DEGRADATION OF AGRICULTURAL LAND DUE TO OVER IRRIGATION IN DAUND TAHSIL OF PUNE DISTRICT, MAHARASHTRA

A Thesis

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SUBMITTED BY

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UNDER THE GUIDANCE OF

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CERTIFICATE OF THE SUPERVISOR

It is certified that work entitled "**Degradation of Agricultural Land due to over irrigation in Daund Tahsil of Pune District, Maharashtra**" is an original research work done by **Mr. Ashok Bhagwan Divekar,** under my supervision for the degree of Doctor of Philosophy (Ph. D.) in Geography, to be awarded by Tilak Maharashtra Vidyapeeth, Pune.

To best of my knowledge this thesis

- embodies the work of candidate himself
- has duly been completed
- fulfils the requirement of the ordinance related to Ph. D. degree of the TMV
- is upto the standard in respect of both content and language for being referred to the examiner.

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UNDERTAKING

I, **Mr. Ashok Bhagwan Divekar**, is the Ph. D Scholar of the Tilak Maharashtra Vidyapeeth in Geography subject. Thesis entitled **"Degradation of Agricultural Land due to over irrigation in Daund Tahsil of Pune District, Maharashtra"** - under the supervision of **Dr. Sunil W. Gaikwad**, solemnly affirm that the thesis submitted by me is my own work. I have not copied it from any source. I have gone through extensive review of literature of the related published / unpublished research works and the use of such references made has been acknowledged in my thesis. The title and the content of research is original. I understand that, in case of any complaint especially plagiarism, regarding my Ph.D. research from any party, I have to go through the enquiry procedure as decided by the Vidyapeeth at any point of time. I understand that, if my Ph.D. thesis (or part of it) is found duplicate at any point of time, my research degree will be withdrawn and in such circumstances, I will be solely responsible and liable for any consequences arises thereby. I will not hold the TMV, Pune responsible and liable in any case. I have signed the above undertaking after reading carefully and knowing all the aspects therein.

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Place: Pune **Ashok Bhagwan Divekar**

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CHAPTER I

INTRODUCTION

1.1 Introduction:

Land is an extremely precious natural resource having wide variety of uses. Land in most parts of the world has been highly subjected to greater degrees and forms of degradation. The problem of land degradation is one of the most significant environmental problems faced by the world in the past few decades.

The highly competing demand for land resources in terms of the increased demand for expansion of urban areas, intensified agricultural activities and intensive industrial development caused by the ever increasing population are the root causes of land degradation worldwide. Large scale drastic changes in the land use and land cover pattern are degrading the valuable land resources.

The major issues related to land degradation are soil erosion, water logging, desertification and salinization. Land degradation has a direct impact on the productivity of soil. There is decrease in productivity of land over time due to various natural and man-made factors. The significant causes of land degradation include deforestation, improper crop rotation practices, imbalanced or excessive usage of chemical fertilizers, excessive surface irrigation, and improper soil conservation practices.

Injudicious use and improper maintenance of canal irrigation also significantly contributes to the problem of soil degradation. In semi-arid areas extension of canal irrigation has resulted in the problem of water logging and salinization. Therefore, efficient management of land resources has become the prime necessity in most of the countries all over the world.

1.2 Over Irrigation and Salinization:

Soil salinization has become a very serious and widespread environmental problem, all over the world, especially in arid and semi-arid regions. Soil salinity can occur either naturally or it can be induced by human activities.

Soil salinity is a condition in which the concentration of salts in the soil becomes significantly high. Soil salinity results from the excess accumulation of soluble salts in soil, typically maximum pronounced at the soil surface. Soils with high to very high proportions of salts are called saline soils.

Saline soils occur in desert as well as humid regions. The most extensive occurrences of saline soils are in arid and semi-arid regions, where they most usually are found in low-lying areas. Through capillary action, salts are transported to the soil surface from a salt-laden water table and then due to evaporation they get accumulated. The low-lying or plain areas have the highest value for agriculture as these areas are cultivated and irrigated most suitably. The problems associated with soil salinity in these low-lying regions of river basins with highly specialized agriculture have assumed the greatest significance.

Irrigated agriculture is the most widely practiced anthropogenic activity, which has been highly responsible for soil salinization in semi-arid and arid regions. Development of saline soils is basically due to over irrigation, mono-cropping pattern of water intensive cash crops such as sugarcane and excessive usage of chemical fertilizers.

The condition of soil salinity is caused by the presence of dissolved salt content in excessive amounts. The concentrations of ions in different combinations such as calcium (Ca^{++}), sodium (Na^{+}), magnesium (Mg^{++}), chloride (Cl^{-}), sulphate (SO_4^{--}) and even bicarbonate (HCO_3^{-}) ions is higher in saline soils.

Presence of salts on the surface of the soil and in the root zone of crops is characteristic of soil salinity. It is the most ubiquitous and widespread problem responsible for infertility and unproductiveness of agriculture. It limits crop production in irrigated agriculture. Increase in the degree of soil salinity results in degradation of soils and vegetation.

Soil salinization is a very complex and dynamic process which has extremely serious consequences for the soil environment as well as economic impacts. High to very high levels of salinity negatively affect crop growth and agricultural productivity, and which ultimately leads to land degradation. Saline soils in agricultural areas are responsible for reducing the annual yields of crops.

1.3 Significance of the study:

The problem of land degradation has become a serious issue for Indian agriculture on which almost two-third of the country's population depends for their livelihood. According to the estimates of Ministry of Agriculture and Farmer's Welfare, Government of India, almost around 120.4 million hectares (37%) of India's total geographical area i.e. 328.73 million hectares is affected by various kinds of land degradation including soil acidity (15%), soil alkalinity / sodicity (3%), soil salinity (1.8%), water logging (1%), soil erosion by water and wind (79%) and mining industrial waste (0.2%). Land degradation in India has resulted in annual soil loss of about 5.3 billion tonnes through erosion.

As estimated by the Indian Council of Agricultural Research (ICAR) land under cultivation is substantially degraded. As estimated by the Directorate of Economics and Statistics, Ministry of Agriculture, Government of India based on the Land Use Statistics data (2010-11), the total arable land in India is 182 million hectares and out of this about 104 million hectares of land (around 57%) is subjected to land degradation and suffers from some form of degradation, according to the Indian Council of Agricultural Research (ICAR).

The problem of land degradation has taken a larger dimension and greater significance in India and particularly in states such as Maharashtra because of the large scale irrigation and increasing area under sugarcane cultivation. Maharashtra is one of the leading states in irrigated agriculture and area under sugarcane cultivation. There are many small to big sized dams, canals, wells, tube wells which have been constructed for water supply for domestic use and for irrigation of agricultural land.

In India, about 25% of land area is under canal irrigation out of the net irrigated area of the country. In India and more particularly in Maharashtra, a significant proportion of all canal command area is water logged (perennial and seasonal) and saline rendering land not available for cultivation. The excessive use of water for irrigation and large scale sugarcane cultivation, without applying the soil and water management measures has created the severe problem of water logging and soil salinization. Water stagnation problem in sugarcane tracts over Western Maharashtra region have become so acute that many hectares of land have been degraded and turned saline. It is anticipated that if remedial measures are not taken, the saline land will grow every year. In canal-irrigated sugar cane tracts, excessive use of water and chemical fertilizers has degraded the soil. Fertility of sugarcane cultivating areas of Maharashtra has been greatly affected by over irrigation.

The soil condition in irrigated areas of Maharashtra is brittle and especially the soils of canal command area are prone to degradation due to salinity and sodicity owing to imprudent management of canal irrigation water. Cultivation of sugarcane can add to soil degradation impacting the soil quantity by increased rates of erosion and soil removal at the time of harvest as well as the soil quality. Although sugarcane is a competent converter of biomass from water, it still needs about 1500-2000 mm per ha per year and ranks among a group of crops noted for their significant water consumption (along with rice and cotton). Moreover, it is a deep-rooted crop, which remains in the soil all-year round and is able to extract soil water from depths well below one metre.

Sugarcane cultivation is on the rise in Western Maharashtra including Daund because it does not require any special efforts of crop management. There is no concern of unseasonal rains which affect the growth of this crop. Farmers have been earning significant profits without investing much for this crop in comparison with other cash crops. Farmers apply the flood system to provide water to the crop in which there is a continuous and uninterrupted flow of water in the fields. Every sugar factory in Daund tahsil has assured that farmers in its area get enough water for cultivation through irrigation. But, there is no control on the over use of water in the study area. As the saline lands have been multiplying every year, around 10 per cent of the total land area under the cultivation will be impacted. The fine textured clayey black soils in the Daund tahsil have been continuously irrigated for a number of decades with the same monoculture cropping pattern of sugarcane crop. This has resulted in the spread of area under saline soils in the study region. The increasing soil salinity has been affecting the crop production in the study region. The increase in soil salinity reduces the yield of sugarcane on the same land in successive years (Jayan, 2003). Thus, the major challenge is to prevent or reduce further soil salinization so as to sustain agricultural land in Daund tahsil.

For systematic management of areas facing the problem of soil salinity, the first requirement is to demarcate the extent of saline soils. As soil salinization is a severe environmental issue and it affects crop productivity, the timely identification of saline lands and assessment of its coverage and severity has become very important at local level. Therefore, it is important to monitor and map soil salinity at an early stage so that effective programmes for soil recovery can be undertaken which will reduce the increase in soil salinity in future.

Salt affected soil areas are increasing annually at significantly higher rates all over the earth due to high evaporation, low precipitation, irrigation with saline water etc. Some key factors which play highly significant role in increasing salinity are water table depth, soil permeability, topography, salinity of perched groundwater, soil parent material, and geo-hydrology of the area.

About 50% of the arable land in the world would convert to saline land by the year 2050 (Jamil et al., 2011). The black soils having shrink-swelling property occupy an area of 66 mha in India and 35% of such soils are found in Maharashtra (Kolhe, et al. 2011).

With the availability of sufficient amount of water in the reservoir, irrigation associated salinity is also increasing in amount and intensity over the years (Ghassemi, et al., 1995). The isolated clay particles occupy the annular pores in soil mass and develop clogging of fine textured black soils leading to reduction of infiltration rate and hydraulic permeability.

Improper management of water and land resources has resulted in the emergence of salinity in Pravara river and Nira Irrigation Projects in western Maharashtra (Singh and Chatrath, 2001). The unfavorable physiography and rainfall, presence of black soil (vertisols), absence of natural drainage, lack of proper water infrastructure and irrigation facilities results in the higher extent of salt affected soils in the Deccan Plateau (Challa et al. 1995) where sugarcane is grown extensively for the past two to three decades (Balpande et al. 1996). Since 1960, several reservoirs were constructed within the proximity of the mountain range that encouraged aggressive cultivation in their command areas. Due to cultivation of sugarcane (70% of irrigated area in Kolhapur, Pune and Sangli districts of Maharashtra) year after year continuously and excessive application of water to crops, the land has become sodden and saline over the years. Daund taluka followed by Baramati taluka have the major areas under saline / alkali soils (more than 14,000 hectares each) in Pune district. Figure 1.1 shows the salt affected soil areas in India and irrigation related soil salinity in Maharashtra state.

There is a need to identify the vulnerable areas for soil salinization and correct the irrigation practices, before it becomes unmanageable. The updated and accurate spatial information on salinity parameters across the area of interest is essential for soil management practices (Pozdnyakova and Zhang 1999).

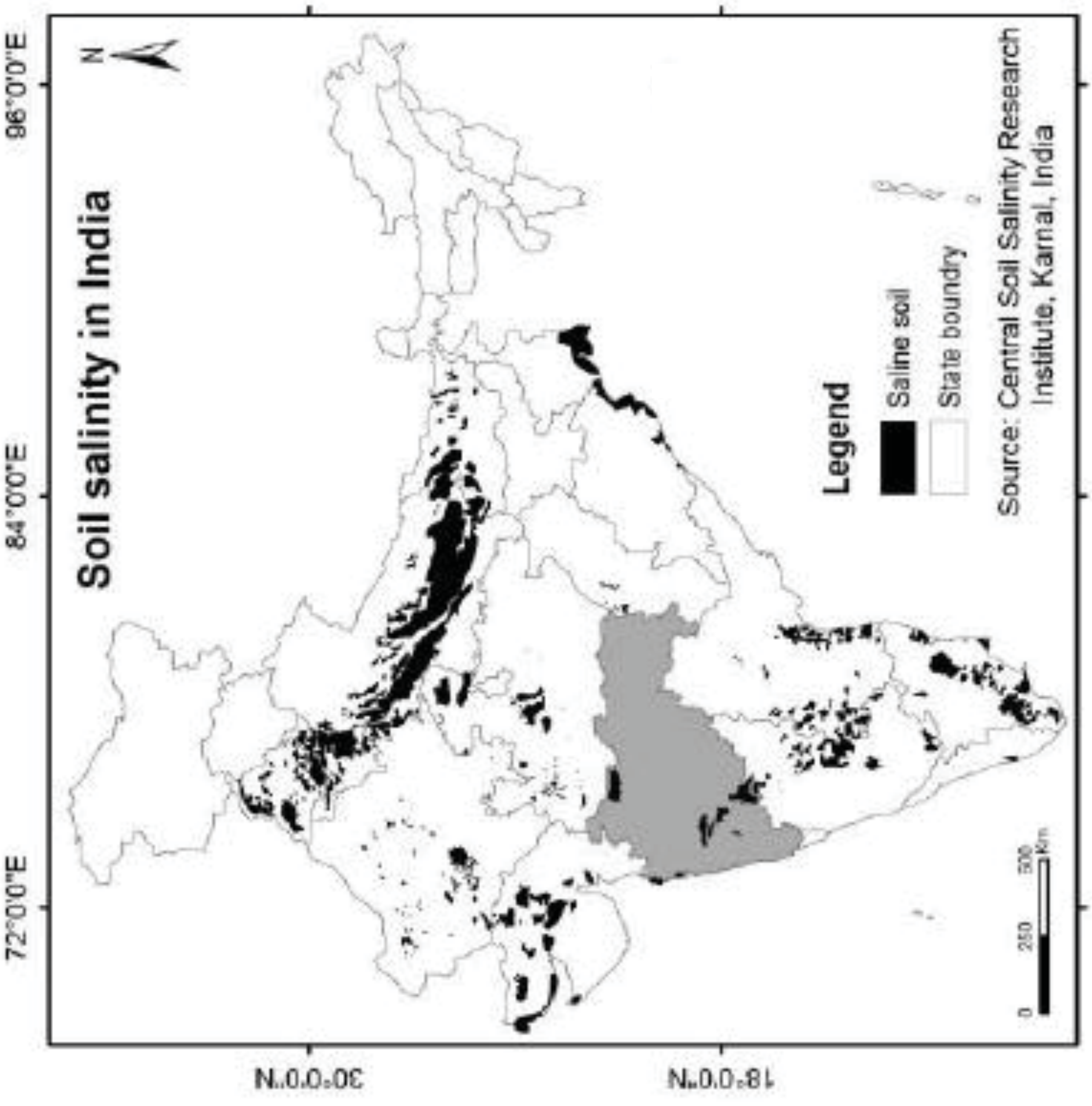

Soil salinity in India
N
Legend
Saline soil
State boundry
Source: Central Soil Salinity Research Institute, Karnal, India
72°0'0"E
84°0'0"E
96°0'0"E
30°0'0"N
18°0'0"N
0
250
500
Km

Fig: 1.1

1.4 Application of Remote Sensing in Soil Salinity Studies:

Soil salinity has been traditionally assessed using the conventional technique of collecting *in situ* Adopting such a kind of method, especially over a large area such as Daund tahsil is not cost effective as well as it is time consuming.

Remote sensing has provided an excellent alternative method for mapping and monitoring the status of soil salinity very efficiently. Remote sensing data has enormous potential in order to acquire latest information about the extent, degree of severity and, spatial distribution of saline lands. Multispectral satellite image analysis has become a scientifically accepted method for identifying, mapping and monitoring the dynamic process of soil salinization, which is basically due to the low cost of satellite imageries and also their capability to map the expressions of extreme surface soil salinity.

There are some limitations of multispectral satellite data which are mainly the limitations related to their spatial and spectral resolution. High resolution satellite images are costly and limited availability. Hyperspectral satellite imageries, with their high spatial resolution and fine spectral resolutions due to numerous spectral bands, can be used for soil salinity mapping in greater detail.

There are many satellites and sensors, which are capable of detecting and monitoring the saline soil. Multispectral data such as SPOT (Satellite Pour l' Observation de la Terre), LANDSAT, IKONOS, Quick Bird and the IRS (Indian Remote Sensing) series of satellites and Terra-ASTER with the resolution that ranges from medium to high, as well as hyper spectral data such as EO-1 Hyperion and HyMap, have been found to be useful in mapping, monitoring, and detecting soil salinity.

A very valuable application of remote sensing in agricultural studies is the study of soil salinity indices. Various remote sensing data based indices such as the soil adjusted vegetation index (SAVI),the normalized difference salinity index (NDSI), the brightness index (BI) and soil salinity indices can be implemented for soil salinity mapping in the semi-arid regions.

Salinization being a complex process, identification of salt affected regions and sub-classification into slightly low and moderately affected areas is challenging and tough job (Bouaziz et al. 2011).

1.5 Review of Literature:

Many scholars have worked on over irrigation and its effects on soil productivity. Agarwal (1982) reported factors which are responsible for the formation of salt affected soils. Salinization is more associated with impacts induced by irrigation such as alkalization and water logging. Deshmukh (2001) has reported impact of irrigation on the soils in sugarcane cultivation areas.

Many researchers such as Agarwal & Gupta (1968), Gupta & Gupta (1997), Mehta et al (2000), have worked on the issues regarding the salinity, water logging, irrigation etc. Irrigation of agriculture has tremendous effects on the environment. In general, the effects at first appear favorable. However, after passage of time the salinization of the soil is usual problem created in nearly all arid and semi-arid lands that are under irrigation. Thus, research work has been done on such salt affected soils.

Recent literature has several research papers on the issue of over irrigation and soil salinization. The paper “Irrigation and the Great Indian Rural Database”, (Christophe Z.Guilmoto, 2002-Vignettes from South India) seeks to demonstrate that irrigation data from the Indian census has been severely underutilized in this regard and also offers a view on the issues that can be researched using village level statistics.

The Australian Dry land Salinity Assessment 2000 report, part of the National Land and Water Resources Audit (NLWRA), provides a good summary of the key issues set out in the context of natural resource management.

J.M. de Paz, F. Visconti, J. Sanchez have studied Methodology to elaborate a map of soil salinization risk in the Valencian community in Spain.

Vijay Kumar (1978) has done comprehensive work in the direction of soil salinization while studying the impact of the Bhakra system on the erstwhile dry lands of Haryana. The negative consequences of canal irrigation can however be checked through scientific measures.

A full discussion of the impacts and extent of dry land salinity is contained in the *Land Theme Report*. A recent study concluded that 5.7 million hectares of land are currently affected by or at risk from dry land salinity due to shallow groundwater tables (NLWRA, 2001).

PAL le Roux, CC du Preez, MG Strydom, LD van Rensburg and ATP Bennie (Department of Soil, Crop and Climate Sciences, University of the Free State, South Africa) have studied the effect of irrigation on soil salinity profiles along the Lower Vaal River, South Africa.

Sharma and Mandal (1998) described in their paper "Characterization of some salt affected soil of Indira Gandhi Nahar Pariyojana (IGNP) Command area." that significant amount of calcium carbonate ($CaCO_3$) was present at places below the depth of 0.5 to 2.0 meters and that different degrees of salinity was due to concentration of soluble chlorides of sodium, calcium and magnesium. Sodium was the dominant cation followed by Calcium and Magnesium.

In a similar study, Sharma and Mathure (1991) have reported a considerable degradation of irrigated soils due to fluctuation of water table in IGNP (Indira Gandhi Nahar Pariyojana) command area. The present condition of the command area is thus very critical and needs immediate control measures. For this an estimate of nature and extent of area affected becomes the pre- requisite.

Metternicht (2001) described an expert system to map landscape features related to salinity. Metternicht and Zink (1998) reported that multi-temporal optical and microwave remote sensing can significantly contribute to detecting temporal changes of salt-related surface features.

C. T. Pawar and A. A. Pujari (2000) have analyzed soil degradation in sugarcane farming at micro level.

Pharande, Durgude and Kadlag in their research paper ‘Severity of soil salinity and sodicity problems in Maharashtra and their reclamation’ have stated that nearly over 6 lakh hectares (6,06,759 ha) of land in Pune, Sangli, Ahmednagar, Solapur and Nashik districts has been highly salt affected. It is estimated that if remedial measures are not taken, the saline land will grow by 10 per cent every year.

Mabeye Sylla (1994) has studied the spatial variability of soil salinity and acidity and their effects on rice production in West Africa's mangrove zone.

Mahmoud A. Abdelfattah, Shabbir A. Shahid, Yasser R. Othman (2009) have mapped Soil Salinity areas and developed Model using Remote Sensing and GIS for a region from Abu Dhabi, United Arab Emirates. Mehmet Ali Çullu (2003) has estimated the effect of Soil Salinity on Crop Yield Using Remote Sensing and Geographic Information System.

R. C. Sharma and G. P. Bhargava (1988) have used Landsat satellite imagery for mapping saline soils and wet lands in north-west India. S. Natrajan, K. Govindan, P. K. Kirshan & C. Kalaiselvi (1997) have published a paper on Remote Sensing for land degradation studies in lower Gundar Basin, Tamil Nadu. – Remote Sensing for Natural Resources.

Saptarshi, P. G. and Bhagat, Vijay (2004) have worked on “GIS Application for Agricultural Regionalization Based on Water Resources and Agronomy”.

The tradition of using remote sensing data and GIS techniques has been demonstrated in several scholarly research works. Remote sensing data and techniques have been progressively applied to monitor and map soil salinity since 1960s when black-and-white and color aerial photographs are used to delineate salt-affected soils.

M. A. Mulders and G. F. Epema have used the LANDSAT TM (Thematic Mapper) data for soil mapping in arid areas. S. K. Saha, M. Kudrat, and S. K. Bhan have performed digital processing of Landsat TM data for wasteland mapping in parts of Aligarh District (Uttar Pradesh).

B. R. Rao, R. S. Dwivedi, L. Venkataratnam et al., have mapped the magnitude of sodicity in part of Indo-Gangetic plains of Uttar Pradesh, Northern India using Landsat-TM data. A. A. Darvishsefat, M. H. Damavandi, M. Jafari, and G. R. Zehtabiyan have assessed Landsat TM images for their use in soil salinity classification.

T. Zhang, G. Zhao, C. Chang et al., have developed an information extraction method of soil salinity in typical areas of the yellow river delta based on Landsat imagery. R. S. Dwivedi and K. Sreenivas, have delineated salt-affected soils and waterlogged areas in the Indo-Gangetic plains using IRS-1C LISS-III data.

The comprehensive use of satellite remote sensing and GIS has been recognized to be a cost-effective method for monitoring soils salinization in poorly drained basins.

R. Goossens, M. De Dapper, A. Gad, and Th. Ghabour, have formulated a model for monitoring and prediction of soil salinity and waterlogging in the Ismailia area (Egypt) based on remote sensing and GIS. S. Casas (1995) has worked on salinity assessment based on combined use of remote sensing and GIS.

1.6 Aims and objectives of the study:

The present study has been undertaken with an objective to examine the degradation of agricultural land due to over irrigation in Daund tahsil of Pune district.

The main sub-objectives of this study are as follows:

(1) To identify short term significant changes in the land use and land cover pattern in the study region and analyse the causes for the changing patterns.

(2) To prepare thematic maps of soil properties applying GIS techniques.

(3) To assess the soil productivity with the help of Storie index of soil productivity.

(4) To calculate various salinity and vegetation indices for the study region by using latest LANDSAT satellite image of the study area and prepare thematic maps showing the distribution of saline areas on the basis of estimated soil salinity indices.

(5) To classify the salt affected regions into slightly low, moderately and highly saline lands.

(6) To quantitatively and effectively assess the degradation of agricultural land in Daund tahsil with the help of thematic maps showing the distribution of saline areas based on estimated soil salinity indices.

x-x-x

CHAPTER II

STUDY AREA, DATABASE AND METHODOLOGY

2.1 Introduction:

Daund tahsil was developed extensively during the British rule. The Mumbai-Solapur railway line passed through Daund. When railways started in 1870, the Daund-Baramati meter gauge track was constructed. Daund became a major railway junction after the establishment of the Daund-Manmad railway link. Hence, Daund became an important place on India's map.

Daund and Shrigonda were connected after a bridge was constructed over river Bhima in 1928. During the period of British rule, Daund was an important center for coal engines. The activity of brick making started in Daund due to abundance of coal ash and then it flourished to other cities. Numerous job opportunities were generated due to the development of Daund as a major railway junction.

Daund tahsil is situated in the eastern region of Pune district of Maharashtra state in India. Daund tahsil has been divided into six parts for the convenience of administration. These six divisions are Daund, Rahu, Yawat, Kedgaon, Kurkumbh and Ravangaon.

The study area is a part of the Deccan Basalt Province (DBP). The maximum part of Daund tahsil has plain physiography. The region under study has tropical type of climate highly influenced by the southwest monsoon rainfall. The climate of Daund tahsil is semi-arid type of climate. The Bhima river and its tributaries, namely, Mula-Mutha are the major rivers in the study region.

Agriculture is a dominant activity practiced in the study region. Crops such as sugarcane and wheat are grown on deep black soil along the low lying areas of Bhima and Mula-Mutha rivers in the study region. The principal cash crop in the study region is sugarcane. A significant area of Daund taluka is irrigated land which is mainly used for sugarcane cultivation. There are many sugar-based industries in the study region.

The density of population has tremendously increased from 1951 to 2011 in Daund Tahsil. The transport network is well developed in the study region in terms of road and rail network.

2.2 Geographical Profile of Daund Tahsil:

2.2.1 Location:

The study region selected for the present study is situated on the eastern side of Pune. There are 14 talukas in Pune district, namely Pune city, Haveli, Mulshi, Maval, Bhor, Junnar, Velhe, Khed, Ambegaon, Shirur, Indapur, Baramati, Purandar and Daund. Daund tahsil is one of the main tahsils in Pune. Daund tahsil is situated in the eastern region of Pune district of Maharashtra state in India.

Daund taluka is surrounded by Purandhar taluka (Pune district) in the southwest, Baramati and Indapur talukas (Pune district) in the south, Karmala (Solapur district) and Karjat (Ahmednagar district) talukas to the east, Shrigonda (Ahmednagar district) and Shirur (Pune district) talukas to the north and Haveli taluka (Pune district) to the west.

Daund tahsil is situated on the southern bank of Bhima river which is the biggest river in Pune District. The study region is drained by river Bhima in the northern and eastern parts.

The Bhima river and its important tributary Mula-Mutha river form a major river system in the study region. The confluence of rivers Mula-Mutha and Bhima is at Sangameshwar Mandir near Pargaon in Daund tahsil.

The urban town of Daund is the headquarters of Daund tahsil and it is the main market place and one of the two major urban areas in this predominantly rural tahsil. Daund railway station is a major railway junction of the South Central Zone of Indian railways.

Daund tahsil has a total geographical area of around 1360 square kilometers. The east-west extent of Daund tahsil is about 74 kilometers and the north-south extent of Daund tahsil is around 40 kilometers. Daund taluka has an elongated shape running from northwest to southeast direction.

Daund taluka extends from 18° 17’ to 18° 40’ North latitudes and 74° 08’ to 74° 50’ East longitudes.

