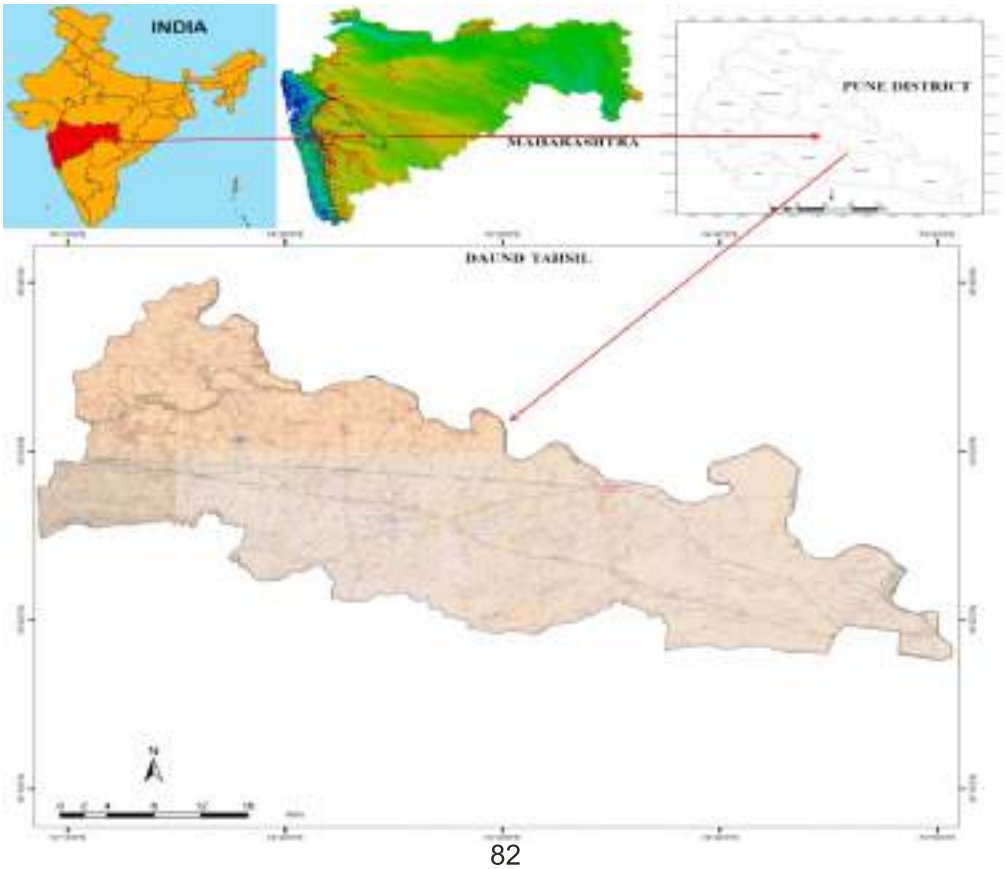
Objectives:

In the present research paper, soil productivity in Daund Tahsil of Pune District has been analyzed with the help of Storie index rating. The aims and objectives of the present study are:

(i) To estimate the Storie index ratings for determining soil productivity in the study area.

(ii) To categorize the soils in the study area into various grades according to their productivity based on Storie index ratings.

Figure 1: Location Map of Daund Tahsil



Database:

(i) Toposheet: S.O.I. Topographical Maps on 1:50,000 scale have been used as base maps. Survey of India Toposheets having Index Numbers: 47 J/2, 47 J/3, 47 J/6, 47 J/7, 47 J/10, 47 J/11 & 47 J/15, covering Daund tahsil, have been georeferenced in GIS software and merged together. The georeferencing of the base map has been performed in Global Mapper Software version 22. The stream network, contours, railway line, roads, wells, etc. have been digitized using S.O.I. Toposheets.

