ESTIMATION OF ERODIBILITY AT SELECTED LOCATIONS IN KONKAN REGION

A Thesis submitted to the

DR. BALASAHEB SAWANT KONKAN KRISHI VIDYAPEETH

DAPOLI - 415 712

Maharashtra State (India)

In the partial fulfillment of the requirements for the degree

of

MASTER OF TECHNOLOGY

(AGRICULTURAL ENGINEERING)

in

SOIL AND WATER CONSERVATION ENGINEERING

by

Sneha Maroti Thawakar

DEPARTMENT OF SOIL AND WATER CONSERVATION ENGINEERING

COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

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I hereby declare that this thesis or part thereof has not been submitted

by me or any other person to any other

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The assistance and help received during the course of this investigation and source of the literature have been duly acknowledged.

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Place : *Dapoli* ***(Sneha Maroti Thawakar)***

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Abbreviations	**Meanings**
%	Per cent
<	Less than
>	Greater than
=	Equal
x	Multiply by
^{o}	Degree
’	Minute
-	Minus
+	Plus
db	Bulk density
CAET	College of Agricultural Engineering and Technology
m tonne	Million tonne
Sq.km	Square kilometer
mm	millimeter
VRN	Very high rainfall non lateritic
VRL	Very high rainfall lateritic
tonne/ha/yr	Tonne per hectar per year
SPAW	Soil Plant Air Water
USLE	Universal soil loss equation
et.al	And others
cm	centimeter
m	Meter
nm	Nanometer
PLS	Partial least square
kg/m^3	Kilogram per cubic meter
mg	Milligram
mg/m^3	Milligram per cubic meter
g/cc	Gram per cubic centimeter

C	Clay content
Si	Silt content
S	Sand content
Vfs	Very fine sand
OMC	Organic matter content
ADR	Amplitude Domain Reflectometry
TUAT	Tokyo University of Agriculture and Technology
cm^3	Cubic centimeter
USDA	United State Department of Agriculture
NRCS	Natural Resources Conservation Service
OC	Organic carbon
kg	Kilogram
SOM	Soil organic matter
OM	Organic matter
TOC	Total organic carbon
P	Content of non erodibility particles in the soil
V	Relative moisture content
Vm	Instantaneous moisture content
R	Wind velocity at the soil surface
K	Soil erodibility factor
M	Particle size parameter
i.e.	That is
t-ha-hr/ha-MJ-mm	Tonne hectare hour per hectare Mega Joule millimeter
Ki	Interill erodibility
Kr	Rill erodibility
N	North
E	East
Mha	Million hectare
km^2	Kilo meter square
tonne/ha	Tonne per hectar
Fig.	Figure
m^3	Meter cube

cm/hr	Centimeter per hour
DF	Density Adjustment Factor
NBSS	National Bureau of Soil Survey
No.	Number
R^2	Coefficient of determination
mm/hr	Millimeter per hour
IARI	Indian Agriculture Research Institute
Sq.	square
t	Tonne
LUP	Land Use Planning
GIS	Geographical Information System
H.C	Hydraulic conductivity
viz.	Namely
R	Rainfall erosivity factor
L	Slope length factor
S	Steepness factor
C	Cover and management factor
P	Support practice factor
Vol.	Volume
Ph.D.	Doctrate of Philosophy
Publ.	Publication
Dist.	District
M.Sc.	Master of Science
Agril.	Agriculture
B.Tech.	Bachelor of Technology
CAET	College of Agricultural Engineering and Technology
J.	Journal
Jpn.	Japan
Soc.	Society

ABSTRACT

ESTIMATION OF ERODIBILITY AT SELECTED LOCATIONS IN KONKAN REGION

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Research Guide	**:**	**Dr. S. B. Nandgude**
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A soil erodibility, which is major factor in erosion prediction and land-use planning, is a complex property dependent on capacity to resist detachment and transport by rainfall and runoff. Erodibility is the susceptibility and vulnerability of soil to get eroded and have importance in soil erosion prediction and its control. The data required for erodibility estimation about soil properties is not easily available in the Konkan region. So it is necessary to determine the erodibility based on available data with the help of advanced modeling tools. Soil-Plant-Air-Water (SPAW) model is considered one of the accurate models in determining soil characteristics from easily available data. It is therefore consider useful and essential to use SPAW model for determination of erodibility at various locations in Konkan region in the present study.

Present investigation was carried out in the very high rainfall lateritic zone (VRL) and very high rainfall non-lateritic zone (VRN) of Konkan region. Soil properties data of 210 villages from 45 tahsils/block of four districts in Konkan region were collected. Lateritic soils are found in whole Sindhudurg and Ratnagiri districts (South Konkan) and non-lateratic soils are found in northern part i.e Raigad and Thane district. The physico-chemical properties of soil, calibration and validation of

SPAW model, hydraulic conductivity estimation, permeability determination, structural analysis, erodibility estimation and generation of soil erodibility maps using Arc GIS 9.3 were performed.

Majority of soils in Sindhudurg district were sandy clay loam type and Ratnagiri district were loam type of South Konkan region. Raigad district soils were sandy loam type and Thane district soils were sandy clay loam type of North Konkan region. The average organic carbon of soils in Sindhudurg district were 1.44 per cent. In soils of Ratnagiri district average organic carbon were 1.38 per cent. Average organic carbon in Raigad district soils were 1.76 per cent. In soils of Thane district average organic carbon were 1.33 per cent. It was observed that organic carbon increased with decreasing clay content. The organic matter (OM) content of soils were estimated from organic carbon. The average organic matter of soils in Sindhudurg district were 2.47 per cent. In soils of Ratnagiri district average organic matter were 2.37 per cent. Average organic matter in Raigad district soils were 3.03 per cent. In soils of Thane district average organic matter were 1.97 per cent.

Hydraulic conductivity of soils were determined by using the SPAW model. It was found that hydraulic conductivity was nearly same in the four districts of Konkan region. The permeability of soils of 210 villages of Konkan region were obtained from hydraulic conductivity of soils. The permeability class varied within moderate to rapid class and moderate class and accordingly permeability codes were assigned as 2 and 1, respectively. Structural analysis was carried out based on textural data. Soils of Konkan region falls under the class fine granular and moderate with structure code 2 and 3, respectively.

The erodibility factor (K) of soils varied between 0.12 to 0.41, 0.26 to 0.48, 0.24 to 0.64 and 0.11 to 0.51 for Sindhudurg, Ratnagiri, Raigad and Thane districts, respectively. Average erodibility factors are 0.32, 0.36, 0.40 and 0.30 for Sindhudurg, Ratnagiri, Raigad and Thane districts, respectively. The overall erodibility of Konkan region varied between 0.11 to 0.64 with mean value of 0.35. It was observed that erodibility has increased with decreasing clay content of soils.

Soil erodibility maps showed that majority of region on steep slopes are having high erodibility factors as clay content of these soils was less. These erodibility maps will be helpful for better performance of erosion prediction models in Konkan region.

I. INTRODUCTION

Plant growth depends on the use of two important natural resources, soil and water. Soil provides the mechanical and nutrient support necessary for plant growth. Water is essential for plant life processes. There are many physical characteristics of soil like texture, structure, bulk density, and porosity which impact how soil, water and air interact. Efficient management and cultivation of these resources is important to increase the crop production and productivity. Agriculture is facing a problem of low productivity. One of the principle reasons for low productivity is progressive deterioration of soil due to erosion. The main factors for soil erosion in India are excessive bourdon over land and faulty agriculture practices.

Soil is a mixture of mineral matter, organic matter and pores. The mineral matter makes up about one-half of the total soil volume. This mineral matter consists of small mineral particles of sand, silt, or clay. Organic matter is made up of decaying plant and animal substances and is distributed in and among the mineral particles. Organic matter accounts for about 1 to 5 percent of the overall soil makeup. The combination of mineral and organic matter is referred to as the solids. The pores spaces that occur around the mineral particles are important because they store air and water in the soil. Approximately 50 percent of the soil makeup is pores. The amount of water and air present in the pore spaces varies over time in an inverse relationship (Anonymous, 2006). This means that for more water to be contained in the soil there has to be less air. The quality of the water is also important for plant development.

It is estimated that out of total geographical area of India (329 million hectares), 174 million hectares of land (53 percent) is affected by serious problems such as water erosion, wind erosion, water logging and salinity. According to an estimate, about 5334 m tonnes (16.4 tonnes/ha) soil is lost annually due to agriculture and associated activities (Narayana and Babu, 1981). Apart from detached soil, which is 2052 m tonnes (6.25 tonnes/ha) per year, about 480 m tonnes silt is transported by rivers and deposited in reservoirs. This results in about 1-2 percent decrease in storage capacity of reservoirs per year.

Konkan region consist of four districts Sindhdurg, Ratnagiri, Raigad and Thane. Sindhudurg district has area 5,207 sq.km and rainfall 3,287 mm. Ratnagiri district has area 8,208 sq.km and rainfall 3,591 mm. Raigad district has area 7,148 sq.km and rainfall 3,884 mm and Thane district has area 9,558 sq.km and rainfall 2,576 mm. The soils of Konkan are mainly of alluvial and residual types. The residual soil occurs on the hilltops or slopes while alluvial is seen along the river valleys. Lateritic soil is formed in the hilly upland where the rainfall is more than 2000 mm, which is rich in Fe, Al and Ti. Nevertheless, it is devoid of lime and poor in organic matter. Soil is lateritic in the South (Sindhudurg and Ratnagiri districts) while it is red and loamy and alluvial towards the North (Raigad and Thane district). There is wide variation in the physico-chemical properties of coastal salt affected soils in the Konkan. The region can broadly be classified in two types - very high rainfall Non-lateritic (VRN) soil zone of north Konkan and very high rainfall lateritic (VRL) soil zone in the southern coastal parts. In Konkan region soil loss potential is estimated to the tune of 40-50 t/ha/yr (Kadam and Rathod, 2008). So it becomes essential to study the soil characteristics of various soil types which are responsible for this phenomenon.

Soil erosion in catchment areas and the subsequent deposition in rivers, lakes and reservoirs are of great concern for two reasons. Firstly, rich fertile soil is eroded from the catchment areas. Secondly, there is a reduction in reservoir capacity as well as degradation of downstream water quality. Reduction of storage capacity of a reservoir beyond a certain limit hampers the purpose of the reservoir for which it was designed.

Soil erodibility is susceptibility and vulnerability of soil to get eroded. It is important hydrologic property of soil which helps researchers and planners in study of soil erosion characteristics. The erodibility is influenced by various soil characteristics mainly soil texture, structure, permeability, organic matter content. However in India at majority of locations and Konkan in particular values of all these parameters are not recorded. In such situations it is challenging to estimate the various soil parameters which are not recorded. In Maharashtra every district is having soil testing laboratory. Where textural classes and organic carbon of soils of many villages are recorded but other parameters like conductivity, permeability and erodibility are not available. These parameters are important from the point of view of soil mechanics and hydrology of the region. Therefore if these unavailable parameters of major representative soils are estimated from the knowledge of available parameters and their relationships, it will be grateful help to researchers, academicians and planners.

Advance modeling tools can be of great help in development of relationship among unknown parameters to estimate the unknown parameters. These model can give us the values of soil parameters which are known and based on these parameters further we can determine required variables of the erodibility. The Soil-Plant-Air-Water model (Saxton and Rawls, 2006) is one of the advance tools which is used to determine the hydraulic conductivity. The SPAW (Soil-Plant-Air-Water) is a computer model that simulates the daily hydrologic water budgets. It is a set of generalized equations which describe soil tension and hydraulic conductivity relationship versus moisture content as a function of sand, clay, textures and organic matter.

Erodibility is essential parameter for the estimation of soil loss using USLE. Studies on erodibility are not conducted so far in Konkan region where soil erosion is very high. Therefore the project entitled “Estimation of Erodibility at Selected Locations in Konkan Region” is undertaken with the following objective:

1) Determination of soil characteristics required for erodibility of representative soils at selected locations.
2) Estimation of erodibility of representative soils at selected locations.

II. REVIEW OF LITERATURE

This chapter deals with the review of research work done by various researchers on, physical, chemical properties of soil, Soil Plant Air Water model and erodibility of soil. The available literature is presented under the following heads:

1) Physical properties of soil

2) Chemical properties of soil.

3) Soil-Plant-Air-Water Model.

4) Soil Erodibility.

2.1 Physical Properties of the soil

The physical properties of soil include soil texture, particle density and porosity. These properties play an important role directly in the soil fertility, soil productivity, soil erodibility and soil management practices to be followed for attaining the optimum crop productivity from unit cultivated area.

2.1.1 Soil texture

Soil texture may be defined as the relative proportion of the various soils separates namely sand, silt and clay in a given soil. The proportion of each size group in a given soil cannot be altered easily, that is why texture is considered as a basic property of a soil.

Dongle and Patil (1987) studied the physico-chemical properties of lateritic soils in relation to their irrigability classifications. The studies revealed that effective soil depth and surface of the textural soils (0 to 20 cm) range between 0.52 m and 1.25 m and 28 percent and clay loam to clay, respectively. Further studies on the lateritic soils of Sindhudurg District, indicated that gravel content varied from 9.9 to 47.82 % and from 0.94 to 38.42 percent with the corresponding mean values of 24.14 to 12 percent respectively. The soils from Ratnagiri were found to be more gravely than Sindhudurg district. The gravel showed increasing trend with the soil depth.

Presley and Thien (2008) estimating soil texture by feel method in Kansas State University. The Laboratory analyses of soil texture were costly and take time, while feeling soil texture by hand was quick, free, and, with practice, highly accurate. There are two basic steps in the texture by feel method. After completing these two steps, soil textural class is determined. The textural triangle organizes the textures into

12 classes. The term coarse-textured is often used for soils that are dominated by sand. Fine-textured refers to soils that are dominated by clay, and medium-textured soils are more balanced mixture of sand, silt, and clay particles.

Senol *et.al* (2012) determined some physical characteristics of different particle sizes in soils with reflection spectroscopy which is in Isparta (Atabey) district Turkey. In this study, 60 soil samples were collected from the fields including different soil orders (entisols, inceptisols, vertisols and mollisols) in Isparta (Atabey) district; crushed samples were subjected into five different mesh sizes (4.76 to 2.00, 2.00 to 1.00, 1.00 to 0.50, 0.5 to 0.25 and <0.25 mm, respectively). Each soil sample was scanned with a visible near-infrared spectrometer, with a spectral range of 350 to 2500 nm, at five different particular sizes. The spectral reflectance's were used to predict some physical properties of the soil (texture, field capacity and wilting point) using partial least squares (PLS) regression. PLS analysis was used to develop calibration models between smoothed-first derivative 6-nm-spaced spectral reflectance data and soil physical analysis measured clay, silt, sand, field capacity and wilting point. The results showed that while soils need to be crushed to pass through 0.25 mm sieve in order to determine wilting point and amount of clay, mesh size was found non-significant in determining sand, silt and field capacity and the results obtained from the reflectance values taken from field samplings proved to be satisfactory.

2.1.2 Bulk density, particle density and porosity

Brady (1974) studied the physico-chemical properties of lateritic soils and it was revealed that bulk density of fine textured of soils commonly ranges from 0.0011 to 0.0013 tonne/m^3 and coarse textured soils from 0.0014 to 0.0018 tonne /m^3. The bulk humus is very low that was 0.37 kg/m^3 which product of organic matter generally lowers the bulk density of soils and also particle density for most soils usually varies between 2.6 to 2.75 Mg/ m^3 Organic matter weights much less than equal volume of the soil that was 1.1 to 1.4 Mg/ m^3. Consequently, mineral surface with higher organic matter than sub soils, usually have lower particle densities in surfaces.

Dabke (1987) studied physico-chemical properties of Phondaghat (Sindhudurg District). It was revealed that the bulk and particle density varied from 1.09 to 1.50

g/cc and 2.21 to 2.53 g/cc, respectively. The porosity of surface soils ranged from 37.35 to 55.31 percent.

Revendkar (1990) studied the physico-chemical properties of lateritic soils of Awashi (District Ratnagiri). It was revealed that bulk density of surface soils varied from 0.99 to 1.18 g/cc, with an average value of 1.07 g/cc. Particle density of surface soils varied from 2.43 to 2.72 g/cc, with an average value of 2.58 g/cc and porosity varied from 51.88 to 61.65 percent, with an average value of 58.4 percent.

Askin and Ozdemir (2003) showed the relationships between some soil physical and chemical properties such as, clay content (C), silt content (Si), sand content (S), very fine sand content (Vfs) and organic matter content (OMC) with soil bulk density (ρb). It was studied using path analysis on 77 surface soil samples (0-20 cm). Soil bulk density showed positive relationships with S and Vfs and negative relationships with Si, C and OMC. It was determined that the direct effects of some soil properties on ρb were in the following order; S>C>Si>OMC>Vfs. It was suggested that the sand fraction of soils should also be assessed in soil management.

Wijaya *et.al* (2004) estimated field soil dry bulk density by using Amplitude Domain Reflectometry (ADR) data. The experiment was sited at the Sakae-cho experimental field of Tokyo University of Agriculture and Technology (TUAT) covered by Andisol soil. The field of 4×4 m was divided into 81 small plots of 0.5×0.5 m each. The ADR probe was operated in every small plot, and the ADR output voltage was measured by using digital voltmeter. Soil samples were taken by using the steel ring of 100 cm^3 in volume. The results showed that the estimated dry bulk density agreed well with the measured dry bulk density. The regression coefficient (R^2) ranged from 0.4 to 0.7. Dry bulk density estimated by using the ADR data and wet bulk density (R^2 = 0.5-0.7) had greater accuracy than that by using the ADR data and mass wetness (R^2 = 0.4-0.6).

Heuscher *et.al* (2005) estimated bulk density using soil physical and chemical properties. A step wise multiple regression procedure was developed to predict oven-dried bulk density from soil properties using the 1997 USDA- NRCS National Soil Survey Characterization Data. The database includes both subsoil and topsoil samples. An overall regression equation for predicting oven-dried bulk density from soil properties (R^2 = 0.45, P<0.001) was developed using almost 47000 soil samples. Partitioning the database by soil suborders improved regression relationships (R^2 = 0.62, P<0.001). Of the soil properties considered, the stepwise multiple regression indicated that organic carbon content was the strongest contributor to bulk density prediction. Other significant variables included clay content, water content and to a lesser extent, silt content, and depth. In general, the accuracy of regression equations was better for suborders containing more organic C (most Inceptisols, Spodosols, Ultisols, and Mollisols). Bulk density was poorly predicted for suborders of the Aridisol and Vertisol orders which contain little or no organic C. Although organic C was an important variable in the suborder analysis, water content explained most (>30%) of the variation in bulk density for Udox, Xererts, Ustands, Aquands, and Saprists. Relationships between bulk density with soil volume measured on oven-dried natural clods and bulk density with soil volume measured at field-moisture content and one-third bar were also determined ($R^2 = 0.70$ and 0.69, respectively; $P < 0.001$).

Zhang *et.al* (2009) conducted experiments to measure the porosity and the saturated hydraulic conductivity of binary mixtures with different fractions of coarse and fine components and they proposed a mixing-coefficient model to estimate the porosity and a power-averaging method to determine the effective particle diameter and further to predict the saturated hydraulic conductivity of binary mixtures. The proposed methods were able to estimate the porosity and saturated hydraulic conductivity of the binary mixtures for the full range of gravel contents.

Chaudhari *et.al* (2013) investigated the dependence of bulk density on texture, organic matter content and available nutrients (macro and micro nutrients) for soil of Coimbatore. The relationships between some physical and chemical properties of soil such as, clay content (C), silt content (Si), sand content (S), CaCO3, organic matter content (OMC), total macro and micro nutrient content with soil bulk density (ρb) were studied for eight surface soil samples (0-15 cm). Soil bulk density showed negative relationships with all soil properties (Si, C, CaCO3, OMC, total macro and total micro nutrient content) except with sand content (S). Besides texture and OMC, the nutrient concentration was also the most effective factor that affected the bulk density of soils.

Pawar *et.al* (2013) studied the physico-chemical properties of soils in relation to depth in thirty two representative soil samples from mango orchards of four tehsils namely Kudal, Vengurle, Deogad and Kankavali of Sindhudurg district in Konkan region. In general, textural class for profile soils of mango orchards was found to be sandy clay loam, sandy clay and clay loam. The particle density and bulk density in soil profiles did not follow any specific trend. A declining trend of maximum water holding capacity down the profile was recorded in all mango orchards. Further, the soil pH increased with depth, while electrical conductivity and organic carbon decreased with depth.

2.2 Chemical properties of soil

2.2.1 Organic carbon and Organic matter

Longanathan and Krishnamoorthy (1976) studied black, red, alluvial and lateritic soils profile of Tamilnadu and reported that the organic carbon content varied from 0.0005 to 0.031 kg/kg.