(Fig. 2.1 and 2.2)

Daund tahsil - Location Map

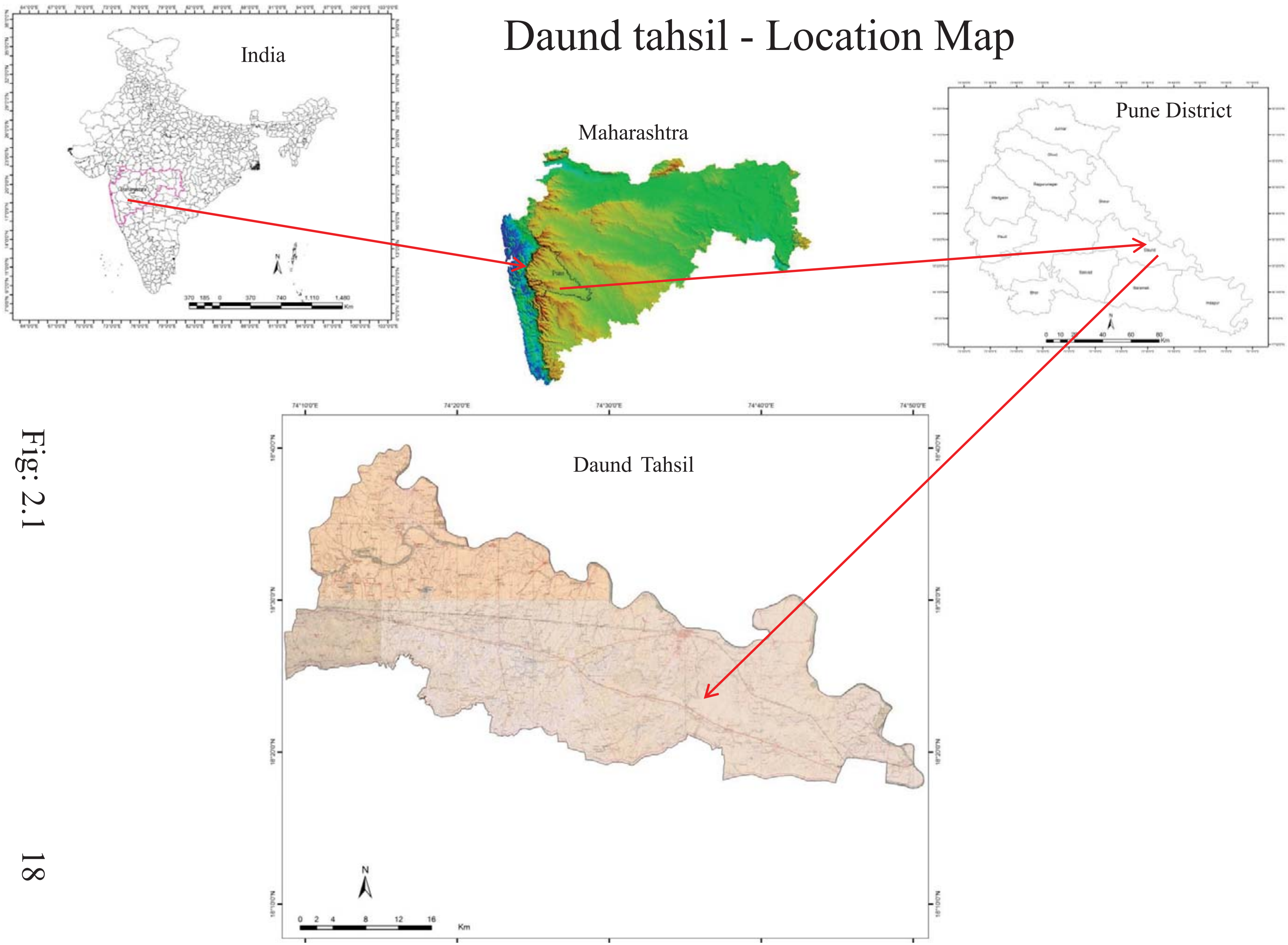


Fig: 2.1

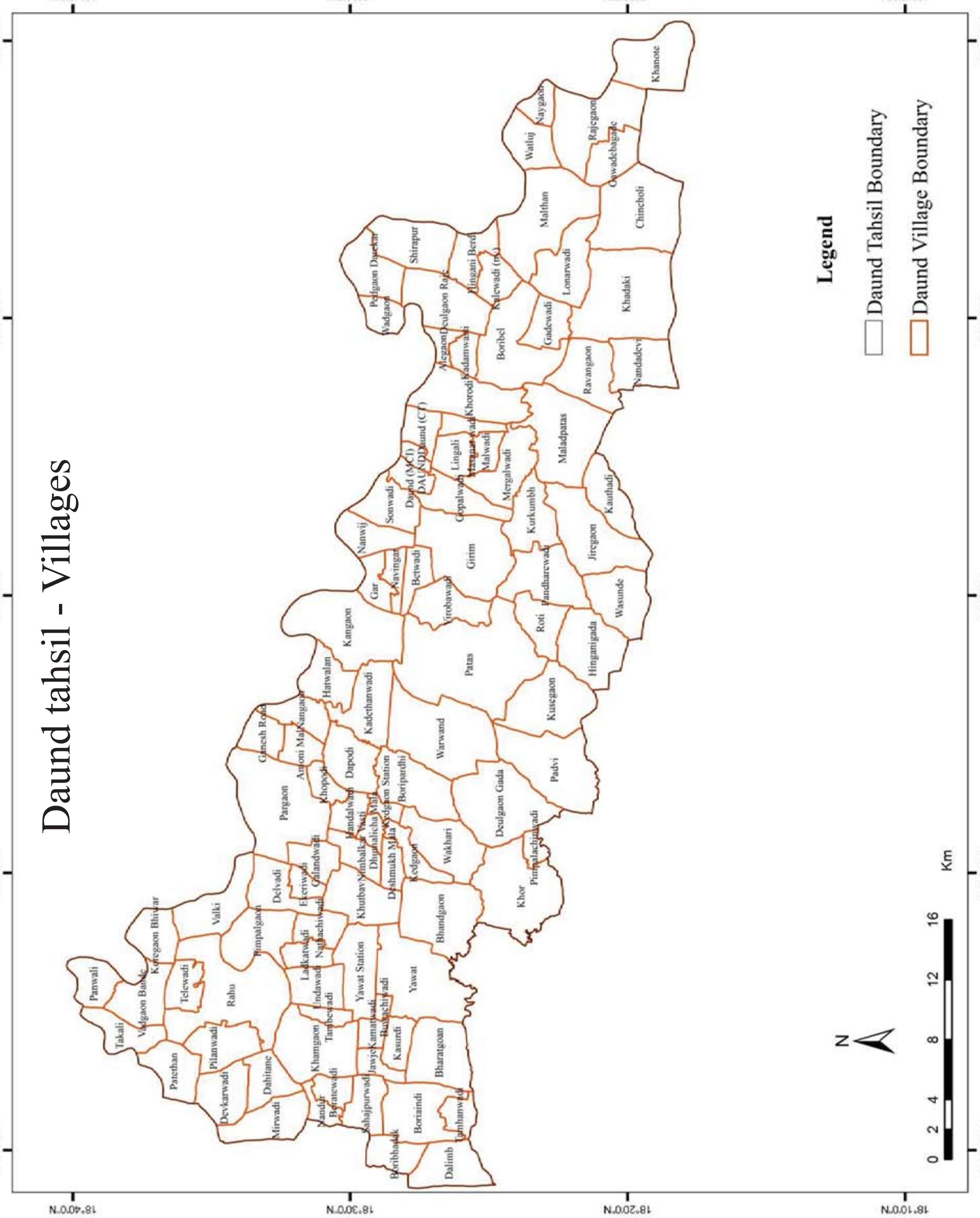

Daund tahsil - Villages
Legend
Daund Tahsil Boundary
Daund Village Boundary
N
Km
0 2 4 8 12 16
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°10'0"N
18°20'0"N
18°30'0"N
18°40'0"N
Panwali
Takali
Koregaon Bhivar
Valki
Telewadi
Rahu
Patethan
Pilanwadi
Devkarwadi
Dahitane
Mirwadi
Pimpalgaon
Delvadi
Pargaon
Ganesh Road
Khamgaon
Yawat Station
Yawat
Kasurdi
Bharatgoan
Boriaindi
Dalimb
Bhandgaon
Khor
Wakhari
Deulgaon Gada
Padvi
Warwand
Kusegaon
Patas
Kangaon
Hatwalan
Kadethanwadi
Dapodi
Boripardhi
Roti
Hinganigada
Wasunde
Jiregaon
Kauthadi
Kurkumbh
Girim
Betwadi
Nanwij
Sonwadi
Lingali
Gopalwadi
Mergalwadi
Maladpatas
Ravangaon
Nandadevi
Khadaki
Boribel
Lonarwadi
Gadewadi
Malthan
Chincholi
Watluj
Naygaon
Rajegaon
Khanote
Shirapur
Pedgaon
Malwadi

Fig: 2.2

2.2.2 Geology:

Daund tahsil which lies on the Deccan plateau region of Maharashtra is geologically covered with igneous basalt rock. The Deccan Basalt Province (DBP) or the Deccan Trap composed of basaltic lava flows was formed due to numerous eruptions during the early Eocene to late Cretaceous period.

In the Deccan Basalt Province, there are two types of basaltic lava flows viz. compound “pahoehoe” and “aa” flows. The term compound “pahoehoe” flows indicates smooth unbroken lava while the term “aa” flows indicates stony rough lava. In the study region, both types of basaltic lava flows i.e. compound “pahoehoe” as well as “aa” flows are found.

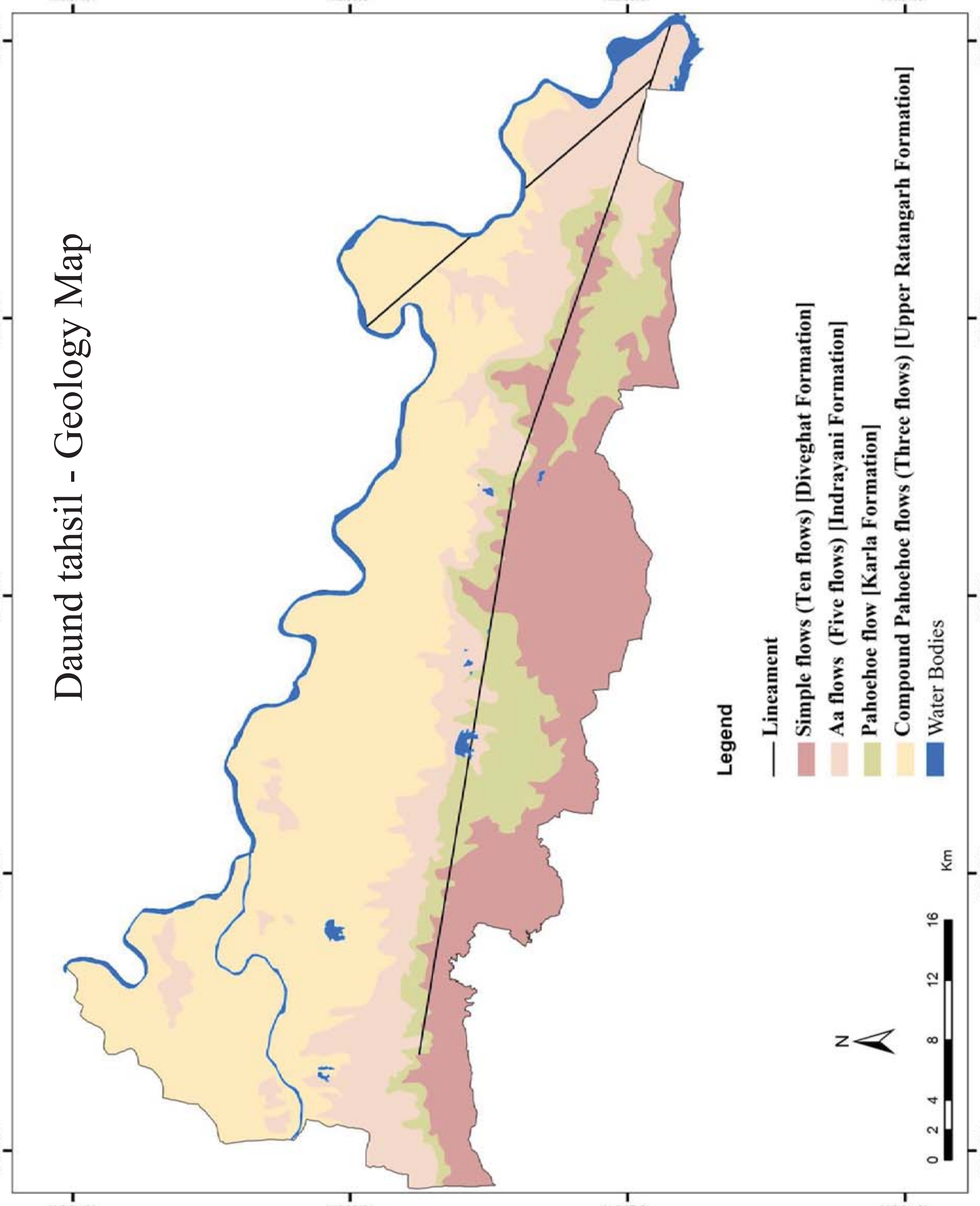
There is one major lineament and some minor lineaments running perpendicular to the major one in the study region. There are two significant lineaments in the study region, one running from west to east for a distance of about 40 kilometers and another running in northwest to southeast direction in the eastern region of Daund tahsil. These lineaments are the major controls of the drainage system.

The northern part of the study region in the surroundings of Bhima river is highly undissected and the degree of dissection increases towards the southern part of the study region. The central part of the study region is characterized by upland plateau.

In Pune district, seven lava formations are found which are named as Lower and Upper Ratangarh formations, Karla formation, Indrayani formation, Diveghat formation, Purandargarh formation and Mahabaleshwar formation. Out of these seven lava formations in Pune district, Daund taluka is covered with Upper Ratangarh Formation, Indrayani Formation, Karla Formation and Diveghat Formation. Daund tahsil has ten simple flows of Diveghat formation, five “aa” flows of Indrayani formation and three compound “pahoehoe” flows of Upper Ratangarh formation (Source: Geological Survey of India’s Geological Quadrangle Map 47 J).

The upper Ratangarh formation of only compound "pahoehoe" flows is the oldest basalt lava flows which are mostly restricted towards the northern region of the study area along the plains of Bhima river. Overlying the upper Ratangarh formation is the Indrayani formation consisting of five thick "aa" flows which covers the entire stretch of the study area from west, central and eastern parts. The Indrayani formation is succeeded by "pahoehoe" flows of Karla formation. Similar to the Indrayani formation, "pahoehoe" flows of Karla formation cover the west, central and eastern part of the study area, but in narrow stretches. Overlying the Karla formation, there is a sequence of ten simple lava flows forming the Diveghat Formation which covers south western and southern regions of the study area.

(Fig. 2.3)



Source : Geological Survey of India

Fig:2.3

2.2.3 Physiography:

Daund tahsil is a part of the Deccan Basalt Province (DBP). The study region is situated on the Upper Maharashtra Plateau physiographic unit. Daund tahsil lies in the Upper Bhima basin region.

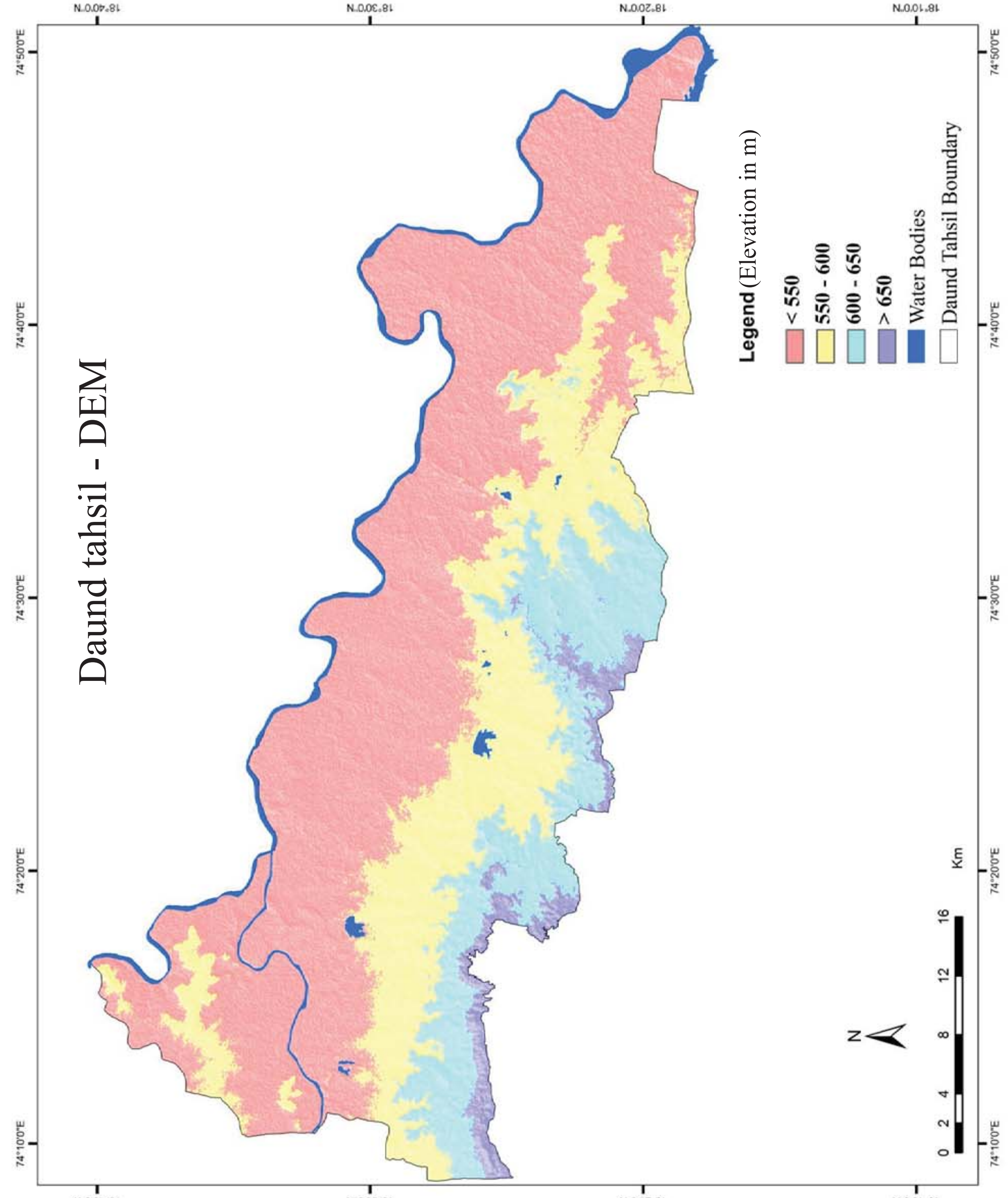
The maximum area in the study region has plain physiography. Bhima river and its tributaries Mula-Mutha are the major rivers in the study region. The northern part of Daund tahsil which is along the Bhima river has low relief as compared to the southern part of the tahsil. The entire area is nearly flat with fewer variations.

The southern boundary of Daund tahsil is demarcated by a small hill range running in east-west direction. There are numerous isolated residual hills in the study region.

A considerable area of Daund tahsil is covered by moderately shallow to deep soils which are well drained and clayey in texture on gently sloping lands with few mesas and buttes.

The average elevation of the study region is about 555 meters above the mean sea level. The elevation in Daund tahsil varies from as low as 489 meters to as high as 890 meters. There are few peaks in the southwestern region of the study area viz. peak on which Dhavaleshwar temple is situated, Manjar Tok, Sulki Tok etc. The highest elevation is 890 meters (trigonometric station) at Dhavaleshwar temple in Dalimb village, which is situated in the southwestern region of the study area. While the minimum elevation is 489 meters (spot elevation) on the right bank of Bhima river near Rajegaon village, which is situated in the eastern region of the study area. The elevation is less than 550 meters in the maximum area of the study region i.e. in the northern region and the southeastern region which is along the Bhima river. In the southern and southwestern regions of the study area, the elevation is greater than 600 meters.

(Fig. 2.4 and 2.5)



Daund tahsil - DEM
Legend (Elevation in m)
< 550
550 - 600
600 - 650
> 650
Water Bodies
Daund Tahsil Boundary
0 2 4 8 12 16
Km
N
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°40'0"N
18°30'0"N
18°20'0"N
18°10'0"N

Fig: 2.4

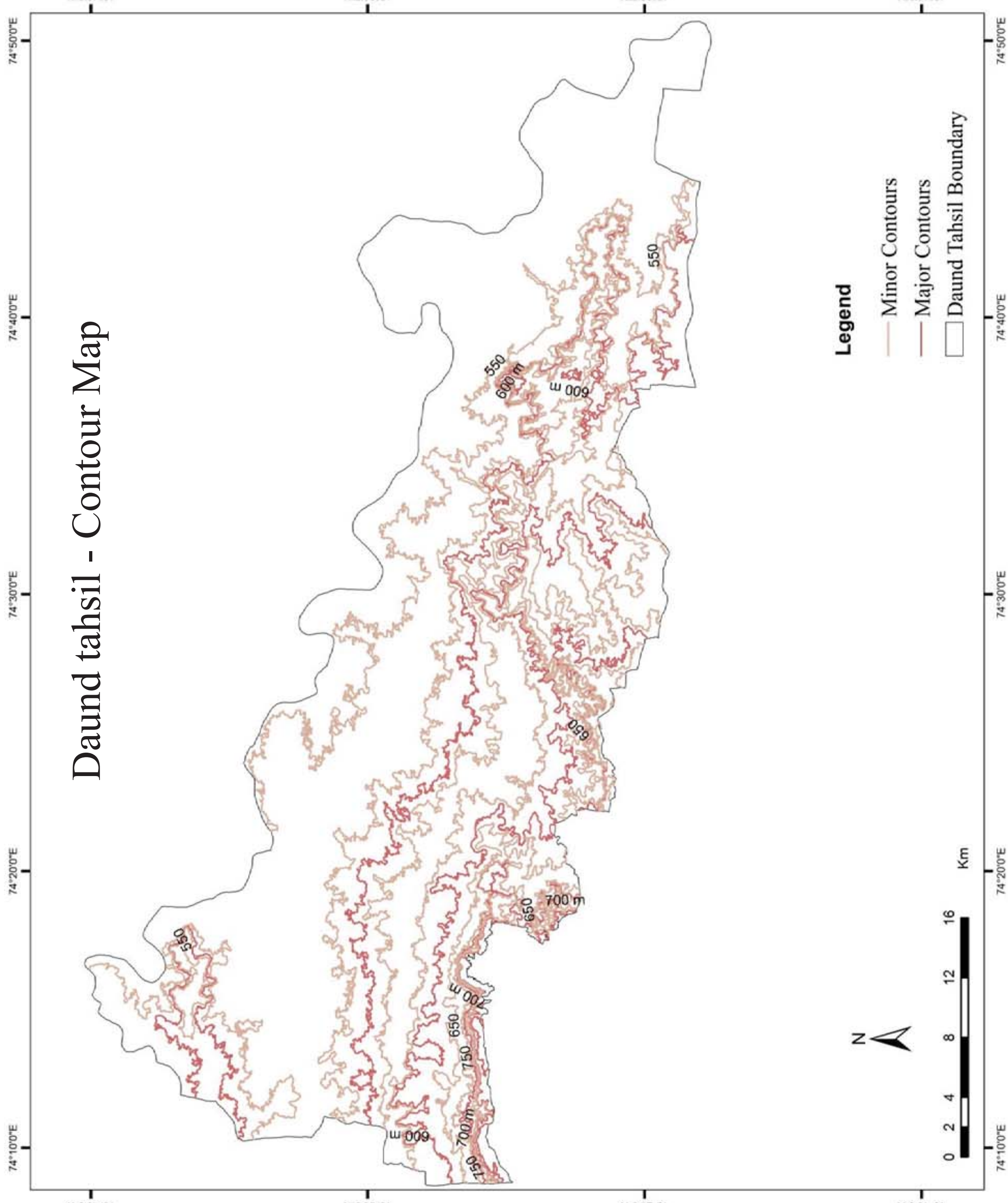

Daund tahsil - Contour Map
Legend
Minor Contours
Major Contours
Daund Tahsil Boundary
N
0 2 4 8 12 16
Km
18°40'0"N
18°30'0"N
18°20'0"N
18°10'0"N
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
550
600 m
650
700 m
750

Fig: 2.5

Aspect:

The values from the aspect map indicate the compass directions that slopes face. The slope in the southwestern region of the study area has a north to north westerly aspect i.e. north and northwest-facing slopes.

(Fig. 2.6)

Slope:

The general slope of Daund tahsil is from south to north along the right bank of Bhima river as the elevation decreases from south towards north. The southwestern region of the study area has steeper slope (more than 20 percent).

(Fig. 2.7)

Absolute Relief:

The term absolute relief refers to the maximum elevation within a unit area. The absolute relief map provides basic ideas about the pattern of distribution of relief over the study region. High values of absolute relief are noticed mainly in the mountainous region in the south western marginal area of Daund tahsil. While lower values of absolute relief are noticed in the plains along Bhima river. The absolute relief is higher i.e. more than 700 meters in the south western region and it is lower i.e. less than 600 meters in the northern, eastern and southeastern regions of the study area. The absolute relief is moderate i.e. between 600 to 700 meters in the southern and central regions of the study area.