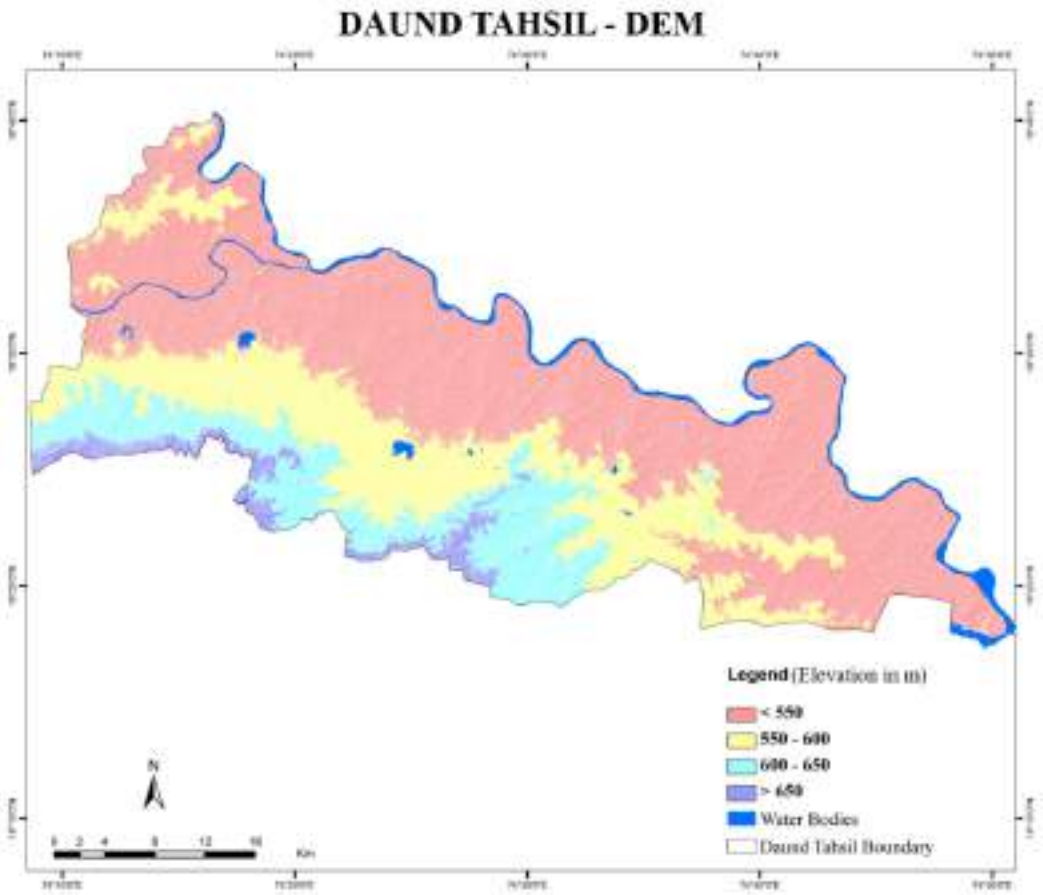
(ii) DEM: The ASTER GDEM (Global Digital Elevation Model) data of the Daund Tahsil area having a spatial resolution of 30 meters (Figure 2) has been used for the preparation of slope (%) map.

(iii) GPS Data: The entire study area has been tracked with the help of GPS. The soil sample points were tracked by using GPS to acquire the location data.

(iv) Soil Data: The soil data has been obtained from soil samples which were collected during the field work and subsequently analysed in the soil laboratory. The soil samples were collected randomly. In order to analyze various soil characteristics, soil data from Mati Parikshan has been utilized.

(v) WRIS Data: Data about physical and hydrological characteristics of soils has been obtained from Water Resources Information System (WRIS) of India which is a Web GIS portal.

Figure 2: DEM (Digital Elevation Model) of Daund Tahsil



Methodology:

The ratings for the determination of Storie index are mainly based on characteristics of soils which are obtained by the assessment of physical and chemical properties of soils, sub surface characteristics and landscape surface features. The rated parameters include the degree of soil profile development in terms of soil depth and gravel content (factor A), the textural characteristics of the surface soil (factor B), the slope in % (factor C), and other important properties of the soil and landscape conditions such as drainage class e.g. well drained or poorly drained, alkali content, degree of acidity, fertility status or content of nutrients, degree of soil erosion i.e. wind and water erosion, and micro-relief features (factor X or "dynamic factor" which can be modified by management). The most ideal settings or favourable conditions with respect to each attribute are rated at 100%. Lower percentage ratings are given for less favourable conditions for crop production. A value ranging from 0 to 100% is given for each factor, and the ratings are then multiplied together to generate the Storie index. Each factor is given a percentage score. While multiplying the factors, decimal values are taken into consideration. The final Storie index is given as a percentage after multiplying the answer by 100.