Kadrekar *et.al* (1981) reported that the literate and lateritic soils of Maharashtra were fairly supplied with organic carbon (0.0060 to 0.0230 kg/kg).

Pareira *et.al* (1986) studied on physiochemical properties and micronutrient status of the mango orchard hill soils of Konkan. They reported that the organic carbon content was in the range of 0.24 to 2.59 per cent with an average value of 1.68 per cent.

Dongale and Patil (1987) studied the physico-chemical properties of lateritic soils and reported that organic carbon content was medium to high (0.0057 to 0.0123 kg/kg).

Terse (1989) studied that the benchmark lateritic soils from Wakavali, Pangari, Phondaghat and Vengurla series of South Konkan indicated that the organic carbon was in range of 0.0065 to 0.0135 kg/kg. Studies on profile samples showed that the organic carbon declined with increasing depth.

Das *et.al* (1991) studied on subsoil's of West Bengal in literatic zone. They indicated that these soils were low in organic carbon (0.0021 to 0.0057 kg/kg) which may be explained by high temperature and alternate wet and dry seasons prevailing in this zones.

Dongale and Kadrekar (1992) reported that soils in Ratnagiri district were derived from basalt parent material after laterization and contained higher organic carbon (1.87%), while in Sindhudurg district soils were derived mainly from granite and gneiss at many places and contained less (1.26%) organic carbon.

Craswell and Lefroy (2001) studied the role and function of organic matter in tropical soils. Soil organic matter (SOM) had many functions, the relative importance of which differs with soil type, climate, and land use. Commonly the most important function of OM in soil was as a reserve of the nitrogen and other nutrients required by plants, and ultimately by the human population. Other important functions include: the formation of stable aggregates and soil surface protection; maintenance of the vast array of biological functions, including the immobilization and release of nutrients; provision of ion exchange capacity; and storage of terrestrial carbon (C).

Schumacher (2002) studied the method for the determination of total organic carbon in soils and sediments. Carbon can be present in elemental, inorganic, or organic forms. Carbon was usually derived from weathering of the parent material/geology, the decomposition of plant and animal matter, or by addition through anthropogenic activities. There were numerous methods and variations of the methods for the identification and quantitation of TOC. These methods may be qualitative, semi-quantitative, or quantitative depending upon the technique used. Quantitative methods generally involve some form of sample preparation to remove water and/or inorganic carbonates, where present. After sample preparation was complete, either wet chemistry digestion or combustion techniques were used to convert the organic matter in the sample to CO_2 which is then quantified. Quantitation techniques range from simple gravimetric determinations through volumetric and manometric measurements through the more complex spectrophotometric and chromatographic methods.

Emmauel and Oguche (2013) studied that the physicochemical properties of rhizosphere of oil palm (*Elaeis guinensis*) for a period of 28 days. Soil samples were collected weekly from five Faculties of Kogi State University, Anyigba and analysed for pH, moisture, organic carbon, organic matter content, nitrogen and available phosphorus. The pH ranged from 6.07±0.18 to 6.47±0.09. The moisture content, organic carbon, organic matter content and phosphorus were high. There were significant differences ($p<0.05$) in pH, organic carbon, organic matter content, nitrogen and phosphorus concentration of the soil samples. The results indicated that the oil palm rhizosphere had close to neutral pH, high organic carbon, and organic matter content and available phosphorus. This is an indication of a fertile environment which may favour the growth of soil organisms, nutrient mineralization and uptake by the plant.

2.3 Soil- Plant-Air-Water Model

Hayhoe and Jong (1987) studied two soil water models for soybeans. A diffusion-based soil water model and the SPAW model were tested on soybeans grown on a Caledon sandy loam soil near Simcoe, Ontario. Two different root water uptake functions in the diffusion-based model were compared with the SPAW model. Water retention curves were measured. Hydraulic conductivity and root growth characteristics were based on soil texture and observed soybean growth characteristics. The models were driven by daily evapotranspiration and precipitation data. They suggested that the diffusion-based approach can provide useful estimates of soil water and evapotranspiration. By using specified soil hydraulic properties for a range of soil textures the model became a versatile tool for simulation. The SPAW model was also found to provide a good correspondence between measured and estimated data. It required less computer time to execute a simulation. One advantage of the diffusion-based approach is that it does not rely on the empirical relationships between the availability of soil water to plants and soil moisture content.

Saxton and Rawls (2006) estimated the soil water characteristics by texture and organic matter for hydrologic solutions. Hydrologic analyses often involve the evaluation of soil water infiltration, conductivity, and storage and plant-water relationships. To define the hydrologic soil water effects requires estimating soil variables such as texture, organic matter (OM), and structure. They developed new soil water characteristics equations from currently available USDA soil database using only the readily available variables of soil texture and OM.

2.4 Soil erodibility

Bousyoucos (1935) suggested that the soil erodibility depends on mechanical composition of soil such as sand, silt and clay. It is presented in the ratio, given as:

$$\text{Erodibility} = \frac{\%\ \text{Sand} + \%\ \text{Silt}}{\%\ \text{Clay}} \qquad \ldots (2.1)$$

The range of particles diameter of clay, sand and silt is given as under:

Clay: Below 0.002 mm

Sand: From 0.06 - 2.0 mm

Silt: From 0.002 – 0.06 mm

Pasak (1967) developed a relationship between soil erodibility, content of nonerodible particles, moisture content of soil and wind velocity at the soil surface. The equation is given as under:

$$E = 22.02-0.72\,P-1.69V+2.64R \qquad \dots (2.2)$$

where,

E = soil erodibility

P = content of nonerodible particles in the soil

V = relative moisture content

Vm = instantaneous moisture content

R = Wind velocity at the soil surface

Wischmeier *et.al* (1971) developed the procedure for determination of soil erodibility factor K by developing an equation based on five soil parameters. The values of K obtained using a nomograph (Wischmeier and Mannering, 1969) were found close.

Soil erodibility factor ‘K’ is of major importance in soil erosion prediction and its control. Direct measurement of ‘K’ from experimental plots is expensive and time consuming. Therefore, a simple nomograph is developed by Wischemeier *et al*. (1971)

$$100K = 2.1\times 10^{-4} \times M^{1.14}(12-a) + 3.25\times(b-2) + 2.5\times(c-3) \qquad \dots (2.3)$$

Where,

K = soil erodibility factor

M = (% silt + % very fine sand)* (100-% clay)

a = organic matter content

b = structure of soil

c = profile permeability of soil

Tejwani *et.al* (1975) reported that the lateritic soils of Ootacamund have low erosion ratio and low dispersion ratio and are generally non-erodible in nature. The six years average soil loss measured was 39.3 tonnes/ha from up and down cultivation of potato-after potato. The K value is 0.04 tonnes/ha/yr of runoff plot of 25 % slope and 11 m length.

Nema *et.al* (1978) determined the value of K at Vasad which varied from 0.052 to 0.066 on 2 % slope for sandy loam, deep calcareous soils. They also studied for a number of crops under various management conditions. He used gram, groundnut and cowpea with available C values. It was observed that cowpea is the most effective crop with C value of 0.32 followed by groundnut and gram.

Narain *et.al* (1980) conducted study on Kota clay loam soil at 1 % slope on plot of 22.13 m length. The values of K were found to vary from 0.03 to 0.23 t/ha/R.

Bajracharya and Lal (1991) studied seasonal soil loss and erodibility variation on a Miamian silt loam soil, at the Ohio state University Agronomy Farm, Columbus and monitored runoff and soil loss. The erodibility was estimated using Wischemeier model for two years. It was found that the soil erodibility was high under wet, thawing soil condition during winter and spring due to low soil strength and greater susceptibility to detachment.

Sharma *et.al* (1995) worked out raindrop induced soil detachment and sediment transport from inter-rill areas. The value of K has been worked out to be 0.07 based on the average soil loss from these plots.

Atawoo and Heerasing (1997) studied that estimation of soil erodibility and erosivity of rainfall patterns in Mauritius, conducted to test two models for predicting R. The erodibility factor (K) of soils from five erosion-prone areas was calculated in parallel using the nomograph developed by Wischmeier et al (1971). They concluded that in the first case the model developed by Arnoldus (1977) gives a close approximation to calculated R. In the other case there were indications that the soils tested were relatively resistant to soil erosion.

Bryan (2000) conducted experiment on soil erodibility and processes of water erosion on hill slope. He observed that rill and inter rill erosion using simulated rainfall and recently developed techniques that provide data at appropriate temoporal and spatial scales, essential for event-based soil erosion prediction and resulted that many components of erosional response, such as partitioning between rill and inter rill or surface and subsurface processes, threshold hydraulic conditions for rill incision, rill network configuration and hill slope sediment delivery, were strongly affected by spatially variable and temporally dynamic soil properties.

Xuezheng and Dongsheng (2001) studied the measurement of erodibility for soils in subtropical china by simulated and natural rainfall. Erodibility factor K of seven different soil types in subtropical China was measured under both simulated and natural rainstorms. Soils included in the study were, eroded Acrisol, cultivated Acrisol and barren land Acrisol on quaternary red clay; barren land cambisol and cultivated cambisol on red sandstone; calcaric regosol from purpule shale and cambisol on granite. Results showed that K measured by simulated rainfall varied widely, with the cultivated cambisol derived from red sandstone being the highest (about 0.390) and the barren land cambisol derived from the same parent material being the lowest (0.054). The erodibility K for these soils was also measured by using field plots without vegetation cover and under natural rainfall. The results showed that calcaric regosol on purple shale had the highest K value 0.451, while the eroded acrisol on quaternary red clay being the lowest, only 0.107. K measurement by simulated and natural rainfall were compared and discussed.

Keli *et.al* (2002) studied the erodibility of agricultural soils in the Loess Plateau of China. The purpose of this study was to choose an index reflecting the impact of soil properties on erosion for soil loss prediction in China, and to calculate a set of erodibility values for main soils on the loess plateau based on the data from several field stations. The standard unit in China was recommended as a plot which is 20 meters long and 5 meters wide with a slope of 15 degree in continuous fallow. The results showed that the soil-erodibility factor K defined as soil loss per rainfall erosion index unit as measured on a unit plot in the USLE more directly and accurately reflects the effect of loess properties on erosion than other available indices of soil erodibility even on the steep farmlands. Values of factor *k* for loessial soils ranged from 0.3 to 0.7, with the maximum appearing in Zizhou from where values of *k* decrease southward, northward, and eastward. The high value 0.61 appears in the tract of Zizhou and Suide from where *k* values gradually fall southward to 0.3278 in Ansai, eastward to 0.4372 in the region of Lishi, Shanxi, and northward to 0.531 in the watershed of Huangfuchuang river.

Chaudhary *et.al* (2003) studied erodibility under different land uses in soil of Eastern Ghat high landzone of Orisa. The result revealed shifting cultivated land was highly erodible due to steep slopes, low permeability, etc. the study was conducted on red lateritic silt clay loam to loamy sand soil. It was found that soil erodibility ranged from 0.05 to 0.1, 0.07 to 0.21 and 0.08 to 0.22, respectively in forest soil, grazing land and shifting cultivated soils for 0-15 cm layers.

Ali and Sharda (2005) used the standard runoff plot data from 1956 to 1998 to evaluate various parameters of the USLE in Rajasthan. The seasonal and annual rainfall factor (R) was found to be 341.6 and 404.5 respectively. Crop season and annual soil erodibility factor (K) of clay soil under climatic condition of south-eastern Rajasthan was found 0.15 and 0.11 t/ha/unit of EI30 (R) respectively. Cover and management factor (C) for row crops, legumes, and intercropping of row crops with legumes were about 0.52, 0.45 and 0.35 respectively. The C value of grasses ranged from 0.007 to 0.14, whereas natural cover has value of 0.15. They concluded that information generated on R, K, C and P factors of the USLE is useful in planning of soil and water conservation and watershed management programmes.

Yadav *et.al* (2005) studied the erodibility of major soils of Delhi. They determined soil erodibility for all families of Delhi from four soils characteristics viz., particle density, organic matter, soil structure and permeability. The Wischemeier and Smith (1978) regression equation was used to determine soil erodibility. It was found that coarse loamy and fine loamy were the most erodible soil. The erodibility was found to be in the range of 0.2 to 0.4 t-ha-hr / ha-MJ-mm.

Idah *et.al* (2008) determined of erodibility indices of soils in owerri west local government area of imo state, Nigeria. The problem of soil erosion, especially in the south-eastern part of Nigeria, was enormous. This problem was affecting the development because infrastructures such as houses, roads and many others were being destroyed yearly and this in turn constitutes an environmental menace. To effectively tackle this problem, there was a need to evaluate those factors of soils that affect erosion. In this study, some indices of soil erosion in owerri west local government area were determined. This study involved taking measurements of some soil parameters such as permeability, soil texture, and classification index on the field as well as laboratory tests from which the erodibility indices were computed. The results showed that Ohi with index of 0.044 had the highest erodibility index while Ava with 0.030 has the least one. The practical implication of these findings was in the area of design of control structures that would be able to stand the test of time.

Korkanc *et.al* (2008) determined the effects of land use conversion on soil properties, soil erodibility and the relationships among soil properties and some erodibility indices. Duplicate topsoil samples were taken by using steel cylinders at 100 different sampling points from three different land use types; 34 of them were in farmlands, 34 in rangelands and 32 in forestlands. Soil particle size distribution, loss of ignition, pH, electrical conductivity, skeleton percentage and three erodibility indices were determined. Data were analyzed by using Pearson correlation analysis (at 95% and 99% significance level), ANOVA and Tukey’s test at 95 % significance level. According to study results, land use conversion affects some properties of soils significantly. Loss of ignition of soils in forests was significantly higher than soils in farmlands and rangelands. Soil skeleton percentage in rangelands and farmlands were significantly different. The study results showed that there was significant difference between pH of soils in forests and farmlands ($p < 0.05$). Pearson correlation analysis showed significant correlations among erodibility indices and certain soil properties such as clay and sand fraction of soils ($p < 0.05$ and $p < 0.01$). Top soils of the study area were sensitive to erosion according to all three erodibility indices. The most sensitive soils were in farmlands.

Shabani *et.al* (2010) investigated the effects of land use and slope on soil erodibility factor in four adjacent land use in northern Iran. Land uses were forest, pasture, irrigated farming, and dry farming that were located in three sites with different slopes of 3-8, 8-18, and 18-40 percent. Three replicated soil samples were collected from each land use at each site. Some chemical and physical properties of soil samples were determined. K values were estimated by using the nomograph method (k equation). Data analysis showed that there were significant differences between different slopes and land uses. K value increased with slope for most land uses due to changing erodibility components such as SOM, texture, structure, and permeability. Pasture land with slope of 8-18% had minimum value of erodibility (0.023). The maximum K value was for irrigated farming with 8- 18% slope (0.078). In addition, forest has the second highest value; however dry farming has much more erosivity than forest.

Singh and Khera (2010) estimated that soil erodibility by different techniques. It was concluded that direct measurement of soil erodibility, resistance offered by the soil to both detachment and transport processes, was not only costly but time consuming also. So, efforts had been made to predict it from the soil properties. To evaluate soil erodibility under different land uses using natural and simulated rainfall and to estimate soil erodibility by nomographic and fuzzy logic method, a field experiment was conducted both under natural and simulated rainfall conditions under four land uses viz. barren, cultivated, grassland and forest in the sub-mountainous tract of Punjab (India). Measured soil erodibility (K) values varied from 0.33 to 0.67 under natural rainfall conditions and from 0.23 to 0.40 under simulated rainfall conditions. Values of the soil erodibility factor estimated by nomograph and FUZKBAS program were very low as compared to the observed values. The trends were also in contrast to these observed values of soil erodibility under simulated and natural rainfall conditions.

Pazhouhesh *et.al* (2011) determined soil erodibility factor using fuzzy rule base system. Sixty samples were collected from sixty homogenous units based on the Wischmeier's nomograph method. After generating the fuzzy rules and calculating the soil erodibility factor, the results were compared with those of Wischmeier's nomograph method. The results showed that the values of K- factor calculated by the fuzzy system were quite close to the values obtained by the USLE model and therefore, the fuzzy rule base model was introduced as the most suitable site selection strategy for determining soil erodibility factor.

Andoh *et.al* (2012) studied that estimation of soil erodibility and rainfall erosivity patterns in the agroecological zones of Ghana. They investigated that the temporal variability of rainfall erosivity using the Fournier Index Method and assessed the soil erodibility parameters of sawah site using WEPP technology and resulted that soil organic matter content ranged from 1.95 to 5.52%, interrill erodibility (Ki) values ranged from 44.26 × 105 to 51.70 × 105 kg s m-4 under all land uses, rill erodibility (Kr) values ranged from 0.005 to 0.012 s m-1 under all land use.

Isikwue *et.al* (2012) studied the erodibility of soils of the south west benue state, Nigeria. Data on the soils from this area which was necessary for the completion of the Universal Soil Loss Equation, soil erosion risk assessment, and design of conservation structures, was lacking. Soil samples from different parts of the South West Benue comprising Ogbadibo, Ohimini, and Okpokwu local government areas were studied for their susceptibility to erosion. Some soil properties and indices of erodibility were determined and an erodibility map was developed. Moisture content, porosity, shear strength, and clay content were low while permeability, specific gravity, and bulk density were high. Dispersion ratio and modified clay ratio were found to be averagely high while erosion ratio and water stable aggregates were low. Erodibility factor K was computed and found to be between 0.03 at Okpoga and Idobe to 0.32 at Orokam. Soil loss was also noticed to be highest at Orokam (65 t/ha/yr). A correlation analysis between soil loss and the indices of erodibility was carried out where it was observed that dispersion ratio, modified clay ratio correlated positively with soil loss while negative correlation existed between soil loss with Erosion ratio and Water Stable Aggregates. Based on known standards and values of Erodibility factor (K) obtained Erodibility map of the South-West Benue State was developed.

Erodibility factor of soil is important parameter in soil erosion determination. Few soil data required for estimation of erodibility like %Sand, %Silt, %Clay and %O.C is easily available, in District Soil Testing Laboratories. Primary data is available but other parameters required for erodibility viz-permeability code, structure code are not available. So it is necessary to determine the erodibility based on available data with the help of advance modelling tools which uses the relationship between available parameters and required parameters. Erodibility studies are very rare in Indian conditions. Whenever erodibilities are determined, they are widely spaced from each other. Literature shows that using erodibility factors of locations far away from study area does not give accurate results. Many soils have not covered so far in the studies of erodibility in India. This lack of knowledge of erodibility factors leads to inaccurate estimation of soil erosion from area. If all soil parameters are available, then soil erodibilities can be determined. Otherwise soil parameters from available data need to be determined. Various models are developed to extrapolate the relationships among various parameters. Soil Plant Air Water model (SPAW) is considers one of the accurate model to determine soil characteristics from easily available data. It is therefore consider useful and essential to use SPAW model for determination of erodibility at various lacations in Konkan region. In Konkan region no details study concerning soil characteristics, soil erodibility estimation of Konkan region have been reported in the literature. It affects the accurate estimation of the actual erosion in Konkan region. This leads to improper planning of North region of Maharashtra. The recent research of determination of soil characteristics using advance modelling tool will not only aid in estimation of erodibility factor in Konkan region soil but it will also give detail knowledge of Konkan soils. This additional description of soil will also aid in crop planning of watershed. Therefore based on literature it is felt essential to carry out the research related to erodibility in Konkan region.

III. MATERIALS AND METHODS

This chapter deals with the description of study area, data collected, procedure for collection of soil samples, procedure adopted to determine characteristics of soil by using Soil-Plant-Air-Water (SPAW) model, procedure for estimation of erodibility of soils and generation of soil erodibility map. The details regarding the materials used and the methods followed are as follows.

3.1 Study Area

Konkan region is located between $15^0$44' and 20°20' N latitude and $70^0$10' and $73^0$50' E longitude. It has longitudinal distance of 500 kms and a width of 35- 40 kms. The total geographical area of Konkan region is 3.09 Mha. It comprises of five districts, namely Sindhudurg, Ratnagiri, Raigad, Thane and Mumbai. The northern part of the Konkan coast has a narrow alluvial belt and relatively flat residual hill tops of lateritic exposures. The southern part has rugged topography with steep hills, ridges, plateaus and valleys. Konkan region receives an average annual rainfall of 2500-4000 mm mostly through southwest monsoon during the months June to October. The rainfall is of high intensity with total rainy days ranging from 73 to 101. The rainfall and rainy days generally increases from northern region to southern region (Challa *et al.* 2001).

Out of the nine agro-climatic zones of Maharashtra state, the Konkan region covers three zones *viz*., very high rainfall lateritic zone (VRL), very high rainfall non-lateritic zone (VRN) and ghat zone. Lateritic soils are found in whole Sindhudurg and Ratnagiri districts (South Konkan) and non-lateratic (red soil) found in northern part i.e Raigad and Thane district.