(Fig. 2.8)

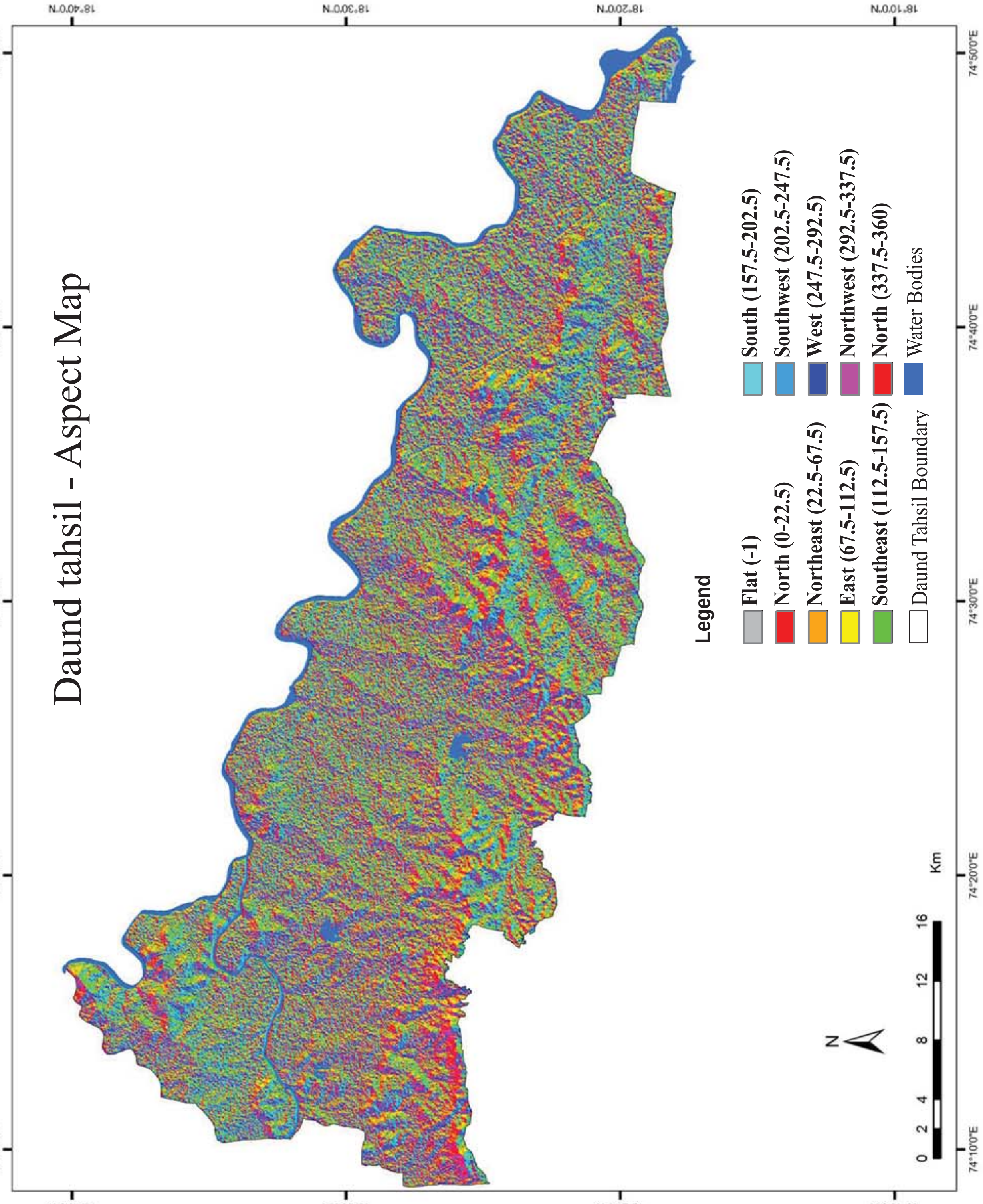

Daund tahsil - Aspect Map
Legend
Flat (-1)
North (0-22.5)
Northeast (22.5-67.5)
East (67.5-112.5)
Southeast (112.5-157.5)
Daund Tahsil Boundary
South (157.5-202.5)
Southwest (202.5-247.5)
West (247.5-292.5)
Northwest (292.5-337.5)
North (337.5-360)
Water Bodies
N
0 2 4 8 12 16
Km
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°10'0"N
18°20'0"N
18°30'0"N
18°40'0"N

Fig: 2.6

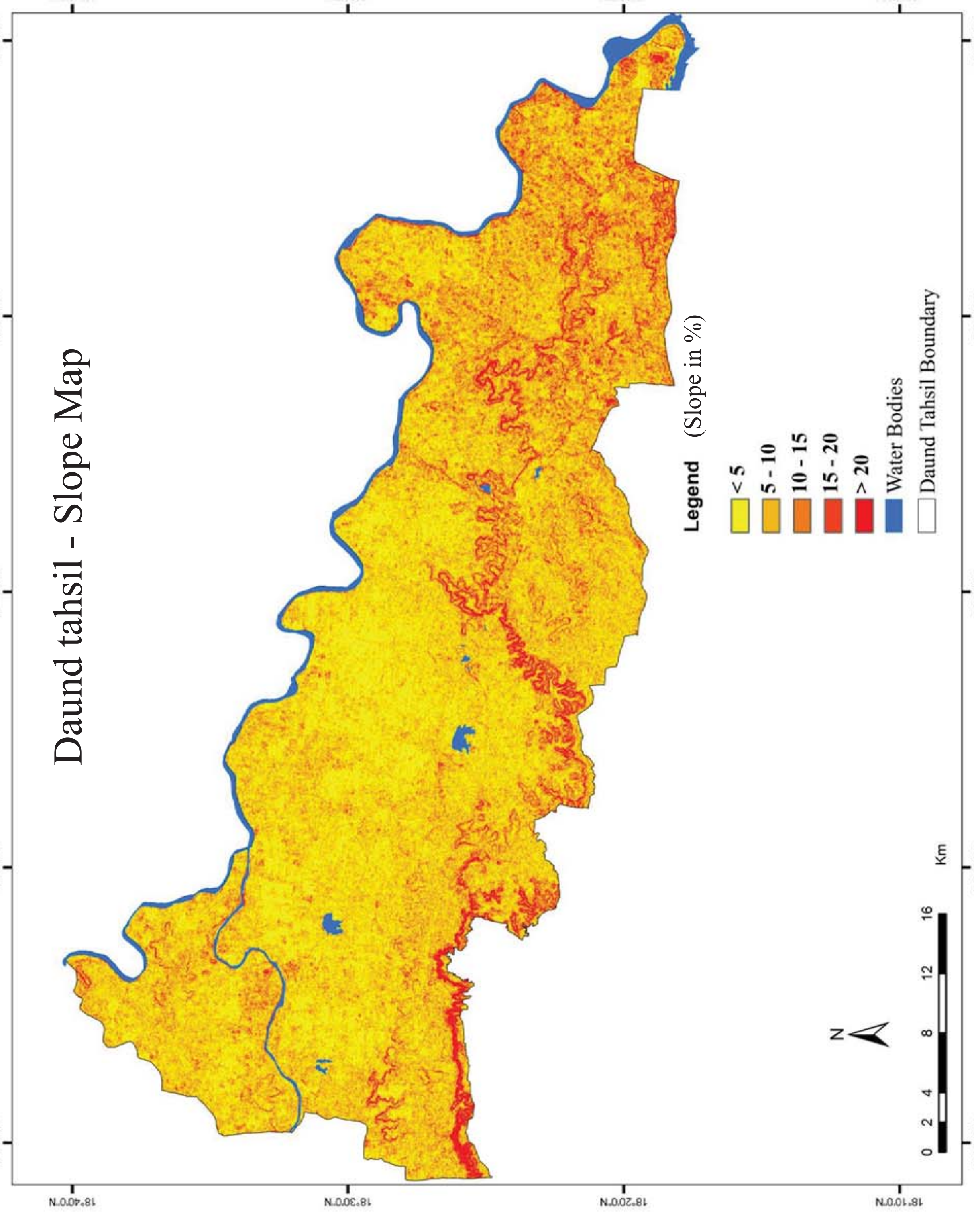

Daund tahsil - Slope Map
Legend
(Slope in %)
< 5
5 - 10
10 - 15
15 - 20
> 20
Water Bodies
Daund Tahsil Boundary
N
0
2
4
8
12
16
Km
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°40'0"N
18°30'0"N
18°20'0"N
18°10'0"N

Fig: 2.7

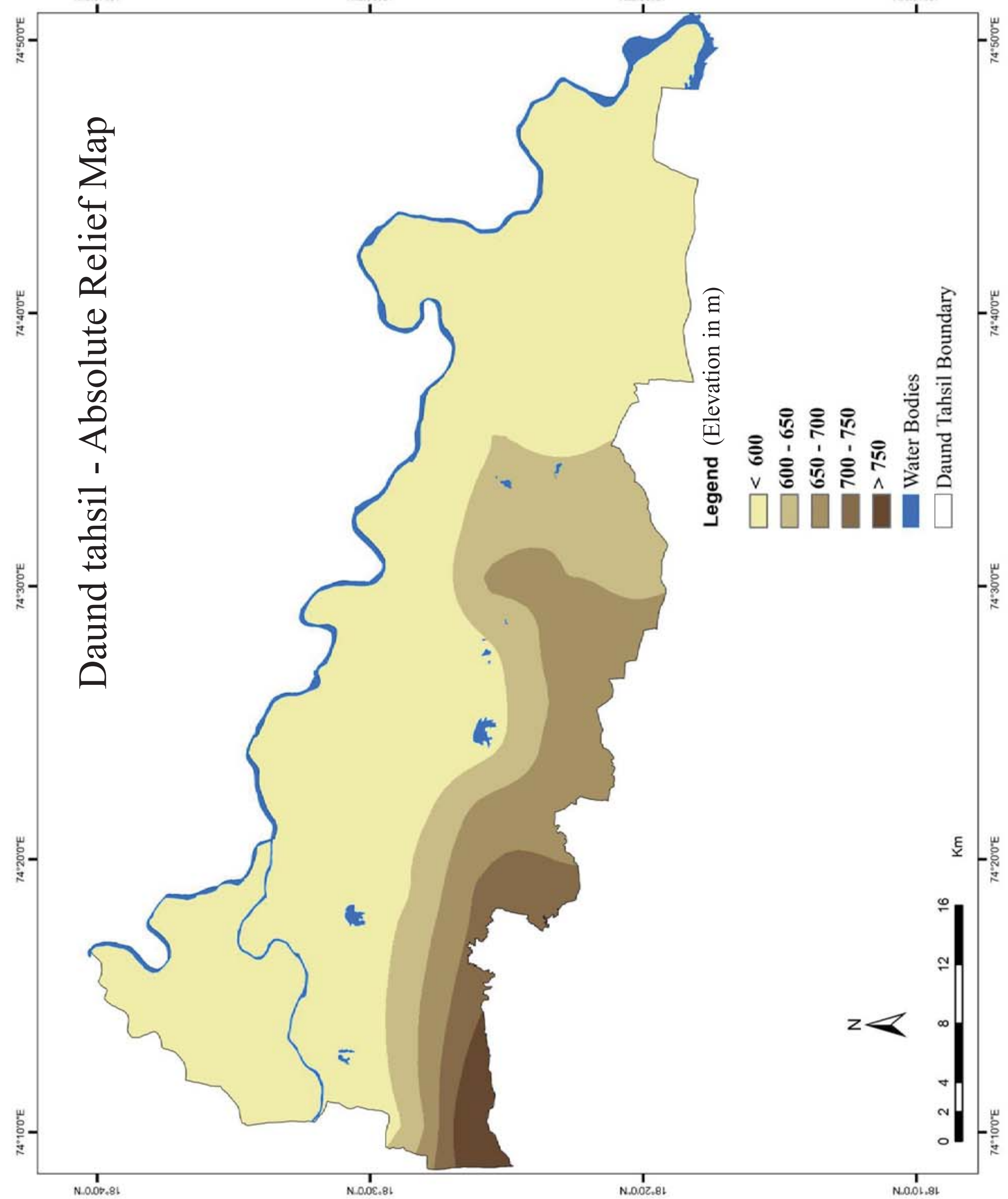

Daund tahsil - Absolute Relief Map
Legend (Elevation in m)
< 600
600 - 650
650 - 700
700 - 750
> 750
Water Bodies
Daund Tahsil Boundary
N
0 2 4 8 12 16
Km
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°10'0"N
18°20'0"N
18°30'0"N
18°40'0"N

Fig: 2.8

Relative Relief:

Relative relief gives an idea about the local relief. It is the difference between the highest and the lowest elevations in a unit area The relative relief is higher i.e. more than 100 meters in the south western region and one patch in the central region. It is lower i.e. less than 50 meters in the northern, southeastern and some patches of southern region of the study area. The relative relief is moderate i.e. between 50 to 100 meters in the eastern and central regions of the study area.

(Fig. 2.9)

Dissection Index:

The dissection index is the ratio of relative relief to absolute relief. It is an indicator of the dissection of terrain. The dissection index is higher i.e. more than 15 percent in the south western region and few patches in the central and eastern regions. It is lower i.e. less than 5 percent in the northern and northwestern regions of the study area. The relative relief is moderate i.e. between 5 to 15 percent in the central, eastern and some part of western regions of the study area.

(Fig. 2.10)

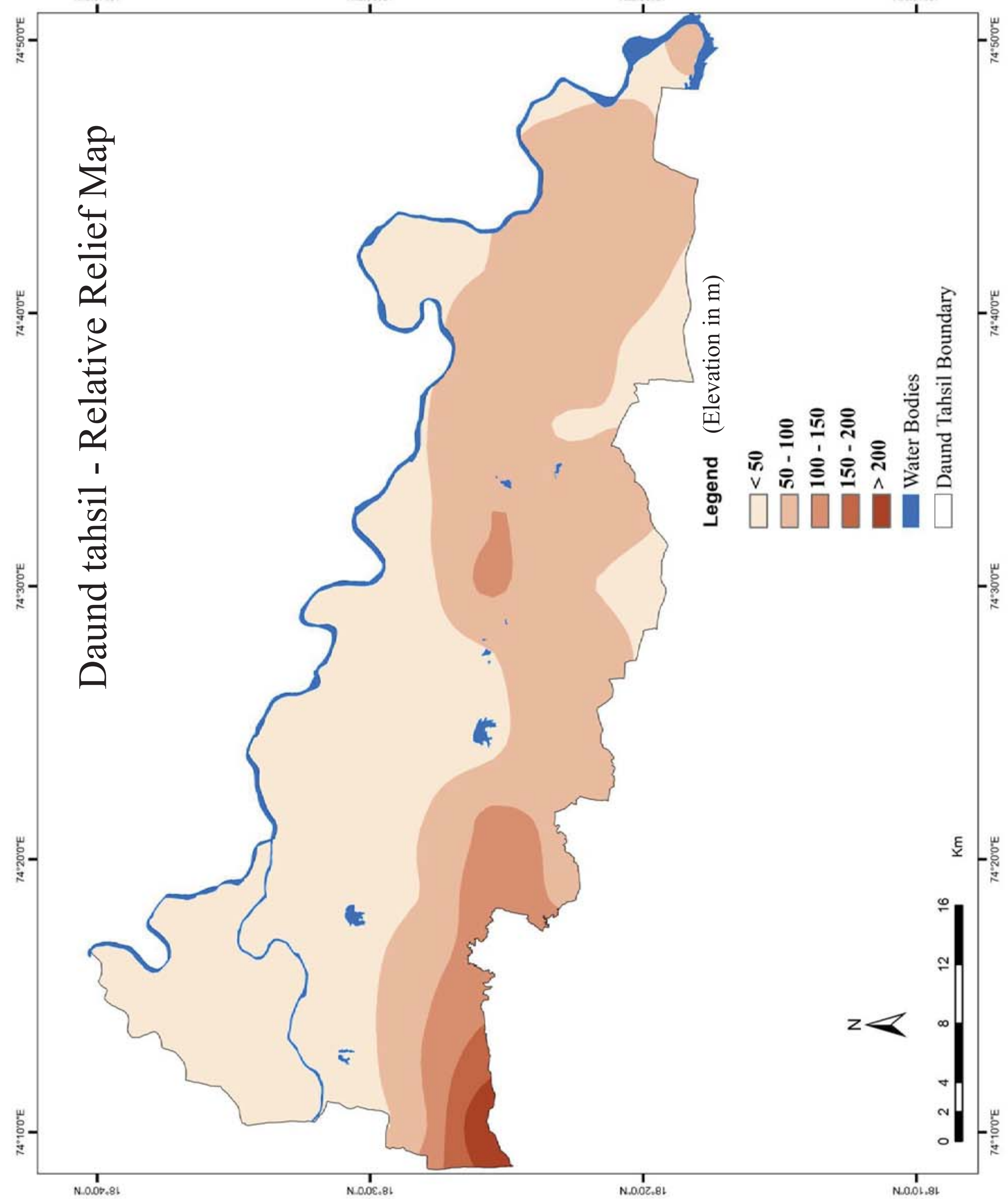

Daund tahsil - Relative Relief Map
Legend
(Elevation in m)
< 50
50 - 100
100 - 150
150 - 200
> 200
Water Bodies
Daund Tahsil Boundary
N
0 2 4 8 12 16
Km
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°10'0"N
18°20'0"N
18°30'0"N
18°40'0"N

Fig: 2.9

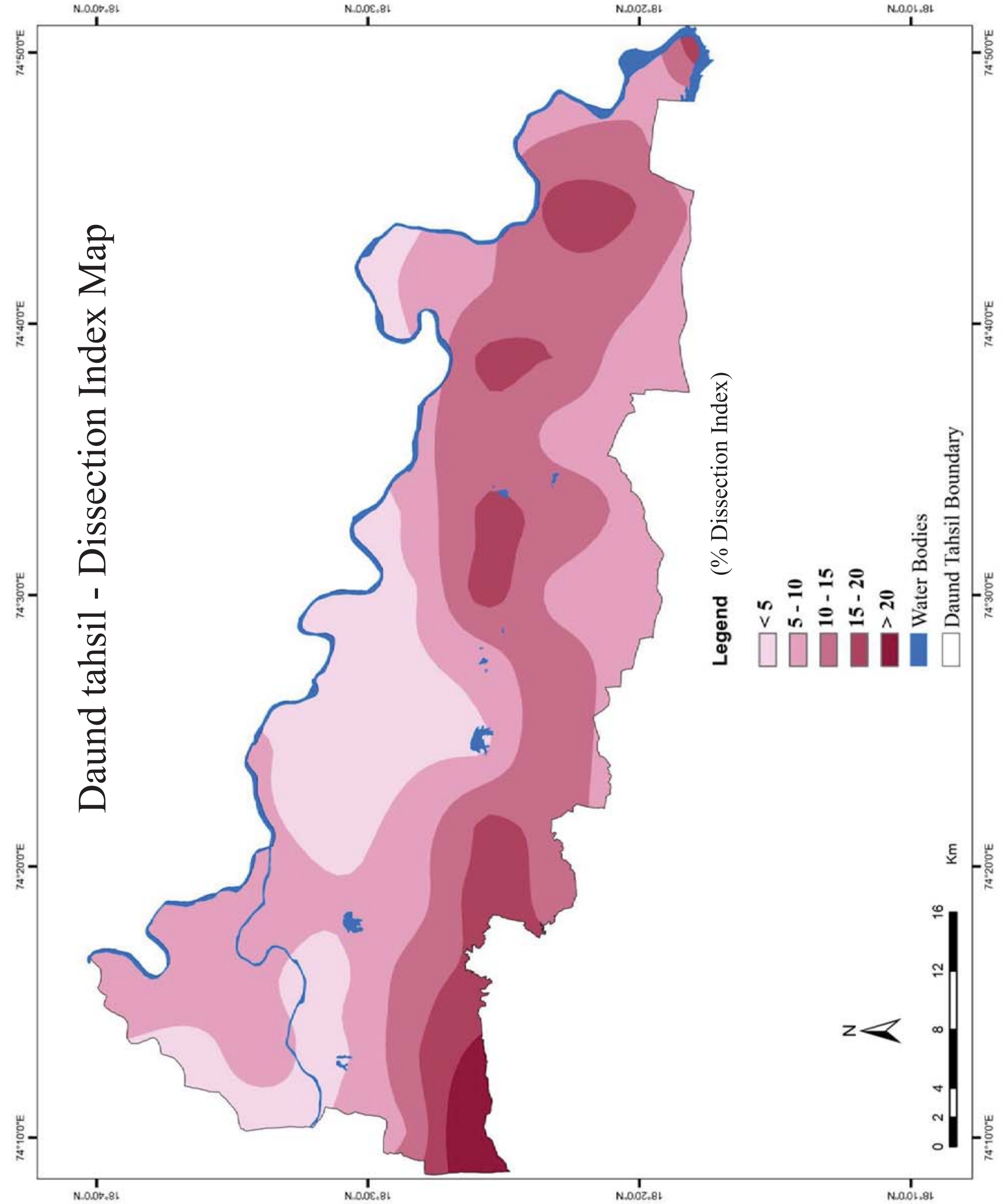

Daund tahsil - Dissection Index Map
Legend (% Dissection Index)
< 5
5 - 10
10 - 15
15 - 20
> 20
Water Bodies
Daund Tahsil Boundary
N
0 2 4 8 12 16
Km
18°40'0"N
18°30'0"N
18°20'0"N
18°10'0"N
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E

Fig: 2.10

2.2.4 Climate:

Daund tahsil lies in the semi-arid tract of Maharashtra and its climate is highly characterized by dryness during major part of the year and hot summer. According to Koeppen's climatic classification system, the study region of Daund tahsil experiences 'Aw' (Tropical Savanna) type of climate. The climate of Daund tahsil is hot and dry during most of the time of the year. Daund tahsil receives scanty rainfall. The climate from the month of January to April is relatively drier than other months of the year. The rate of evaporation is found to be highest in the month of May. The relative humidity in the study region is usually high in the months of July, August and September. The months of May and June are considered to be the hottest months of the year in the study region with temperatures reaching up to 40° C and above. The air temperature decreases up to 12° C in the months of December and January in Daund.

The prime seasons which are experienced in the study region are winter season, rainy season and summer season. The winter season commences from the month of November and lasts till the end of February month. The summer season commences from the month of March and lasts till the end of May. The southwest monsoon season commences from the month of June and lasts upto September month. The northeast retreating monsoon season commences from the month of October and ends in the month of November. The rainfall from the southwest monsoon winds is the prime source of water for the study region. There are great temporal variations in the average annual rainfall. In 2003, the average annual rainfall of Daund taluka was 156.3 mm, while in 2005 it was 739 mm. The amount of rainfall decreases towards the northeastern region of the study area. There is not much spatial variation in the amount of rainfall. The western and southwestern region of the study area receives comparatively maximum rainfall. The northeastern region of the study area receives comparatively less rainfall. As the amount of rainfall which decreases towards the northeastern and eastern regions of the study area, it has affected the growth of agricultural crops in this region. The maximum amount of rainfall in Daund is received during the months of June, July August and September. **(Fig. 2.11)**

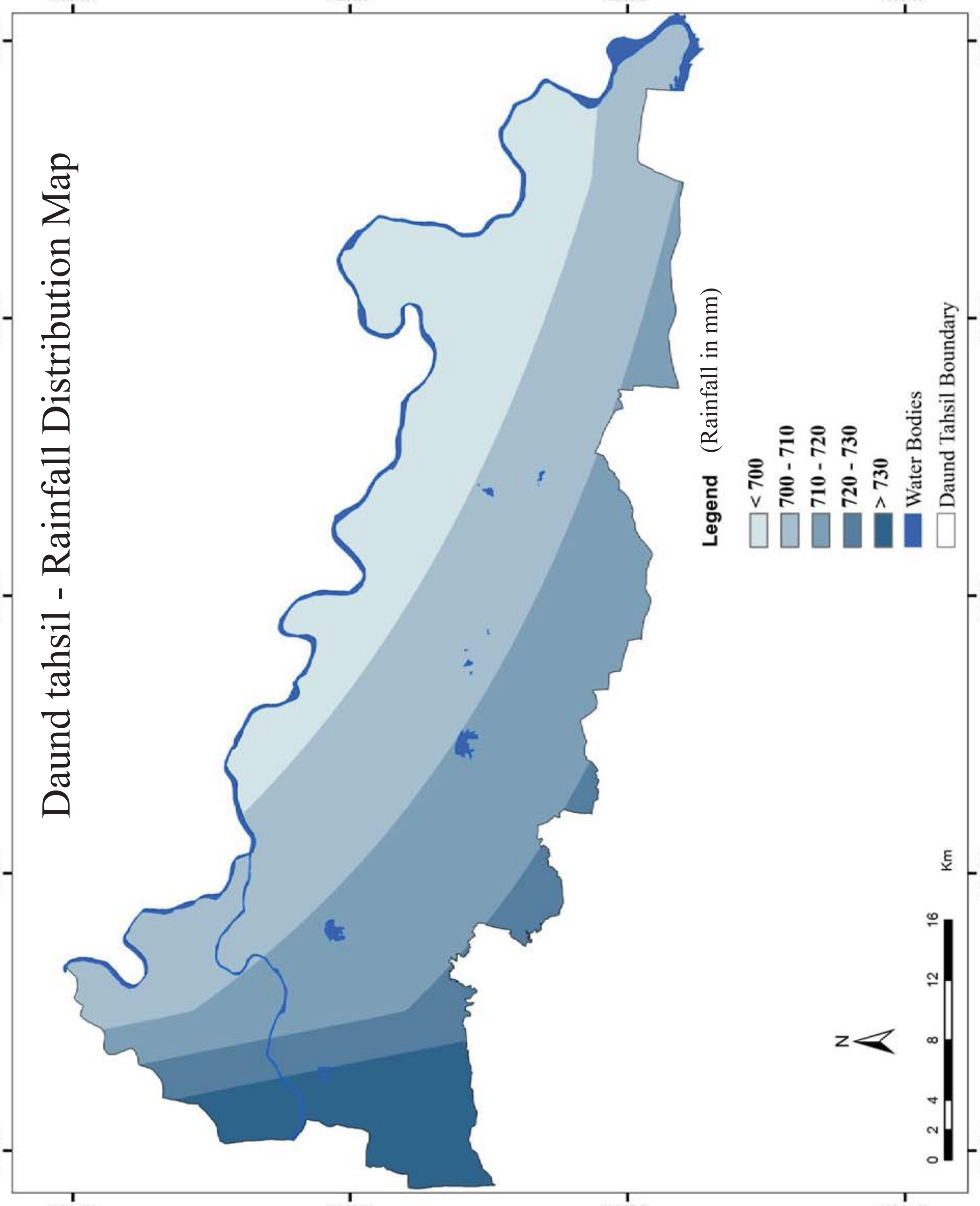
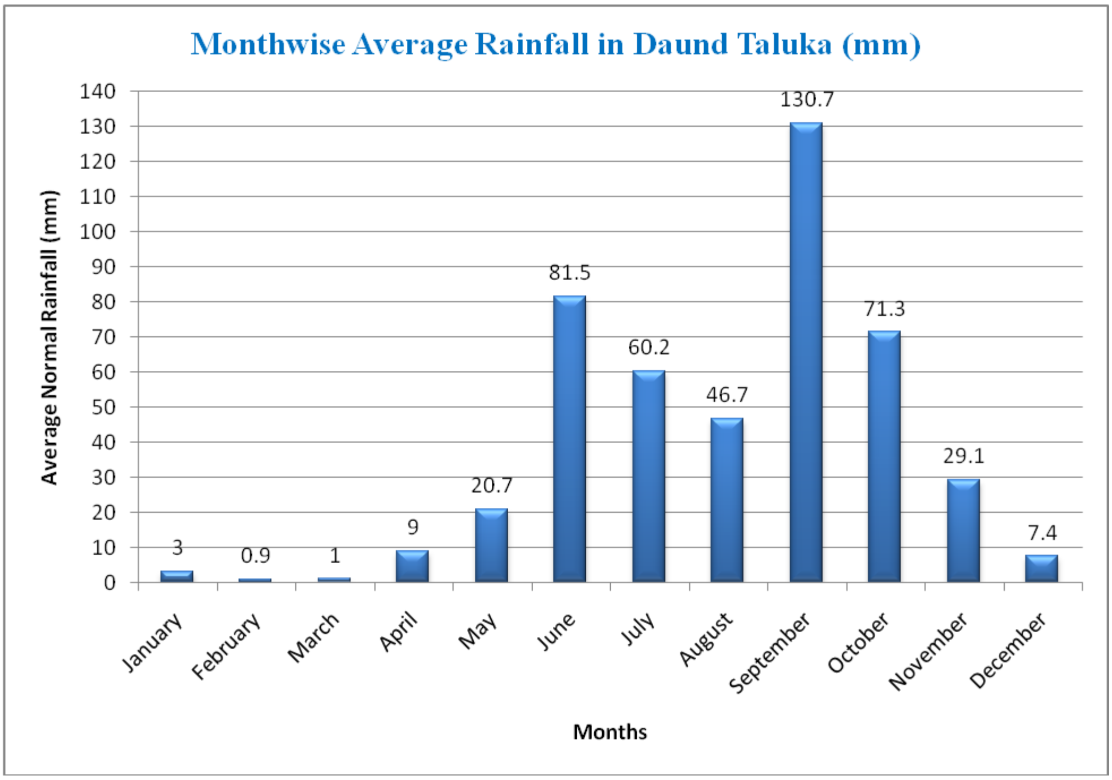

Daund tahsil - Rainfall Distribution Map
Legend (Rainfall in mm)
< 700
700 - 710
710 - 720
720 - 730
> 730
Water Bodies
Daund Tahsil Boundary
N
0 2 4 8 12 16
Km
18°40'0"N
18°30'0"N
18°20'0"N
18°10'0"N
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E

Fig: 2.11

Table 2.1: Month wise Average Rainfall (mm) in Daund taluka

Month	Average Rainfall (mm)
January	3.0
February	0.9
March	1.0
April	9.0
May	20.7
June	81.5
July	60.2
August	46.7
September	130.7
October	71.3
November	29.1
December	7.4



2.2.5 Drainage:

Bhima is a major river which flows toward east in Daund tahsil of Pune. The Bhima river originates from Bhimashankar hills in the Sahyadris (Western Ghats) in Khed tahsil of Pune district. Bhima river flows towards the east along with its sub-rivers Mula-Mutha. These rivers have played a very important role in the development of Daund Tahsil. Mula-Mutha rivers join Bhima river at Sangameshwar Mandir in Pargaon village, which is towards the northwest direction of Daund. Bhima river joins Krishna river downstream which finally drains into the Bay of Bengal.