Storie Soil Index Rating (SIR):

$$SIR = [\,(Factor\,A/100) \times (Factor\,B/100) \times (Factor\,C/100) \times (Factor\,X/100)\,] \times 100$$

Factor A:

The soil profile groups have been classified on the basis of the degree of development of soil profile and the nature of the parent material. The soils in the study area can be classified in the group of soils on upland areas underlain by hard igneous bedrock or soils derived from hard igneous bedrock i.e. basalt rock on the Deccan Plateau of Maharashtra. The rating of factor A i.e. the character of physical profile of soils is based on the soil depth to a lithic (hard rock) contact. The scores become higher with the increasing depth of soil. The India-WRIS (Water Resources Information System of India) Web GIS (Geographical Information System) has been used for acquiring information of soil depth in the study area.

Factor B:

The rating of factor B is based on the texture of the surface soil. Soils with medium texture i.e. loamy soils have been given the highest ratings, while heavy or fine-textured soils have been given lesser ratings. Clay-rich and sandy soils are given lower ratings. The India-WRIS (Water Resources Information System of India) Web GIS (Geographical Information System) and the soil texture analysis data were used for acquiring information of soil textural classes in the study area.

Factor C:

The rating of factor C is based on the slope of land surface. High ratings have been given to nearly level to gently sloping lands (0% to 8% slope). Lower ratings have been given to land areas having slopes greater than 30%. The India-WRIS (Water Resources Information System of India) Web GIS (Geographical Information System) and the slope map prepared with the help of ASTER GDEM were used for acquiring information of slope classes in the study area.

Factor X:

The rating of factor X is based on dynamic properties of soil and landscape which require particular attention. These properties can be grouped into soil chemical and fertility properties such as alkalinity, acidity, content of nutrients etc. and hydrologic and physical properties of soil such as drainage class, soil erosion etc. An assessment of factor X has not been attempted because these are very dynamic properties in agricultural settings, which can be modified by practices of management of soils such as applying fertilizers.

The original "Soil Rating Chart" after Storie, 1976 is given in Table 1:
Table 1: Storie - Soil Rating Chart

Factor A - Rating on character of physical profile	
Soils on upland areas underlain by hard igneous bedrock:	
at less than 1 foot	10-30
at 1 to 2 feet	30-50
at 2 to 3 feet	50-70
at 3 to 4 feet	70-80
at 4 to 6 feet	80-100
at more than 6 feet	100
Factor B - Rating on basis of surface texture	
Medium textured:	
fine sandy loam	100
Loam	100
silt loam	100
sandy loam	95
Heavy or fine-textured:	
silty clay, highly calcareous	70-90
silty clay, non-calcareous	60-70
clay, highly calcareous	70-80
clay, non-calcareous	50-70
Factor C - Rating on basis of slope	
A-Nearly level (0 to 2%)	100
AA-Gently undulating (0 to 2%)	95-100
B-Gently sloping (3 to 8%)	95-100
BB-Undulating (3 to 8%)	85-100
C-Moderately sloping (9-15%)	80-95
CC-Rolling (9 to 15%)	80-95
D-Strongly sloping (16 to 30%)	70-80
DD-Hilly (16 to 30%)	70-80
E-Steep (30 to 45%)	30-50
F-Very steep (45% and over)	5-30

The entire study area has been divided into 523 grid cells of 1 minute by 1 minute (1' x 1') dimension. The Storie index rating for a map unit (grid cell) has been obtained by multiplying rating values for individual soil parameters viz. factor A, factor B and factor C. Any of the general factors – A or B or C can influence the final rating. For each grid cell, factors – A, B, C were determined according to the criteria mentioned in Storie Soil Rating Chart. After obtaining the factor ratings for every grid cell, all the factor rating values were multiplied for every grid cell in order to determine the Storie index. Thematic map showing the soil productivity using Storie soil index ratings has been prepared in Surfer Software Version 10 by applying the technique of spatial interpolation. GIS software - Global Mapper Version 22 has been used for the grid analysis in order to determine the factor ratings. The final map output has been prepared using Arc GIS Software Version 10.3. The soil productivity map based on Storie soil index ratings has been interpreted.