Present investigation was carried out in all three zones of Konkan region. Total 210 villages from 45 tahsils/block of four districts excluding Mumbai were selected for soil sample data collection. Mumbai is megapolic city with very high degree of urbanisation and neglegible exposed soil. List of villages from each Tahsil and District are given in Table 3.1 to 3.4. These 210 villages are spread throughout Konkan region from North to South and East to West, to give proper representation of soils of Konkan region. Majority of soils of Konkan region belongs to the order Inceptisols followed by Entisols, Alfisols and Vertisols (Challa *et al*. 1995).

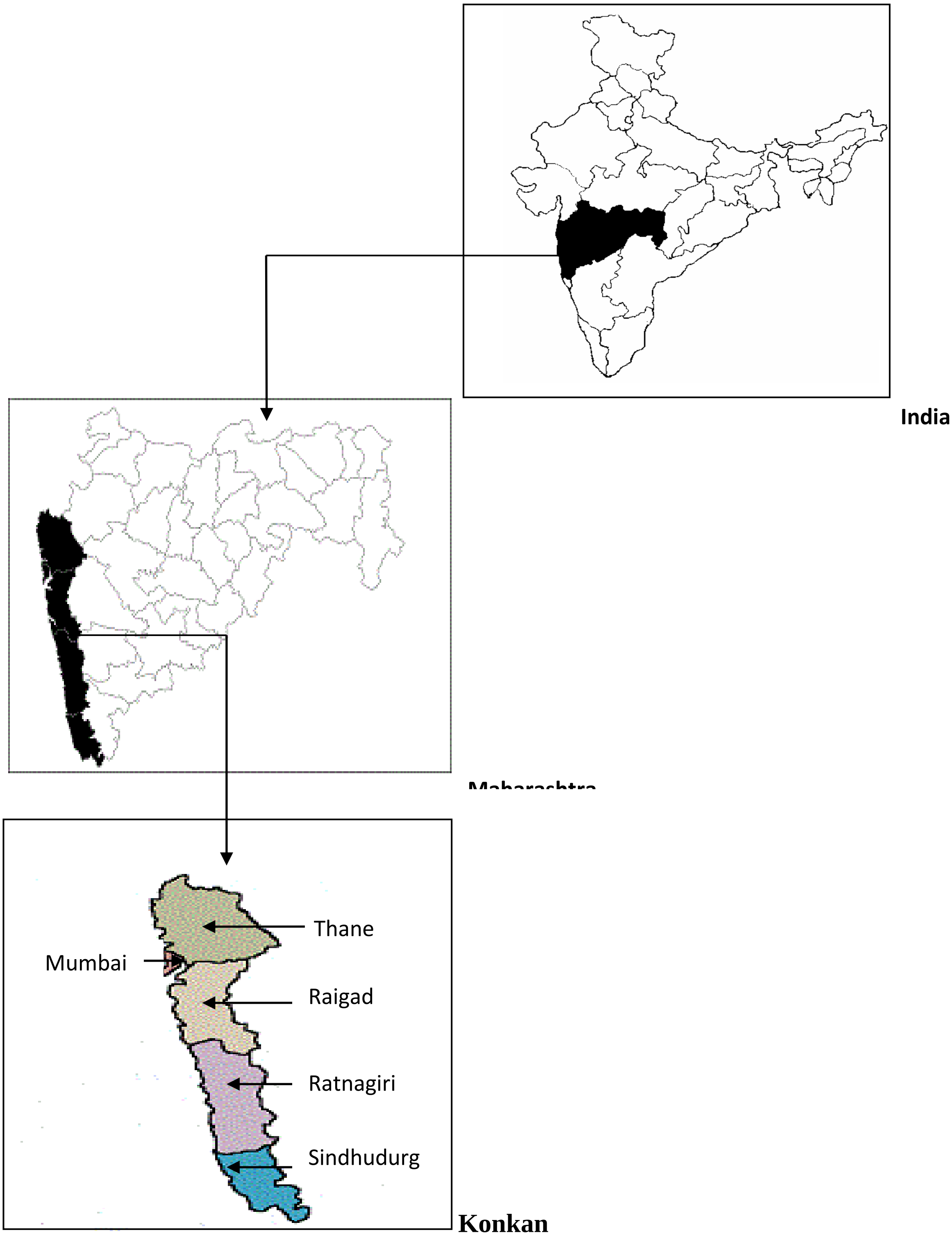


Fig.3.1 Location map of study area

Table 3.1: List of villages in Sindhudurg district

Sr. No	Tahsil	Village	Sr. No	Tahsil	Village
1	Kudal	Naiknagar	5	Vaibhavwadi	Wabhave
		Pawashi			Khambale
		Oros khurd			Lore
		Aanav			Mohitewadi
		Pinguli			Tembwadi
2	Vengurla	Aadeli	6	Devgad	Dabhole
		Tulas			Vitthaladevi
		Pal			Naringre
		Mochemad			Pombhurle
		Matond			Nad
3	Malwan	Tondavali	7	Savantwadi	Bhalawal
		Bagwadi			Madkhol
		Nandrukh			Malgaon
		Chafekhol			Sangeli
		Varad			Nanos
4	Kankavali	Sambhajinagar	8	Dodamarg	Maneri
		Janavali			Hewale
		Shirval			Morgaon
		Wargaon			Zarebambar
		Vayangani			Ghatiwade

Table 3.2: List of villages in Ratnagiri district

Sr. No	Tahsil	Village	Sr. No	Tahsil	Village
1	Ratnagiri	Nachne	6	Guhaghar	Chikhli
		Jaygad			Abloli
		Vasani			Naravan
		Ganpatipule			Pomendi
		Jambhrun			Kotaluk
2	Lanja	Gavane	7	Khed	Lote
		Khan Vali			Khopi
		Agave			Kudeshi
		Kurne			Sukavali
		Harche			Musad
3	Rajapur	Jaitapur	8	Mandngad	Kumbale
		Nanar			Surle
		Niveli			Kuduk
		Mith Gavane			Pimpoli
		Sagve			Ranvali
4	Chiplun	Pimpali	9	Dapoli	Shirsoli
		Savarde			Burondi
		Tiwre			Unhavare
		Dhameli			Gavhe
		Bamnoli			Avashi
5	Sangmeshwar	Nive			
		Ozare			
		Sakharpa			
		Dhamapur			
		Tulsani			

Table 3.3: List of villages in Raigad district

Sr. No	Tahsil	Village	Sr. No	Tahsil	Village
1	Tala	Maluk	8	Alibag	Veshvi
		Tala			Karle
		Tokarde			Nagaon
		Girne			Ambeghar
		Washi Haveli			Beloshi
2	Mhasala	Kavat	9	Murud	Bhoighar
		Bhabat			Saigaon
		Pandare			Nagshet
		Toradi			Wawdungi
		Dehen			Amboli
3	Khalapur	Kambe	10	Poladpur	Punalkond
		Wadgaon			Wakan
		Vat			Sawad
		Talavali			Dharwali
		Golewadi			Faujdar
4	Karjat	Shirshe	11	Panvel	Pali
		Sangavi			Jatade
		Sugave			Morbe
		Wave			Wardoli
		Pashane			Taloje
5	Shrivardhan	Nagaloli	12	Mangaon	Saje
		Bagmandale			Warachiwadi
		Saigaon			Sanaswadi
6	Roha	Mhasadi			Umbardi
		Jamgaon	13	Mahad	Khaire tarf
		Chinchwali	14	Pen	Jirne
		Khamb			Shedashi
		Kokban			Banase
7	Sudhagad	Dharechiwadi			Gadab
		Kasarwadi			Gangode
		Jambhulpada	15	Uran	Ransai
		Nadsur			

Table 3.4: List of villages in Thane district

Sr. No	Tahsil	Village	Sr. No	Tahsil	Village
1	Vada	Adivali		Dahanu	Dehane
		Musarne			Kainad
		Ainshet			Nikane
		Kharivali			Vaki
		Sange	9	Shahapur	Ambivali
2	Jawhar	Aalond			Patol
		Aaling			Shendrun
		Mohkhurd			Khardi
		Kurze			Sarlambe
3	Vasai	Khardi	10	Murubad	Eklahare
		Bhuigaon			Tokawade
		Sandor			Vaishakhare
		Chandansar			Inde
		Naringi			Karavale
4	Talasari	Udhawa	11	Palghar	Unbhat
		Vasa			Tandulwadi
		Kurze			Paragon
		Talasari			Varkhunti
		Sutrakar			Virathankhurd
5	Kalyan	Anakharpada	12	Ulhasnagar	Ambarnath
		Mamnoli			Ambhe
		Rayate			Asnoli
		Shirdhon			Karand
6		Dahagaon			Chargaon
7	Bhivandi	Khanivali	13	Vikramgad	Khand
		Palkhane			Tolepda
		Katai			Balapur
		Kurund			Rampur
		Gorsai	14	Mokhada	Medhi
8	Dahanu	Bordi			Veti
		Bendgaon			Suksale

3.2 Data Collection and Pre-processing

Soil parameters such as sand, silt, clay and organic carbon were collected from District Soil Testing Laboratories of Sindhudurg, Ratnagiri, Raigad and Thane Districts of Maharashtra State. Minimum four villages were selected from each tahsil/block of four districts depending upon availability of required data. According soil parameter data were collected from 210 villages of 45 tahsils/block of Konkan region for proper representation of all majority soils from three agro-meteorological zones. The data were checked for any abnormalities and classified according to districts once proper representation was given to all zones. The data is presented in Table 4.1 to Table 4.4. The soil data regarding texture, organic matter content, permeability, structure were used to derive soil erodibility factors (K).

The District Soil Testing Labortories follows the standard procedure for collection of soil samples.

1) Five soil samples from each field were to be collected for analysis.
2) Four samples from four corners and one sample from centre of the field were mixed thoroughly and used in laboratory for analysis.
3) They were analysed for parameters like sand%, silt% clay% and organic carbon%.
4) Soil samples of common range were put together for getting the mean of parameter values.
5) From one village 20-40 fields soil samples were collected depending upon area of village.

Fig. 3.2 Location map of sample points

3.3 Determination of Organic Matter

Organic matter has a variable influence on soil and affects both its chemical and physical properties. The effect of organic matter on physical properties relates largely to its abilities to bind soil particles together. So the organic constituents of soil are important because of their influence on aggregate stability. Soil with less than 3.5% organic carbon can be considered erodible. In present study organic carbon data was available. So organic matter of soil was determined by following equation (Hesse, 1971), for all 210 villages of Konkan region.

$$\text{Organic matter} = \text{organic carbon} \times 1.724 \qquad \ldots (3.1)$$

3.4 Estimation of Hydraulic Conductivity

Hydraulic conductivity is the ability of particular soil to transmit the water through it. The hydraulic conductivity (cm/hr) was obtained from different soil parameters such as sand (%), silt (%), clay (%) and organic carbon (%). The hydraulic conductivity was determined by using Soil-Plant-Air-Water (SPAW) model. Hydraulic conductivity of soils were used to obtained permeability codes of soils. (Smith and Browning, 1946).

3.5 Calibration and Validation of SPAW Model

It is recognized that soil texture is having a dominant effect on soil water characteristics. However, four additional variables (organic matter, density, gravel, hydraulic conductivity) that can have important effect were included in the erodibility estimation method. Hydrologic analyses often involve the evaluation of soil water infiltration characteristics, conductivity, storage and plant water relationships. To understand the hydrologic behavior of soils, it is essential to estimate soil water characteristics for water potential and hydraulic conductivity using soil variables such as texture, organic matter and structure. Models of soil texture, soil water potential and hydraulic conductivity provide estimates sufficiently accurate for many analyses and decision. In one of Models "**Soil - Plant- Air -Water"** (SPAW) which is developed by (Saxton and Rawls, 2006), the hydraulic conductivity (cm/hr) was obtained from values of sand (%), clay (%) and organic carbon (%).

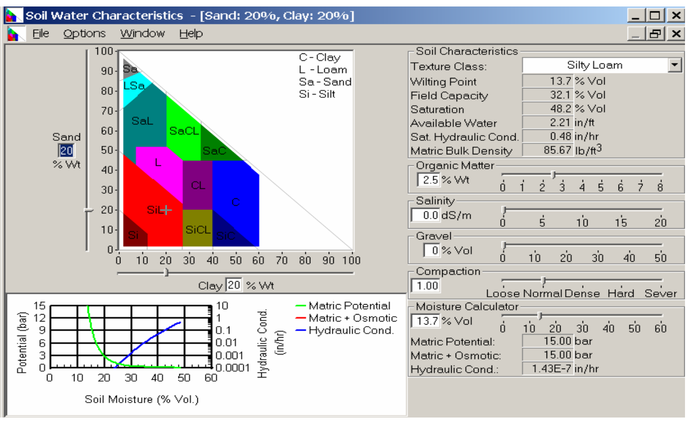


Fig. 3.3 Soil Water Characteristics (SPAW Model)

Model calibration is the adjustment of constants and other model parameters in estimated or asserted models in an effort to make the models replicate observed data and produce reasonable results. Hydrological models only provide an approximation of the underlying actual processes. Therefore they exhibit a certain degree of conceptualisation and these parameters are not physically measurable. Manual hydraulic conductivity of saturated soil was estimated by using Inverse Auger Hole method (Kadam *et al.* 2008). Following procedure was followed for the estimation of manual hydraulic conductivity:

1) Holes were made in soil with the help of auger and fill the hole with water and let it drain.
2) They were refill with water several times until the soil around the hole, saturated over a considerable distance and the infiltration rate had attained a more or less constant value.
3) Measured the rate of infiltration and Record the depth of water level against time using scale and stop watch.
4) By using volume of water and area of hole were calculated Q and using the required values were calculated the value of hydraulic conductivity.

Hydraulic conductivity was estimated by following equation.

$$K = 1.15\,\frac{\log(ho+\frac{1}{2})-\log(ht+\frac{1}{2}r)}{t-to} \qquad \ldots (3.2)$$

Where,

K = hydraulic conductivity (cm/hr)

t = time since start measuring

h_t = height of water column in the hole at time t

h_o = h_t at time t=0

r = radius of hole

The calibrating parameters of SPAW model were selected for the Priyadarshani watershed where manually calculated values of hydraulic conductivity and erodibility were available at 22 locations. The Density adjustment factor (DF) was selected for the calibration of model for the region. Model was calibrated for 15 locations. Simulated and Observed values of hydraulic conductivity and erodibility of these locations were compared. After getting close match between observed and simulated values based on statistic parameter, i.e. coefficient of determination (R^2), the model was validated for remaining 7 locations. Simulated and Observed values of hydraulic conductivity and erodibility were compared for the validated locations with the help of statistical tools.

3.6 Determination of Permeability

Permeability is the property of porous material which permits the passage or seepage of water through its interconnecting voids. Water intake of soils is maximum when soil is fairly dry. After water is added the pore space get filled. Then clods swells and the rate of entry of additional water declines to uniform level. Wischemeir *et al*. (1971) presented the integrated effect of various factors influencing infiltration rate, by a single factor of permeability to determine erodibility of soils. Smith and Browning (1946) have given the relationship between permeability classes and hydraulic conductivity (Table 3.5).

Table 3.5: Permeability classes based on Hydraulic conductivity of soil

Permeability classes	Hydraulic conductivity(cm/hr)
Extremely slow	< 0.0025
Very slow	0.0025-0.025
Slow	0.025-0.25
Moderate	0.25-2.5
Rapid	2.5-25.0
Very rapid	> 25

(Source: Smith and Browning, 1946)

Permeability classes of soils in Konkan region were determined from the hydraulic conductivity. Based on these permeability classes, permeability codes were identified for various soils (Table 3.6). Then these permeability codes were used in erodibility equations for all the villages.

Table 3.6: Permeability code for different types of soil

Code	Description	Rate (mm/hr)
1	Rapid	>130
2	Moderate to rapid	60-130
3	Moderate	20-60
4	Slow to moderate	5-20
5	Slow	1-5
6	Very slow	<1

(Source: Smith and Browning, 1946)

3.7 Determination of Soil Structure Code

Soil structure is defined as the manner in which soil particles are assembled in aggregate form. Aggregation depends on the cohesive nature of the finer particles and natural forces that organize and retain them in specific structural units with definite shapes and sizes. Structures are designated as blocky, prismatic, granular and platy. Very fine granular structure is considered stable. It does not break down under cultivation and possesses high infiltration capacity. Blocky and platy structures are considered more erodible. Structure of soil is greatly influenced by textural class of soil (Bouyoucos, 1935). So first textural class of soil was determined by using SPAW model. Based on these textural descriptions, structural classes were assigned to each soil of villages as proposed by NBSS and LUP (1988) (Table 3.7). Accordingly structural codes were identified for each type of soils (Table 3.8). These structural codes were used in erodibility equations for all villages.

Table 3.7: Structural Classes of different soil

Class	Range
Very fine	Less than 1 mm thickness
Fine	1 – 2 mm thickness
Medium	2 – 5 mm thickness
Coarse	5 – 10 mm thickness
Very Coarse	More than 10 mm thickness

(Source: NBSS and LUP, 1988)

Table 3.8: Structure code for different types of soil

Code	Structure	Size (mm)
1	Very fine granular	<1
2	Fine granular	1 – 2
3	Moderate or Coarse granular	2 – 10
4	Blocky, platy or massive	>10

(Source: NBSS and LUP, 1988)

3.8 Concept of Soil Erodibility

Soil erosion is a process of detachment and transportation of soil materials from its original place by the action of various erosive forces. Soil erosion is highly dependent on degree of erodibility of particular soil along with other factors. Soil erodibility is different form of soil erosion in that the total soil erosion influenced by the various soil characteristics. Soil Erodibility (K) is an important hydrologic property of soil which helps researchers and planners in study of soil erosion characteristics. Soil erodibility is the function of both the physical characteristics of soil and land management practices. It is a total effect of a combination of soil properties. Some of these properties influence the capacity to infiltrate and therefore, help to determine the amount and rate of runoff. Some other properties influence capacity to resists detachment by erosive forces of falling raindrops and flowing water and thereby determine soil content of runoff. The interrelation of these variables is highly complex. It is major consideration in developing sound management practices for agricultural, forest and other land to protect fertile soil.

3.9 Estimation of Soil Erodibility of Konkan region (K)

The soil erodibility factor (K) was estimated for each soil type of study area with the help of data obtained from District Soil Testing Laboratories of Sindhudurg, Ratnagiri, Raigad and Thane. Available data of Sand, Silt, Clay and Organic carbon were used to get the soil parameters essential for erodibility estimation.

Based on these data, soil parameters required for estimation of soil erodibility were determined by using various relationships among soil characteristics. Organic matter content has been calculated from organic carbon of soil. Permeability code has been obtained from permeability classes based on hydraulic conductivity obtained by using SPAW model. Soil structure codes were obtained from textural description of soil. The erodibility values were computed for all 210 villages of Konkan as per Wischmeier and Smith (1971) formula.

$$100\,K = 2.1\times 10^{-4} \times M^{1.14}(12 - a) + 3.25 \times (b-2) + 2.5\times (c-3) \quad \text{... (3.3)}$$

Where,

K= soil erodibility factor

M= (% silt + % very fine sand) × (100-% clay)

a= organic matter content

b= structure of soil

c= Permeability of soil

Very fine sand was determined by following equation.

Very fine sand = 0.7 x % sand … (3.4)

3.10 Estimation of Particle Size Parameter (M)

Particle size of soil affects the erodibility. The fine particles are easy to transport but difficult to erode and inverse relation is found to be true for the sand particle. Particle size parameter (M) in erodibility equation is used to exhibit the combine influence of various sizes of particles on vulnerability of soil mass. This combine effect is given by empirical relationship based on silt, very fine sand and clay. Particle size parameter was estimated by following equation.

$$M = (\%Silt + \%Very\ fine\ sand) \times (100 - \%\ Clay) \qquad \ldots (3.5)$$

Based on above equation, particle size parameter (M) was estimated for all villages. These estimated values were used as input parameter in erodibility estimation of each village.

3.11 Generation of Soil Erodibility Map

Soil erodibility factor (K) values for 210 villages were calculated using the procedure given in section 3.9. Soil erodibility factor (K) value was assigned to each village of four districts of Konkan region in Arc GIS 9.3. The Inverse Distance Weighted Technique was used for interpolation. Five thematic maps of erodibility viz -four districts maps of Sindhudurg, Ratnagiri, Raigad and Thane and one whole Konkan region map were generated after interpolation.

IV. RESULTS AND DISCUSSION

The data analysis results and interpretation of different outcomes is discussed in this chapter. In the present investigation, efforts were made to determine the physico-chemical properties (sand, silt, clay and organic carbon), calibration and validation of SPAW model, hydraulic conductivity of soils, permeability of soils, structural classes of soils, estimation of erodibility of soils and generation of soil erodibility maps. To study the interrelationships among various physico-chemical properties of soils simulation modeling study was undertaken. This chapter has been divided into following sub-heads, for convenience in presentation of results.