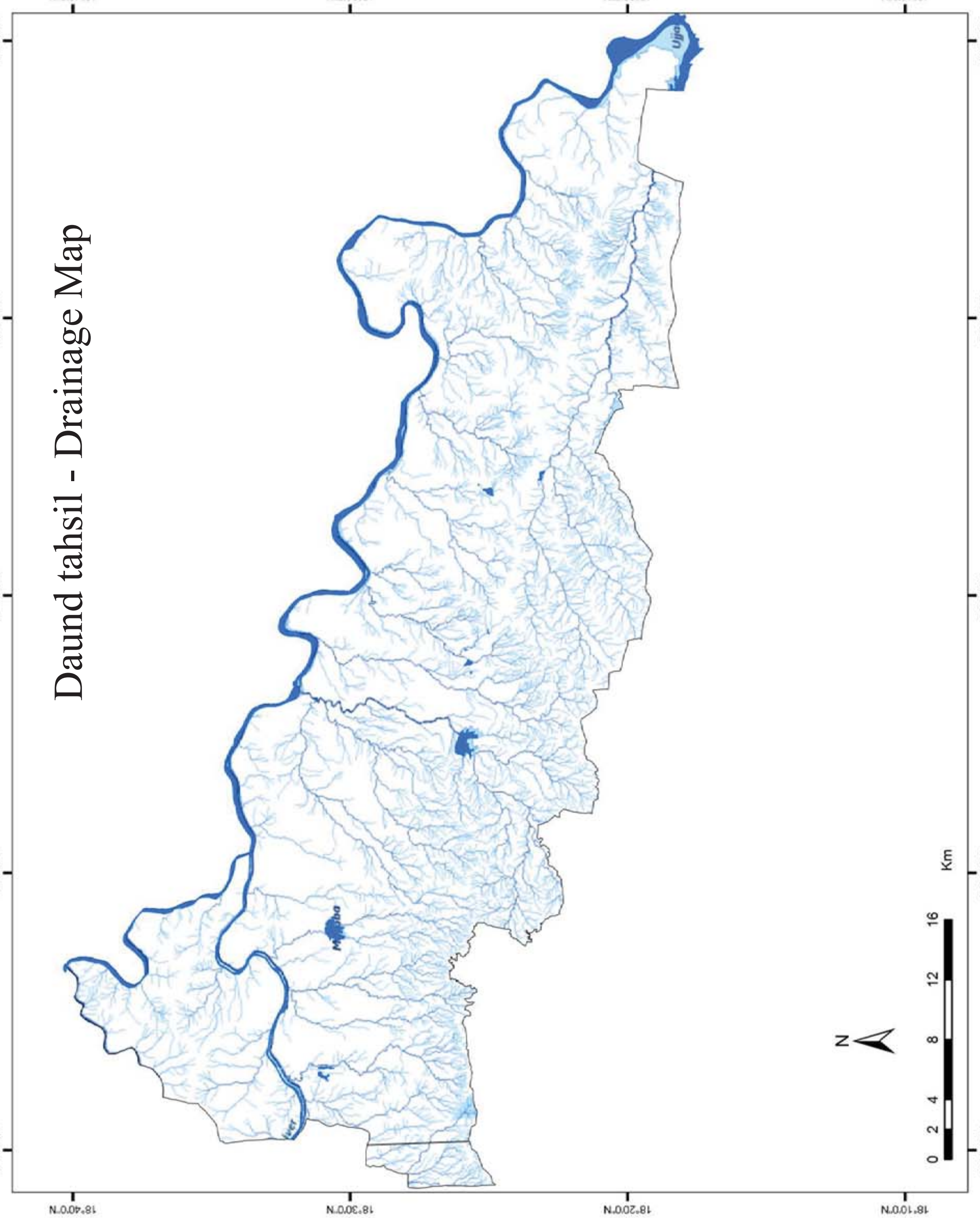
In the study region, the length of Bhima river accounts for 123 kilometers, whereas Mula-Mutha river contribute to total length of 29 kilometers. The western region of the Daund tahsil is drained by Mula-Mutha and its tributaries, while the remaining region is drained by Bhima river and its tributaries. During monsoon season, all these rivers flow with full volume of water but they contract into narrow streams during the summer season except the major rivers.

The streams over the study area have formed dendritic type of drainage pattern. The drainage pattern is characterized by irregular branching of tributaries in various directions. Mostly the streams are non-perennial in nature except Mula-Mutha and Bhima rivers, which are perennial rivers. All the tributaries of Mula-Mutha in the study region and most of the tributaries of Bhima river, flow only for short duration in monsoon season and dry up after monsoon.

More than one-fourth of the villages in Daund tahsil are situated along the right bank of Bhima river in the northern region. The southern part has an undulating and hilly topography. This region is the source area of water for many seasonal streams flowing towards the northern and eastern regions in the study area.

The Ujjani reservoir constructed on river Bhima, is situated at about 25 kilometers distance southeast of Daund. Important lakes such as Warwand, Kasurdi, Gupteshwar and Matoba are the major surface water resources in Daund Tahsil.

(Fig. 2.12)



Source : http://www.india-wris.nrsc.gov.in/

Fig: 2.12

2.2.6 Ground Water Resources:

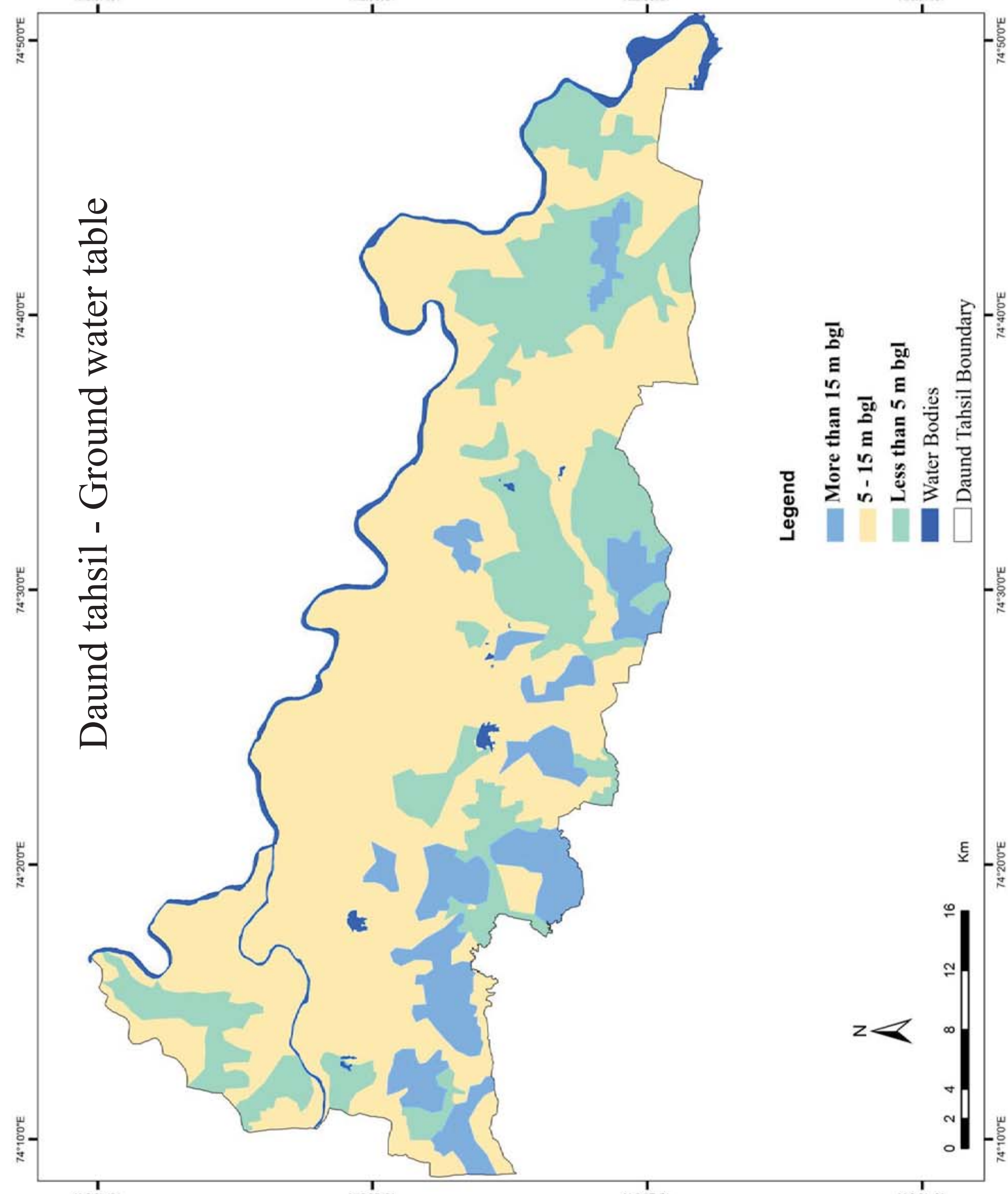
In Daund tahsil, there are many wells (lined) as well as tube wells. Most of these wells are perennial in nature i.e. these wells have water even during summer season. Most of the tube wells and wells are found over northern, western, central and southern regions of Daund tahsil. There are no wells and tube wells in the eastern region of the study area.

There is only one spring in the study area which is in Bharatgaon village. It is between 740 to 760 meters elevation.

The ground water table in the Daund tahsil has a range from less than 5 m below ground level to greater than 15 m below ground level. The entire Daund tahsil has been divided into three categories according to the ground water table i.e. less than 5 m bgl, 5 to 15 m bgl and greater than 15 m bgl.

Most of the area in Daund tahsil has 5 to 15 m bgl water table. The ground water table of less than 5 m bgl is present in patches over western, southern and eastern regions of the study area. While greater than 15 m bgl water table occurs over southern and southwestern regions of the study area.

(Fig. 2.13)



Source : Mpcb .gov.in/DEA Pune Maps

Fig: 2.13

2.2.7 Soils:

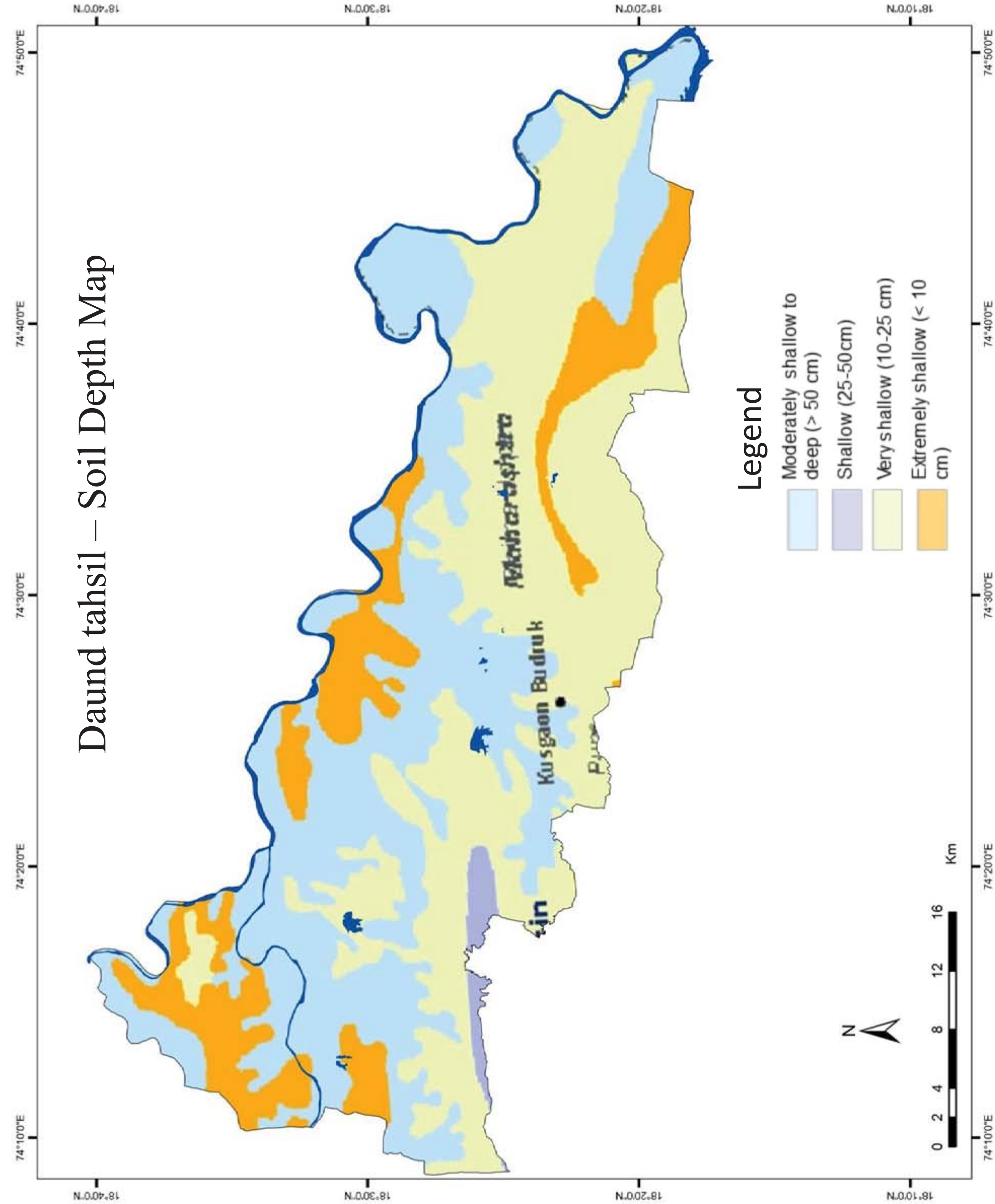
In the Daund tahsil, four types of soil can be distinguished according to the depth viz. deep soil (above 50 cm depth), moderately shallow to deep soil (25 to 50 cm in depth), shallow soil (10 to 25 cm depth) and extremely shallow soil (below 10 cm depth).

Moderately shallow to deep soil covers the maximum portion of the study region. The soil can support crops such as sugarcane, jowar, bajra, groundnut and onion.

The southern side of the river Bhima in the northern region of the study area is agriculturally well developed because this region is covered with fertile black soil.

Deep black soil is found along the low lying areas of Bhima and Mula-Mutha rivers. This soil is clayey, well drained and it is dark brown to grayish black in colour due to excessive humus content. This soil has high moisture holding capacity with varying proportions of calcium carbonate. This soil is suitable for cultivation of crops when supplemented by irrigation. Crops such as sugarcane and wheat are grown on deep black soil in the study region.

(Fig. 2.14)



Source : http://www.india-wris.nrsc.gov.in/

Fig: 2.14

2.2.8 Natural Vegetation:

In the study region, there is less and scattered vegetation cover due to irregular and scanty rainfall. In Daund tahsil, there are very less variations in natural vegetation. Natural vegetation occupies only 104 hectares of land that is 0.08 % of the total geographical area of Daund tahsil.

The type of natural vegetation is tropical dry deciduous, except along river Bhima which is mixed deciduous vegetation. The distribution of natural vegetation is strongly associated with the physiographic units of the study region. There are few patches of reserved forest around the right bank of Bhima river and the banks of Mula-Mutha river. The trees in the study region are highly scattered. The common trees in the study region are mango, sitaphal and other small trees with low density.

(Fig. 2.15)

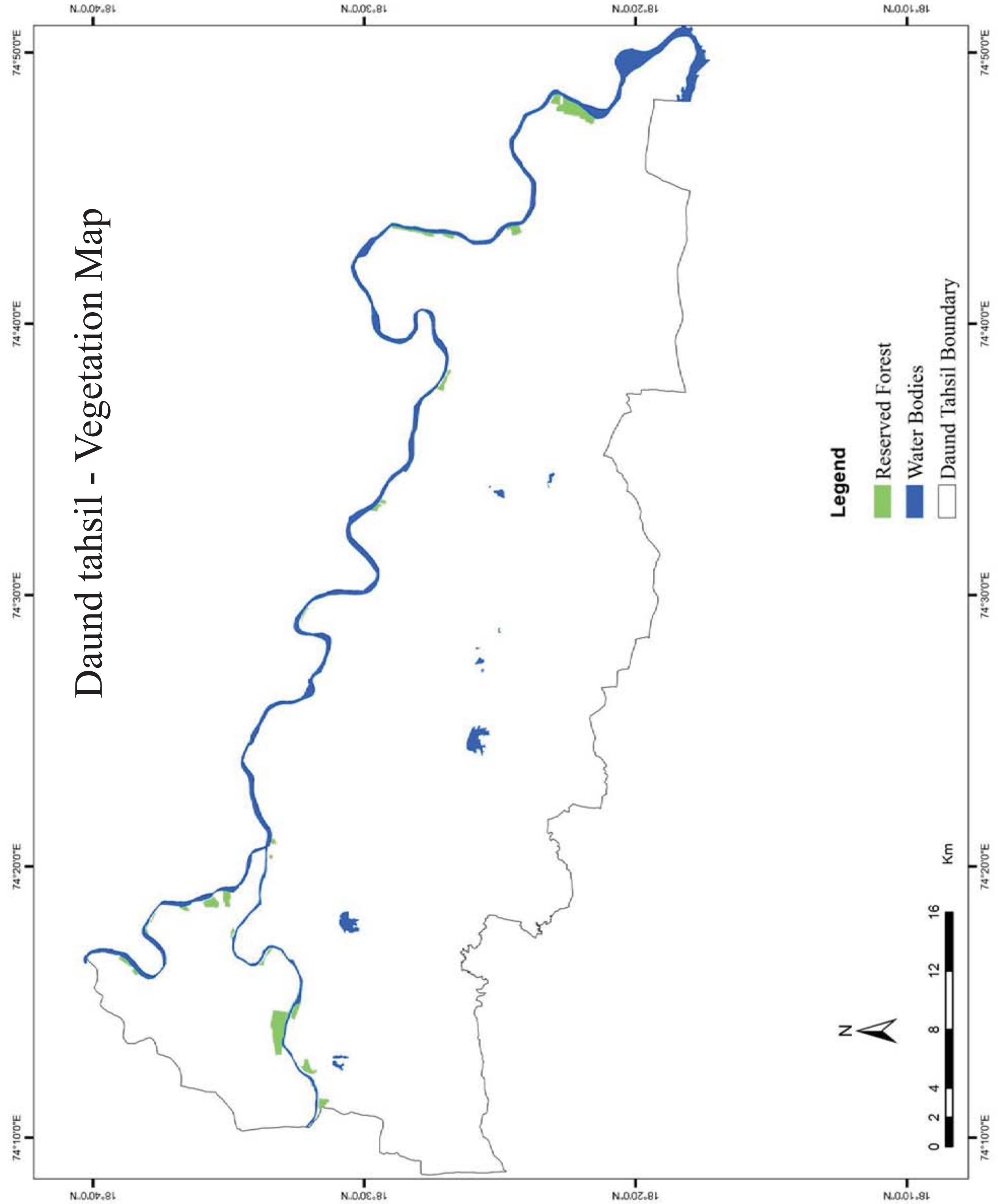

Daund tahsil - Vegetation Map
Legend
Reserved Forest
Water Bodies
Daund Tahsil Boundary
N
0 2 4 8 12 16
Km
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°40'0"N
18°30'0"N
18°20'0"N
18°10'0"N

Fig: 2.15

2.2.9 Demographics:

According to the Census data of 2011, the total population of the Daund taluka was 3,80,496 persons, out of which 196,283 are males while 184,213 are females. The sex ratio of Daund taluka was 939 females per thousand males in 2011. Daund tahsil consists of 3,24,183 (85.2 %) rural population and 56,313 (14.8 %) urban population. In Daund tahsil, Patas village has the highest population of 17,495 people and Naygaon village has the lowest population of 380 persons (according to the 2011 census).

The density of population was 67 persons per square kilometer in 1951, 179 persons per square kilometer in 1991, 265 persons per square kilometer in 2001 and 291 persons per square kilometer in 2011. This shows a tremendous increase in the density of population in Daund Tahsil from 1951 to 2011 (60 years). The main cause of increase in the density of population is the increasing rate of population growth. The decadal growth rate of population from 2001 to 2011 was almost more than 11 per cent. The density of population is low in most of the rural regions of Daund tahsil. In the central part of Daund taluka, the density of population is moderate. The density of population is higher in the central and central-western region of Daund tahsil. The highest density of population in the central region in Daund tahsil has been attributed to the growth of industrial region, fertile agricultural land, connectivity by transport network and urban centre. Kedgaon, Yawat, Warwand, Patas and Daund markets are located in this region of high density of population.

According to the Census data of 2011, the total literacy rate of Daund tahsil was 79.09%. The literacy rate of rural areas in Daund tahsil was 77.64%, whereas in urban areas it was 87.32%.

In Daund taluka, out of 1,82,359 workers, 74,196 were cultivators (owner or co-owner) while 40,985 were agricultural labourer.

The pattern of distribution and composition of population in Daund tahsil can be attributed to the agriculture, industrial development and urbanization.

Table 2.2: Village wise / Town wise Population of Daund tahsil (2011 Census)

Sr. No.	Name of the Village / Town	Total Population
1	Alegaon	548
2	Amoni Mal	935
3	Betwadi	2,255
4	Bhandgaon	4,076
5	Bharatgoan	2,340
6	Boratewadi	993
7	Boriaindi	3,012
8	Boribel	2,518
9	Boribhadak	3,330
10	Boripardhi	13,415
11	Chincholi	3,440
12	Dahitane	1,608
13	Dalimb	2,724
14	Dapodi	4,546
15	Delvadi	3,542
16	Deshmukh Mala	1,004
17	Deulgaon Gada	3,051
18	Deulgaon Raje	3,913
19	Devkarwadi	1,800
20	Dhumalicha Mala	1,748
21	Ekeriwadi	2,080
22	Gadewadi	1,391
23	Galandwadi	2,076
24	Ganesh Road	2,118
25	Gar	1,339
26	Gawadebagade Wasti	890
27	Girim	5,951
28	Gopalwadi	7,211
29	Handalwadi	1,215
30	Hatwalan	2,054
31	Hingani Berdi	1,417
32	Hinganigada	1,889
33	Jawje Buwachiwadi	1,452
34	Jiregaon	2,078
35	Kadamwasti	2,178

Sr. No.	Name of the Village / Town	Total Population
36	Kadethanwadi	2,866
37	Kalewadi	2,104
38	Kamatwadi	1,458
39	Kangaon	6,375
40	Kasurdi	2,755
41	Kauthadi	1,310
42	Kedgaon	3,492
43	Kedgaon Station	6,354
44	Khadaki	6,403
45	Khamgaon	5,813
46	Khanote	2,830
47	Khopodi	910
48	Khor	2,977
49	Khorodi	3,547
50	Khutbav	4,737
51	Koregaon Bhiwar	1,288
52	Kurkumbh	5,322
53	Kusegaon	2,832
54	Ladkatwadi	1,323
55	Lingali	5,753
56	Lonarwadi	1,604
57	Maladpatas	3,535
58	Malthan	4,103
59	Malwadi	564
60	Masanarwadi	2,096
61	Mergalwadi	1,774
62	Mirwadi	2,179
63	Nandadevi	2,172
64	Nandur	934
65	Nangaon	2,576
66	Nanwij	1,770
67	Nathachiwadi	3,233
68	Navingar	1,550
69	Naygaon	380
70	Nimbalkar Vasti	1,575
71	Padvi	3,523

Sr. No.	Name of the Village / Town	Total Population
72	Pandharewadi	3,067
73	Panwali	858
74	Pargaon	8,253
75	Patas	17,495
76	Patethan	1,774
77	Pedgaon	1,236
78	Pilanwadi	3,691
79	Pimpalachiwadi	1,057
80	Pimpalgaon	5,126
81	Rahu	10,220
82	Rajegaon	4,198
83	Ravangaon	4,241
84	Roti	1,010
85	Sahajpurwadi	3,232
86	Shirapur	2,069
87	Sonwadi	3,969
88	Takali	1,458
89	Tambewadi	1,333
90	Tamhanwadi	666
91	Telewadi	1,792
92	Undawadi	2,181
93	Vadgaon Bande	1,570
94	Valki	2,768
95	Virobawadi	2,186
96	Wadgaon Darekar	1,596
97	Wakhari	2,602
98	Warwand	12,690
99	Wasunde	1,727
100	Watluj	1,926
101	Yawat	13,983
102	Yawat Station	4,055
103	Daund Municipal Council	49,450
104	Daund Census Town	6,863

2.2.10 Agriculture and Irrigation:

Agriculture is the most predominant economic activity and it provides livelihood to maximum population in Daund tahsil. The agro ecological region of which Daund taluka is a part is the Western Maharashtra Plain Zone.

The principal cash crop in the study area is sugarcane. The other important primary crops include Wheat, Jowar, Bajra etc. along with onion and sweet limes. In the study region, it is noticed that the area under sugarcane cultivation has become larger with the increasing availability of irrigation facilities. But the area under other crops under cultivation has declined considerably with corresponding increase in the area under sugarcane crop.

The agricultural activity of Daund tahsil is totally dependent on the rainfall received in Kharif and Rabi seasons. The total area under cultivation in Daund Taluka is **1,03,844.9** hectares.

Irrigation is the major source of water for crop growth in the study area. The primary source of irrigation in Daund tahsil is canal irrigation along with wells, tanks and ponds.

Victoria tank is the major tank in the study region which supplies water for irrigation to villages such as Warwand and Patas. Lift irrigation is practiced along the south bank of Bhima river. Villages situated on Bhima river side irrigate land by using pump sets for land cultivation as well as drinking purpose. Irrigation through exploitation of ground water has been higher in the study area.

The irrigated land in study region is more than **50** per cent. Out of this, maximum area is irrigated by canal in Daund tahsil. This is followed by irrigation with the help of tanks and wells and to some extent with the help of bore wells.

In the context of problems related to agriculture being experienced in the study region, there is a need to shift to drip irrigation in order to control soil salinity and water logging.

2.2.11 Industries:

Bhima Sahakari Sakhar Karkhana (Sugar Factory) in Patas established in 1976 in Daund taluka has brought about revolutionary development in the socio-economic conditions of the people living in the Daund tahsil. Also, some private industries have been set up in the Daund tahsil which includes Anuraj Sugars near Yawat, Daund Sugars in Daund, Bora Agro industry in Jawje Buwahchiwadi, Shrinath Mhaskoba Sahakari Karkhana in Patethan, Mahavir Steel Industry in Bhandgaon etc. The major sugar factories are spread in all the directions of Daund Taluka. These factories depend on the sugarcane harvest. It has been the general trend all over Maharashtra that wherever a sugar factory is situated, development takes place there.

Kurkumbh industrial estate of Maharashtra Industrial Development Corporation (MIDC) specialized in chemical industries is located in the Daund tahsil. Daund has been developed as a hub for pharmaceutical industries.

2.2.12 Transport Network:

Daund tahsil is well connected with surrounding places by a dense network of roads and railway line. The National Highway (Pune - Solapur NH-9) runs from west to east through Daund Tahsil. The road transport network in Daund Tahsil also has some major State Highways, district roads and village roads.

The South Central Railway Main line runs from west to east of the Daund Tahsil and it connects to important places in Daund taluka. Daund is a very important and a major railway junction of the Central Zone of Indian Railways. The study area has Pune-Solapur broad gauge section and Daund-Baramati meter gauge section of the South Central railway.

2.3 Database and Methodology:

The data used in the present study is obtained from primary as well as secondary sources. The two components of the present study were field work and laboratory work. The field work consisted of field survey for the entire Daund tahsil by tracking the saline soil sample points with the help of GPS instrument.