Results:

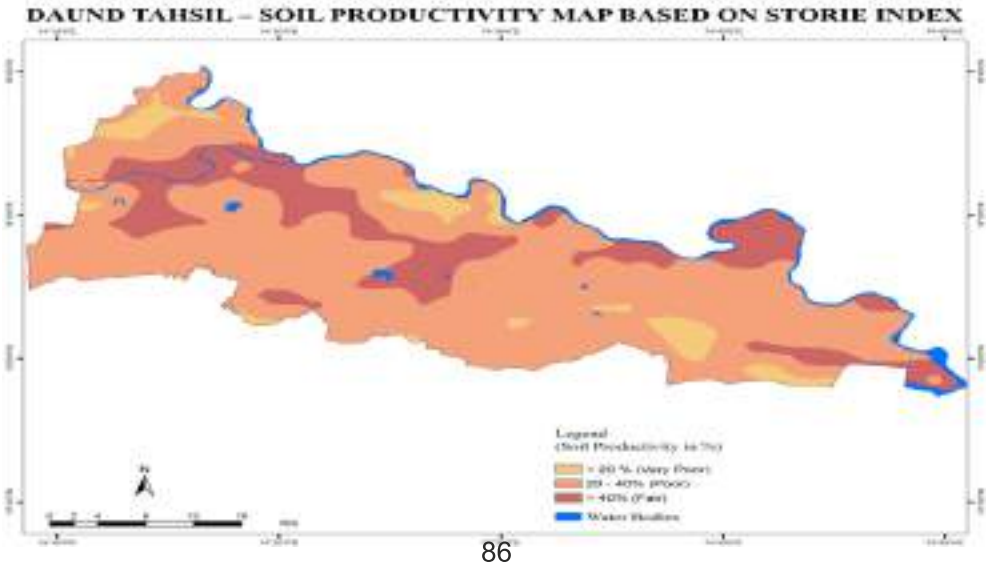
The maximum Storie index value is 45.0% and the minimum Storie index value is 15.3% in the study area. The average value of Storie index in the study area is 31.4 %. The three classes of soil productivity or soil grades based on Storie index in the study area are fair grade soils, poor grade soils and very poor grade soils (Figure 3). The three classes of soil productivity or soil grades based on Storie index in Daund Tahsil are as follows:

1. Fair Grade: Soils that rate between 40 to 60 percent are generally of fair quality, and may give good results with certain specialized crops. The area having fair grade soils is confined along Mula-Mutha river banks in the northern part, a small area in the central part and along banks of Bhima River in the eastern part.

2. Poor Grade: Soils that rate between 20 to 40 percent have a narrow range in their agricultural possibilities. The maximum part of Daund Tahsil has comparatively lower Storie index values (between 20% and 40%) which indicates poor grade of soils having a narrow range in their agricultural possibilities.

3. Very Poor Grade: Soils that rate less than 20 percent are of very limited use except for pasture, because of adverse conditions such as shallowness, roughness, and alkali content. There are few patches of land in the north-western, northern and south-eastern parts of the study area having very low Storie index values (less than 20% rating) indicating very poor grade of soils that are not suitable for agriculture. Such soils are very poorly suited to agriculture and are seldom cultivated. They are more commonly used as pasture, rangeland, or woodland.

Figure 3: Daund Tahsil – Soil Productivity based on Storie Soil Index Ratings



Conclusion:

The Storie index values ranged between 15.3% and 45% with an average value of 31.4 % in Daund Tahsil. The maximum part of Daund Tahsil poor grade of soils having a narrow range in their agricultural possibilities. There are few patches of land in the north-western, northern and south-eastern parts of Daund Tahsil having very poor grade of soils which are not suitable for agriculture. The area in Daund Tahsil having fair grade soils is confined along Mula-Mutha river banks in the northern part, a small area in the central part and along banks of Bhima river in the eastern part. Under the system of ranking given by Storie, soils which have been considered as less than prime may function as good soils when limitations such as poor drainage, slopes, or soil nutrient deficiencies are removed.

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