1) Physical properties of soils
2) Chemical properties of soils
3) Calibration and Validation of SPAW model
4) Hydraulic conductivity of soils
5) Permeability of soils
6) Structural class of soils
7) Soil erodibility
8) Generation of soil erodibility maps

4.1 Physical properties of soils

4.1.1 Mechanical composition of soils

4.1.1.1 Sand content

The data presented in Table 4.1 to 4.4 revealed that the percent distribution of sand in soils of Sindhudurg district was found to vary from 32.08 to 61.08 percent with a mean value of 56.22 percent. Ratnagiri district soils have shown that the sand content ranged between 23.73 to 72.7 percent with a mean value of 42.94 percent. Raigad district soils have sand content ranging from 42.67 to 83.05 percent with the mean value of 69.08 percent. Thane district soils have the sand content range between 23.83 to 61.94 percent with the mean value of 41.93 percent. Above results showed the sand content in Konkan region varied from 23.73 to 83.05 percent with the mean value of 53.02 percent.

Lateritic soils of Konkan region were having high range of sand content as compare to the silt and clay content. The sand content of Raigad district was highest as compare to other three districts of Sindhudurg, Ratnagiri and Thane. Due to high sand content very little force was required to detach the soil particles making then more susceptible to the erosion. The effect of sand content on soil bulk density was found to be higher than that of other soil properties (Chaudhari *et al.* 2013) which ultimately affects the erodibility characteristics of soils.

4.1.1.2 Silt content

The percent distribution of silt content in the soils of the Sindhudurg district ranged from 17.98 to 27.06 percent with the mean value of 21.08 percent (Table 4.1). Ratnagiri district soils have silt content in the range of 13.49 to 52.16 percent with the mean value of 36.56 percent (Table 4.2). Raigad district soils have silt content in the range of 7.30 to 54.02 percent with mean value of 20.83 percent (Table 4.3) and in Thane district values ranged from 13.70 to 56.21 percent with mean value of 30.03 percent (Table 4.4). The overall silt content in Konkan region soils was found in the range of 7.3 to 56.21 percent with the mean value of 26.97.

Silt content was found to be higher in Ratnagiri district. Silty soils are known to lack cohesion as their particles are loose therefore require little drag force to be transported by the force of moving water (Isikwue *et al*. 2012).

4.1.1.3 Clay content

The clay fraction soils of Sindhudurg district varied from 17.56 to 47.95 percent with the mean value of 22.67 percent (Table 4.1). Ratnagiri district soils clay content varied from 12.97 to 29.4 percent with the mean value of 20.48 percent (Table 4.2). Raigad district soils was found to have clay content in the range of 2.39 to 28.61 percent with the mean value of 10.13 percent (Table 4.3). Clay content in Thane district soils was found to be in the range of 11.81 to 48.75 percent with the mean value of 28.12 percent (Table 4.4). Konkan region soils the clay content varied from 2.39 to 48.75 percent with the 20.05 percent.

The clay content was found less in Raigad district as compared to other districts like Sindhudurg, Ratnagiri and Thane. Presence of clay material provides the required bondage between the varying soil particles resulting in the formation of more stable aggregates which makes them less susceptible to erosion (Isikwue *et al*. 2012). The lesser clay content reduces the tendency of the soil particles to bind together and form aggregates that are resistible to the shearing force of flowing water thus making the soils vulnerable to soil erosion.

In general, textural classes for all the districts were found to be in the category of sandy clay loam type for Sindhudurg district, loam type for Ratnagiri district, sandy loam type for Raigad district and sandy clay loam type for Thane district (Table 4.9 to 4.12).

Table 4.1: Physico-chemical properties and hydraulic conductivity of soils of Sindhudurg district

Sr. No.	Villages	% Sand	% Silt	% Clay	% O.C	O.M	H.C (cm/hr)
1	Naiknagar	58.02	20.88	21.1	1.66	2.9	12.57
2	Pawashi	58.72	20.26	21.02	1.76	3.0	10.89
3	Oros khurd	54.21	21.98	23.51	3.04	5.2	2.89
4	Aanav	60.69	18.72	20.59	1.98	3.4	8.22
5	Pinguli	57.52	18.74	23.74	1.51	2.6	16.02
6	Aadeli	57.07	19.96	22.97	2.31	4.0	18.82
7	Tulas	58.00	18.75	23.25	2.06	3.6	15.82
8	Pal	56.91	21.28	21.81	1.26	2.2	15.01
9	Mochemad	32.08	20.48	47.14	2.27	3.9	24.81
10	Matond	33.04	19.01	47.95	2.27	3.9	2.56
11	Tondavali	58.86	17.98	23.16	1.41	2.4	12.26
12	Bagwadi	58.10	20.57	21.33	1.13	1.9	11.60
13	Nandrukh	55.65	22.28	22.07	1.21	2.1	17.37
14	Chafekhol	57.90	21.09	21.09	1.71	2.9	12.67
15	Varad	58.08	20.16	21.76	0.18	0.3	16.23
16	Sambhajinagar	57.30	20.66	22.04	0.70	1.2	14.09
17	Janavali	59.23	19.43	21.34	1.13	1.9	9.77
18	Shirval	58.11	21.47	20.42	2.44	4.2	13.43
19	Wargaon	58.00	20.95	21.05	2.49	4.3	14.52
20	Vayangani	56.71	21.35	21.94	1.41	2.4	15.29
21	Wabhave	55.10	27.06	17.78	2.03	3.5	24.89
22	Khambale	54.82	19.99	25.19	1.73	3.0	2.66
23	Lore	54.87	20.01	25.12	1.23	2.1	2.56
24	Mohitewadi	56.47	21.81	21.72	1.73	3.0	18.41
25	Tembwadi	54.82	19.99	25.19	1.73	3.0	2.66
26	Dabhole	59.15	21.19	19.66	0.25	0.4	4.64
27	Vitthaladevi	57.68	19.84	22.48	1.08	1.9	12.49
28	Naringre	56.67	21.7	21.63	0.58	1.0	13.94

29	Pombhurle	58.26	21.25	20.49	0.85	1.5	23.01
30	Nad	57.4	19.20	23.4	1.00	1.7	15.84
31	Bhalawal	59.54	22.88	17.58	0.95	1.6	5.02
32	Madkhol	56.22	24.50	19.28	1.05	1.8	4.39
33	Malgaon	60.26	21.63	18.11	1.48	2.6	23.24
34	Sangeli	61.08	19.72	19.2	0.55	0.9	4.08
35	Nanos	58.12	24.32	17.56	0.95	1.6	6.93
36	Maneri	56.32	24.54	19.14	0.98	1.7	4.87
37	Hewale	55.42	23.12	21.46	1.23	2.1	18.84
38	Morgaon	58.39	22.34	19.27	1.86	3.2	11.37
39	Zarebambar	57.33	20.87	21.59	1.43	2.5	15.31
40	Ghatiwade	56.74	21.52	21.74	0.98	1.7	14.50

Table 4.2: Physico-chemical properties and hydraulic conductivity of soils of Ratnagiri district

Sr. No.	Villages	% Sand	% Silt	% Clay	% O.C	O.M	H.C (cm/hr)
1	Nachne	35.53	51.16	13.31	1.14	2.0	6.14
2	Jaygad	39.19	47.84	12.97	1.77	3.1	23.57
3	Vasani	44.01	40.25	15.74	1.61	2.8	4.49
4	Ganpatipule	33.81	43.65	22.54	1.90	3.3	16.23
5	Jambhrun	37.68	41.68	20.64	1.98	3.4	11.78
6	Gavane	33.81	43.65	22.54	1.77	3.1	16.43
7	Khan Vali	52.77	31.85	15.54	0.93	1.6	8.25
8	Agave	38	36.38	25.62	1.16	2.0	20
9	Kurne	45.73	32.42	21.85	1.48	2.6	6.04
10	Harche	44.62	26.04	29.34	1.43	2.5	9.32
11	Jaitapur	46.15	40.67	13.18	1.19	2.1	3.17
12	Nanar	43.1	38.55	18.35	1.72	3.0	15.29
13	Niveli	50.66	32.83	16.51	1.46	2.5	15.62
14	Mith Gavane	62.70	13.49	23.81	1.30	2.2	6.90
15	Sagve	40	43.63	16.37	1.48	2.6	9.01
16	Pimpali	45.04	38.77	16.19	1.71	2.9	3.60
17	Savarde	47.82	28.76	23.42	1.40	2.4	5.13
18	Tiwre	30.64	45.16	24.2	1.46	2.5	20.82
19	Dhameli	48.31	27.32	24.37	1.63	2.8	5.38
20	Bamnoli	38.78	31.82	29.4	1.04	1.8	14.68
21	Nive	47.72	37.96	14.32	1.81	3.1	16.15
22	Ozare	47.4	33.54	19.06	1.16	2.0	11.86
23	Sakharpa	36.76	37.33	25.91	1.15	2.0	15.13
24	Dhamapur	48.45	27.15	24.4	1.37	2.4	5.41

25	Tulsani	40.87	42.37	16.76	1.19	2.1	5.79
26	Chikhli	32.42	51.01	16.57	1.51	1.5	7.39
27	Abloli	41.16	40.14	18.7	1.49	2.6	24.10
28	Naravan	35.1	46.31	18.59	1.37	2.4	2.64
29	Pomendi	38.75	39.66	21.59	1.50	2.6	11.45
30	Kotaluk	48.49	34.13	17.38	0.83	1.4	5.05
31	Lote	46.01	34.74	19.25	1.60	2.8	7.67
32	Khopi	38.42	43.49	18.09	1.92	3.3	18.92
33	Kudeshi	47.84	31.97	20.19	0.14	0.2	6.17
34	Sukavali	48.16	28.23	23.61	1.02	1.8	5.46
35	Musad	56.89	22.11	21	1.04	1.8	13.53
36	Kumbale	42.46	41.67	15.87	1.69	2.9	4.82
37	Surle	59.94	20.61	19.45	1.12	1.9	20.87
38	Kuduk	37.21	33.21	29.34	1.58	2.7	15.51
39	Pimpoli	55.65	18.67	25.68	1.36	2.3	25.32
40	Ranvali	36.82	39.44	23.74	1.30	2.2	14.22
41	Shirsoli	40.94	40.50	18.56	1.10	1.9	22.55
42	Burondi	23.73	51.03	25.24	1.16	2.0	3.17
43	Unhavare	52.86	23.85	23.29	1.29	2.2	2.84
44	Gavhe	28.07	52.16	19.77	1.63	2.8	23.64
45	Avashi	42.10	38.3	19.6	1.41	2.4	8.45

Table 4.3: Physico-chemical properties and hydraulic conductivity of soils of Raigad district

Sr. No.	Villages	% Sand	% Silt	% Clay	% O.C	O.M	H.C (cm/hr)
1	Maluk	75.61	15.50	8.89	1.89	3.3	16.43
2	Tala	67.95	18.09	13.96	1.52	2.6	5.94
3	Tokarde	66.09	29.57	4.34	1.66	2.9	4.49
4	Girne	61.77	21.54	16.69	2.49	4.3	7.41
5	Washi Haveli	60.34	21.32	18.34	1.34	2.3	2.81
6	Kavat	60.80	31.81	7.39	4.32	7.4	14.32
7	Bhabat	51.19	40.76	8.05	3.02	5.2	18.49
8	Pandare	56.59	38.47	4.94	3.58	6.2	18.44
9	Toradi	56.17	23.81	20.02	1.63	2.8	15.92
10	Dehen	70.20	25.13	4.67	2.65	4.6	17.88
11	Kambe	72.82	22.83	4.35	0.95	1.6	13.43
12	Wadgaon	69.68	22.16	8.16	3.08	5.3	12.47
13	Vat	72.38	17.28	10.34	1.31	2.3	6.45
14	Talavali	68.04	23.35	8.61	0.76	1.31	8.28
15	Golewadi	64.37	26.72	8.91	2.20	3.8	8.76
16	Shirshe	68.72	14.10	17.18	0.80	1.4	20.42
17	Sangavi	64.42	19.50	16.08	0.12	0.2	3.75
18	Sugave	58.59	28.42	12.96	3.18	5.5	4.52
19	Wave	62.79	26.30	10.91	1.78	3.1	6.27
20	Pashane	70.25	20.93	8.82	0.95	1.6	4.14
21	Nagaloli	70	15.77	14.23	2.95	5.1	4.11

22	Bagmandale	56.95	22.25	20.8	1.72	3.0	13.84
23	Saigaon	65.35	13.81	20.84	2.21	3.8	4.31
24	Mhasadi	75.41	18.09	6.5	2.89	5.0	22.27
25	Jamgaon	76.33	18.96	4.71	3.37	5.8	13.46
26	Chinchwali	79.10	16.7	4.2	2.97	5.1	3.07
27	Khamb	76.94	20.67	2.39	1.98	3.4	2.56
28	Kokban	82.35	11.73	5.92	1.87	3.2	4.21
29	Dharechiwadi	73.63	22.88	3.49	3.24	5.6	9.67
30	Kasarwadi	74.17	22.95	2.88	1.90	3.3	21.74
31	Jambhulpada	68.82	22.79	11.65	2.75	4.7	23.21
32	Nadsur	55.93	33.52	10.55	1.45	2.5	2.64
33	Veshvi	74.25	16.87	8.88	1.50	2.6	5.99
34	Karle	73.25	21	5.75	1.83	3.2	3.22
35	Nagaon	74.70	21.51	3.79	0.43	0.7	4.95
36	Ambeghar	55.93	33.52	10.55	1.54	2.7	3.35
37	Beloshi	65.11	30.28	4.61	2.70	4.7	3.25
38	Bhoighar	79.90	13.71	6.39	1.06	1.8	6.42
39	Saigaon	64.16	30.90	4.94	0.55	0.9	3.20
40	Nagshet	72.38	20.33	7.29	0.36	0.6	5.96
41	Wawdungi	64.96	31.25	3.79	0.39	0.7	9.24
42	Amboli	67.45	29.34	3.21	0.23	0.4	2.94
43	Punalkond	72.82	17.72	9.46	1.29	2.2	11.58
44	Wakan	74.93	21.60	3.47	1.97	3.4	15.77
45	Sawad	71.99	18.93	9.08	0.83	1.4	3.88
46	Dharwali	77.19	13.85	8.96	2.06	3.6	8.78
47	Faujdar	76.6	12.55	10.85	1.91	3.3	3.47
48	Pali	77.26	13.50	9.24	1.22	2.1	5.74
49	Jatade	78.10	15.63	6.27	2.00	3.4	8.17
50	Morbe	76.56	10.54	12.9	1.53	2.6	8.45
51	Wardoli	76.77	19.91	3.32	1.52	2.6	4.03
52	Taloje	83.05	13.83	3.14	1.38	2.4	25.32
53	Saje	72.40	8.41	19.19	1.03	1.8	15.26
54	Warachiwadi	69.48	9.43	21.09	1.40	2.4	12.90
55	Sanaswadi	73.65	7.30	19.05	0.47	0.8	19.91
56	Umbardi	57.14	18.68	24.18	0.20	0.3	16.20
57	Ransai	64.98	11.88	23.14	0.60	1.0	3.30
58	Khaire tarf	57.28	14.11	28.61	1.09	1.9	3.14
59	Jirne	76.55	15.30	8.15	1.88	3.2	2.81
60	Shedashi	75.08	16.88	8.04	2.69	4.6	8.53
61	Banase	72.52	10.88	16.6	0.40	0.7	3.17
62	Gadab	42.67	54.02	3.31	2.83	4.9	4.08
63	Gangode	79.21	11.05	9.74	3.46	6.0	18.28

Table 4.4: Physico-chemical properties and hydraulic conductivity of soils of Thane district

Sr. No.	Villages	% Sand	% Silt	% Clay	% O.C	O.M	H.C (cm/hr)

1	Adivali	48.2	19.75	32.05	0.8	1.4	9.70
2	Musarne	54.28	20.97	24.75	1.12	1.9	2.89
3	Ainshet	39.28	27.25	33.47	0.67	1.2	18.05
4	Kharivali	37.99	31.75	30.26	0.86	1.5	16.58
5	Sange	38.51	25.75	35.74	1.26	2.2	19.02
6	Aalond	30	28.75	41.25	0.92	1.6	2.94
7	Aaling	43.02	26.98	30	1.47	2.5	11.27
8	Mohkhurd	46.8	20.16	33.04	1.47	2.5	11.35
9	Kurze	43.29	32.5	24.21	0.83	1.4	9.06
10	Khardi	58.15	20.6	21.25	1.98	3.4	13.25
11	Bhuigaon	54.62	23.6	21.78	0.62	1.1	19.27
12	Sandor	54.13	22.935	22.935	0.38	0.7	23.90
13	Chandansar	52.41	18.51	29.08	0.32	0.8	5.28
14	Naringi	53.51	19.65	26.84	1.72	3.0	3.60
15	Udhawa	47.2	31.08	21.72	1.44	2.5	5.46
16	Vasa	45.66	28.2	32.22	1.44	2.5	10.59
17	Kurze	44.82	34.45	20.73	1.21	2.1	6.52
18	Talasari	45.8	33.75	20.45	1.15	2.0	8.43
19	Sutrakar	47.63	25.79	26.56	1	1.7	6.14
20	Anakharpada	34.89	44.75	20.36	0.36	0.6	4.75
21	Mamnoli	53.68	26.25	20	0.62	1.1	5.76
22	Rayate	38.46	43.36	18.18	0.88	1.5	6.22
23	Shirdhon	41.3	29.35	29.35	0.38	0.7	13.84
24	Dahagaon	50.04	28.69	21.27	2.77	4.8	3.96
25	Khanivali	32.5	33.75	33.75	0.96	1.7	24.51
26	Palkhane	33.04	35	31.96	0.61	1.1	23.79
27	Katai	47.42	22.58	30	1.1	1.9	8.76
28	Kurund	47.41	31.74	20.85	0.71	1.2	6.62
29	Gorsai	36	36.25	27.75	1.2	2.1	16.89
30	Bordi	57.53	13.7	28.77	2.75	4.7	3.40
31	Bendgaon	52.02	26.75	21.23	0.98	1.7	2.84
32	Dehane	27.5	23.75	48.75	1.23	2.1	3.04
33	Kainad	43.25	25.5	31.25	0.81	1.4	12.72
34	Nikane	48	26.25	25.75	1.35	2.3	6.07
35	vaki	39.25	32	28.75	1.12	1.9	14.55
36	Ambivali	36.91	37.5	25.59	1.49	2.6	14.55
37	Patol	42.04	34.05	23.91	1.07	1.8	9.72
38	Shendrun	23.83	56.21	19.96	1.36	2.3	3.22
39	Khardi	39.05	38.45	22.5	0.94	1.6	11.98
40	Sarlambe	38	42.71	19.29	0.24	0.4	7.84
41	Eklahare	46.55	33.75	19.7	2.97	5.1	5.10
42	Tokawade	36.25	36.25	27.5	1.17	2.0	16.56
43	Vaishakhare	27.96	26.75	45.29	1.59	2.7	2.74
44	Inde	40.84	17.76	41.395	1.5	2.6	22.52
45	Karavale	29	35	36	1.07	1.8	2.74
46	Unbhat	30	31.25	38.75	0.71	1.2	2.97
47	Tandulwadi	40.25	30	29.75	0.91	1.6	14.55
48	Paragon	33.73	26.25	40.02	0.92	1.6	2.66

49	Varkhunti	33.75	22.5	43.75	0.65	1.1	3.07
50	Virathankhurd	25.04	32.53	42.43	1.31	2.3	2.94
51	Ambarnath	33.75	47.5	18.75	1.29	2.2	3.09
52	Ambhe	33.06	29.12	37.82	1.02	1.8	2.56
53	Asnoli	52.51	33.75	13.74	0.36	0.6	3.60
54	Karand	61.94	26.25	11.81	0.29	0.5	5.68
55	Chargaon	58.2	28.32	13.48	1.31	1.9	10.97
56	Khand	37.46	30.04	32.5	1.5	3.2	16.25
57	Tolepda	36.78	30.37	32.85	1.68	2.9	17.24
58	Balapur	32.09	35.42	32.49	2.25	3.9	18.99
59	Rampur	34.38	38.44	27.18	0.93	1.6	19.38
60	Medhi	36.95	35.79	27.26	1.8	3.1	14.40
61	Veti	45.66	27.31	27.03	1.14	2	7.79
62	Suksale	46.41	26.93	26.66	0.63	1.1	8.07

4.2 Chemical properties of soils

4.2.1 Organic carbon

The data related to organic carbon are presented in Table 4.1 to 4.4. The organic carbon of soils varied from 0.18 to 3.04 percent of Sindhudurg district with the mean value of 1.44 percent. In Ratnagiri district, organic carbon was found to be in the range of 0.14 to 1.98 percent with the mean value of 1.38 percent. In Raigad district organic carbon was found to be 0.12 to 4.32 percent with the mean value of 1.76 percent and 0.24 to 2.97 percent of Thane district with the mean value of 1.13 percent. In the whole Konkan region organic carbon was found to be in the range of 0.12 to 4.32 percent with the mean value 1.43.