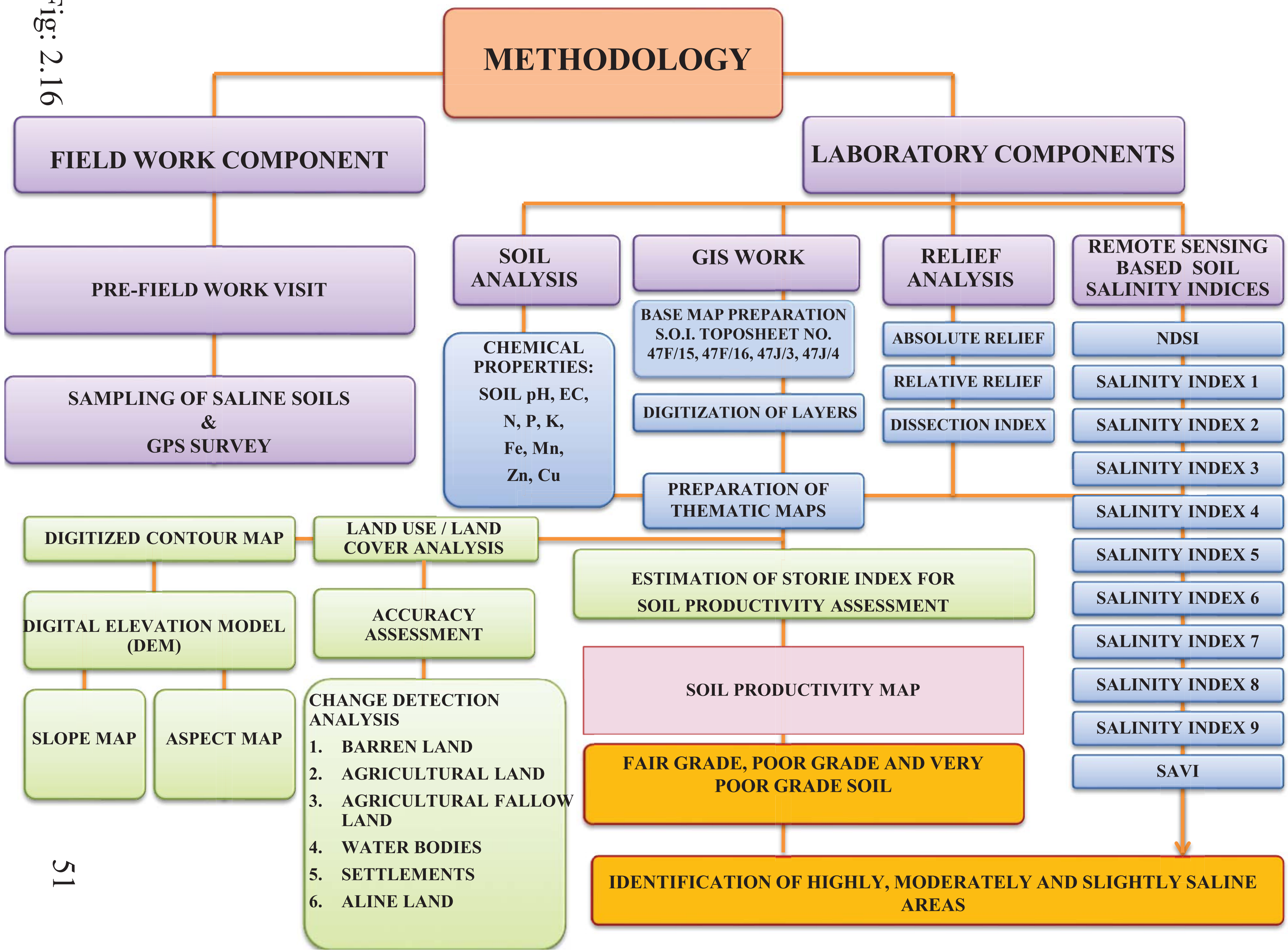
The secondary data about soil chemical properties have been obtained from Mati Parikshan data of agricultural fields in villages of Daund tahsil and data about physical and hydrological characteristics of soils has been obtained from Water Resources Information System (WRIS) which is a Web-GIS.

The laboratory work consisted of base map preparation using Survey of India (S.O.I.) Toposheets. The S.O.I. Toposheets having index numbers 47 J/2, 47 J/3, 47 J/6, 47 J/7, 47 J/10, 47 J/11 and 47 J/15, covering the entire study region i.e. Daund tahsil, were georeferenced in GIS software and merged together. Daund tahsil has been demarcated on Survey of India topographical maps, in GIS software. This layer has been used as base layer for further analysis. The ASTER GDEM digital elevation data (spatial resolution of 30 meters) for Daund tahsil has been used in the study.

Indian Remote Sensing (IRS) satellite data i.e. IRS P6 LISS-III satellite images (spatial resolution of 23.5 meters) were used for the preparation of Land Use / Land Cover Maps of Daund tahsil for the years 2012 and 2015, and change detection analysis. LANDSAT-8 OLI satellite image (spatial resolution of 30 meters) was used for the calculation of soil salinity indices and preparation of Soil Salinity Maps of Daund tahsil.

Various thematic maps showing distribution of soil pH, electrical conductivity (E.C.), nitrogen (N), phosphorus (P), potassium (K), iron (Fe), magnesium (Mg), zinc (Zn), copper (Cu), etc. were prepared by using soil data i.e. Mati Parikshan data of agricultural fields in Daund tahsil. The thematic maps were prepared and processed in GIS softwares: Global Mapper and Golden Software Surfer. All the thematic maps were interpreted.

In order to determine the productivity of soil, Storie index was calculated for each minute – grid square (1’ x 1’) was calculated in the study region. The Storie index is obtained by multiplying ratings for individual soil parameters.



METHODOLOGY
FIELD WORK COMPONENT
PRE-FIELD WORK VISIT
SAMPLING OF SALINE SOILS
&
GPS SURVEY
LABORATORY COMPONENTS
SOIL ANALYSIS
CHEMICAL PROPERTIES:
SOIL pH, EC,
N, P, K,
Fe, Mn,
Zn, Cu
GIS WORK
BASE MAP PREPARATION S.O.I. TOPOSHEET NO. 47F/15, 47F/16, 47J/3, 47J/4
DIGITIZATION OF LAYERS
PREPARATION OF THEMATIC MAPS
RELIEF ANALYSIS
ABSOLUTE RELIEF
RELATIVE RELIEF
DISSECTION INDEX
REMOTE SENSING BASED SOIL SALINITY INDICES
NDSI
SALINITY INDEX 1
SALINITY INDEX 2
SALINITY INDEX 3
SALINITY INDEX 4
SALINITY INDEX 5
SALINITY INDEX 6
SALINITY INDEX 7
SALINITY INDEX 8
SALINITY INDEX 9
SAVI
DIGITIZED CONTOUR MAP
DIGITAL ELEVATION MODEL (DEM)
SLOPE MAP
ASPECT MAP
LAND USE / LAND COVER ANALYSIS
ACCURACY ASSESSMENT
CHANGE DETECTION ANALYSIS
1. BARREN LAND
2. AGRICULTURAL LAND
3. AGRICULTURAL FALLOW LAND
4. WATER BODIES
5. SETTLEMENTS
6. ALINE LAND
ESTIMATION OF STORIE INDEX FOR SOIL PRODUCTIVITY ASSESSMENT
SOIL PRODUCTIVITY MAP
FAIR GRADE, POOR GRADE AND VERY POOR GRADE SOIL
IDENTIFICATION OF HIGHLY, MODERATELY AND SLIGHTLY SALINE AREAS

Fig: 2.16

2.3.1 Database:

Data for the present study is acquired from the following sources:

(1) Toposheets:

S.O.I. Topographical Maps on 1:50,000 scale were used as base maps. The study region of Daund tahsil is totally covered in Survey of India Toposheet numbers 47 J/2, 47 J/3, 47 J/6, 47 J/7, 47 J/10, 47 J/11 and 47 J/15. The administrative boundary of Daund tahsil, stream network, contours (20 m interval), village locations, water bodies, roads, railway line etc. have been digitized using SOI Toposheets. These layers have been used as base layers for further analysis.

(Fig. 2.17)

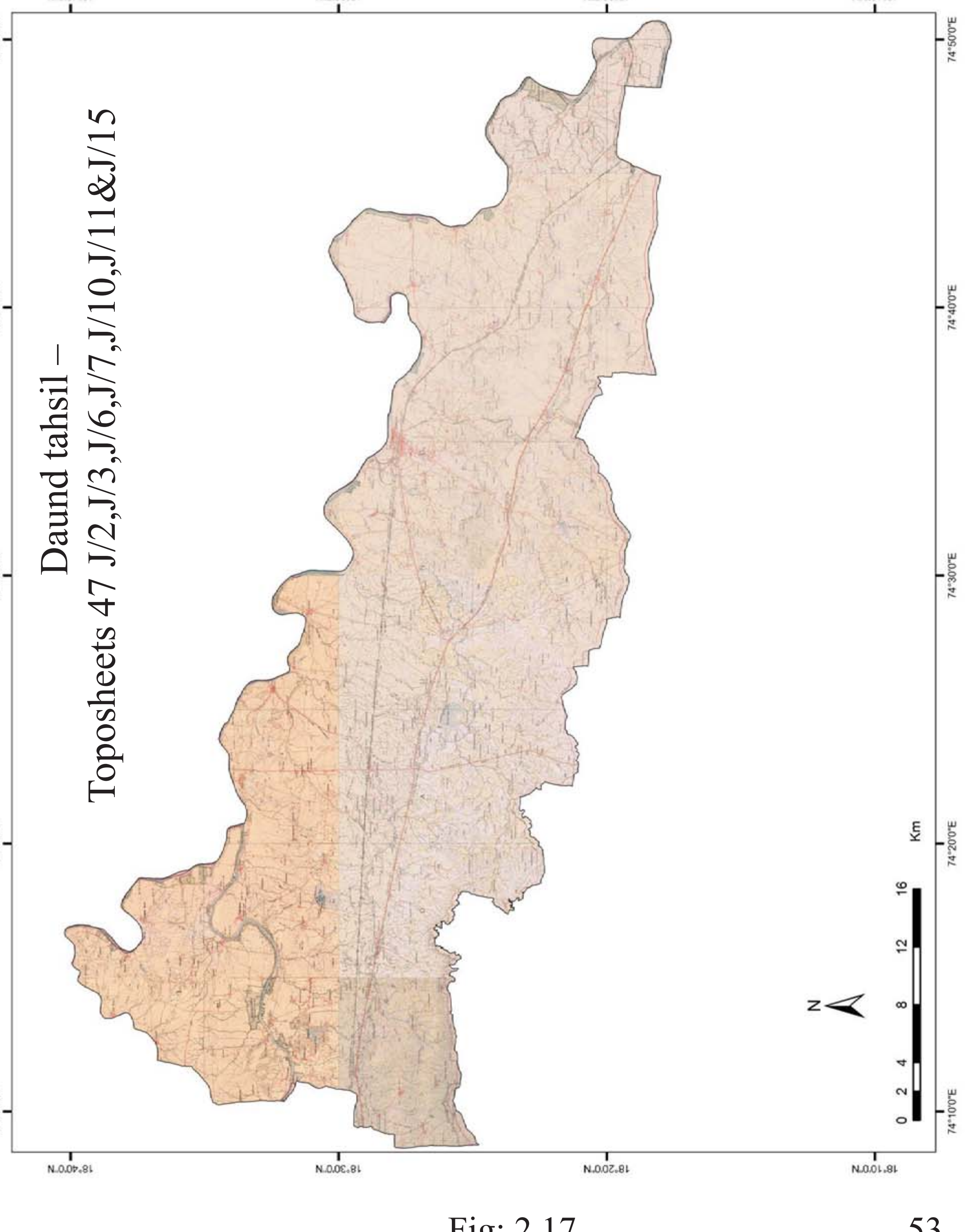

Daund tahsil –
Toposheets 47 J/2,J/3,J/6,J/7,J/10,J/11&J/15
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°10'0"N
18°20'0"N
18°30'0"N
18°40'0"N
N
0 2 4 8 12 16
Km

Fig: 2.17

(2) Satellite Imageries and Digital Elevation Data:

Indian Remote Sensing (IRS) satellite data were used in the present study. IRS P6 LISS-III satellite images having spatial resolution of 23.5 meters were used for the preparation of Land Use / Land Cover Maps of Daund tahsil. The IRS LISS-III satellite images for the years 2012 and 2015 were downloaded from the BHUVAN website. LANDSAT-8 OLI satellite image having spatial resolution of 30 meters was used for the calculation of soil salinity indices and preparation of Soil Salinity Maps of Daund tahsil. The LANDSAT-8 OLI satellite image for April 2017 was downloaded from the USGS website. The digital elevation data for the study region has been obtained from ASTER GDEM data with a spatial resolution of 30 meters.

(3) Soil Data:

The soil data about various chemical properties of soil viz. distribution of soil pH, electrical conductivity (E.C.), nitrogen (N), phosphorus (P), potassium (K), iron (Fe), magnesium (Mg), zinc (Zn), copper (Cu) etc. was obtained from Mati Parikshan data of soil samples of agricultural fields in various villages of Daund tahsil. Data about soil depth and soil texture in Daund tahsil was obtained from Water Resources Information System (WRIS) which is a Web-GIS.

(4) GPS Data:

The entire study region was tracked with the help of GPS. The soil sample points were tracked by using GPS to get location data. Several Ground Control Points (GCP's) have been checked in the field with the help of Garmin, Montana 650 GPS especially from soil salinity point of view.

2.3.2 Field Work:

This included survey of saline soil areas with the help of GPS.

(1) Pre-field work visit was given to the study region to plan the field work methodology.

(2) The entire study region was tracked with the help of GPS.

2.3.3 Laboratory Work:

Following tasks were performed as a part of laboratory work:

(1) Base Map Preparation:

The task of base map preparation was accomplished using toposheet numbers 47 J/2, 47 J/3, 47 J/6, 47 J/7, 47 J/10, 47 J/11 and 47 J/15 (1:50,000) covering the study region. The data from topographical map was processed in Surfer 10 and Global Mapper (version 15.00) softwares. The rectification of the topographical maps was performed in Global Mapper software.

(2) Digitization of Layers:

The contours, spot heights, streams , roads, railway line, taluka boundary etc. layers were digitized from the toposheet in Global Mapper version 15.00 software and these layers were used for further analysis. The delineation of the boundary of the study region of Daund tahsil was done by using Global Mapper version 15.0 software.

(3) Preparation of Land Use / Land Cover Maps and Change Detection Analysis:

The Land Use / Land Cover maps of Daund tahsil for the years 2012 and 2015 were prepared by using ERDAS 9.3 software.

For this purpose, IRS LISS-III (Linear Imaging Self Scanning System – III Sensor) satellite imageries having a high spatial resolution of 23.5 meters were used.

The entire area of Daund tahsil was classified into different classes such as agricultural land, barren land, saline land, settlements, water bodies etc. for both the years.

Finally, change detection analysis indicated the changes in the areas of land use / land cover classes.

(4) Mapping and Analysis of Soil Salinity Indices:

LANDSAT-8 OLI (Operational Land Imager Sensor) satellite image of the year 2017 having spatial resolution of 30 meters was used for the calculation of various soil salinity indices in the study region and preparation of Soil Salinity Maps of Daund tahsil. The satellite image has been acquired for the month of April 2017 as the cloud cover is generally minimum in this month and the satellite image is with higher values of salt accumulation and surface reflectance.

Digital Image Processing of LANDSAT-8 OLI satellite image was performed in ERDAS software for generating various soil salinity indices. As the first step, the digital image pre-processing techniques were applied to multispectral Landsat image. The reflectance calibration was applied by deriving the reflectance value from the Digital Number (DN) and calculating the top of atmosphere reflectance (TOA). Spectral bands with wavelength between 0.450 - 0.515 μm indicates Blue (B), between 0.525 - 0.600 μm indicates Green (G), between 0.630 - 0.680 μm indicates Red (R) and wavelength between 0.845 - 0.885 μm indicates Near Infrared (NIR).

Different band combinations have been evaluated for soil salinity analysis by forming different soil indices.

Eleven different spectral salinity indices and vegetation indices developed in numerous studies related to soil salinity mapping were examined.

These indices along with their formulae are outlined as follows:

i. **Normalized Difference Salinity Index (NDSI)**
NDSI = (R – NIR) / (R + NIR) - Khan et al., 2005

ii. **Salinity Index 1**
SI1 = (Sqrt (B*R)) - Douaoui et al. 2006

iii. **Salinity Index 2**
SI2 = (Sqrt (G*R)) - Khan et al., 2005

iv. **Salinity Index 3**
SI3 = Sqrt ($G^2 + R^2 + NIR^2$) - Douaoui et al. 2006

v. **Salinity Index 4**
SI4 = Sqrt ($G^2 + R^2$) - Douaoui et al. 2006

vi. **Salinity Index 5**
SI5 = (B/R) - Bannari et al. 2008

vii. **Salinity Index 6**
SI6 = (B - R) / (B + R) - Bannari et al. 2008

viii. **Salinity Index 7**
SI7 = (G*R) / B - Bannari et al. 2008

ix. **Salinity Index 8**
SI8 = (B*R) / G - Abbas and Khan, 2007

x. **Salinity Index 9**
SI9 = (R*NIR) / G - Abbas and Khan, 2007

xi. **Soil Adjusted Vegetation Index (SAVI)**
SAVI = [(NIR – R) * (1+L)] / (NIR+R+L) - Huete A.R., 1988

Note:

NIR = the reflectance value of the near infrared band Landsat 8 image.

R = the reflectance value of the red band Landsat 8 image.

L = the correction factor for soil brightness.

B = the reflectance value of the blue band of Landsat 8 image.

G = the reflectance value of the green band of Landsat 8 image.

(5) Preparation of Thematic Maps:

Various thematic maps have been prepared in Surfer Software by the technique of spatial interpolation. Various thematic maps showing distribution of soil pH, electrical conductivity (E.C.), nitrogen (N), phosphorus (P), potassium (K), iron (Fe), magnesium (Mg), zinc (Zn), copper (Cu), etc. were prepared by using soil data i.e. Mati Parikshan data of agricultural fields in Daund tahsil. The thematic maps were prepared and processed in GIS softwares: Global Mapper, Golden Software Surfer and Arc Map. All the thematic maps were interpreted.

(6) Estimation of Storie index:

In order to determine the productivity of soil in the study region, Storie index was calculated. The grid method was used for the purpose of calculation of Storie index wherein the entire study region is covered with a mesh of grid squares and Storie index in each minute – grid square (1’ x 1’) was calculated. The Storie index is obtained by multiplying ratings for individual soil parameters. The rated parameters include the degree of soil profile development in terms of soil depth and gravel content (factor A), the textural characteristics of the surface soil (factor B), the slope in percent (factor C), and other important properties of the soil and landscape conditions such as drainage class e.g. well drained or poorly drained, alkali content, degree of acidity, fertility status or content of nutrients, degree of soil erosion i.e. wind and water erosion, and micro-relief features (factor X or “dynamic factor” which can be modified by management). The most ideal settings or favourable conditions with respect to each attribute are rated at 100 percent. A value ranging from 0 to 100% is given for each factor, and the ratings are then multiplied together to generate the Storie index. Each factor is given a percentage score but decimal values are taken while multiplying the factors.

The formula to determine Storie index in percentage is as follows:

Storie Soil Index rating

= [(Factor A/100) × (Factor B/100) × (Factor C/100) × (Factor X/100)] × 100

Finally, the soils in Daund tahsil have been graded into fair grade soils (more than 40 percent ratings), poor grade soils (20 to 39 percent ratings), and very poor grade soils (less than 20 percent ratings).

(7) Identification of Degraded lands:

Based on a combination of various salinity and vegetation indices derived from remote sensing data, and Storie index ratings for soil productivity, degraded areas which need conservation planning measures will be delineated.

2.4 Framework of the Thesis:

The present research work has been systematically divided into six chapters. The first chapter gives a brief introduction about the research work and problem of over irrigation and soil salinization in the study region. The significance of such type of study has also been explained with reference to the problem of soil salinization in India in general and in Maharashtra in particular. The application of remotely sensed satellite image in detection and mapping of soil salinity has been given due importance. The work of various scholars in the context of soil salinity and remote sensing applications in salinity studies has been reviewed. Finally, the major aims and objectives of the present research work have been summarized.

The second chapter describes the geographical profile of the study area, and the sources of data which form the database along with the methodology adopted for the present study. The geographical environment of Daund tahsil has been described in terms of location, geology, physiography, climate, drainage, ground water resources, soils, natural vegetation etc. The demographics, agriculture and irrigation, industries and transport network in Daund tahsil are also described in brief.

The Database consists of S.O.I. Toposheets, IRS and LANDSAT satellite imageries, GPS data and soil sample data. The methodology has been divided into field work i.e. GPS survey and laboratory work i.e. map-making in GIS softwares, land use land cover change detection analysis, analysis of soil salinity indices generated with the help of satellite image data, and determination of Storie index of soil productivity.

The third chapter is entirely about land use / land cover analysis. The remote sensing application in land use / land cover analysis is the major part of this chapter. This includes satellite image classification into various land use / land cover classes according to standard NRSC scheme. The classification output is the LU/LC map for 2012 and 2015. Also, accuracy assessment of the classification has been performed before change detection analysis. Land Use Land Cover Analysis for 2012 and 2015 has been presented along with the statistics and graphs. Finally, detection of spatio-temporal variations in land use / land cover pattern with reference to change in barren land, agricultural land, agricultural fallow land, water bodies, settlements and saline land has been explained systematically.

In the fourth chapter, various soil salinity indices have been explained. The method of using different bands of LANDSAT 8 satellite image and GIS analysis is explained in brief. The indices which have been analyzed to infer the degree of soil salinity are NDSI (Normalized Difference Salinity Index), Salinity Index 1, Salinity Index 2, Salinity Index 3, Salinity Index 4, Salinity Index 5, Salinity Index 6, Salinity Index 7, Salinity Index 8, Salinity Index 9 and SAVI (Soil Adjusted Vegetation Index). For every index, statistics and map showing various categories of saline land have been given.

The fifth chapter is regarding estimation of soil productivity using Storie index. Firstly, various soil properties such as pH, E.C. and nutrient contents have been analyzed with the help of thematic maps. Various factors required for estimation of soil productivity using Storie index have been outlined.

In the sixth and final chapter, the major findings and conclusions have been discussed. Finally, recommendations to overcome the problem of soil salinization have been given.

x-x-x

CHAPTER III

LAND USE LAND COVER ANALYSIS

3.1 Introduction:

Land Use Land Cover (LULC) analysis is the preliminary step towards the determination of areal extent of various Land Use / Land Cover classes. For the sustainable agriculture, proper land utilization and agricultural practices such as utilization of irrigation water is necessary. So, accurate and updated Land Use / Land Cover analysis is of prime importance in present times. Land Use / Land Cover change detection plays a pivotal role because it gives a clear understanding about present conditions of land degradation and with time how land will be degraded which in turn will help in management process.

Remote sensing based data i.e. satellite imageries from multispectral sensors provides essential information in the form of spectral signatures for Land Use / Land Cover analysis. The present chapter deals with application of remote sensing based method applied for LU / LC assessment and change detection analysis which reveals the dominance of salinity conditions over the study area.

3.2 Methodology: Remote Sensing Based Technique for Land Use / Land Cover Analysis:

Remotely sensed data or satellite imageries are the most useful tools to infer spatial and temporal distribution of LU / LC classes. Generally, satellite imageries are acquired in different spectral bands according to the spectral reflectance property of the LU / LC features.

For LU / LC classification in the present study, IRS (Indian Remote Sensing Satellites) RESOURCESAT 1 Ortho rectified LISS III data is used for comparison of LU / LC for two years. LISS III data is of 23.5 m spatial resolution and it consists of four spectral bands viz. Band B2 0.52 - 0.59 micrometers (Green), Band B3 0.62 - 0.68 micrometers (Red), Band B4 0.77 - 0.86 micrometers (Infrared) and Band B5 1.55 - 1.70 micrometers (Shortwave Infrared).

However, the selection of scene is of utmost importance because the presence of cloud cover in satellite imageries can hamper and block the spectral reflectance of the outgoing energy making the image blur as well as incapable for the purpose of LU / LC analysis. So, for the present study, two cloud cover free images are selected viz. 9th April, 2015 and 12th February, 2012.

Each and every feature on the earth's surface has its specific spectral signature and reflects only that energy. These spectral properties of various LU / LC classes are utilized for the identification of features over the earth's surface. The remotely sensed data from satellite plays an important role in land monitoring, evaluating LU / LC as well as the identification of saline lands. Salt encrustation can be very easily detected in the satellite imageries because saline land has different reflectance characteristics than that of natural soils.

The comparison of LU / LC maps of two different years will help to identify the changes in area under various classes. Hence, change detection analysis of LU / LC classes can be performed and the analysis becomes quantitative. It is also possible to monitor the increase in the areal extent of classes (such as increase in area under saline lands) or decrease in the areal extent of classes (like decrease in the water body area).

Methodology Flow Chart

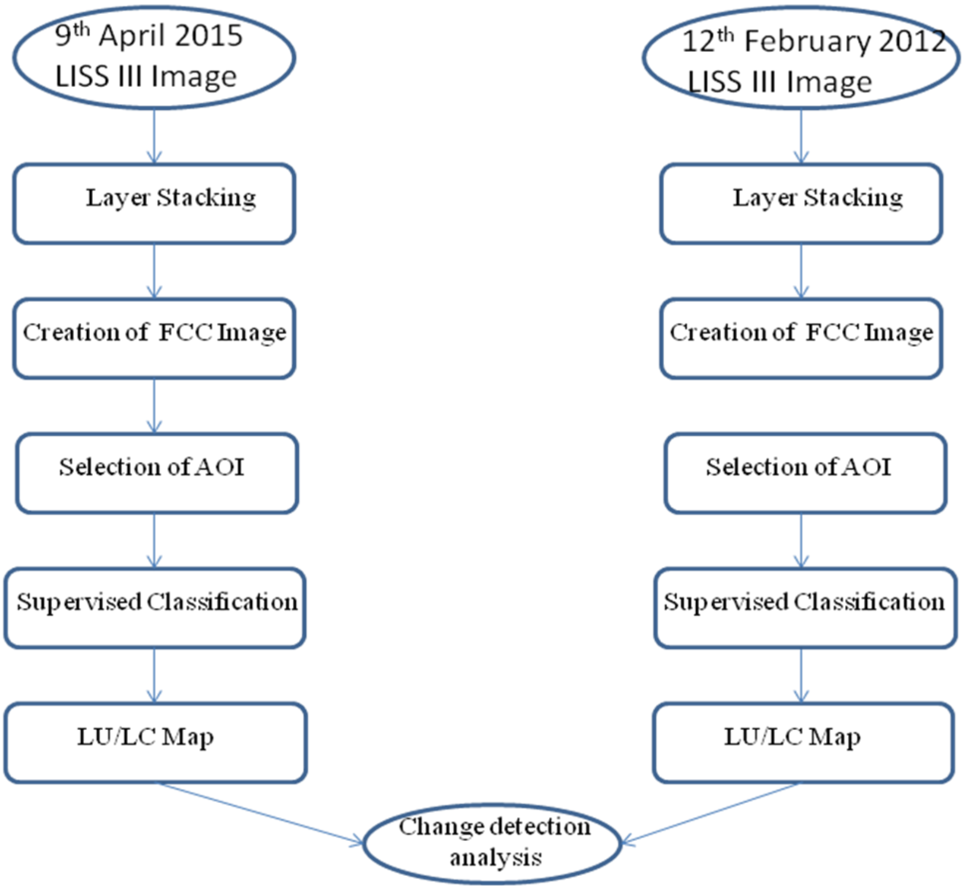


Fig: 3.1

3.2.1 Image Classification:

Image Classification is the most widely used remote sensing based applications for extraction of LU / LC information. For the present study, land use and land cover analysis is pre-requisite to understand the spatio-temporal variations of LU / LC pattern in general and area under saline land cover in particular.

Image classification technique groups image pixels according to their spectral reflectance value. Thus, the whole image is generalized to some meaningful classes or groups. Image classification can be done with the help of two techniques viz. supervised and unsupervised classification.

Supervised classification technique employs selection of AOI (Area of Interest) and the number of such AOI decides the total number of classes. Then, the process requires classification algorithm which then classify the whole image. For supervised classification, selection of AOI needs utmost care specifically for fine classes like saline lands.

Broad classed like barren land, where pure pixels (pixels covering single class) can be easily identified and categorized. Classes with mixed pixel (pixels with more than one class in it) need an extremely careful selection of AOI like that of saline agricultural lands because such class can fall in both agricultural land as well as saline land. The field survey data and GCP's (Ground Control Points) collected from fields as well as from Google Earth can minimize the mixed pixel problem.

In unsupervised classification technique, selection of AOI is not essential because the system itself categorizes the LU / LC classes. In the present study, supervised classification technique with Maximum Likelihood Classifier has been used.

3.2.2 Land Use / Land Cover Classes:

The classification system amenable for the use with remotely sensed data varies with the objectives of the classification and type of the satellite data that is being used. There are many methods of land use classification like U.S.G.S. (United States Geological Survey) scheme, NRSC (National Remote Sensing Centre, India) scheme etc. For the present study, the "National Land Use Land Cover Mapping using Multi-temporal Satellite data" classification scheme given by NRSC, India has been followed (Refer Table 3.1). In the present study, both the satellite images have been classified into six broad classes viz. Settlements, Barren land, Agricultural land, Agricultural fallow land, Water bodies and Saline land.