The data revealed that the organic carbon was maximum in Raigad district and minimum in Thane district. It was observed that organic carbon increased with the decreasing clay content and get simultaneously increased the organic matter due to high content of organic carbon in the soil (Fig 4.1). It may possible to draw graph as a taking O.C% as a ordinant and Clay% as a abscissa because it gives nearly same graph.

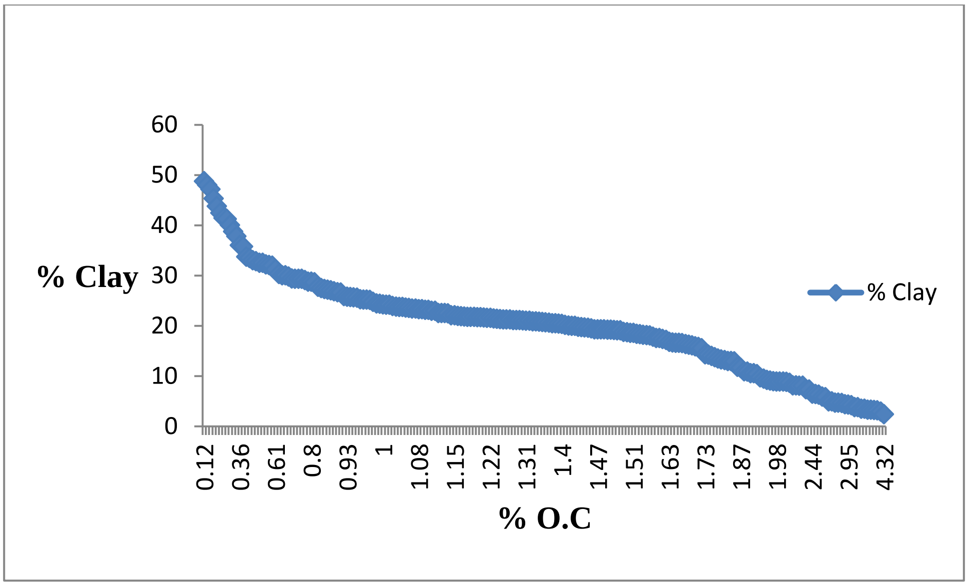


Fig. 4.1 Relationship between clay content and organic carbon

4.2.2 Organic matter content

The organic matter content of soils were obtained from organic carbon as per equation 3.1. In Sindhudurg district it was found that the organic matter varied from 0.3 to 5.2 percent with the mean value of 2.47 percent. Organic matter of Ratnagiri district varied from 0.2 to 3.4 percent with the mean value of 2.37 percent. In Raigad district it was found to be in the range of 0.2 to 7.4 percent with the mean value of 3.03 percent. Range of organic matter in Thane district was from 0.4 to 5.1 percent with the mean value of 1.97 percent. In Konkan region the value of organic matter was found to be in the range of 0.20 to 7.40 percent with the mean value of 2.47 percent (Table 4.1 to 4.4)

Based on the results, it was observed that the Raigad district was having more amount of organic matter content. Organic matter is related with the bulk density, as organic matter increases, the density of soil decreases which is required for the proper growth of the plants (Chaudhari *et al*. 2013).

4.3 Calibration and Validation of SPAW Model

SPAW model was calibrated by adjusting the parameter and comparing simulated and manually estimated values of hydraulic conductivities and in turn soil erodibilities of Priyadarshani watershed. Hydraulic conductivities and erodibility values were used from fifteen locations for comparison during calibration. Calibrated value of density factor (DF) was l.2 for calculating hydraulic conductivities. Simulated and manually calculated hydraulic conductivity values of 15 locations were close to each other (Table 4.5) and exhibited similar trend. Coefficient of determination (R^2) for simulated and manually estimated hydraulic conductivity values was 0.88 and in acceptable range. It showed closer match between simulated and manually estimated values. Based on these values of hydraulic conductivity and other parameters viz. organic matter content, structural code, permeability code and values of M, soil erodibilities were estimated for 15 locations by both the methods.

Simulated soil erodibilities and manually estimated erodibilities were found in the same range with Coefficient of determination (R^2) 0.90, new simulated and new observed soil erodibilities were 0.39 and 0.40 respectively for calibration (Table 4.6). Therefore it is inferred that model performs well during calibration.

Table 4.5: Comparison of calculated and manual hydraulic conductivity in calibration

Sr. No.	Simulated (H.C)	Manual (H.C)
1	4.84	5.43
2	5.84	6.54
3	3.94	4.91
4	3.04	4.56
5	4.57	5.71
6	2.47	3.23
7	4.50	5.29
8	4.33	4.58
9	5.67	7.01
10	3.19	4.39
11	4.83	6.21
12	3.07	3.77
13	4.48	5.08
14	4.73	5.28
15	3.09	3.73
Avg.	**4.17**	**5.05**

Table 4.6: Comparison of simulated and observed soil erodibility factors in calibration

Sr. No.	Simulated(K)	Observed (K)
1	0.39	0.42
2	0.39	0.39
3	0.41	0.44

4	0.43	0.45
5	0.39	0.39
6	0.39	0.39
7	0.39	0.42
8	0.33	0.33
9	0.42	0.44
10	0.38	0.41
11	0.40	0.43
12	0.37	0.37
13	0.37	0.40
14	0.36	0.36
15	0.40	0.43
Avg.	**0.39**	**0.40**

SPAW model was then validated for other seven locations in the same watershed by keeping calibrating parameter density factor (DF) constant. Hydraulic conductivities for seven locations estimated by SPAW model and manual method were close to each other in the range of 1.91 to 4.46 and 2.68 to 6.29 having coefficient of determination 0.80 respectively (Table 4.7). High coefficient of determination (R^2) showed the acceptable performance of model. Based on these hydraulic conductivity values by both methods and other parameters mentioned above. Simulated erodibility and erodibility estimated by traditional method at seven locations were found close to each other. The mean simulated erodibility and mean observed erodibility were 0.45 and 0.44 for validation (Table 4.8). Coefficient of determination (R^2) for erodibility in validation was 0.88 which is in acceptable range. Therefore it is inferred that SPAW model is valid for Konkan region in estimation of erodibility. So SPAW model was used for estimation of erodibility at selected locations in Konkan region.

Table 4.7: Comparison of calculated and manual hydraulic conductivity in validation

Sr. No.	Simulated (H.C)	Manual (H.C)
1	1.91	2.68
2	2.50	3.38
3	3.07	3.19
4	3.34	3.81
5	3.88	4.5
6	4.06	6.29
7	4.46	5.48
Avg.	**3.32**	**4.19**

Table 4.8: Comparison of simulated and observed soil erodibility factors in validation

Sr. No.	Simulated (K)	Observed (K)
1	0.43	0.43
2	0.51	0.51
3	0.44	0.41
4	0.44	0.44
5	0.43	0.43
6	0.45	0.45
7	0.42	0.42
Avg.	**0.45**	**0.44**

4.4 Hydraulic conductivity of soils

Hydraulic conductivity was determined by using the SPAW model. Hydraulic conductivity for four districts is presented in Table 4.1 to 4.4. The hydraulic conductivity of soils varied from 2.56 to 24.89 cm/hr, 2.64 to 25.32 cm/hr, 2.56 to 25.32 cm/hr and 2.56 to 24.51 cm/hr for Sindhudurg, Ratnagiri, Raigad, and Thane districts respectively. It was found that the hydraulic conductivity of Konkan region varied from 2.56 to 25.32 cm/hr with the mean value of 10.54 cm/hr. As per the above result it was found that hydraulic conductivity was nearly same in four district of Konkan region. It is having linear relationship with permeability.

4.5 Permeability of soils

The permeability of soils of 210 villages of Konkan region were obtained from hydraulic conductivity of soil. Permeability was in rare case >25 cm/hr. The permeability classes varied between moderate to rapid class and rapid class and accordingly permeability codes were assigned as 2 and 1 respectively (Table 4.9 to 4.12).

From the above results it was found that permeability of soils of Konkan region is high. The high permeability reduces the shear strength of soil and consequently makes the soil more susceptible to the erosion due to high rate of permeability suggests high pore-pressure

4.6 Soil Structure class

Based on hydraulic conductivity and textural class of the soils, structure type of soils were fine granular and moderate for all soils of Konkan region. Therefore structural codes assigned for all these soils were 2 and 3 in 210 villages of Konkan region (Table 4.9 to 4.12). It was inferred that the soil having more amount of sandy texture, very little force is required for the erosion. In study area rare cases the structural type was fine granular otherwise mostly it was moderate and hence erosion class in Konkan region was found to be high.

Table 4.9: Textural, Structural and Permeability classes and codes of soils of Sindhudurg district

Sr. No.	Villages	Textural classes	Structure classes	Structure codes	Permeability classes	Permeability codes
1	Naiknagar	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
2	Pawashi	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
3	Oros khurd	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
4	Aanav	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
5	Pinguli	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
6	Aadeli	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
7	Tulas	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
8	Pal	Sandy Loam	Fine Granular	2	Moderate To Rapid	2
9	Mochemad	Clay	Moderate	3	Moderate To Rapid	2
10	Matond	Clay	Moderate	3	Moderate To Rapid	2
11	Tondavali	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
12	Bagwadi	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
13	Nandrukh	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
14	Chafekhol	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
15	Varad	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
16	Sambhajinagar	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
17	Janavali	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
18	Shirval	Sandy Loam	Moderate	3	Moderate To Rapid	2
19	Wargaon	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
20	Vayangani	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
21	Wabhave	Sandy Loam	Moderate	3	Moderate To Rapid	2
22	Khambale	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
23	Lore	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
24	Mohitewadi	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
25	Tembwadi	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
26	Dabhole	Sandy Loam	Moderate	3	Moderate To Rapid	2
27	Vitthaladevi	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2

28	Naringre	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
29	Pombhurle	Sandy Loam	Moderate	3	Moderate To Rapid	2
30	Nad	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
31	Bhalawal	Sandy Loam	Moderate	3	Moderate To Rapid	2
32	Madkhol	Sandy Loam	Moderate	3	Moderate To Rapid	2
33	Malgaon	Sandy Loam	Moderate	3	Moderate To Rapid	2
34	Sangeli	Sandy Loam	Moderate	3	Moderate To Rapid	2
35	Nanos	Sandy Loam	Moderate	3	Moderate To Rapid	2
36	Maneri	Sandy Loam	Moderate	3	Moderate To Rapid	2
37	Hewale	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
38	Morgaon	Sandy Loam	Moderate	3	Moderate To Rapid	2
39	Zaremambar	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
40	Ghatiwade	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2

Table 4.10: Textural, Structural and Permeability classes and codes of soils of Ratnagiri district

Sr. No.	Villages	Textural classes	Structure classes	Structure codes	Permeability Classes	Permeability codes
1	Nachne	Textural class	Moderate	3	Moderate To Rapid	2
2	Jaygad	Silty loam	Moderate	3	Moderate To Rapid	2
3	Vasani	Loam	Moderate	3	Moderate To Rapid	2
4	Ganpatipule	Loam	Moderate	3	Moderate To Rapid	2
5	Jambhrun	Loam	Moderate	3	Moderate To Rapid	2
6	Gavane	Loam	Moderate	3	Moderate To Rapid	2
7	Khan Vali	Loam	Moderate	3	Moderate To Rapid	2
8	Agave	Sandy loam	Moderate	3	Moderate To Rapid	2
9	Kurne	Clay loam	Moderate	3	Moderate To Rapid	2
10	Harche	Loam	Moderate	3	Moderate To Rapid	2
11	Jaitapur	Sandy clay loam	Moderate	3	Moderate To Rapid	2
12	Nanar	Loam	Moderate	3	Moderate To Rapid	2
13	Niveli	Loam	Moderate	3	Moderate To Rapid	2

14	Mith Gavane	Loam	Moderate	3	Moderate To Rapid	2
15	Sagve	Sandy clay loam	Moderate	3	Moderate To Rapid	2
16	Pimpali	Loam	Moderate	3	Moderate To Rapid	2
17	Savarde	Loam	Moderate	3	Moderate To Rapid	2
18	Tiwre	Loam	Moderate	3	Moderate To Rapid	2
19	Dhameli	Loam	Moderate	3	Moderate To Rapid	2
20	Bamnoli	Loam	Moderate	3	Moderate To Rapid	2
21	Nive	Clay loam	Moderate	3	Moderate To Rapid	2
22	Ozare	Loam	Moderate	3	Moderate To Rapid	2
23	Sakharpa	Loam	Moderate	3	Moderate To Rapid	2
24	Dhamapur	Loam	Moderate	3	Moderate To Rapid	2
25	Tulsani	Loam	Moderate	3	Moderate To Rapid	2
26	Chikhli	Loam	Moderate	3	Moderate To Rapid	2
27	Abloli	Silty loam	Moderate	3	Moderate To Rapid	2
28	Naravan	Loam	Moderate	3	Moderate To Rapid	2
29	Pomendi	Loam	Moderate	3	Moderate To Rapid	2
30	Kotaluk	Loam	Moderate	3	Moderate To Rapid	2
31	Lote	Loam	Moderate	3	Moderate To Rapid	2
32	Khopi	Loam	Moderate	3	Moderate To Rapid	2
33	Kudeshi	Loam	Moderate	3	Moderate To Rapid	2
34	Sukavali	Loam	Moderate	3	Moderate To Rapid	2
35	Musad	Loam	Moderate	3	Moderate To Rapid	2
36	Kumbale	Sandy clay loam	Moderate	3	Moderate To Rapid	2
37	Surle	Loam	Moderate	3	Moderate To Rapid	2
38	Kuduk	Sandy Loam	Moderate	3	Moderate To Rapid	2
39	Pimpoli	Clay Loam	Moderate	3	Rapid	1
40	Ranvali	Sandy clay loam	Moderate	3	Moderate To Rapid	2
41	Shirsoli	Loam	Moderate	3	Moderate To Rapid	2
42	Burondi	Loam	Moderate	3	Moderate To Rapid	2
43	Unhavare	Silty loam	Moderate	3	Moderate To Rapid	2
44	Gavhe	Sandy clay loam	Moderate	3	Moderate To Rapid	2
45	Avashi	Silty loam	Moderate	3	Moderate To Rapid	2

Table 4.11: Textural, Structural and Permeability classes and codes of soils of Raigad district

Sr. No.	Villages	Textural classes	Structure classes	Structure codes	Permeability classes	Permeability codes
1	Maluk	Sandy Loam	Moderate	3	Moderate To Rapid	2
2	Tala	Sandy Loam	Moderate	3	Moderate To Rapid	2
3	Tokarde	Sandy Loam	Moderate	3	Moderate To Rapid	2
4	Girne	Sandy Loam	Moderate	3	Moderate To Rapid	2
5	Washi Haveli	Sandy Loam	Moderate	3	Moderate To Rapid	2
6	Kavat	Sandy Loam	Moderate	3	Moderate To Rapid	2
7	Bhabat	Loam	Moderate	3	Moderate To Rapid	2
8	Pandare	Sandy Loam	Moderate	3	Moderate To Rapid	2
9	Toradi	Sandy Loam	Moderate	3	Moderate To Rapid	2
10	Dehen	Sandy Loam	Moderate	3	Moderate To Rapid	2
11	Kambe	Sandy Loam	Moderate	3	Moderate To Rapid	2
12	Wadgaon	Sandy Loam	Moderate	3	Moderate To Rapid	2
13	Vat	Sandy Loam	Moderate	3	Moderate To Rapid	2
14	Talavali	Sandy Loam	Moderate	3	Moderate To Rapid	2
15	Golewadi	Sandy Loam	Moderate	3	Moderate To Rapid	2
16	Shirshe	Sandy Loam	Moderate	3	Moderate To Rapid	2
17	Sangavi	Sandy Loam	Moderate	3	Moderate To Rapid	2
18	Sugave	Sandy Loam	Moderate	3	Moderate To Rapid	2
19	Wave	Sandy Loam	Moderate	3	Moderate To Rapid	2
20	Pashane	Sandy Loam	Moderate	3	Moderate To Rapid	2
21	Nagaloli	Sandy Loam	Moderate	3	Moderate To Rapid	2
22	Bagmandale	Sandy Loam	Moderate	3	Moderate To Rapid	2
23	Saigaon	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
24	Mhasadi	Sandy Loam	Moderate	3	Moderate To Rapid	2
25	Jamgaon	Loamy Sand	Fine granular	2	Moderate To Rapid	2
26	Chinchwali	Loamy Sand	Fine Granular	2	Moderate To Rapid	2
27	Khamb	Loamy Sand	Fine Granular	2	Moderate To Rapid	2
28	Kokban	Loamy Sand	Fine Granular	2	Moderate To Rapid	2

29	Dharechiwadi	Loamy Sand	Fine Granular	2	Moderate To Rapid	2
30	Kasarwadi	Loamy Sand	Fine Granular	2	Moderate To Rapid	2
31	Jambhulpada	Sandy Loam	Moderate	3	Moderate To Rapid	2
32	Nadsur	Sandy Loam	Moderate	3	Moderate To Rapid	2
33	Veshvi	Sandy Loam	Moderate	3	Moderate To Rapid	2
34	Karle	Sandy Loam	Moderate	3	Moderate To Rapid	2
35	Nagaon	Loamy Sand	Fine Granular	2	Moderate To Rapid	2
36	Ambeghar	Sandy Loam	Moderate	3	Moderate To Rapid	2
37	Beloshi	Sandy Loam	Moderate	3	Moderate To Rapid	2
38	Bhoighar	Loamy Sand	Fine Granular	2	Moderate To Rapid	2
39	Saigaon	Sandy Loam	Moderate	3	Moderate To Rapid	2
40	Nagshet	Sandy Loam	Moderate	3	Moderate To Rapid	2
41	Wawdungi	Sandy Loam	Moderate	3	Moderate To Rapid	2
42	Amboli	Sandy Loam	Moderate	3	Moderate To Rapid	2
43	Punalkond	Sandy Loam	Moderate	3	Moderate To Rapid	2
44	Wakan	Loamy Sand	Fine Granular	2	Moderate To Rapid	2
45	Sawad	Sandy Loam	Moderate	3	Moderate To Rapid	2
46	Dharwali	Sandy Loam	Moderate	3	Moderate To Rapid	2
47	Faujdar	Sandy Loam	Moderate	3	Moderate To Rapid	2
48	Pali	Sandy Loam	Moderate	3	Moderate To Rapid	2
49	Jatade	Loamy Sand	Fine Granular	2	Moderate To Rapid	2
50	Morbe	Sandy Loam	Moderate	3	Moderate To Rapid	2
51	Wardoli	Loamy Sand	Fine Granular	2	Moderate To Rapid	2
52	Taloje	Loamy Sand	Fine Granular	2	Rapid	1
53	Saje	Sandy Loam	Moderate	2	Moderate To Rapid	2
54	Warachiwadi	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
55	Sanaswadi	Sandy Loam	Moderate	3	Moderate To Rapid	2
56	Umbardi	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
57	Ransai	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
58	Khaire Tarf	Sandy Clay Loam	Moderate	3	Moderate To Rapid	2
59	Jirne	Sandy Loam	Moderate	3	Moderate To Rapid	2
60	Shedashi	Sandy Loam	Moderate	3	Moderate To Rapid	2

61	Banase	Sandy Loam	Moderate	3	Moderate To Rapid	2
62	Gadab	Silty Loam	Moderate	3	Moderate To Rapid	2
63	Gangode	Sandy Loam	Moderate	3	Moderate To Rapid	2

Table 4.12: Textural, Structural and Permeability classes and codes of soils of Thane district

Sr. No.	Villages	Textural classes	Structure classes	Structure codes	Permeability classes	Permeability codes
1	Adivali	Sandy clay loam	Moderate	3	Moderate To Rapid	2
2	Musarne	Sandy clay loam	Moderate	3	Moderate To Rapid	2
3	Ainshet	Clay loam	Moderate	3	Moderate To Rapid	2
4	Kharivali	Clay loam	Moderate	3	Moderate To Rapid	2
5	Sange	Clay loam	Moderate	3	Moderate To Rapid	2
6	Aalond	Clay	Fine granular	2	Moderate To Rapid	2
7	Aaling	Clay loam	Moderate	3	Moderate To Rapid	2
8	Mohkhurd	Sandy clay loam	Moderate	3	Moderate To Rapid	2
9	Kurze	Loam	Moderate	3	Moderate To Rapid	2
10	Khardi	Sandy clay loam	Moderate	3	Moderate To Rapid	2
11	Bhuigaon	Sandy clay loam	Moderate	3	Moderate To Rapid	2
12	Sandor	Sandy clay loam	Moderate	3	Moderate To Rapid	2
13	Chandansar	Sandy clay loam	Moderate	3	Moderate To Rapid	2
14	Naringi	Sandy clay loam	Moderate	3	Moderate To Rapid	2
15	Udhawa	Loam	Moderate	3	Moderate To Rapid	2
16	Vasa	Sandy clay loam	Moderate	3	Moderate To Rapid	2
17	Kurze	Loam	Moderate	3	Moderate To Rapid	2
18	Talasari	Loam	Moderate	3	Moderate To Rapid	2
19	Sutrakar	Sandy clay loam	Moderate	3	Moderate To Rapid	2
20	Anakharpada	Loam	Moderate	3	Moderate To Rapid	2
21	Mamnoli	Sandy loam	Moderate	3	Moderate To Rapid	2
22	Rayate	Loam	Moderate	3	Moderate To Rapid	2
23	Shirdhon	Clay loam	Moderate	3	Moderate To Rapid	2
24	Dahagaon	Loam	Moderate	3	Moderate To Rapid	2

25	Khanivali	Clay loam	Moderate	3	Moderate To Rapid	2
26	Palkhane	Clay loam	Moderate	3	Moderate To Rapid	2
27	Katai	Sandy clay loam	Moderate	3	Moderate To Rapid	2
28	Kurund	Loam	Moderate	3	Moderate To Rapid	2
29	Gorsai	Clay loam	Moderate	3	Moderate To Rapid	2
30	Bordi	Sandy clay loam	Moderate	3	Moderate To Rapid	2
31	Bendgaon	Sandy clay loam	Moderate	3	Moderate To Rapid	2
32	Dehane	Clay	Fine granular	2	Moderate To Rapid	2
33	Kainad	Clay loam	Moderate	3	Moderate To Rapid	2
34	Nikane	Sandy clay loam	Moderate	3	Moderate To Rapid	2
35	Vaki	Clay loam	Moderate	3	Moderate To Rapid	2
36	Ambivali	Loam	Moderate	3	Moderate To Rapid	2
37	Patol	Loam	Moderate	3	Moderate To Rapid	2
38	Shendrun	Silty loam	Moderate	3	Moderate To Rapid	2
39	Khardi	Loam	Moderate	3	Moderate To Rapid	2
40	Sarlambe	Loam	Moderate	3	Moderate To Rapid	2
41	Eklahare	Loam	Moderate	3	Moderate To Rapid	2
42	Tokawade	Loam	Moderate	3	Moderate To Rapid	2
43	Vaishakhare	Clay	Fine granular	3	Moderate To Rapid	2
44	Inde	Clay	Moderate	3	Moderate To Rapid	2
45	Karavale	Clay loam	Moderate	3	Moderate To Rapid	2
46	Unbhat	Clay loam	Moderate	3	Moderate To Rapid	2
47	Tandulwadi	Clay loam	Moderate	3	Moderate To Rapid	2
48	Paragon	Clay	Fine granular	2	Moderate To Rapid	2
49	Varkhunti	Clay	Fine granular	2	Moderate To Rapid	2
50	Virathankhurd	Clay	Fine granular	2	Moderate To Rapid	2
51	Ambarnath	loam	Moderate	3	Moderate To Rapid	2
52	Ambhe	Clay loam	Moderate	3	Moderate To Rapid	2
53	Asnoli	Sandy loam	Moderate	3	Moderate To Rapid	2
54	Karand	Sandy loam	Moderate	3	Moderate To Rapid	2
55	Chargaon	Sandy loam	Moderate	3	Moderate To Rapid	2
56	Khand	Clay loam	Moderate	3	Moderate To Rapid	2

57	Tolepda	Clay loam	Moderate	3	Moderate To Rapid	2
58	Balapur	Clay loam	Moderate	3	Moderate To Rapid	2
59	Rampur	Loam	Moderate	3	Moderate To Rapid	2
60	Medhi	Loam	Moderate	3	Moderate To Rapid	2
61	Veti	Sandy clay loam	Moderate	3	Moderate To Rapid	2
62	Suksale	Sandy clay loam	Moderate	3	Moderate To Rapid	2

4.7 Soil Erodibility

Soil characteristics essential for determination of erodibility were estimated for 210 villages of Konkan region. These characteristics were converted into codes and parameters required for soil erodibility equation (3.3). The erodibility of soils (K) of Sindhudurg district varied from 0.12 to 0.41 with the mean value of 0.32. Ratnagiri district erodibility values varied from 0.26 to 0.48 with the mean values of 0.36. Erodibility in Raigad district soils varied from 0.24 to 0.64 with the mean value of 0.40. Thane district erodibility varied from 0.11 to 0.51 with the mean value of 0.30. Overall the erodibilty of soils of Konkan region varied from 0.11 to 0.64 with the mean value of 0.35. The soil erodibilities were estimated and classified for each district (Table 4.13 to 4.16).

It was observed that the soils in Konkan region are highly erodible having erodibility factor (K) upto 0.64. The average erodibility factor was maximum in Raigad district 0.40 and minimum in Thane district 0.30. The low erodibility factor value could be attributed to the more clay content present in the soils of Thane district which has provided higher binding and inter binding forces which increases cohesion of soil particles and helps in resisting detachability of soil by water. Similar results are shown in other studies (Isikwue *et al*. 2012). Shabani *et al.* 2010 also concluded that if clay content decreases then erodibility factor will increase and percent of clay decreases when the slope increases. Konkan region having steep slopes of Sahyadri mountains in the range of 10-33 percent. So clay content in the soils of Konkan region is less which increased erodibility values of Konkan region.

It was also found that soil erodibility closely related to its particle size distribution, permeability, organic matter content and structure. So differences in soil erodibility are mainly attributed to variations in particle-size distribution among which silt and clay contents were the most important factors in influencing soil erodibility (Zang Keli, 2002). With clay content increasing, soils become more resistant to erosion and, consequently, there is a corresponding decrease in erodibility. With silt content increasing, soils are more sensitive to erosion, which results in greater erodibility.

Table 4.13: Erodibility of soils of Sindhudurg district

Sr. No.	Villages	% Very fine sand	% Silt	% Clay	M	a	b	c	K
1	Naiknagar	40.614	20.88	21.1	4851.877	2.9	3	2	0.31
2	Pawashi	41.104	20.26	21.02	4846.529	3.0	3	2	0.31
3	Oros khurd	37.947	21.98	23.51	4583.816	5.2	3	2	0.22
4	Aanav	42.483	18.72	20.59	4860.13	3.4	3	2	0.30
5	Pinguli	40.264	18.74	23.74	4499.645	2.6	3	2	0.30
6	Aadeli	39.949	19.96	22.97	4614.79	4.0	3	2	0.26
7	Tulas	40.6	18.75	23.25	4555.113	3.6	3	2	0.27
8	Pal	39.837	21.28	21.81	4778.738	2.2	3	2	0.30
9	Mochemad	22.456	20.48	47.14	2269.597	3.9	2	2	0.12
10	Matond	23.128	19.01	47.95	2193.283	3.9	3	2	0.12
11	Tondavali	41.202	17.98	23.16	4547.545	2.4	3	2	0.31
12	Bagwadi	40.67	20.57	21.33	4817.751	1.9	3	2	0.34
13	Nandrukh	38.955	22.28	22.07	4772.044	2.1	3	2	0.33
14	Chafekhol	40.53	21.09	21.09	4862.434	2.9	3	2	0.31
15	Varad	40.656	20.16	21.76	4758.244	0.3	3	2	0.39
16	Sambhajinagar	40.11	20.66	22.04	4737.629	1.2	3	2	0.36
17	Janavali	41.461	19.43	21.34	4789.686	1.9	3	2	0.34
18	Shirval	40.677	21.47	20.42	4945.658	4.2	3	2	0.27
19	Wargaon	40.6	20.95	21.05	4859.373	4.3	3	2	0.27
20	Vayangani	39.697	21.35	21.94	4765.329	2.4	3	2	0.32
21	Wabhave	38.57	27.06	17.78	5396.099	3.5	3	2	0.33
22	Khambale	38.374	19.99	25.19	4366.211	3.0	3	2	0.27
23	Lore	38.409	20.01	25.12	4374.415	2.1	3	2	0.30
24	Mohitewadi	39.529	21.81	21.72	4801.617	3.0	3	2	0.30
25	Tembwadi	38.374	19.99	25.19	4366.211	3.0	3	2	0.27
26	Dabhole	41.405	21.19	19.66	5028.882	0.4	3	2	0.41
27	Vitthaladevi	40.376	19.84	22.48	4667.944	1.9	3	2	0.33
28	Naringre	39.669	21.7	21.63	4809.489	1.0	3	2	0.37
29	Pombhurle	40.782	21.25	20.49	4932.164	1.5	3	2	0.37
30	Nad	40.18	19.20	23.4	4548.508	1.7	3	2	0.33
31	Bhalawal	41.678	22.88	17.58	5320.87	1.6	3	2	0.39
32	Madkhol	39.354	24.50	19.28	5154.295	1.8	3	2	0.37
33	Malgaon	42.182	21.63	18.11	5225.565	2.6	3	2	0.35
34	Sangeli	42.756	19.72	19.2	5048.061	0.9	3	2	0.40
35	Nanos	40.684	24.32	17.56	5358.93	1.6	3	2	0.40
36	Maneri	39.424	24.54	19.14	5172.129	1.7	3	2	0.38
37	Hewale	38.794	23.12	21.46	4862.726	2.1	3	1	0.34
38	Morgaon	40.873	22.34	19.27	5103.185	3.2	3	2	0.32
39	Zarebambar	40.131	20.87	21.59	4783.088	2.5	3	2	0.32
40	Ghatiwade	39.718	21.52	21.74	4792.486	1.7	3	2	0.35

Table 4.14: Erodibility of soils of Ratnagiri district

Sr. No.	Villages	% Very fine sand	% Silt	% Clay	M	a	b	c	K
1	Nachne	24.871	51.16	13.31	6591.12739	2.0	3	2	0.48
2	Jaygad	27.433	47.84	12.97	6551.00919	3.1	3	2	0.43
3	Vasani	30.807	40.25	15.74	5987.26282	2.8	3	2	0.40
4	Ganpatipule	23.667	43.65	22.54	5214.37482	3.3	3	2	0.32
5	Jambhrun	26.376	41.68	20.64	5400.92416	3.4	3	2	0.33
6	Gavane	23.667	43.65	22.54	5214.37482	3.1	3	2	0.33
7	Khan Vali	36.939	31.85	15.54	5809.91894	1.6	3	2	0.43
8	Agave	26.6	36.38	25.62	4684.4524	2.0	3	2	0.33
9	Kurne	32.011	32.42	21.85	5035.28265	2.6	3	2	0.34
10	Harche	31.234	26.04	29.34	4046.98084	2.5	3	2	0.27
11	Jaitapur	32.305	40.67	13.18	6335.6895	2.1	3	2	0.46
12	Nanar	30.17	38.55	18.35	5610.988	3.0	3	2	0.36
13	Niveli	35.462	32.83	16.51	5701.69908	2.5	3	2	0.39
14	Mith Gavane	43.89	13.49	23.81	4371.7822	2.2	3	2	0.30
15	Sagve	28	43.63	16.37	5990.4169	2.6	3	2	0.41
16	Pimpali	31.528	38.77	16.19	5891.67538	2.9	3	2	0.39
17	Savarde	33.474	28.76	23.42	4765.87972	2.4	3	2	0.32
18	Tiwre	21.448	45.16	24.2	5048.8864	2.5	3	2	0.34
19	Dhameli	33.817	27.32	24.37	4623.79131	2.8	3	2	0.30
20	Bamnoli	27.146	31.82	29.4	4162.9996	1.8	3	2	0.29
21	Nive	33.404	37.96	14.32	6114.46752	3.1	3	2	0.39
22	Ozare	33.18	33.54	19.06	5400.3168	2.0	3	2	0.39
23	Sakharpa	25.732	37.33	25.91	4672.26358	2.0	3	2	0.33
24	Dhamapur	33.915	27.15	24.4	4616.514	2.4	3	2	0.31
25	Tulsani	28.609	42.37	16.76	5908.29196	2.1	3	2	0.42
26	Chikhli	22.694	51.01	16.57	6149.12472	1.5	3	2	0.47
27	Abloli	28.812	40.14	18.7	5605.7976	2.6	3	2	0.38
28	Naravan	24.57	46.31	18.59	5770.3408	2.4	3	2	0.40
29	Pomendi	27.125	39.66	21.59	5236.61185	2.6	3	2	0.35
30	Kotaluk	33.943	34.13	17.38	5624.19126	1.4	3	2	0.43
31	Lote	32.207	34.74	19.25	5405.97025	2.8	3	2	0.36
32	Khopi	26.894	43.49	18.09	5765.15344	3.3	3	2	0.36
33	Kudeshi	33.488	31.97	20.19	5224.20298	0.2	3	2	0.44
34	Sukavali	33.712	28.23	23.61	4731.74938	1.8	3	2	0.34
35	Musad	39.823	22.11	21	4892.707	1.8	3	2	0.35
36	Kumbale	29.722	41.67	15.87	6006.20896	2.9	3	2	0.40
37	Surle	41.958	20.61	19.45	5039.8524	1.9	3	2	0.36
38	Kuduk	26.047	33.21	29.34	4187.09962	2.7	3	2	0.27
39	Pimpoli	38.955	18.67	25.68	4282.69	2.3	3	1	0.26
40	Ranvali	25.774	39.44	23.74	4973.21964	2.2	3	2	0.34
41	Shirsoli	28.658	40.50	18.56	5632.22752	1.9	3	2	0.41
42	Burondi	16.611	51.03	25.24	5056.84116	2.0	3	2	0.36
43	Unhavare	37.002	23.85	23.29	4667.95692	2.2	3	2	0.32
44	Gavhe	19.649	52.16	19.77	5761.23607	2.8	3	2	0.38
45	Avashi	29.47	38.3	19.6	5448.708	2.4	3	2	0.37

Table 4.15: Erodibility of soils of Raigad district

Sr. No.	Villages	% Very fine sand	% Silt	% Clay	M	a	b	c	K
1	Maluk	52.927	15.50	8.89	6234.384	3.3	3	2	0.39
2	Tala	47.565	18.09	13.96	5648.956	2.6	3	2	0.38
3	Tokarde	46.263	29.57	4.34	7254.185	2.9	3	2	0.49
4	Girne	43.239	21.54	16.69	5396.738	4.3	3	2	0.30
5	Washi Haveli	42.238	21.32	18.34	5190.146	2.3	3	2	0.36
6	Kavat	42.56	31.81	7.39	6887.406	7.4	3	2	0.24
7	Bhabat	35.833	40.76	8.05	7042.726	5.2	3	2	0.36
8	Pandare	39.613	38.47	4.94	7422.57	6.2	3	2	0.32
9	Toradi	39.319	23.81	20.02	5049.057	2.8	3	2	0.33
10	Dehen	49.14	25.13	4.67	7080.159	4.6	3	2	0.39
11	Kambe	50.974	22.83	4.35	7059.353	1.6	3	2	0.54
12	Wadgaon	48.776	22.16	8.16	6514.762	5.3	3	2	0.32
13	Vat	50.666	17.28	10.34	6092.038	2.3	3	2	0.43
14	Talavali	47.628	23.35	8.61	6486.679	1.31	3	2	0.51
15	Golewadi	45.059	26.72	8.91	6538.349	3.8	3	2	0.39
16	Shirshe	48.104	14.10	17.18	5151.735	1.4	3	2	0.39
17	Sangavi	45.094	19.50	16.08	5420.728	0.2	3	2	0.46
18	Sugave	41.013	28.42	12.96	6043.448	5.5	3	2	0.29
19	Wave	43.953	26.30	10.91	6258.84	3.1	3	2	0.41
20	Pashane	49.175	20.93	8.82	6392.174	1.6	3	2	0.48
21	Nagaloli	49	15.77	14.23	5555.323	5.1	3	2	0.28
22	Bagmandale	39.865	22.25	20.8	4919.508	3.0	3	2	0.31
23	Saigaon	45.745	13.81	20.84	4714.374	3.8	3	2	0.27
24	Mhasadi	52.787	18.09	6.5	6627	5.0	3	2	0.34
25	Jamgaon	53.431	18.96	4.71	6898.138	5.8	2	2	0.28
26	Chinchwali	55.37	16.7	4.2	6904.306	5.1	2	2	0.32
27	Khamb	53.858	20.67	2.39	7274.678	3.4	2	2	0.43
28	Kokban	57.645	11.73	5.92	6526.8	3.2	2	2	0.39
29	Dharechiwadi	51.541	22.88	3.49	7182.371	5.6	2	2	0.31
30	Kasarwadi	51.919	22.95	2.88	7271.277	3.3	2	2	0.44
31	Jambhulpada	48.174	22.79	11.65	6269.669	4.7	3	2	0.33
32	Nadsur	39.151	33.52	10.55	6500.421	2.5	3	2	0.45
33	Veshvi	51.975	16.87	8.88	6273.156	2.6	3	2	0.43
34	Karle	51.275	21	5.75	6811.919	3.2	3	2	0.44
35	Nagaon	52.29	21.51	3.79	7100.298	0.7	2	2	0.56
36	Ambeghar	39.151	33.52	10.55	6500.421	2.7	3	2	0.44
37	Beloshi	45.577	30.28	4.61	7235.999	4.7	3	2	0.39
38	Bhoighar	55.93	13.71	6.39	6519	1.8	2	2	0.45
39	Saigaon	44.912	30.90	4.94	7206.689	0.9	3	2	0.59
40	Nagshet	50.666	20.33	7.29	6582.039	0.6	3	2	0.55
41	Wawdungi	45.472	31.25	3.79	7381.424	0.7	3	2	0.62
42	Amboli	47.215	29.34	3.21	7409.758	0.4	3	2	0.64

43	Punalkond	50.974	17.72	9.46	6219.555	2.2	3	2	0.44
44	Wakan	52.451	21.60	3.47	7148.143	3.4	2	2	0.42
45	Sawad	50.393	18.93	9.08	6302.847	1.4	3	2	0.49
46	Dharwali	54.033	13.85	8.96	6180.068	3.6	3	2	0.38
47	Faujdar	53.62	12.55	10.85	5899.056	3.3	3	2	0.37
48	Pali	54.082	13.50	9.24	6133.742	2.1	3	2	0.44
49	Jatade	54.67	15.63	6.27	6589.219	3.4	2	2	0.38
50	Morbe	53.592	10.54	12.9	5585.897	2.6	3	2	0.38
51	Wardoli	53.739	19.91	3.32	7120.385	2.6	2	2	0.46
52	Taloje	58.135	13.83	3.14	6970.53	2.4	2	2	0.44
53	Saje	50.68	8.41	19.19	4775.063	1.8	2	2	0.31
54	Warachiwadi	48.636	9.43	21.09	4581.988	2.4	3	2	0.31
55	Sanaswadi	51.555	7.30	19.05	4764.312	0.8	3	2	0.37
56	Umbardi	39.998	18.68	24.18	4448.966	0.3	3	2	0.36
57	Ransai	45.486	11.88	23.14	4409.151	1.0	3	2	0.34
58	Khaire tarf	40.096	14.11	28.61	3869.766	1.9	3	2	0.27
59	Jirne	53.585	15.30	8.15	6327.087	3.2	3	2	0.41
60	Shedashi	52.556	16.88	8.04	6385.335	4.6	3	2	0.35
61	Banase	50.764	10.88	16.6	5141.11	0.7	3	2	0.41
62	Gadab	29.869	54.02	3.31	8111.227	4.9	3	2	0.43
63	Gangode	55.447	11.05	9.74	6002.019	6.0	3	2	0.26

Table 4.16: Erodibility of soils of Thane district

Sr. No.	Villages	%Very fine sand	% Silt	% Clay	M	a	b	c	K
1	Adivali	33.74	19.75	32.05	3634.646	1.4	3	2	0.26
2	Musarne	37.996	20.97	24.75	4437.192	1.9	3	2	0.31
3	Ainshet	27.496	27.25	33.47	3642.251	1.2	3	2	0.27
4	Kharivali	26.593	31.75	30.26	4068.841	1.5	3	2	0.29
5	Sange	26.957	25.75	35.74	3386.952	2.2	3	2	0.22
6	Aalond	21	28.75	41.25	2922.813	1.6	2	2	0.17
7	Aaling	30.114	26.98	30	3996.58	2.5	3	2	0.26
8	Mohkhurd	32.76	20.16	33.04	3543.523	2.5	3	2	0.23
9	Kurze	30.303	32.5	24.21	4759.839	1.4	3	2	0.35
10	Khardi	40.705	20.6	21.25	4827.769	3.4	3	2	0.29
11	Bhuigaon	38.234	23.6	21.78	4836.655	1.1	3	2	0.37
12	Sandor	37.891	22.935	22.935	4687.556	0.7	3	2	0.37
13	Chandansar	36.687	18.51	29.08	3914.571	0.8	3	2	0.30
14	Naringi	37.457	19.65	26.84	4177.948	3.0	3	2	0.26
15	Udhawa	33.04	31.08	21.72	5019.314	2.5	3	2	0.34
16	Vasa	31.962	28.2	32.22	4077.78	2.5	3	2	0.27
17	Kurze	31.374	34.45	20.73	5217.868	2.1	3	2	0.37
18	Talasari	32.06	33.75	20.45	5235.186	2.0	3	2	0.37
19	Sutrakar	33.341	25.79	26.56	4342.581	1.7	3	2	0.31