Table 3.1: NRSC Land Use / Land Cover Classification Scheme

Sr. No	LU / LC Class	LU / LC Sub-Class	Classes from NRSC LULC 50K Mapping Project
1	Built-up	Urban	Residential, Mixed built-up, Public / Semi Public, Communication, Public utilities
			Facility, Commercial, Transportation, Reclaimed land, Vegetated Area
			Recreational, Industrial, Industrial / Mine dump, Ash / Cooling pond
		Rural	Rural
		Mining	Mine/Quarry, Abandoned Mine Pit, Land fill area
2	Agriculture	Crop land	Kharif, Rabi, Zaid, 2 cropped, More than 2 cropped
		Plantation	Plantation - Agricultural, Horticultural, Agro Horticultural
		Fallow	Current and Long Fallow
		Current Shifting cultivation	Current Shifting cultivation
3	Forest	Evergreen / Semi evergreen	Dense / Closed and Open category of Evergreen / Semi evergreen
		Deciduous	Dense / Closed and Open category of Deciduous and Tree Clad Area
		Forest Plantation	Forest Plantation
		Scrub Forest	Scrub Forest, Forest Blank, Current and Abandoned Shifting Cultivation
		Swamp / Mangroves	Dense / Closed and Open Mangrove

4	Grass/ Grazing	Grass/ Grazing	Grassland: Alpine / Sub-Alpine, Temperate / Sub Tropical, Tropical / Desertic
5	Barren/ Un-culturable/ Wet lands	Salt affected Land	Slight, Moderate and Strong Salt Affected Land
		Gullied / Ravinous	Gullied, Shallow ravine and Deep ravine land area
		Scrub land	Dense / Closed and Open category of scrub land
		Sandy area	Desertic, Coastal, Riverine sandy area
		Barrenrocky	Barren rocky
6	Wet lands / Water Bodies	Inland Wetland	Inland Natural and Inland Manmade wetland
		Coastal Wetland	Coastal Natural and Coastal Manmade wetland
		river/stream canals	Perennial and Dry River/stream and line and unlined canal/drain
		Water bodies	Perennial, Dry, Kharif, Rabi and Zaid extent of lake/pond and reservoir and tanks
7	Snow and Glacier		Seasonal and Permanent snow

3.2.3 Classification Output:

The output of the supervised classification image was obtained as thematic maps for each year i.e. 2012 and 2015. The classified remotely sensed image, with earlier defined classes was displayed using various colors. Both the classified images were used for the visual interpretation and for quantitative analysis of area under different LU / LC classes for understanding the changes in land use and land cover pattern in Daund tahsil.

3.2.4 Accuracy assessment

Before performing change detection analysis, accuracy assessment was also performed because it is essential to test and check the accuracy of the classified images.

Accuracy assessment means to check how far classified image resembles the ground reality. In other words, accuracy assessment implies that how far classes assigned to classified image matches classes actually present over the ground. After the image classification, it is always necessary to assess the accuracy of the image.

Generally, accuracy assessment compares the classified image with map or image (like Google Earth image) of same area. The producer and user accuracy is then calculated for each class.

For RESOURCESAT-1 Ortho rectified LISS III image of 2012, the producer accuracy is 90.91% for saline lands, 37.50% for settlements, 54.55% for barren land, 50% for agricultural land, 50% for agricultural fallow and 100% for water bodies. The user accuracy is 71.43% for saline lands, 60% for settlements, 40% for barren land, 80% for agricultural land, 100% for agricultural fallow and 100% for water bodies. The overall accuracy for the classified image of 2012 is 84.00%.

For RESOURCESAT-1 Ortho rectified LISS III image of 2015, the producer accuracy is 60% for saline lands, 100% for settlements, 50% for barren land, 100% for agricultural land, 100% for agricultural fallow and 100% for water bodies. The user accuracy is 75% for saline lands, 33.33% for settlements, 54.55% for barren land, 85.71% for agricultural land, 50% for agricultural fallow and 100% for water bodies. The overall accuracy for the classified image of 2015 is 86.00%.

The Kappa coefficient calculated for 2012 and 2015 is 0.74 and 0.77 respectively.

3.3 Land Use Land Cover Classification of 2012:

The False Colour Composite (FCC) image of 2012 (Fig 3.2) shows barren land in whitish tone, water body in blackish blue color, settlements in cyan color, agricultural patches in red tone and agricultural fallow land in brownish tone. Saline land in the FCC image is very difficult to identify with the help of image interpretation keys because this class mainly comes in mixed pixels as saline lands are actually agricultural fallow lands or they can even belong to agricultural lands. In order to delineate saline lands, GCP's of saline patches were collected from Google earth image of 2012 and then the AOI for saline land has been selected.

The LU / LC classified image shows that barren land covers 26.40% area, agricultural land 16.40%, agricultural fallow 5.97%, water body 5.84%, settlements 13.41% and saline land 32.97% of the Daund tahsil in 2012 (Table 3.2). It is evident from the classified image and the data derived from it that salinization problem has become a serious concern during 2012 (Fig 3.3).

Table 3.2: Area under various LU / LC classes in Daund, 2012

Classes	Area in Ha	Area in sq. km	Area in %
1. Barren Land	35915.15	359.15	26.40
2. Agricultural Land	22315.41	223.15	16.40
3. Agricultural Fallow	8118.59	81.19	5.97
4. Water Body	6584.72	65.85	4.84
5. Settlement	18247.14	182.47	13.41
6. Saline land	**44858.34**	**448.58**	**32.97**
Total	136039.35	1360.39	100.00

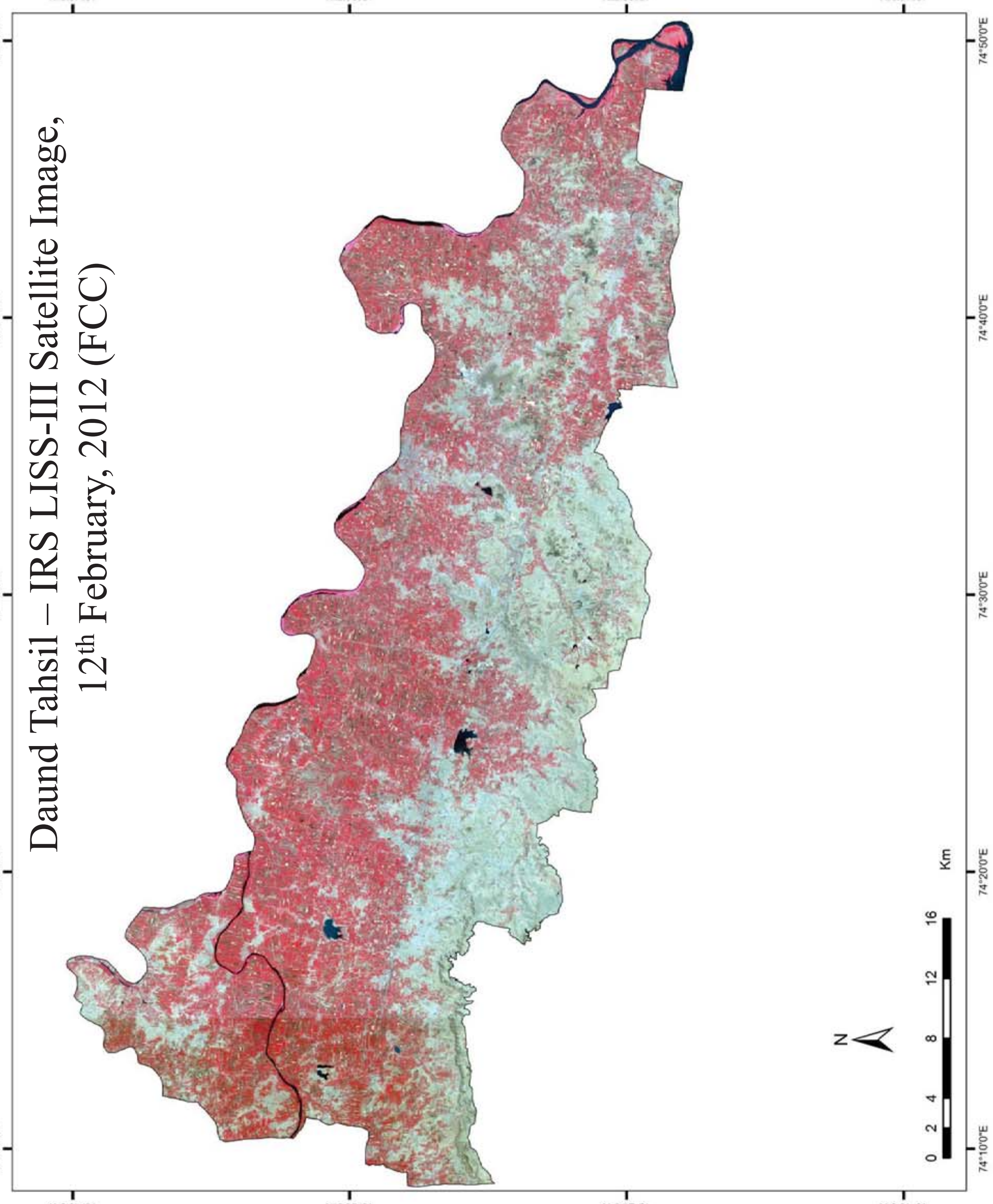

Daund Tahsil – IRS LISS-III Satellite Image,
12th February, 2012 (FCC)
18°40'0"N
18°30'0"N
18°20'0"N
18°10'0"N
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
N
0 2 4 8 12 16
Km

Fig: 3.2

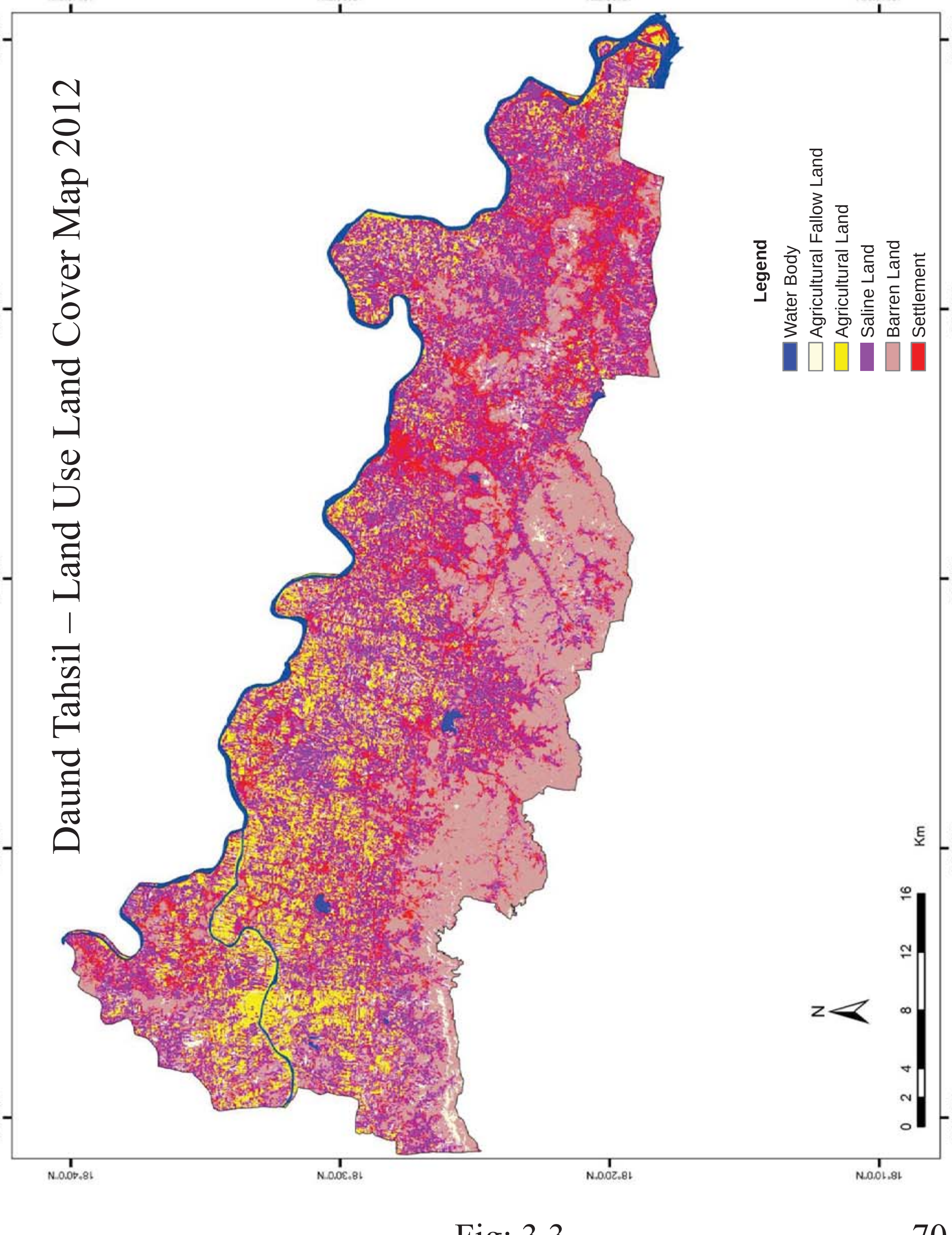

Daund Tahsil – Land Use Land Cover Map 2012
Legend
Water Body
Agricultural Fallow Land
Agricultural Land
Saline Land
Barren Land
Settlement
N
0 2 4 8 12 16
Km
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°40'0"N
18°30'0"N
18°20'0"N
18°10'0"N

Fig: 3.3

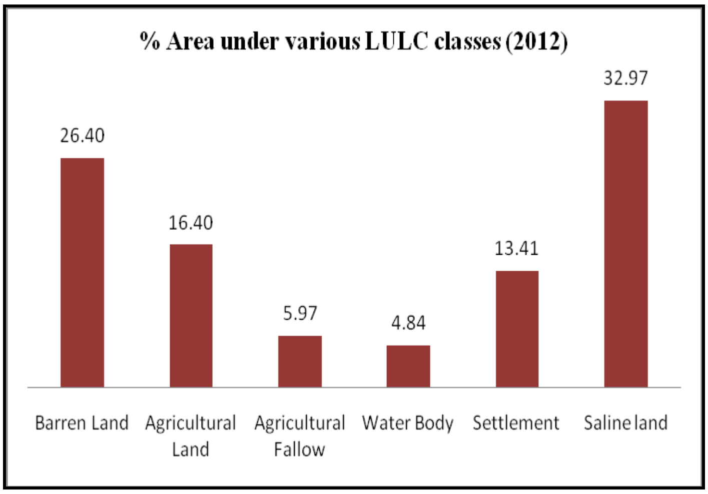


Fig: 3.4

3.4 Land Use Land Cover Classification of 2015:

The False Colour Composite (FCC) image of 2015 (Fig 3.5) shows barren land in whitish tone, water body in blackish blue color, settlements in cyan color, agricultural patches in red tone and agricultural fallow in brownish tone. Saline land in FCC image is very difficult to identify with the help of image interpretation keys because this class mainly comes in mixed pixel as saline lands are actually agricultural fallow lands or even they can belong to agricultural lands. In order to delineate saline lands, GCP's of saline patches were collected from Google earth image of 2015 as well from ground truth data and then the AOI for saline land has been selected.

The LU / LC classified image shows that barren land covers 22.37% area, agricultural land 15.61%, agricultural fallow land 6.20%, water bodies 4.59%, settlements 13.62% and saline land 37.61% of the Daund tahsil in 2015 (Table 3.3). It is evident from the classified image and the data derived from it that salinization problem has become intensified from 2012 to 2015 (Fig 3.6).

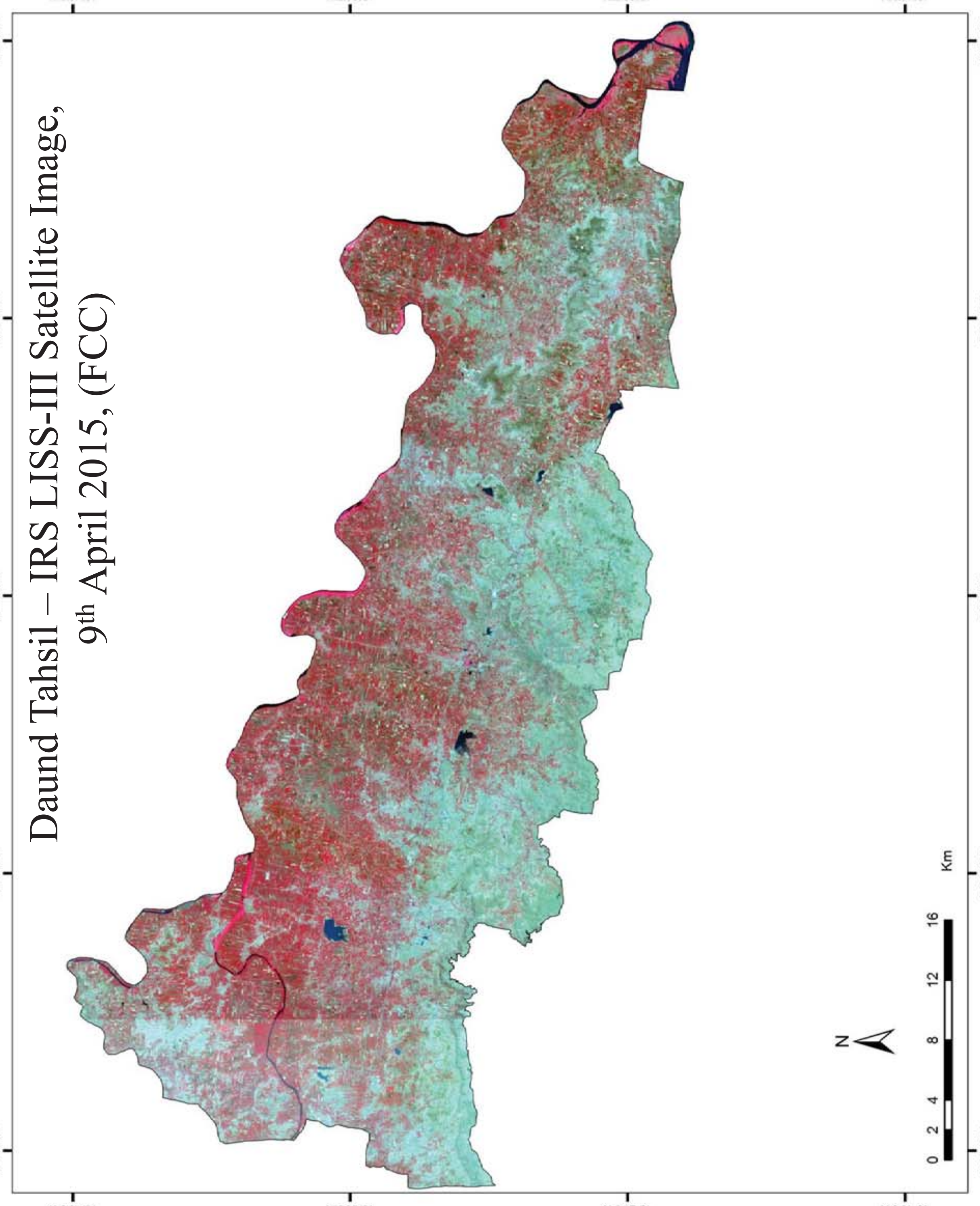

Daund Tahsil – IRS LISS-III Satellite Image,
9th April 2015, (FCC)
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°40'0"N
18°30'0"N
18°20'0"N
18°10'0"N
N
0 2 4 8 12 16
Km

Fig: 3.5

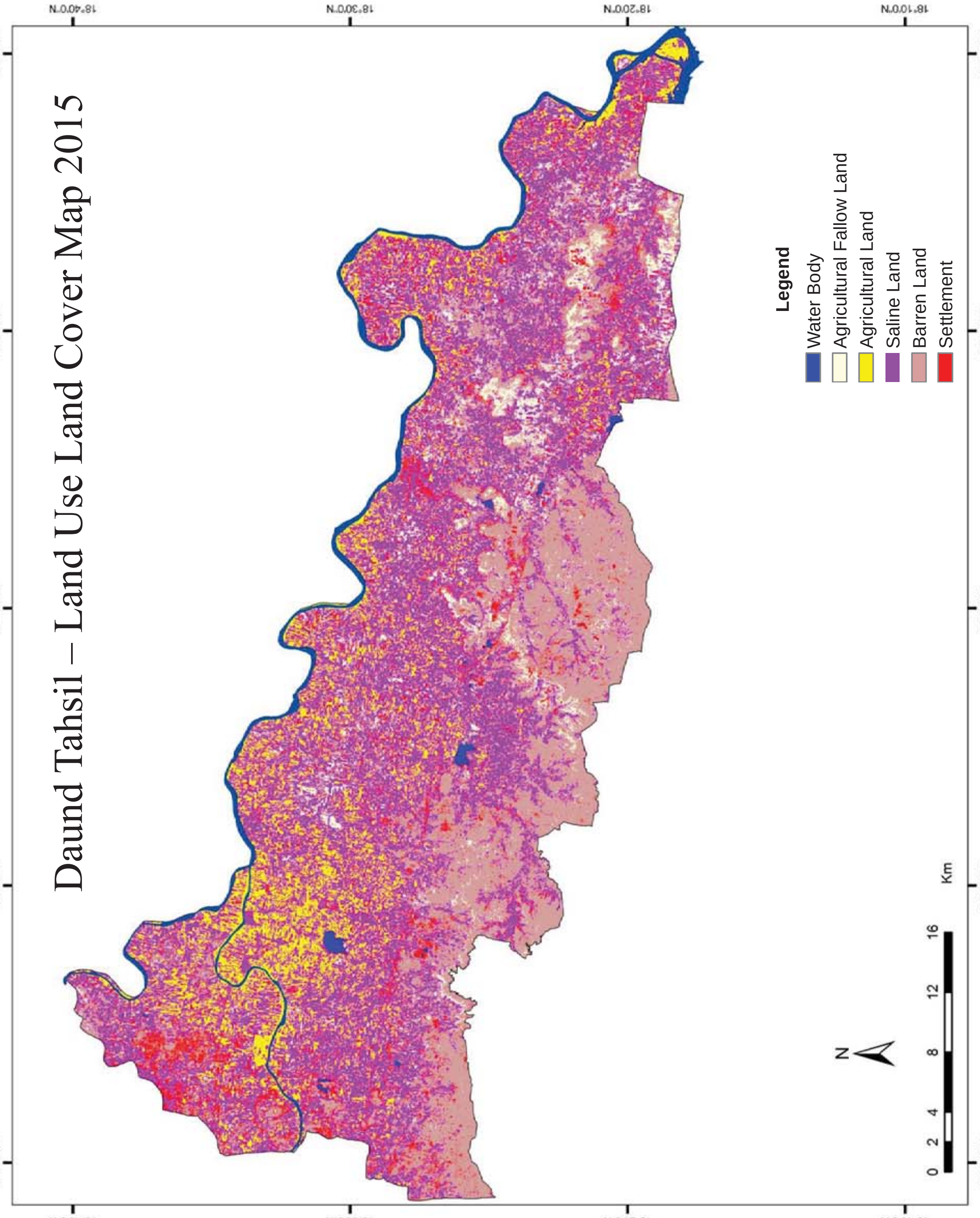

Daund Tahsil – Land Use Land Cover Map 2015
Legend
Water Body
Agricultural Fallow Land
Agricultural Land
Saline Land
Barren Land
Settlement
N
0 2 4 8 12 16
Km
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°10'0"N
18°20'0"N
18°30'0"N
18°40'0"N

Fig: 3.6

Table 3.3: Area under various LU / LC classes in Daund, 2015			
Classes	Area in Ha	Area in sq. km	Area in %
1. Barren Land	30438.60	304.39	22.37
2. Agricultural Land	21231.30	212.31	15.61
3. Agricultural Fallow	8440.30	84.40	6.20
4. Water Body	6237.45	62.37	4.59
5. Settlement	18530.00	185.30	13.62
6. Saline land	**51161.70**	**511.62**	**37.61**
Total	136039.35	1360.39	100.00

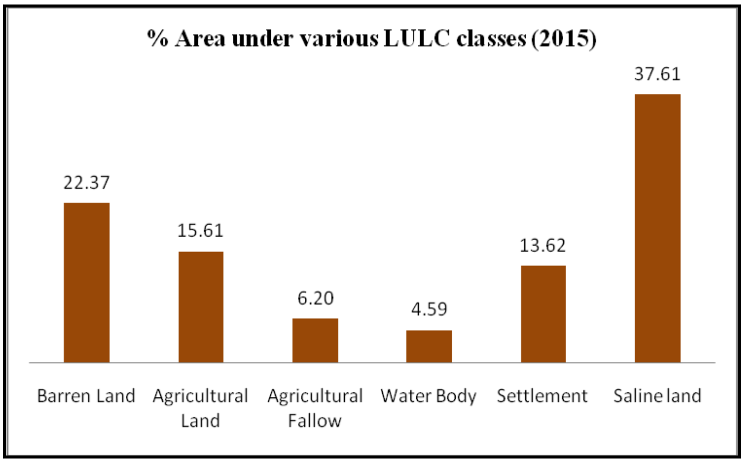


Fig: 3.7

3.5 Detection of Spatio-temporal Variations in Land Use / Land Cover Pattern:

The term Land Use Land Cover is indivisible or inseparable. Land cover refers to all the features on earth’s surface which exist naturally such as natural vegetation, soil cover, rivers and water bodies etc.

On the other hand, the term Land use describes the human use of land, or immediate actions that modify or convert land cover (Sherbinin A.D. 2002). Land use includes agricultural lands, man-made infrastructures, roads etc. that is a part of the land surface. The information about land use and land cover is very important and useful mainly for the purpose of the management of natural resources, their utilization, conservation and management.

Fig 3.3 shows the land use / land cover classes for February 2012. Six major land use classes were obtained from the remotely sensed image. During the classification of image, major emphasis has been given on saline land delineation because it can be clearly observed that almost throughout the Daund tahsil there are significant and noticeable patches of salt encrustation especially over northern part of the study area which is low lying. Hilly slopes of southern part land is unaffected by salinization during 2012. Agricultural land, agricultural fallow land and salt encrusted land are in close proximity among each other. Generally, farmers are mostly misusing irrigation water as a result of which salinization problem has been increasing.

Fig 3.6 shows the land use / land cover classes for April 2015. Six major land use classes were obtained from the remotely sensed image. During the classification of image, major emphasis has been given on saline land delineation because it can be clearly observed that almost throughout the Daund tahsil there are significant and noticeable patches of salt encrustation especially over northern part of the study area which is low lying. During 2015, it is also observed that over valleys in the southern hilly terrain part the process of salinization has started. This indicates that improper use of irrigation water is boosting the salinization problem in the study area and area under salt affected land has been increasing day by day due to continual improper use of irrigation water.

Land use / land cover change detection analysis has been conducted in the study region for a span of 3 years. The reason for selection of a short duration was to analyse vulnerability extent of saline lands in the study region. LU / LC change detection study is increasing as it is attracting attention of researchers and planners since past few decades. In order to study landscape dynamics, change detection analysis is a key tool. For sustainable agricultural practice, natural resource management and environmental monitoring, change detection is of utmost importance. Land use / land cover dynamics have been recognized as an important reason for environmental change on spatial as well as on temporal scales (Tansey et al., 2006). From change detection analysis, it is evident that Daund tahsil has under gone huge changes as far as its saline land extent is concerned. This change is visible even within a short span of 3 years. From the change detection analysis, it is observed that saline land, agricultural fallow land and settlements have witnessed a positve change i.e. areal extent of these classes have increased whereas barren land, agricultural land and water bodies have witnessed negative changes i.e. these areal extent of these classes has decreased (Fig 3.8 Table 3.4).