20	Anakharpada	24.423	44.75	20.36	5508.938	0.6	3	2	0.45
21	Mamnoli	37.576	26.25	20	5106.08	1.1	3	2	0.39
22	Rayate	26.922	43.36	18.18	5750.473	1.5	3	2	0.43
23	Shirdhon	28.91	29.35	29.35	4116.069	0.7	3	2	0.32
24	Dahagaon	35.028	28.69	21.27	5016.518	4.8	3	2	0.26
25	Khanivali	22.75	33.75	33.75	3743.125	1.7	3	2	0.26
26	Palkhane	23.128	35	31.96	3955.029	1.1	3	2	0.30
27	Katai	33.194	22.58	30	3904.18	1.9	3	2	0.27
28	Kurund	33.187	31.74	20.85	5138.972	1.2	3	2	0.39
29	Gorsai	25.2	36.25	27.75	4439.763	2.1	3	2	0.31
30	Bordi	40.271	13.7	28.77	3844.354	4.7	3	2	0.19
31	Bendgaon	36.414	26.75	21.23	4975.428	1.7	3	2	0.36
32	Dehane	19.25	23.75	48.75	2203.75	2.1	2	2	0.11
33	Kainad	30.275	25.5	31.25	3834.531	1.4	3	2	0.28
34	Nikane	33.6	26.25	25.75	4443.863	2.3	3	2	0.30
35	vaki	27.475	32	28.75	4237.594	1.9	3	2	0.30
36	Ambivali	25.837	37.5	25.59	4712.906	2.6	3	2	0.31
37	Patol	29.428	34.05	23.91	4830.041	1.8	3	2	0.35
38	Shendrun	16.681	56.21	19.96	5834.196	2.3	3	2	0.41
39	Khardi	27.335	38.45	22.5	5098.338	1.6	3	2	0.38
40	Sarlambe	26.6	42.71	19.29	5594.01	0.4	3	2	0.46
41	Eklahare	32.585	33.75	19.7	5326.701	5.1	3	2	0.26
42	Tokawade	25.375	36.25	27.5	4467.813	2.0	3	2	0.31
43	Vaishakhare	19.572	26.75	45.29	2534.277	2.7	3	2	0.16
44	Inde	28.5915	17.76	41.395	2716.43	2.6	3	2	0.17
45	Karavale	20.3	35	36	3539.2	1.8	3	2	0.25
46	Unbhat	21	31.25	38.75	3200.313	1.2	3	2	0.23
47	Tandulwadi	28.175	30	29.75	4086.794	1.6	3	2	0.29
48	Paragon	23.611	26.25	40.02	2990.663	1.6	2	2	0.18
49	Varkhunti	23.625	22.5	43.75	2594.531	1.1	2	2	0.15
50	Virathankhurd	17.528	32.53	42.43	2881.839	2.3	2	2	0.15
51	Ambarnath	23.625	47.5	18.75	5778.906	2.2	3	2	0.41
52	Ambhe	23.142	29.12	37.82	3249.651	1.8	3	2	0.22
53	Asnoli	36.757	33.75	13.74	6081.934	0.6	3	2	0.50
54	Karand	43.358	26.25	11.81	6138.73	0.5	3	2	0.51
55	Chargaon	40.74	28.32	13.48	5975.071	1.9	3	2	0.44
56	Khand	26.222	30.04	32.5	3797.685	3.2	3	2	0.23
57	Tolepda	25.746	30.37	32.85	3768.189	2.9	3	2	0.24
58	Balapur	22.463	35.42	32.49	3907.681	3.9	3	2	0.22
59	Rampur	24.066	38.44	27.18	4551.687	1.6	3	2	0.33
60	Medhi	25.865	35.79	27.26	4484.785	3.1	3	2	0.28
61	Veti	31.962	27.31	27.03	4325.078	2	3	2	0.30
62	Suksale	32.487	26.93	26.66	4357.643	1.1	3	2	0.33

4.8 Generation of Soil Erodibility Maps

Soil erodibility maps of Sindhudurg, Ratnagiri, Raigad and Thane districts of Konkan region and map of whole Konkan were generated in Arc GIS 9.3. The values of erodibility factors were assigned to respective villages of each district. By using the Inverse Distance Weighted Technique the maps were interpolated for Sindhudurg, Ratnagiri, Raigad, Thane districts and Konkan region. The map of the each district and Konkan region are shown Fig.4.2, 4.3, 4.4, 4.5 and 4.6.

From the maps, it is observed that erodibility factor is highest in Raigad district and lowest in the Thane district. The areas with erodibility factor ranging from 0.568 – 0.64 are observed to be highly prone to erosion. Generally in Konkan region it is observed that along with soil characteristics, geo-morphological characteristics like steepness of slope and length of slopes are greatly influence the erodibility factor. These steep slopes areas of four districts are observed to have high erodibility factors as clay content in these soils is very less. This information will be useful in planning of crops and conservation practices in Konkan region.

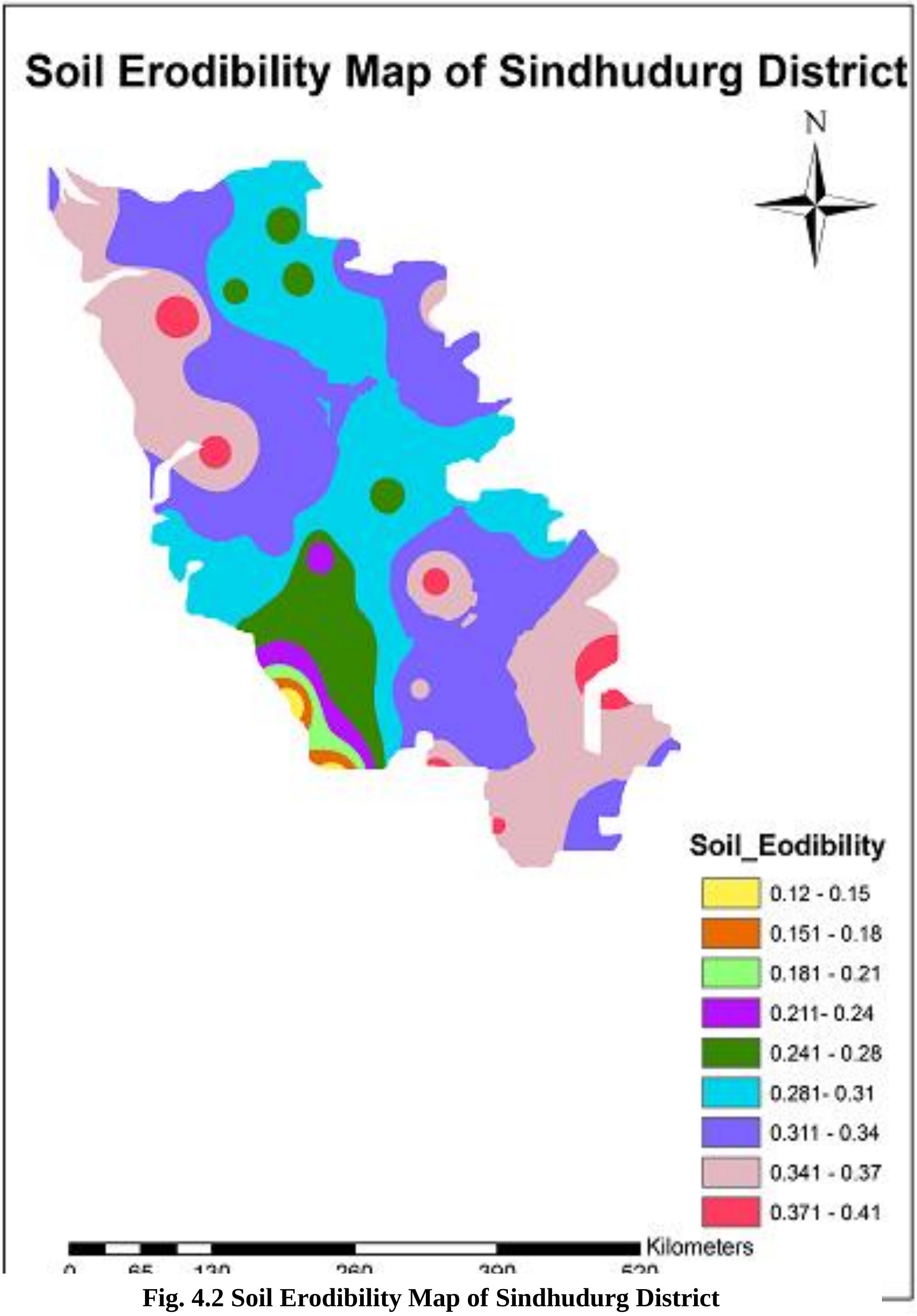


Fig. 4.2 Soil Erodibility Map of Sindhudurg District

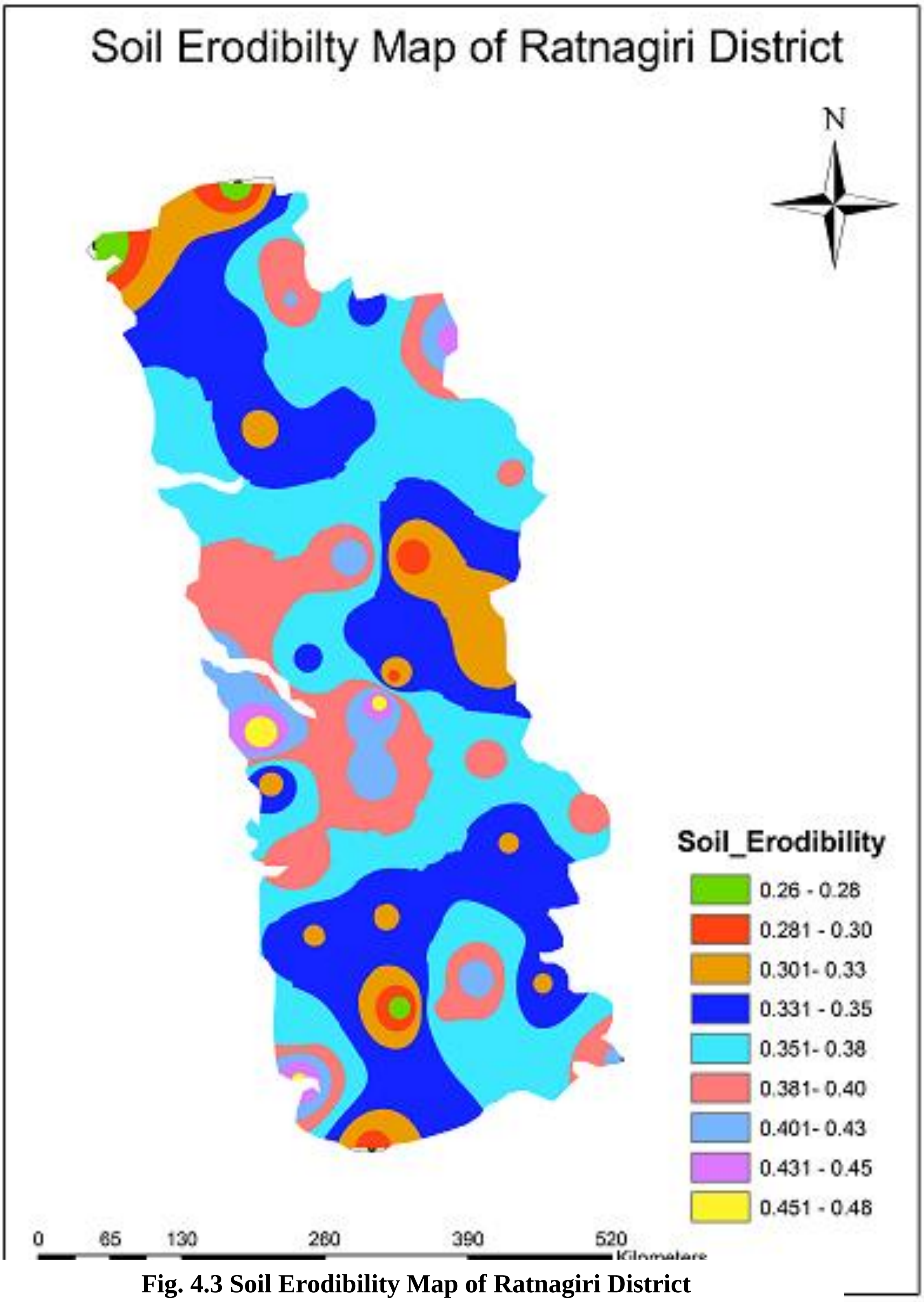


Fig. 4.3 Soil Erodibility Map of Ratnagiri District

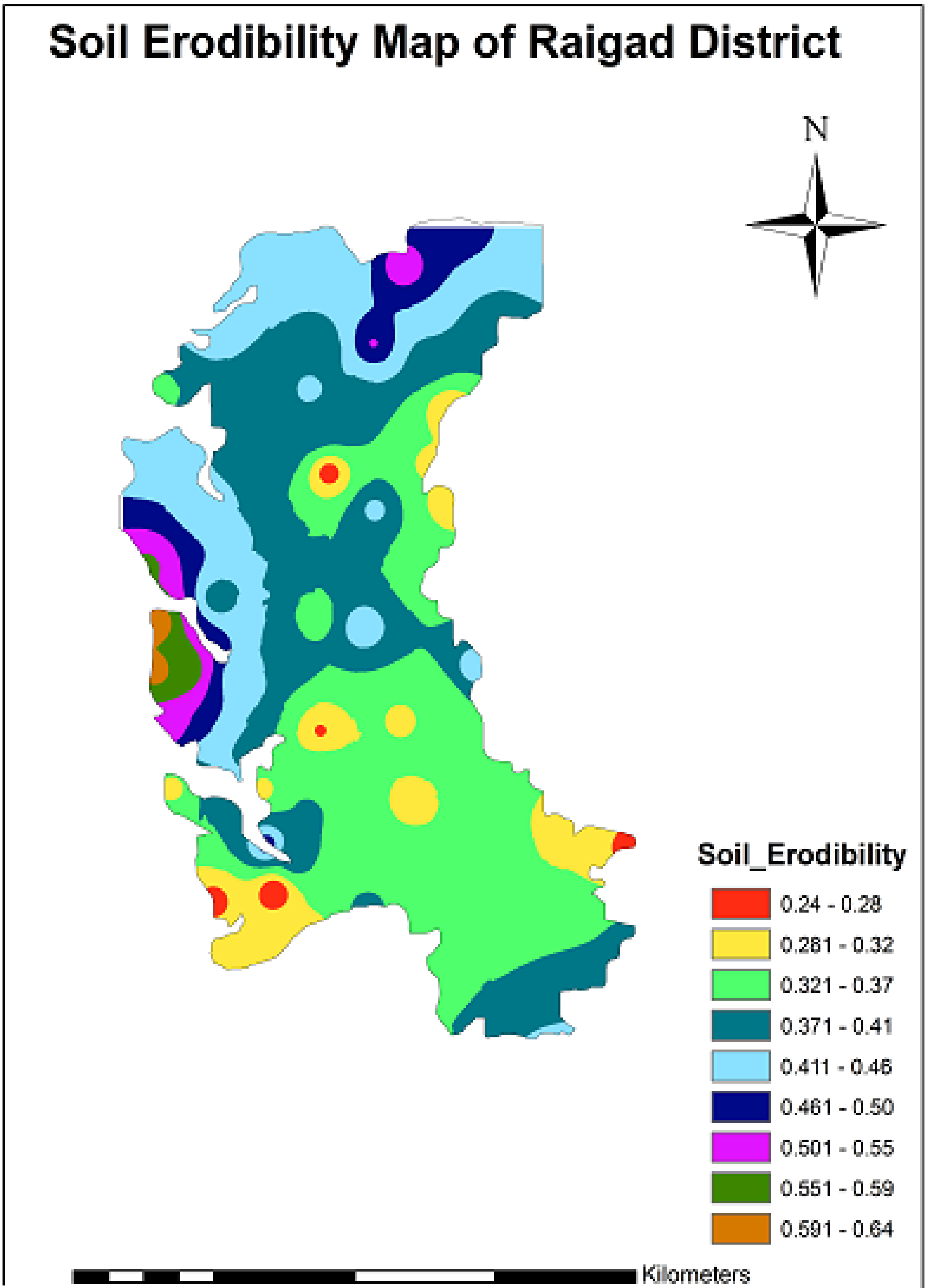
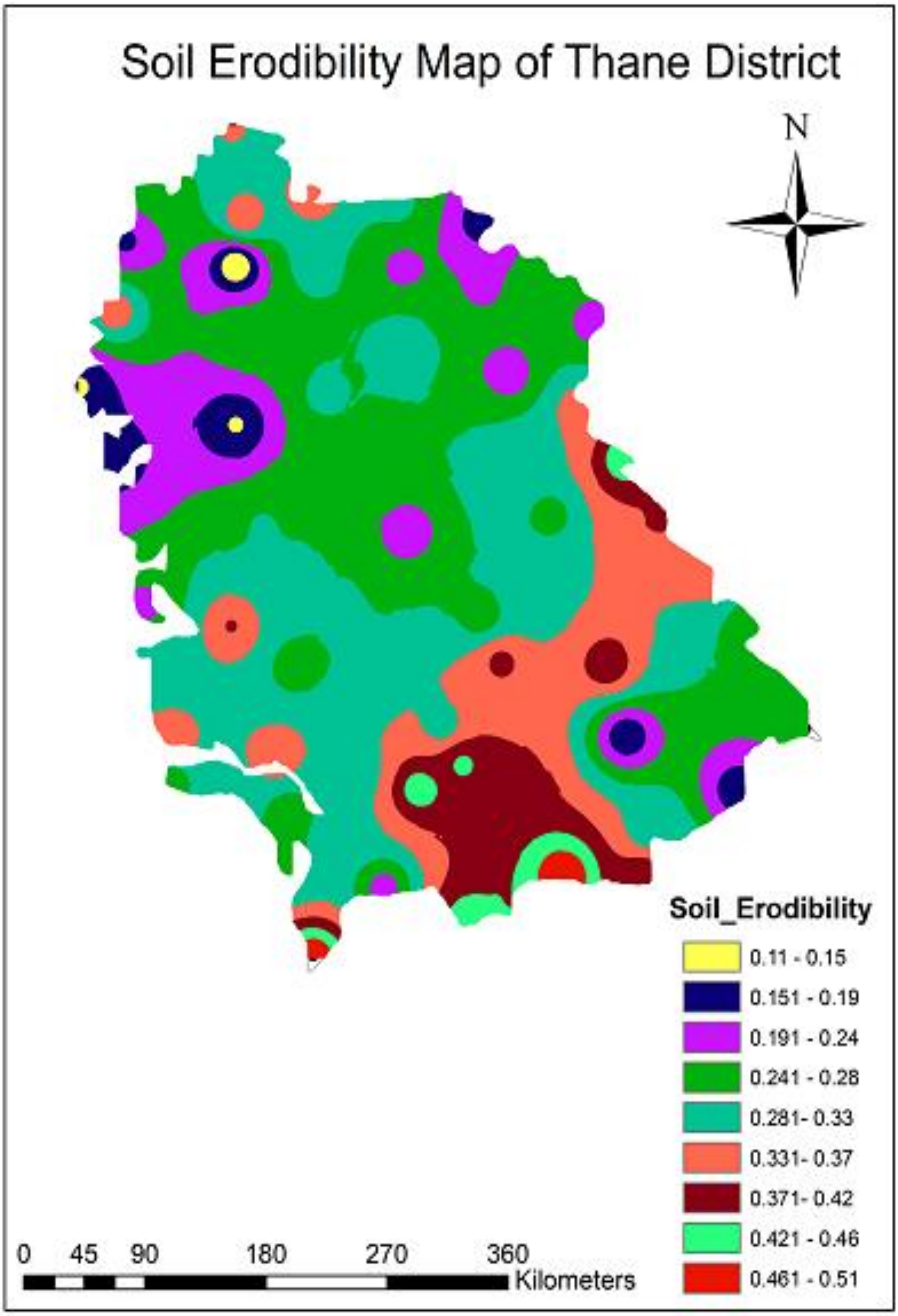


Fig. 4.4 Soil Erodibility Map of Raigad District


Soil Erodibility Map of Thane District
N
Soil_Erodibility
0.11 - 0.15
0.151 - 0.19
0.191 - 0.24
0.241 - 0.28
0.281- 0.33
0.331- 0.37
0.371- 0.42
0.421 - 0.46
0.461 - 0.51
0 45 90 180 270 360
Kilometers

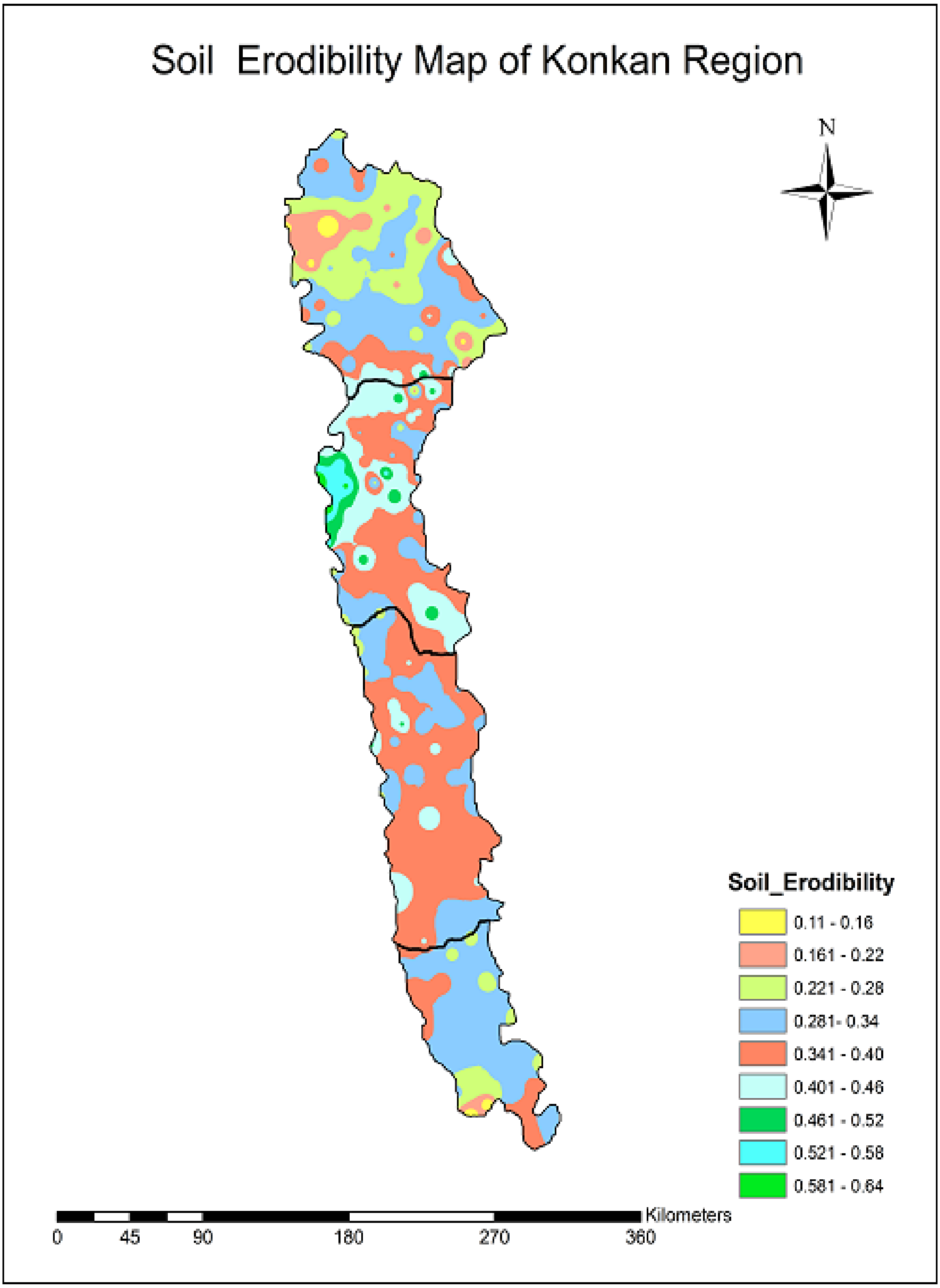


Fig. 4.5 Soil Erodibility Map of Thane District

V. SUMMARY AND CONCLUSIONS

Agriculture is facing a challenge of low productivity. One of the principle reasons for low productivity is progressive deterioration of soil due to erosion. Abundant soil loss and land degradation are problems of severe consequences of all future generations of people. They need to be tackled with the top most priority and scientific aptitude. Scientific basic data is prerequisite for technological development to back up its strategy on sustainable ground. Soil erosion is occurring in the main phases as detachment, transportation and deposition. According to Universal Soil Loss Equation (USLE), soil loss mainly depends on six parameters i.e. rainfall erosivity (R), soil erodibility (K), slope length (L), steepness (S), cover and management (C) and support practice (P) respectively. Out of them erodibility (K) is one of the important parameter, which is mainly influenced by soil characteristics. Estimation of erodibility requires data of various parameters which are not easily available. Konkan region is major victim of the soil erosion. Accurate estimation of soil loss needs information on aforesaid parameters. Keeping in mind the study was undertaken for determination of soil characteristics required for erodibility of representative soils and estimation of erodibility of representative soils.

Konkan region of Maharashtra State is located between $15^{0}44'$ and 20°20' N latitude and $70^{0}10'$ and $73^{0}50'$ E longitude. It has longitudinal distance of 500 kms and a width of 35- 40 kms. The total geographical area of Konkan region is 3.09 Mha. It comprises of five districts, namely Sindhudurg, Ratnagiri, Raigad, Thane and Mumbai. Konkan region receives an average annual rainfall of 2500-4000 mm mostly through southwest monsoon during the months of June to October. Soil data of 210 villages from 45 tahsils/block of 4 districts were collected for representation of whole Konkan region.

In the present study, physical and chemical properties of soils were determined from the soil data collected. Soil-Plant-Air-Water (SPAW) model was used to determine hydraulic conductivity of soils. The model was calibrated and validated for Konkan condition before using for the Konkan region. Permeability code was derived based on hydraulic conductivity of soil (Smith and Browning, 1946). Texture of soil was determined by using SPAW model. Structural code was obtained from different particle size proposed by using NBSS and LUP (1988). The erodibility of soils were determined by using Wischmeier and Smith (1971) relationship. Soil erodibility maps of Sindhudurg, Ratnagiri, Raigad and Thane districts of Konkan region and map of whole Konkan were generated in Arc GIS 9.3.

The average sand, silt and clay contents of the Sindhudurg district were 56.22, 21.08 and 22.67 percent respectively. In Ratnagiri district there values were 42.94, 36.57, and 20.48 percent. Raigad district sand, silt, and clay contents were 69.08, 20.83 and 10.13 percent respectively and 41.93, 30.03 and 28.12 percent for Thane district. The result showed that the sand content of Raigad district was highest as compare to other three districts. Due to high sand content very little force was required to detach the soil particles making then more susceptible to the erosion. Silt content was found to be higher in Ratnagiri district. The clay content was found less in Raigad district as compare to other three districts. Majority of soils in Sindhudurg district were sandy clay loam type, loam type in Ratnagiri district, sandy loam type in Raigad district and sandy clay loam type in Thane district of the Konkan region.

Organic carbon content of Konkan region was found to be in the range of 0.12 to 4.32 percent with the mean value 1.43. The data revealed that the organic carbon was maximum at Raigad district and minimum in Thane district. In Konkan region the value of organic matter was found to be in the range of 0.20 to 7.40 percent with the mean value of 2.47 percent. Based on the results it was observed that the Raigad district was having more amount of organic matter content.

SPAW model was applied for estimation of hydraulic conductivity of soils after calibration and validation for Konkan region. The hydraulic conductivity of soils varied from 2.56 to 24.89 cm/hr, 2.64 to 25.32 cm/hr, 2.56 to 25.32 cm/hr and 2.56 to 24.51 cm/hr for Sindhudurg, Ratnagiri, Raigad, and Thane districts respectively. It was found that hydraulic conductivity was nearly same in four districts of Konkan region. The permeability of soils of 210 villages of Konkan region were obtained from hydraulic conductivity of soils. The permeability classes varied between moderate to rapid class and moderate class and accordingly permeability codes were assigned as 2 and 1 respectively. Structure type of soils were fine granular and moderate for all soils of Konkan region. Therefore structural codes assigned for all these soils were 2 and 3 in 210 villages of Konkan region.

Based on these soil parameters and codes assigned to them, soil erodibilities were estimated. It was observed that the soils in Konkan region are highly erodible having erodibility factors (K) in the range of 0.11 to 0.64 with mean value of 0.35. The average erodibility factor was maximum in Raigad district (0.40) and minimum in Thane district (0.30). Erodibility maps of district were generated using Arc GIS. The areas with erodibility factor ranging from 0.568 – 0.64 were observed to be highly prone to erosion. Majority of area in Konkan region falls under this category.

This study has looked at the various soil properties in relation to their degree of influence on soils susceptibility to erosion and concludes that:

- ❖ High sand, silt content and low clay content have made the soils of Konkan region more susceptible to erosion.
- ❖ Soil-Plant-Air-Water (SPAW) model can be successfully used for estimation of soil characteristics from the easily available soil data in Konkan region.
- ❖ Average erodibility factor for Sindhudurg and Ratnagiri districts of South Konkan region are 0.32 and 0.36 respectively.
- ❖ Average erodibility factor for Raigad and Thane districts of North Konkan region are 0.40 and 0.30 respectively.
- ❖ Overall erodibility of soils of Konkan region varies from 0.11 to 0.64 with mean value of 0.35.
- ❖ Erodibility of Konkan region on steep slopes is very high due to less clay content.

VI. BIBLOGRAPHY

Ali, S. and V.N. Sharda. 2005. Evaluation of the Universal Soil Loss Equation (USLE) in semi-arid and sub-humid climates of India. *Applied engineering in Agriculture*, 21(2): 217-225.

Andoh, H.F., B.O. Antwi, T. Wakatsuiki and E.T. Atakora. 2012. Estimation of soil erodibility and rainfall erosivity patterns in the agroecological zones of Ghana. *Journal of Soil Science and Environmental Management*, 3(11): 275- 279.

Anonymous, 2006. Natural resources conservation service, Soil- fundamental concepts, Scoop on Soil Educational CD.

Askin, T. and N. Ozdemir. 2003. Soil bulk density as related to soil particle size distribution and organic matter content. Karadeniz Technical University, Faculty of Agriculture, Department of Soil Science.

Atawoo, M.A and J.M. Heerasing. 1997. Estimation of soil erodibility and erosivity of Rainfall patterns in mauritius. Food and Agricultural Research Council, Reduit, Mauritius.

Bajaracharya, R.M. and R. Lal. 1991. Seasonal soil loss and erodibility variation on a Miamian silt loam soil. *Journal of soil science society of America*, 56: 1565.

Bousyoucos, G. J. 1935. The clay ratio as a criterion of susceptibility of soils to erosion, *Journal of American Society of Argon*, 27:738-741.

Brady, N.C. 1974. The nature and properties of the soils of eighth edition. Macmillan publishing Co. Inc. New York.

Bryan, R.B. 2000. Soil erodibility and processes of water erosion on hillslope. Geomorphology 32: 385–415.

Challa, O., S. Vadiwelu and J. Sehgal. 1995. Soils of Maharashtra for optimizing land use. Published by National Bureau of Soil Survey and Land Use Planning, Nagpur 440010 (NBSS Pub1.54).

Challa, R.S., K.S Kurothe and G. Ajbhiye. 2001. Soil Erosion in Maharashtra. NBSS Publications No. 82, NBSS&LUP, Nagpur.

Chaudhari, P.R., D.V. Ahire, V.D. Ahire, M. Chkravarty and S. Maity. 2013. Soil Bulk Density as related to Soil Texture, Organic Matter Content and available total Nutrients of Coimbatore Soil. *International Journal of Scientific and Research Publications.* 3(2).

Chaudhary, R.S., H. Gadekar and U.S. Patnaik. 2003. Erodibility under different land uses in soils of eastern ghat high land zone. *Indian Journal of Soil Conservation,* Vol. 27(2): 118-121.

Craswell, E.T and R.D.B. Lefroy. 2001. The role and function of organic matter in tropical soils. *International Board for Soil Research and Management, Nutrient Cycling in Agroecosystems,* 61: 7–18.

Dabke, D.J. 1987. Studies on the physio-chemical properties and available micronutrients status of the rice soils from Agri. Research station, Phondaghat (Dist.Sindhudurg). Msc. (Agril) Thesis submitted to Konkan Krishi Vidyapeeth, Dapoli. (Unpublished) (India).

Das, A.N., B.K. Laskar., G.K. De and N.C Debnath. 1991. Nature of acidity of some acid soils of West Bengal. *Journal of Indian Society Soil Science,* 39: 246 -251.

Dongle, J.H. and B.P. Patil. 1987. Physio-chemical properties of lateritic soils in relation to their irrigability classification. *Journal of Maharashtra Agriculture Univerrsity,* 12:6-8.

Dongale, J.H. and S.B. Kadrekar. 1992. Phosporus fractions in lateritic soils of Konkan region. *Journal of Maharashtra Agriculture University,* 17(3): 357-362.

Emmauel, S., Oguche and A. Oguche. 2013. Studies of Physicochemical Properties of Rhizosphere of *Elaeis guinensis* in Ayingba. *International Journal of Scientific Research in Knowledge (IJSRK),* 1(9): 358-362.

Hayhoe, H.N and R.D. Jong. 1987. Comparison of two soil water models for soybean Land resource Research Institute, Agriculture Canada, Ottawa, Ontario.

Hesse, P.R. 1971. A text book of Soil Chemical Analysis. John Murray publ. ltd. London WLX- 4 BD.

Heuscher, S.A., C.C. Brandt and P. M. Jardine. 2005. Using Soil Physical and Chemical Properties to Estimate Bulk Density. *Journal of Soil Science Society of America*., 69:1-7.

Idah, P.A., H.I. Mustapha., J.J. Musa and J. Dike. 2008. Determination of erodibility indices of soils in Owerri West local government area of Imo state, Nigeria, *AU J.T.* 12(2): 130-133.

Isikwue, M.O., C. Abutu and S.B. Onoja. 2012. Erodibility of Soils of the South West Benue State, Nigeria. *The Pacific Journal of Science and Technology*, 13(2):437-443.

Kadam, P.A. and P.P Rathod. 2008. Study of soil Erodibility of Priyardarshini watershed. Unpublished B.Tech. Thesis Submitted to Department of Soil and Water Conservation Engineering, CAET Dapoli (India).

Kadam, U.S., R.T. Thokal, S.D. Gorantiwar and A.G. Pawar. 2008. Agricultural Drainage-Principles and Practices, 202-206.

Kadrekar, S.B., A.S. Chavan, and J.H. Dongale. 1981. Literite and lateritic soils of Maharashtra. *Indian Journal of Agriculture Chemestry*, 14: 73-92.

Keli, Z., Li. Shuangcai and P. Wenying. 2002. Erodibility of Agricultural Soils in the Loess Plateau of China. Dept. Resource and Environmental Sciences, Beijing Normal University, Beijing.

Korkanc, S.Y., N. Ozyuvaci and A. Hizal. 2008. Impacts of land use conversion on soil properties and soil erodibility. *Journal of Environmental Biology*, 29 (3):363-370.

Longnathan, S. and K.K. Krishnamurthy. 1976. Morphological, physical and chemical properties in certain black, red, alluvial and lateritic soil profiles of Tamilnadu. *Mysore Journal of Agriculture Science,* 10: 584-598.

Narain, P., B. Verma and D.H. Rao. 1980. Prediction of rainfall erosion potential and some parameters of universal soil loss equation in Kota, Rajasthan. Presented at National Symposium on Soil Conservation and water Management in 1980's at Dehradhun.

Narayana, V.V.D. and Ram Babu. 1981. Estimation of soil erosion in India. *Journal of Irrigation and Drainage Engineering,* 109 (4): 419-434.

NBSS and LUP. 1988. Field handbook, printed at cartography Div. NBSS & LUP, New Delhi. Agrobias India, 29-34.

Nema, J.P., B.Verma and A.P. Patel. 1978. Predicting universal soil loss parameters. *Indian Journal of Soil Conservation*, 6(2): 75-79.

Pareira, A.J., A.S. Chavan and P.A. Varade. 1986. Physico-chemical properties and micronutrients status of the mango orchard hill soils of Konkan. *Journal of Maharashtra Agriculture University,* 11(2): 134-136.

Pasak, V. 1967. Factors influencing the wind erosion, Inscientific work of the research institute of Ameliorations, Prague.

Pawar, S.S., N.H. Khobragade, M.R. Nagrale and A.L. Shinde. 2013. Vertical distribution of macro- and micro-nutrients in lateritic soils from mango orchards of Sindhudurg District of Konkan. *Green Farming, International Journal Applied Agricultural and Horticultural Sciences.* 4 (3): 334-337.

Pazhouhesh, M., M. Gorji, S.M. Taheri and A. Keshavarzi. 2011. Determination of soil erodibility factor using fuzzy rule base system. *International journal of environmental sciences,* 1(7): 1874-1883.

Presley, D. and S.J. Thien. 2008. Estimating soil texture by feel. Department of Agronomy, Kansas State University.

Revendkar, N.S. 1990. Physio-chemical properties and fertility maps of soils from the soil conservation research solution Awashi (Ratnagiri Dist.).Msc. (Agril). Thesis submitted to Konkan Krishi Vidyapeeth, Dapoli. (Unpublished) (India).

Saxton, K.E. and W.J. Rawls. 2006. Soil Water Characteristic Estimates by Texture and Organic Matter for Hydrologic Solutions. *Journal of Soil Science Society of America,* 70: 1569- 1578.

Saxton, K.E., P.H. Willey and W.J. Rawls. 2006. Field and pond hydrologic analysis with SPAW model. *Proceedings of Annual International Meeting Sponsored by ASABE Portland Convention Center Portland, Oregon 9 - 12 July 2006.*

Schumacher, B.A. 2002. Methods for the determination of total organic carbon (TOC) in soils and sediments. United States environmental protection agency, Environmental sciences division national exposure research laboratory.

Senol, H., M. Akgul, M. Mujdeci and L. Basayigit. 2012. The determination of some physical characteristics of different particle sizes in soils with reflection spectroscopy. *African Journal of Agricultural Research,* 7(14), pp. 2225-2235.

Shabani, F., M. Gorji., A. Heidari and A. Esmeili. 2010. Effects of landuse types at different slopes on soil erodibility factor (A case study from Amol area, north of Iran). *19th World Congress of Soil Science*, Soil Solutions for a Changing World. Brisbane, Australia. 14-17.

Sharma, P.P., S.C. Gupta and G.R. Foster. 1995. Raindrop induced soil detachment and sediment transport from inter-rill areas. *Journal of Soil Science Society of America,* 59: 727-734.

Singh, M.J. and K.L. Khera. 2010. Evaluation and estimation of soil erodibility by different techniques and their relationships. *19th World Congress of Soil Science*, Soil Solutions for a Changing World. Brisbane, Australia. 37- 40.

Smith, R.M. and D.R. Browning. 1946. Some suggested laboratory standards of subsoil permeability. *Soil Science Society of American Proceedings,* 11: 21-26.

Tejwani, K.G., S.K. Gupta and H.N. Mathur. 1975. Soil and water Conservation Research, 1956-71. *Indian Council of Agricultural Research, New Delhi.*

Terse, G.V. 1989. Characterization of soil potassium in benchmark soils of South Konkan. Msc.(Agril). Thesis submitted to Konkan Krishi Vidyapeeth, Dapoli.(Unpublished) (India).

Wijaya, K., T. Nishimura., M. Kato and M. Nakagawa. 2004. Field estimation of soil dry bulk Density Using Amplitude domain reflectometry data. Estimation of dry bulk density of soil using amplitude domain reflectrometry, *J. Jpn. Soc. Soil Phys*, 97:3-12.

Wischmeier, W.H., C.B. Johansons, and B.V. Cross. 1971. An erodibility nomograph for formaland and construction, *Journal of Soil and Water Conservation*, 26: 189-193.

Wischmeier, W.H. and J.V. Mannering. 1969. Relation of soil properties to its erodibility. *Proceedings of American Soil Science Society*, 33: 131-137.

Xuezheng, S. and Y. Dongsheng. 2001. Measurement of erodibility for soils in subtropical china by simulated and natural rainfall. Institute of soil science, Chinese Academy of Sciences, Nanjing.

Yadav, R.P., S.K. Mahapatra, R.K. Arrgawal, S.P. Singh and J.S. Samara. 2005. Erodibility of major soils of Delhi. *Journal of Indian Society of Soil Science*, Vol. 53 (2): 178-183.

Zhang, Z.F., A.L. Ward and J.M. Keller. 2009. Determining the Porosity and Saturated Hydraulic Conductivity of Binary Mixtures. Pacific Northwest laboratory, United States department of energy.