Table 3.4: Land Use / Land Cover Change Detection Analysis of Daund tahsil

Classes	Area in % 2012	Area in % 2015	Change Detection (in %)
Barren Land	26.40	22.37	-4.03
Agricultural Land	16.40	15.61	-0.80
Agricultural Fallow	5.97	6.20	0.24
Water Body	4.84	4.59	-0.26
Settlement	13.41	13.62	0.21
Saline land	32.97	37.61	4.63
Total	100	100	

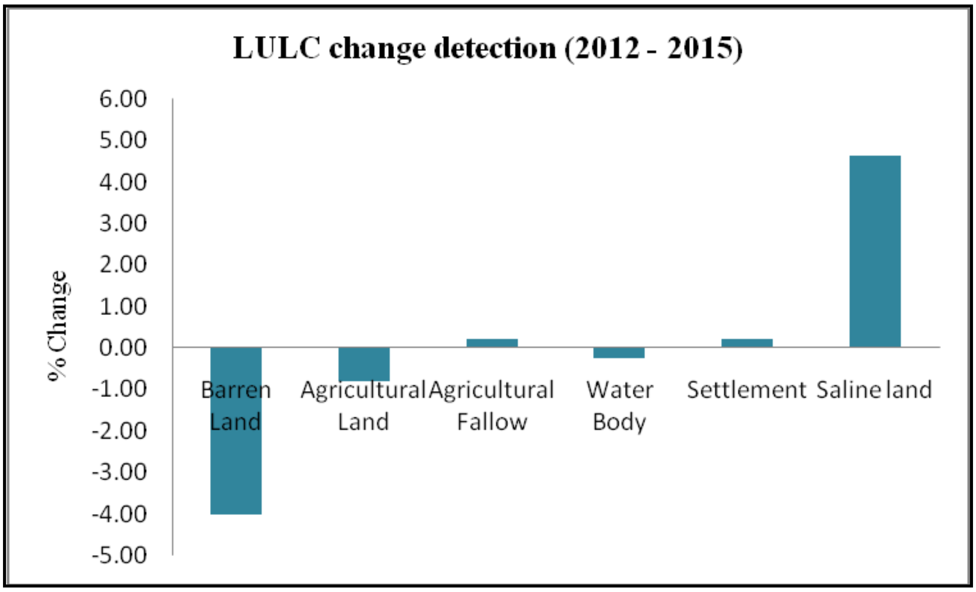


Fig: 3.8

3.5.1 Change in Barren land:

The visual image interpretation of FCC images (2012 and 2015) reveals barren land in whitish tone. From both the images, it is evident that extent of barren land has decreased which is mainly because of increasing land use for settlements. It is also observed that over southern part of the study area, saline land has increased which is replacing the barren land category. Barren land is showing decrease of -4.03% area from 2012 to 2015.

3.5.2 Change in Agricultural land:

The visual image interpretation of FCC images (2012 and 2015) reveals agricultural land in red tone. This class is very hard to distinguish from agricultural fallow land and saline lands because these three classes are closely associated with one another. It has also been observed from the field visit that there are some agricultural fields which are facing the salinization problem. Over some fields, salt encrustation is not visible but as the top soil is few centimeters thick, salts are visible below it. All these agricultural fields are considered as areas under saline lands. Agricultural land is showing a decrease of -0.80% area from 2012 to 2015. This decrease in area is coming under saline land category in 2015.

3.5.3 Change in Agricultural Fallow land

The visual image interpretation of FCC images (2012 and 2015) reveals agricultural fallow land in brownish colour. Agricultural fallow land in the study area is mainly because farmers have abandoned the fields due to salinization problem.

This category of land is mainly observed over villages with acute problem of salinization such as Nangaon, Amonimal etc. Agricultural fallow land is showing an increase of 0.24% area from 2012 to 2015.

3.5.4 Change in Water bodies:

The visual image interpretation of FCC images (2012 and 2015) reveals water bodies in blackish blue colour. Daund tahsil is mainly drained by river Bhima and its right bank tributary. There are many lakes in the study area like Victoria *talav*, Matoba *talav* and Khamgaon *talav.*

Water bodies are showing an -0.26% decrease in area from 2012 to 2015. This decrease is mainly due to the anthropogenic activities and their impacts.

3.5.5 Change in Settlements:

The visual image interpretation of FCC images (2012 and 2015) reveals settlements in cyan colour. The settlements over the study area have increased by 0.21% in 2015 over taking the barren land category.

The visual interpretation of satellite images of Daund city indicates an increase in area from 2012 to 2015.

3.5.6 Change in Saline land:

The saline land class is very difficult to delineate visually because this class encounter the problem of mixed pixels. Remote sensing analysis has made it possible to distinguish and identify this class separately because spectral reflectance values for this class are unique. For saline land delineation, both Google Earth and field data are matched with the data of satellite imageries. Special care has been taken to classify this category of LU / LC.

Saline lands are showing an increase of 4.63% in the study area which is the highest percentage increase among all classes from 2012 to 2015. Saline lands are increasing day by day mainly because of improper use of irrigation water, water logged condition in the fields, reluctant nature of farmers towards the problem and closed water draining channels. Saline lands are also observed over the southern part of the study area which is coming under hilly region. In 2012, only few patches over valleys have experienced the salinization problem, but in 2015 the extent of these saline patches have increased which indicates that salinization issue is continuously intensifying in Daund tahsil making most of the agricultural land infertile for crop growth and agricultural production.

-x-x-x-

CHAPTER IV

SOIL SALINITY INDICES USING REMOTE SENSING

4.1 Introduction:

Modern geospatial technology techniques such as remote sensing and GIS (Geographical Information System) have been extensively used to identify soil salinity. Such techniques reduce the laborious work of field soil data collection and laboratory based soil testing work to a great extent. Satellite imageries can also be used to monitor both spatial and temporal variations of soil salinity (Csillag et al. 1993).

Remotely sensed data i.e. satellite imageries and digital image processing (D.I.P.) techniques are extremely effective in the detection of the soil salinity by generating various vegetation and salinity indices.

In remote sensing, generally the electromagnetic energy reflected from targets is used to acquire information about the earth’s surface. The spectral reflectance of the salt features at the surface of soil has been extensively studied using remote sensing data and it has been used as a direct indicator for detection and mapping of soil salinity. Soil salinity indices detect salt mineral in soils based on the different responses of salty soils to various spectral bands of a satellite image.

The sensors scan only the surface of soil, while the entire soil profile is involved in the process of soil salinization and it is important the entire soil profile should be considered. This limitation of remote sensing data indicates the necessity of using other data and techniques, along with remote sensing data (Farifteh, 2006).

When the amount of soil moisture is too high or the salt in the surface of the crust is not clearly visible or totally invisible on the surface of soil or the salts are mixed with other components of soil, this approach of soil salinity mapping becomes complicated and may yield incorrect results as these factors highly influence the spectral reflectance of soil.

Satellite remote sensing data is the only useful data source when data is required for large areas or regions. Hence, this method gives a wide coverage, it is faster than ground methods of soil salinity mapping, and it also facilitates long term monitoring of the soil salinity changes.

4.2 Methodology:

LANDSAT satellite images were used for the purpose of soil salinity mapping. Latest remotely sensed data i.e. latest available satellite image was downloaded from the U.S.G.S (United States Geological Survey) website.

LANDSAT-8 OLI (Operational Land Imager Sensor) satellite image of the year 2017 having spatial resolution of 30 meters was used for the calculation of various soil salinity indices in the study region and preparation of soil salinity maps of Daund tahsil.

The satellite image has been acquired for the month of April 2017 as the cloud cover is generally minimum in this month and the satellite image is mostly with higher values of salt concentration and surface reflectance. The date of acquisition of LANDSAT satellite image was April 17th, 2017. (Fig. 4.1)

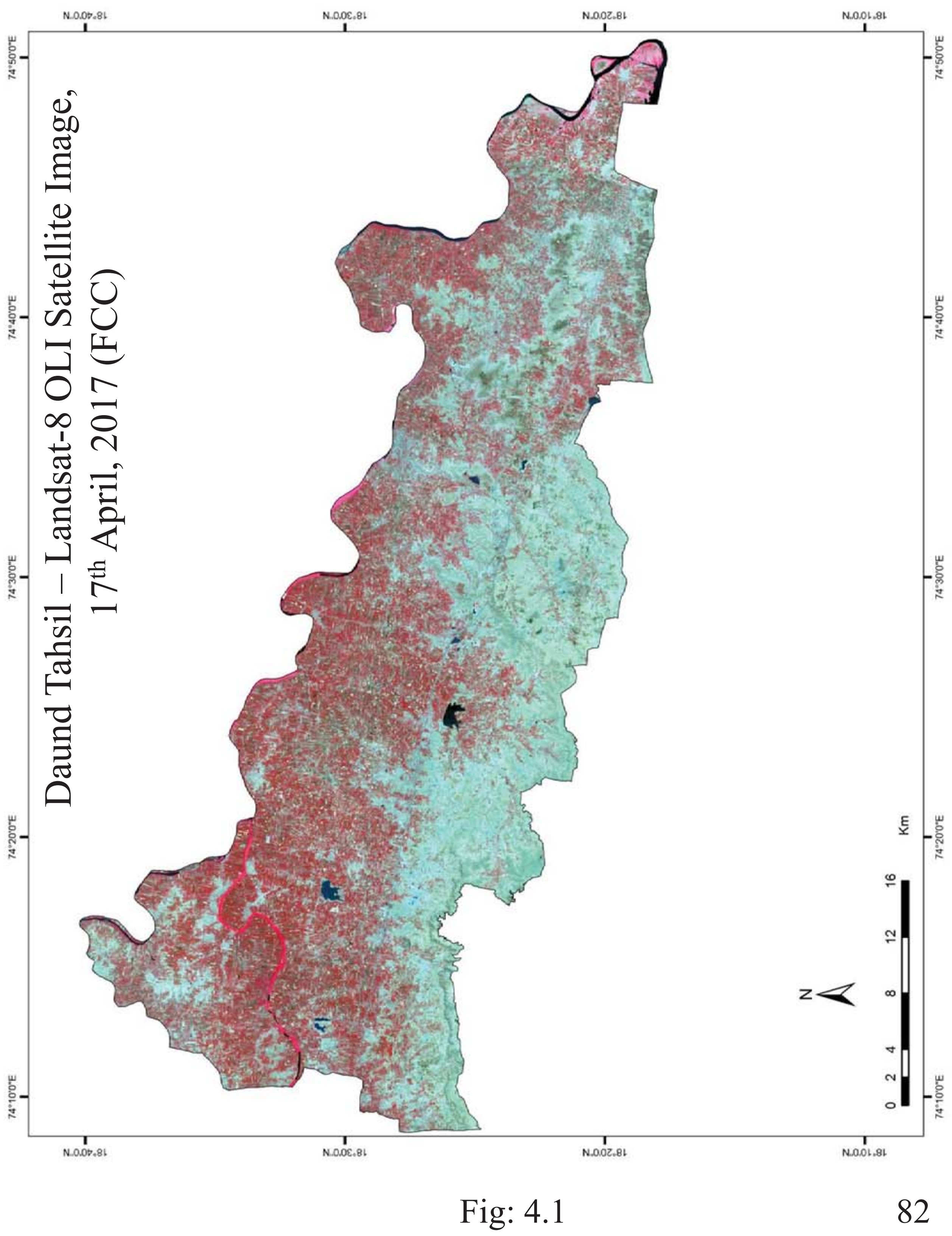

Daund Tahsil – Landsat-8 OLI Satellite Image,
17th April, 2017 (FCC)
18°40'0"N
18°30'0"N
18°20'0"N
18°10'0"N
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
N
0 2 4 8 12 16
Km

Fig: 4.1

Digital Image Processing of LANDSAT-8 OLI satellite image was performed in ERDAS software for generating various soil salinity indices. The first step in the digital image analysis is the application of pre-processing techniques to the multi-temporal and multi-spectral LANDSAT satellite image. The calibration of reflectance has been applied by deriving the reflectance value from the Digital Number (DN) and calculating the top of atmosphere reflectance (TOA). In other words, the digital satellite image has been pre-processed in GIS software to convert digital numbers to top of atmosphere reflectance by using metadata provided.

Standard atmospheric and radiometric corrections and spatial resolution enhancement techniques were applied for each image band separately.

Various combinations of spectral bands along with the reflectance of individual bands have been examined for the assessment of soil salinity by generating different vegetation and soil salinity indices.

These indices which are useful to infer the degree of soil salinity are SAVI (Soil Adjusted Vegetation Index), NDSI (Normalized Difference Salinity Index), Salinity Index 1, Salinity Index 2, Salinity Index 3, Salinity Index 4, Salinity Index 5, Salinity Index 6, Salinity Index 7, Salinity Index 8, and Salinity Index 9.

Soil salinity indices based on different band ratios of LANDSAT along with their formulae are outlined as follows:

i. **Normalized Difference Salinity Index (NDSI)**
NDSI = (R – NIR) / (R + NIR) - Khan et al., 2005

ii. **Salinity Index 1**
SI1 = (Sqrt (B*R)) - Douaoui et al. 2006

iii. **Salinity Index 2**
SI2 = (Sqrt (G*R)) - Khan et al., 2005

iv. **Salinity Index 3**
SI3 = Sqrt ($G^2 + R^2 + NIR^2$) - Douaoui et al. 2006

v. Salinity Index 4

SI4 = Sqrt ($G^2 + R^2$) - Douaoui et al. 2006

vi. Salinity Index 5

SI5 = (B/R) - Bannari et al. 2008

vii. Salinity Index 6

SI6 = (B - R) / (B + R) - Bannari et al. 2008

viii. Salinity Index 7

SI7 = (G*R) / B - Bannari et al. 2008

ix. Salinity Index 8

SI8 = (B*R) / G - Abbas and Khan, 2007

x. Salinity Index 9

SI9 = (R*NIR) / G - Abbas and Khan, 2007

xi. Soil Adjusted Vegetation Index (SAVI)

SAVI = [(NIR – R)*(1+L)] / (NIR+R+L) - Huete A.R., 1988

Where:

NIR = the reflectance value of the near infrared band Landsat 8 image.

R = the reflectance value of the red band Landsat 8 image.

L = the correction factor for soil brightness.

B = the reflectance value of the blue band of Landsat 8 image.

G = the reflectance value of the green band of Landsat 8 image

The formulae of various vegetation and salinity indices used have been written using abbreviations used for spectral bands. Band with wavelength ranging between 0.450 - 0.515 μm is indicated as Blue (B), between 0.525 - 0.600 μm as Green (G), between 0.630 - 0.680 μm as Red (R) and wavelength ranging between 0.845 - 0.885 μm as Near Infrared (NIR).

4.3 Soil Salinity Indices:

Eleven different spectral salinity indices and vegetation indices which have been developed in numerous studies related to salt detection and soil salinity mapping by various scholars were examined for the LANDSAT 8 OLI satellite image in the present study.

For the purpose of calculation of soil salinity indices, a water mask has been prepared for water bodies, because water body class will not be a part of the salinity index classes. Due to the water mask, water body area remains constant for all the maps of salinity indices.

4.3.1 Normalized Difference Salinity Index (NDSI):

The Normalized Difference Salinity Index (NDSI) takes into consideration the Near Infra Red band and Red band for the purpose of assessment of soil salinity. The brightness values in white encrustation can be considered as salt encrusted land. The formula for Normalized Difference Salinity Index (NDSI) is as follows:

NDSI = (R – NIR) / (R + NIR)   - Khan et al., 2005

Where:

R = the reflectance value of the red band Landsat 8 image.

NIR = the reflectance value of the near infrared band Landsat 8 image.

Table 4.1 : Area under various classes of soil salinity according to Normalized Difference Salinity Index (NDSI)

Classes	Area in ha	Area in sq. km	Area in %
Highly Saline (< -0.40)	32362.26	323.62	23.79
Moderately Saline (-0.40 to -0.30)	27205.01	272.05	20.00
Slightly Saline (-0.30 to -0.20)	31435.91	314.36	23.11
Non Saline Land (> -0.20)	37370.77	373.71	27.47
Water bodies	7665.40	76.65	05.63
Total	136039.35	1360.39	100.00

The Normalized Difference Salinity Index (NDSI) classified the image (Fig. 4.2) into four classes viz. highly saline (< -0.40), moderately saline (-0.40 to -0.30), slightly saline (-0.30 to -0.20), and non saline land (> -0.20). The quantitative analysis of this index shows that highly saline area covers 23.79 %, moderately saline area 20 %, slightly saline area 23.11 %, non saline land area 27.47% and area under water bodies is 5.63% of the total area.

Among all these classes, highly saline land covers a major part of the study area under saline land category. Highly saline lands are observed almost over the entire region including western, northern, central and eastern parts which cover a large portion of the study area. Moderately saline lands are scattered all over the study area in association with the highly saline lands.

Slightly saline lands are mainly found over valleys in southern part of the study area and also in patches over northern, western and eastern part of the Daund tahsil in association with highly saline lands. This category of land indicates severity of salinization problem because land coming under this category indicates that salinization problem has just started over this zone.

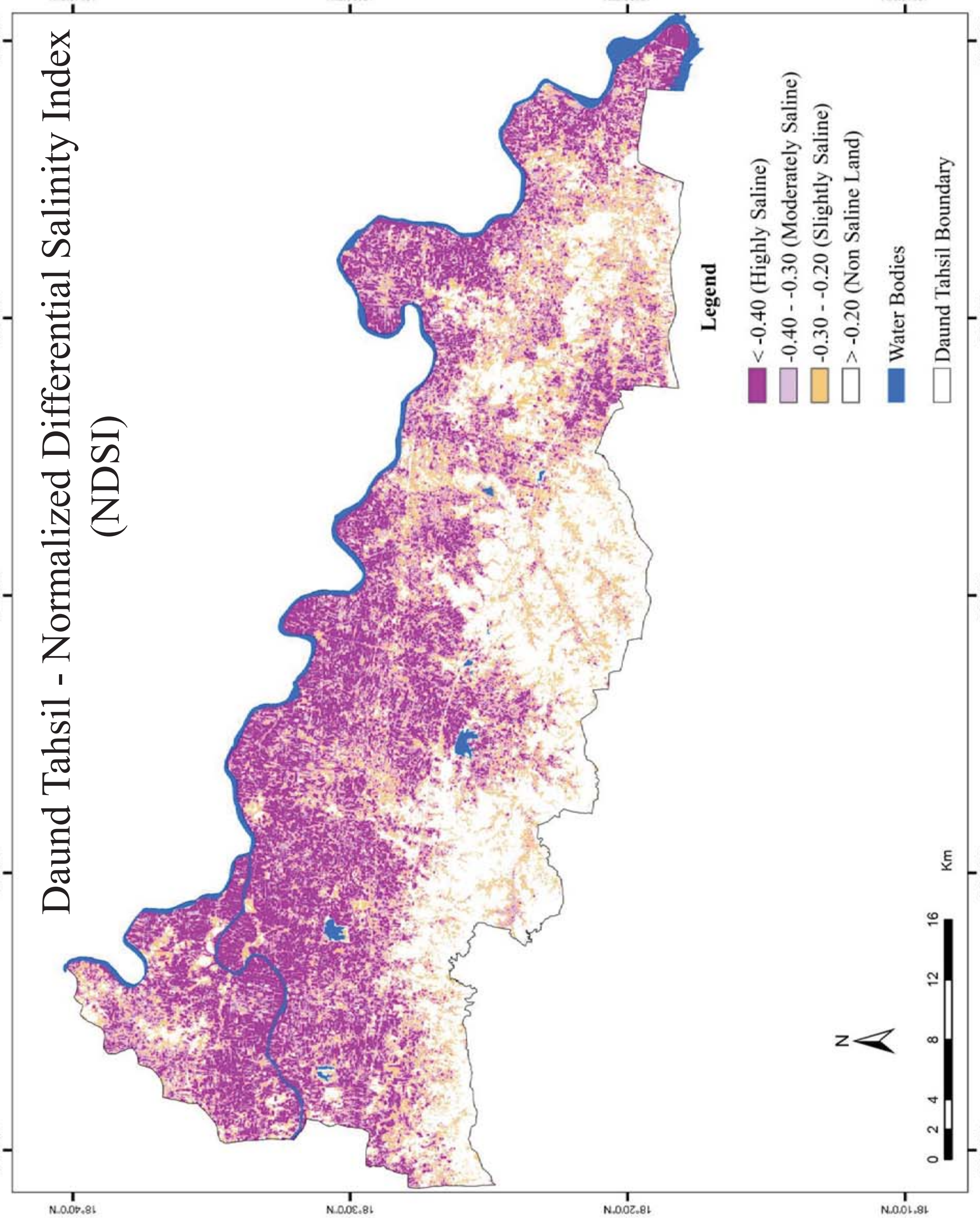

Daund Tahsil - Normalized Differential Salinity Index (NDSI)
Legend
< -0.40 (Highly Saline)
-0.40 - -0.30 (Moderately Saline)
-0.30 - -0.20 (Slightly Saline)
> -0.20 (Non Saline Land)
Water Bodies
Daund Tahsil Boundary
N
0 2 4 8 12 16
Km
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°40'0"N
18°30'0"N
18°20'0"N
18°10'0"N

Fig: 4.2

4.3.2 Salinity Index 1:

Salinity index 1 is derived by taking the square root of the product of blue and red bands. The formula for Salinity Index 1 is as follows:

SI1 = (Sqrt (B*R)) - Douaoui et al. 2006

Where:

B = the reflectance value of the blue band of Landsat 8 image.

R = the reflectance value of the red band Landsat 8 image.

Table 4.2: Area under various classes of soil salinity according to Salinity Index 1

Classes	Area in ha	Area in sq. km	Area in %
Highly Saline (< 0.09)	28447.25	284.47	20.91
Moderately Saline (0.09 to 0.10)	22396.47	223.96	16.46
Slightly Saline (0.10 to 0.11)	19636.29	196.36	14.43
Non Saline Land (> 0.11)	57893.94	578.94	42.56
Water bodies	7665.40	76.65	05.63
Total	136039.35	1360.39	100.00

The salinity index 1 classified the image (Fig. 4.3) into four classes viz. highly saline (<0.09), moderately saline (0.09 to 0.10), slightly saline (0.10 to 0.11), and non saline land (> 0.11). The quantitative analysis of this index shows that highly saline area covers 20.91%, moderately saline 16.46%, slightly saline 14.43%, non saline land 42.56% and water bodies cover 5.63% of the total area.

Highly saline lands are observed over the northern part of the study area specifically along the canal. Moderately saline lands are scattered over the northern, central and southern regions. Slightly saline lands are mainly found over valleys in southern part of the study area. This category of land indicates that the process of salinization has also started over the southern part of Daund tahsil.

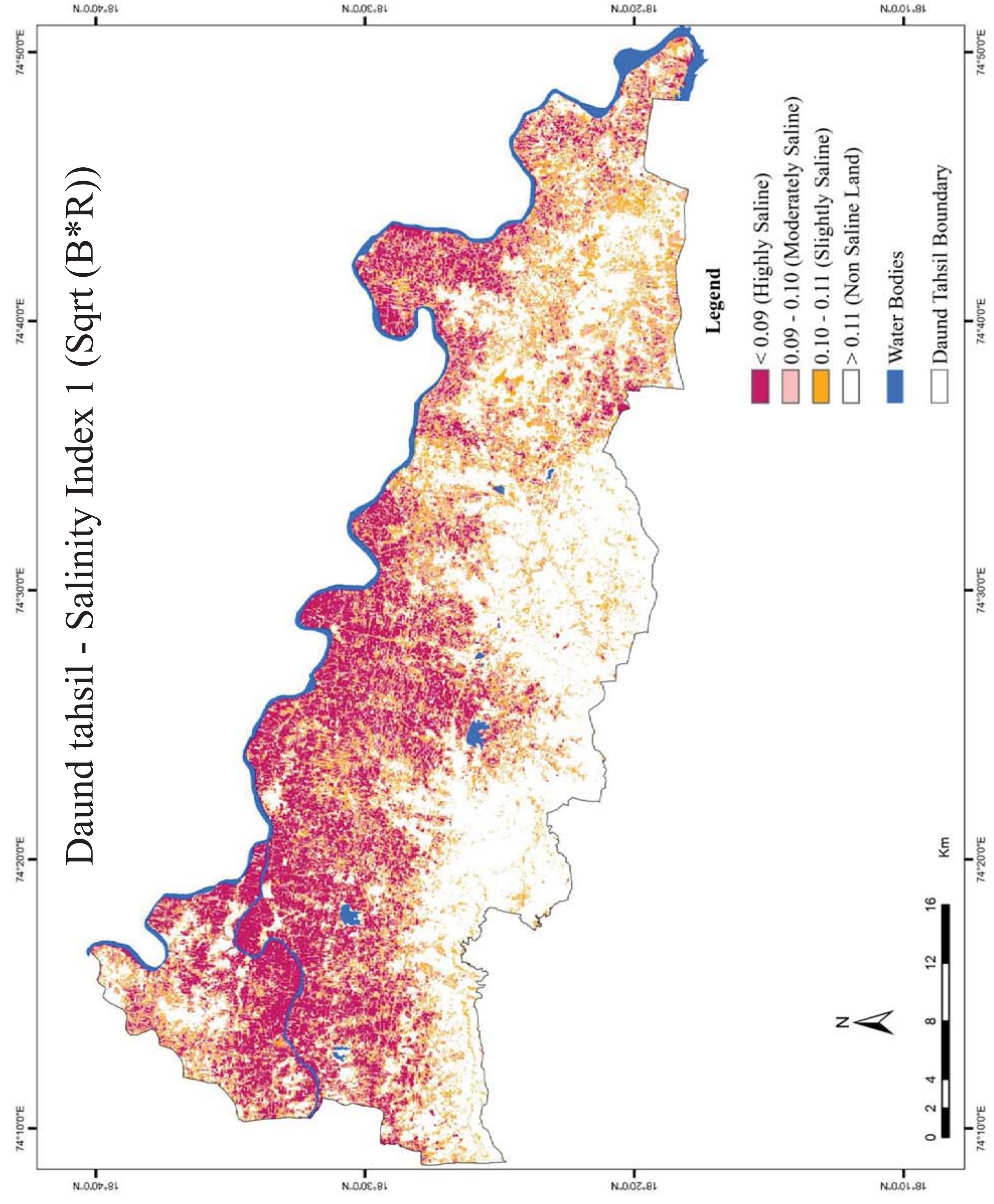

Daund tahsil - Salinity Index 1 (Sqrt (B*R))
Legend
< 0.09 (Highly Saline)
0.09 - 0.10 (Moderately Saline)
0.10 - 0.11 (Slightly Saline)
> 0.11 (Non Saline Land)
Water Bodies
Daund Tahsil Boundary
N
0 2 4 8 12 16
Km
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°10'0"N
18°20'0"N
18°30'0"N
18°40'0"N

Fig: 4.3

4.3.3 Salinity Index 2:

Salinity index 2 is derived by taking the square root of the product of blue and red bands. The formula for Salinity Index 2 is as follows:

SI2 = (Sqrt (G*R)) - Khan et al., 2005

Where:

G = the reflectance value of the green band of Landsat 8 image.

R = the reflectance value of the red band Landsat 8 image.

Table 4.3: Area under various classes of soil salinity according to Salinity Index 2

Classes	Area in ha	Area in sq. km	Area in %
Highly Saline (< 0.08)	18783.36	187.83	13.81
Moderately Saline (0.08 to 0.10)	39532.90	395.33	29.06
Slightly Saline (0.10 to 0.12)	35733.73	357.34	26.27
Non Saline Land (> 0.12)	34323.96	343.24	25.23
Water bodies	7665.40	76.65	05.63
Total	136039.35	1360.39	100.00

The salinity index 2 classified the image (Fig. 4.4) into four classes viz. highly saline (<0.08), moderately saline (0.08 to 0.10), slightly saline (0.10 to 0.12), and non saline land (> 0.12). The quantitative analysis of this index shows that highly saline area covers 13.81 %, moderately saline 29.06 %, slightly saline 26.27 %, non saline land 25.23 % and water bodies cover 5.63% of the total area. Highly saline lands are observed over the northern low lying parts of the study area specifically along the canal and river. Moderately saline lands are scattered all over the study area. Slightly saline lands are mainly found over valleys in southern part of the study area. This category of land is an indication that the salinization problem has also started over the southern part of Daund tahsil.

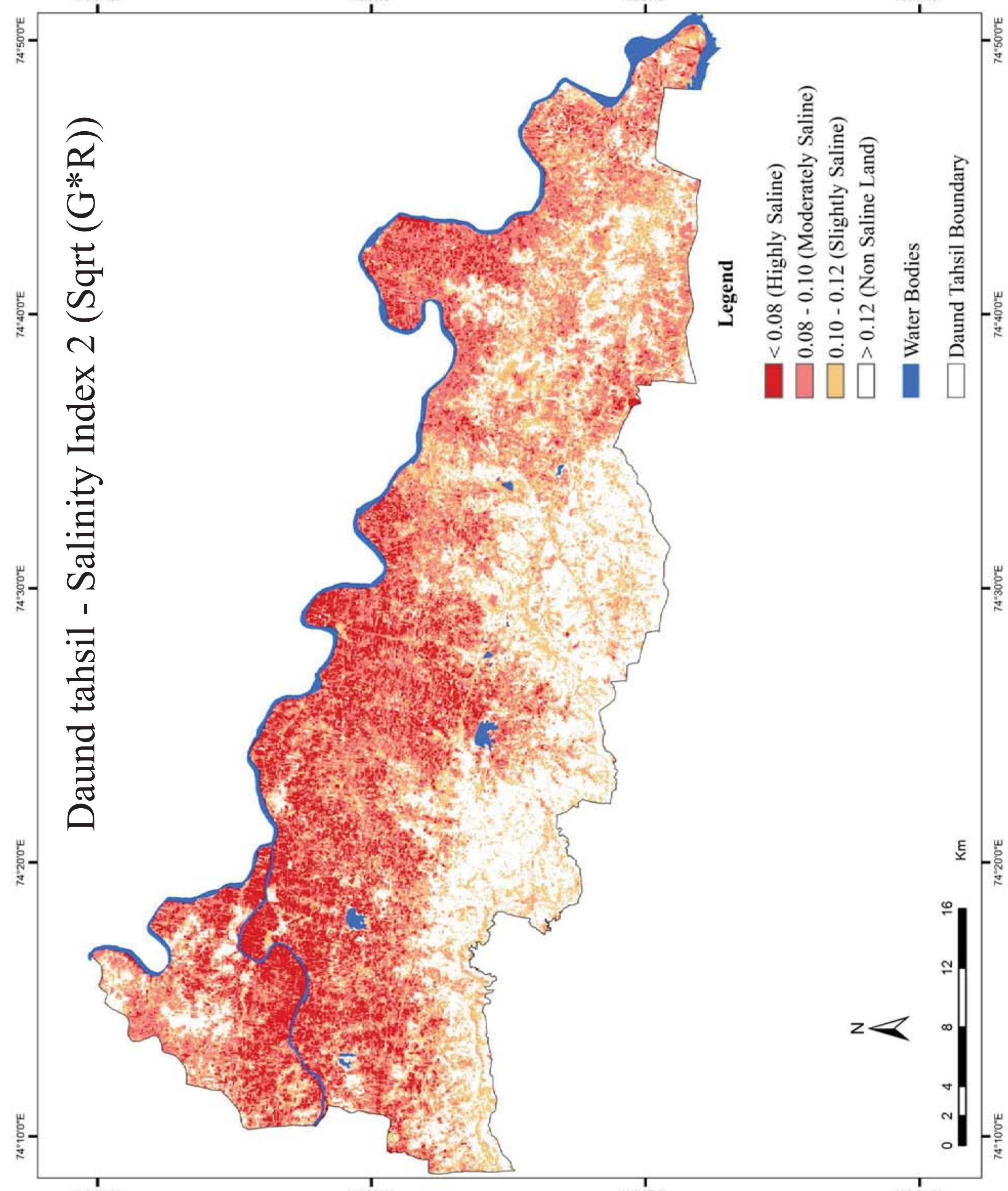

Daund tahsil - Salinity Index 2 (Sqrt (G*R))
Legend
< 0.08 (Highly Saline)
0.08 - 0.10 (Moderately Saline)
0.10 - 0.12 (Slightly Saline)
> 0.12 (Non Saline Land)
Water Bodies
Daund Tahsil Boundary
N
0 2 4 8 12 16
Km
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°10'0"N
18°20'0"N
18°30'0"N
18°40'0"N

Fig: 4.4

4.3.4 Salinity Index 3:

Salinity index 3 is derived by taking the square root of the sum of the squares of green, red and near infra red bands. The formula for Salinity Index 3 is as follows:

$SI3 = Sqrt (G^2 + R^2 + NIR^2)$ - Douaoui et al. 2006

Where:

G = the reflectance value of the green band of Landsat 8 image.

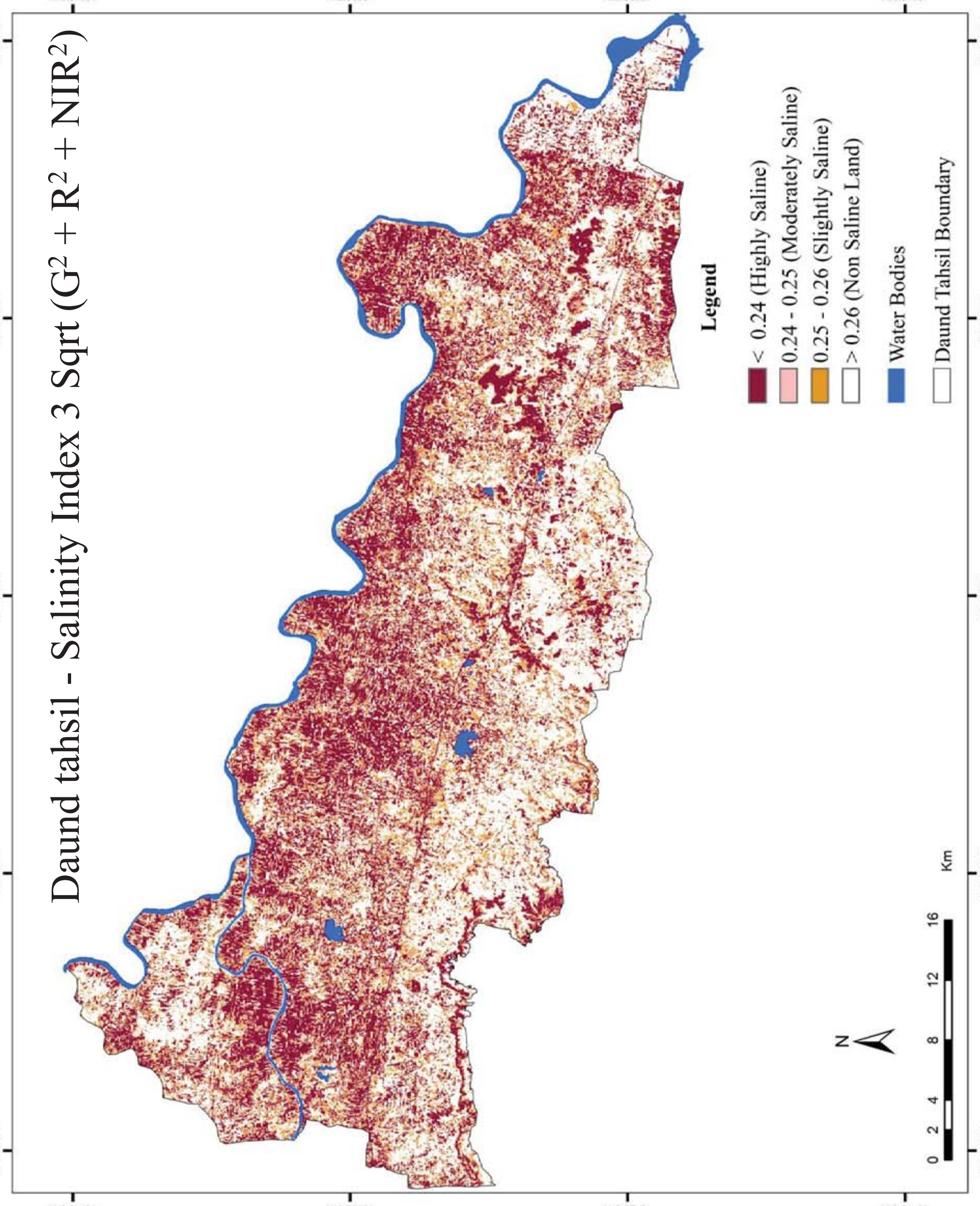
R = the reflectance value of the red band Landsat 8 image.

NIR = the reflectance value of the near infrared band Landsat 8 image.

Table 4.4: Area under various classes of soil salinity according to Salinity Index 3

Classes	Area in ha	Area in sq. km	Area in %
Highly Saline (< 0.24)	40310.17	403.10	29.63
Moderately Saline (0.24 to 0.25)	17469.25	174.69	12.84
Slightly Saline (0.25 to 0.26)	16314.50	163.15	11.99
Non Saline Land (> 0.26)	54280.03	542.80	39.90
Water bodies	7665.40	76.65	05.63
Total	136039.35	1360.39	100.00

The salinity index 3 classified the image (Fig. 4.5) into four classes viz. highly saline (<0.24), moderately saline (0.24 to 0.25), slightly saline (0.25 to 0.26), and non saline land (> 0.26). The quantitative analysis of this index shows that highly saline area covers 29.63 %, moderately saline 12.84 %, slightly saline 11.99 %, non saline land 39.90 % and water bodies cover 5.63% of the total area. Among all these classes, highly saline land covers a major part of the study area. Highly saline lands are observed almost over the entire region. Moderately saline lands are scattered all over the study area. Slightly saline lands are mainly found over valleys in the southern part of the study area. This category of land indicates salinization problem has also started over the southern part of Daund tahsil.



Daund tahsil - Salinity Index 3 Sqrt ($G^2 + R^2 + NIR^2$)
Legend
< 0.24 (Highly Saline)
0.24 - 0.25 (Moderately Saline)
0.25 - 0.26 (Slightly Saline)
> 0.26 (Non Saline Land)
Water Bodies
Daund Tahsil Boundary
N
0 2 4 8 12 16
Km
18°40'0"N
18°30'0"N
18°20'0"N
18°10'0"N
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E

Fig: 4.5

4.3.5 Salinity Index 4:

Salinity index 4 is derived by taking the square root of the sum of the squares of green and red bands. The formula for Salinity Index 4 is as follows:

$SI4 = Sqrt (G^2 + R^2)$ - Douaoui et al. 2006

Where:

G = the reflectance value of the green band of Landsat 8 image.

R = the reflectance value of the red band Landsat 8 image.

Table 4.5: Area under various classes of soil salinity according to Salinity Index 4

Classes	Area in ha	Area in sq. km	Area in %
Highly Saline (< 0.13)	43132.73	431.33	31.71
Moderately Saline (0.13 to 0.15)	22315.83	223.16	16.40
Slightly Saline (0.15 to 0.17)	22705.86	227.06	16.69
Non Saline Land (> 0.17)	40219.53	402.20	29.56
Water bodies	7665.40	76.65	05.63
Total	136039.35	1360.39	100.00

The map of salinity index 4 (Fig. 4.6) shows four classes viz. highly saline (<0.13), moderately saline (0.13 to 0.15), slightly saline (0.15 to 0.17), and non saline land (> 0.17). Highly saline area covers 31.71 %, moderately saline 16.40 %, slightly saline 16.69 %, non saline land 29.56 % and water bodies 5.63% of the total area. Highly saline land covers a major part out of the saline land category in the study area. Highly saline lands are observed almost over the entire region except hilly mountainous regions over the southern part. Moderately saline lands are scattered all over the study area in association with the highly saline lands. Slightly saline lands are mainly found over valleys in southern part of the study area and also in few pockets over northern part of the Daund tahsil. This category of land indicates the severity of salinization problem because land coming under this category indicates that salinization has just started in these regions.

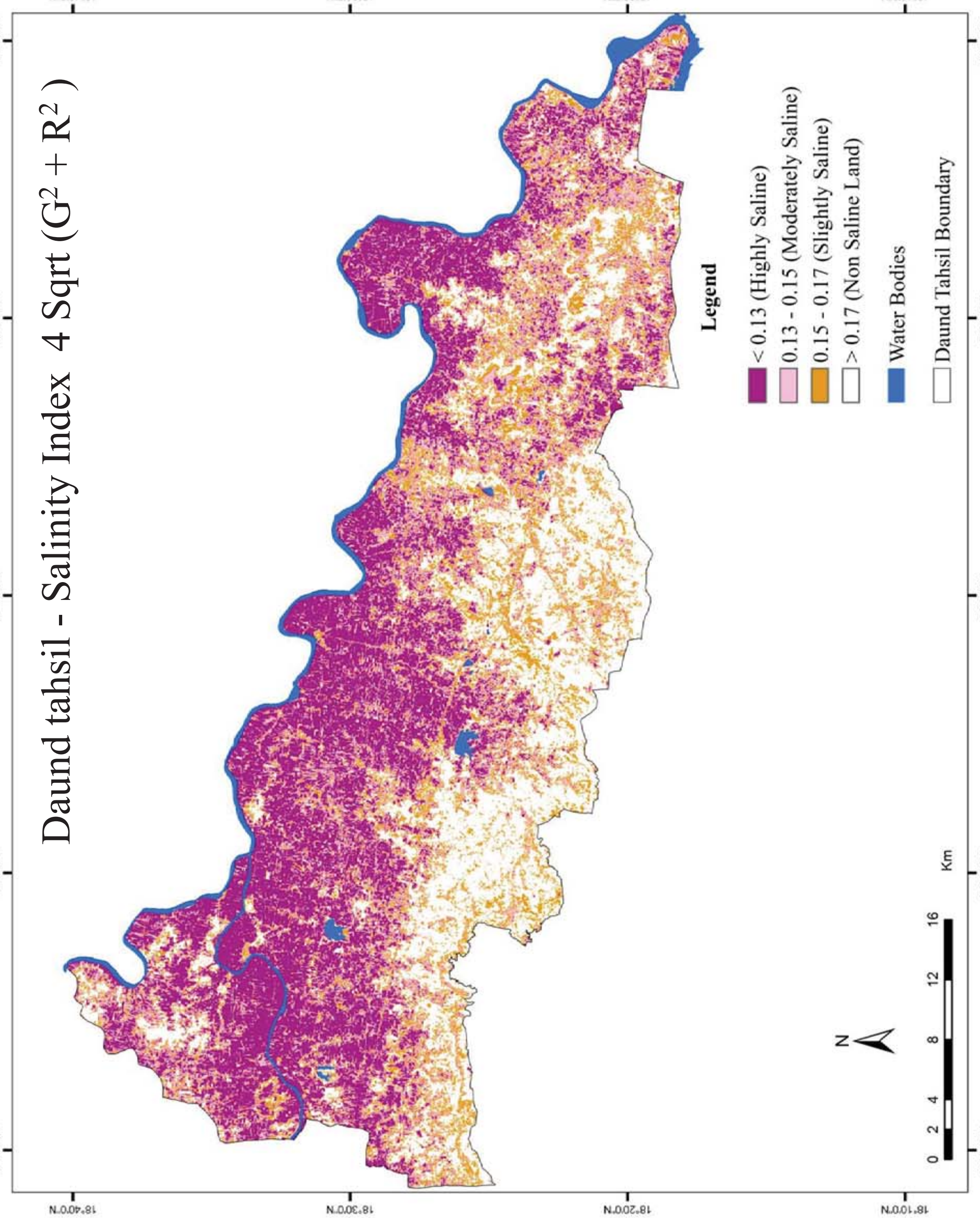

Daund tahsil - Salinity Index 4 Sqrt ($G^2 + R^2$)
Legend
< 0.13 (Highly Saline)
0.13 - 0.15 (Moderately Saline)
0.15 - 0.17 (Slightly Saline)
> 0.17 (Non Saline Land)
Water Bodies
Daund Tahsil Boundary
N
0 2 4 8 12 16
Km
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°40'0"N
18°30'0"N
18°20'0"N
18°10'0"N

Fig: 4.6

4.3.6 Salinity Index 5:

Salinity index 5 is the ratio of blue and red spectral bands. The formula for Salinity Index 5 is as follows:

$$SI5 = (B/R)$$ - Bannari et al. 2008

Where:
B = the reflectance value of the blue band of Landsat 8 image.

R = the reflectance value of the red band Landsat 8 image.

Table 4.6: Area under various classes of soil salinity according to Salinity Index 5

Classes	Area in ha	Area in sq. km	Area in %
Highly Saline (> 1.2)	25103.78	251.04	18.45
Moderately Saline (1.1 to 1.2)	16233.15	162.33	11.93
Slightly Saline (1.0 to 1.1)	18433.52	184.34	13.55
Non Saline Land (< 1.0)	68603.50	686.04	50.43
Water bodies	7665.40	76.65	05.63
Total	136039.35	1360.39	100.00

According to the salinity index 5 (Fig. 4.7), there are four classes viz. highly saline (> 1.2), moderately saline (1.0 to 1.1), slightly saline (1.1 to 1.2), and non saline land (<1.0). Highly saline area covers 18.45 %, moderately saline 11.93 %, slightly saline 13.55 %, non saline land 50.43 % and water bodies cover 5.63% of total area. Highly saline land covers a major part out of the saline land category in the study area. Highly saline lands are observed almost over entire region except hilly mountainous regions over the southern part. Moderately saline lands are scattered all over the study area in association with the highly saline lands. Slightly saline lands are mainly found over valleys in the southern part of the study area and also in few pockets over northern part of the Daund tahsil in association with highly saline lands. This category indicates the concern of the land becoming salinized in this area.

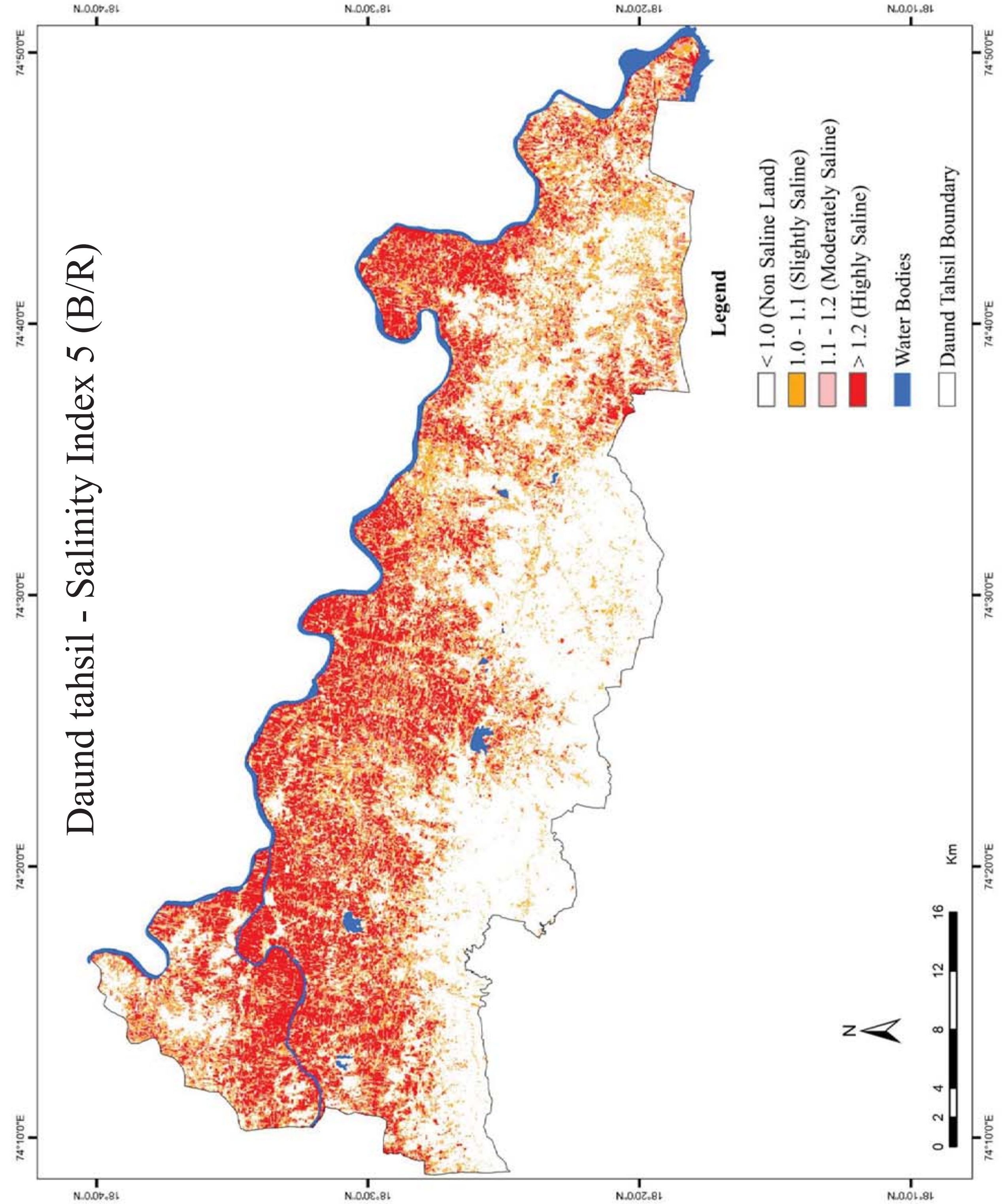

Daund tahsil - Salinity Index 5 (B/R)
Legend
< 1.0 (Non Saline Land)
1.0 - 1.1 (Slightly Saline)
1.1 - 1.2 (Moderately Saline)
> 1.2 (Highly Saline)
Water Bodies
Daund Tahsil Boundary
N
0 2 4 8 12 16
Km
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°40'0"N
18°30'0"N
18°20'0"N
18°10'0"N

Fig: 4.7

4.3.7 Salinity Index 6:

Salinity index 6 is the ratio of the difference between blue and red bands to the sum of blue and red spectral bands. The formula for Salinity Index 6 is as follows:

$$SI6 = (B - R) / (B + R)$$ - Bannari et al. 2008

Where:
B = the reflectance value of the blue band of Landsat 8 image.

R = the reflectance value of the red band Landsat 8 image.

Table 4.7: Area under various classes of soil salinity according to Salinity Index 6

Classes	Area in ha	Area in sq. km	Area in %
Highly Saline (> 0.05)	43567.34	435.67	32.03
Moderately Saline (0.01 to 0.05)	16078.30	160.78	11.82
Slightly Saline (-0.05 to 0.01)	32417.91	324.18	23.83
Non Saline Land (< -0.05)	36310.40	363.10	26.69
Water bodies	7665.40	76.65	05.63
Total	136039.35	1360.39	100.00

According to the salinity index 6 (Fig. 4.8), there are four classes viz. highly saline (> 0.05), moderately saline (0.01 to 0.05), slightly saline (-0.05 to 0.01), and non saline land (< -0.05). Highly saline area covers 32.03 %, moderately saline 11.82 %, slightly saline 23.83 %, non saline land 26.69% and water bodies cover 5.63% of total area. Highly saline land covers a major part of the study area. Highly saline lands are observed almost all over the entire region except hilly mountainous regions over southern part. Moderately saline lands are scattered over southeastern part of the study area in association with the highly saline lands. Slightly saline lands are mainly found over valleys in southern part of the study area and also in patches over northern part of the Daund tahsil in association with highly saline lands. This category of land indicates severity of salinization problem as it has just started over this zone.

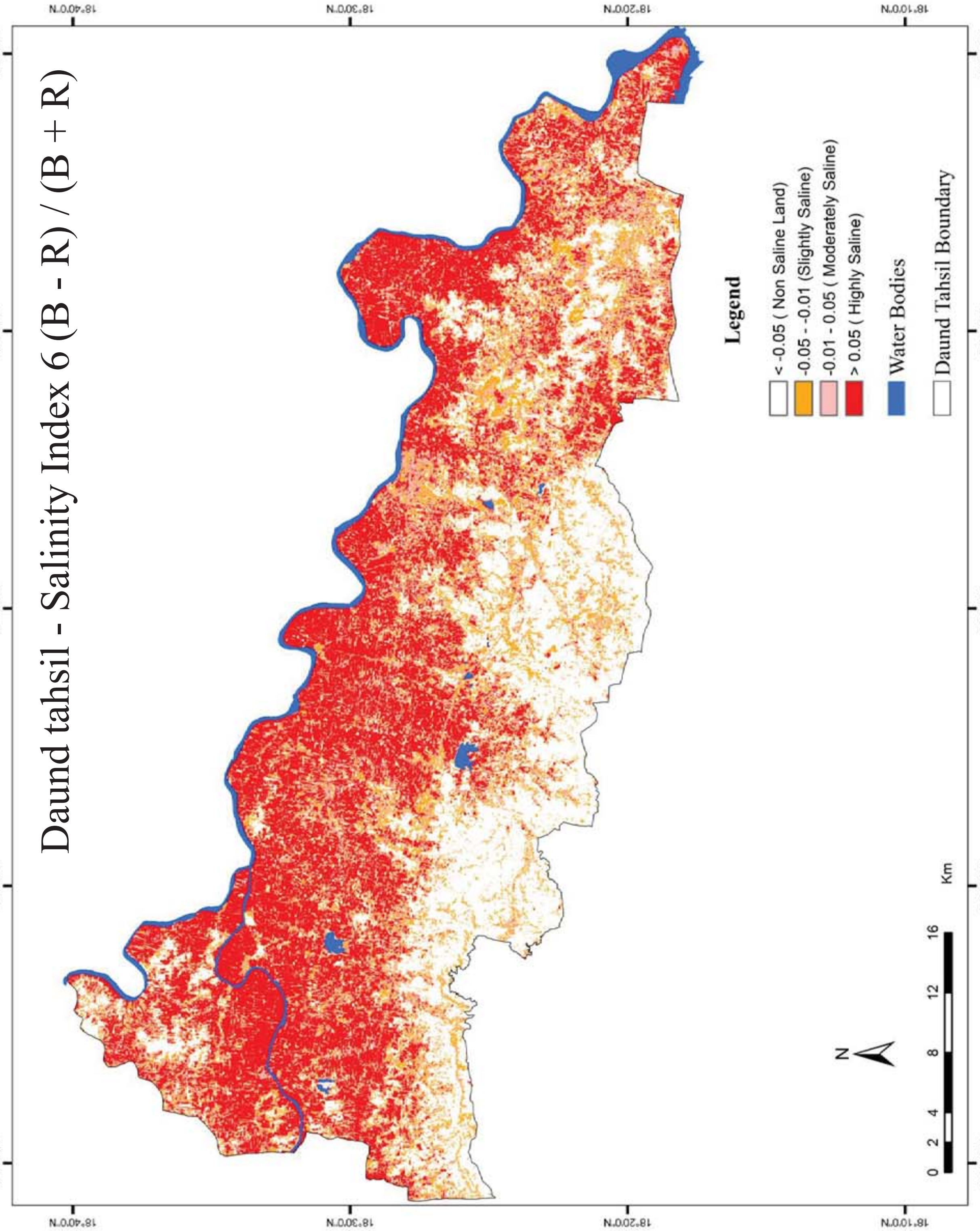

Daund tahsil - Salinity Index 6 (B - R) / (B + R)
Legend
< -0.05 (Non Saline Land)
-0.05 - -0.01 (Slightly Saline)
-0.01 - 0.05 (Moderately Saline)
> 0.05 (Highly Saline)
Water Bodies
Daund Tahsil Boundary
N
0 2 4 8 12 16
Km
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°40'0"N
18°30'0"N
18°20'0"N
18°10'0"N

Fig: 4.8

4.3.8 Salinity Index 7:

Salinity index 7 is the ratio of the product of green and red bands to the blue spectral band. The formula for Salinity Index 7 is as follows:

$$SI7 = (G*R) / B$$ - Bannari et al. 2008

Where:
G = the reflectance value of the green band of Landsat 8 image.
R = the reflectance value of the red band Landsat 8 image.
B = the reflectance value of the blue band of Landsat 8 image.

Table 4.8: Area under various classes of soil salinity according to Salinity Index 7

Classes	Area in ha	Area in sq. km	Area in %
Highly Saline (< 0.08)	40458.34	404.58	29.74
Moderately Saline (0.08 to 0.10)	26936.54	269.37	19.80
Slightly Saline (0.10 to 0.12)	24094.07	240.94	17.71
Non Saline Land (> 0.12)	36885.00	368.85	27.11
Water bodies	7665.40	76.65	05.63
Total	136039.35	1360.39	100.00

The map of salinity index 7 (Fig. 4.9) shows highly saline (< 0.08), moderately saline (0.08 to 0.10), slightly saline (0.10 to 0.12), and non saline land (>0.12). Highly saline area covers 29.74 %, moderately saline 19.80 %, slightly saline 17.71 %, non saline land 27.11%. Highly saline land covers a major part of the study area. Highly saline lands are observed all over the region except hilly mountainous regions over the southern part. Moderately saline lands are scattered over northern, central and southeastern parts and also in few patches in the western part in association with the highly saline lands. Slightly saline lands are found over valleys in southern part and in patches over northwestern part of the Daund tahsil in association with highly saline lands, indicating that the land is becoming salinized in this area.

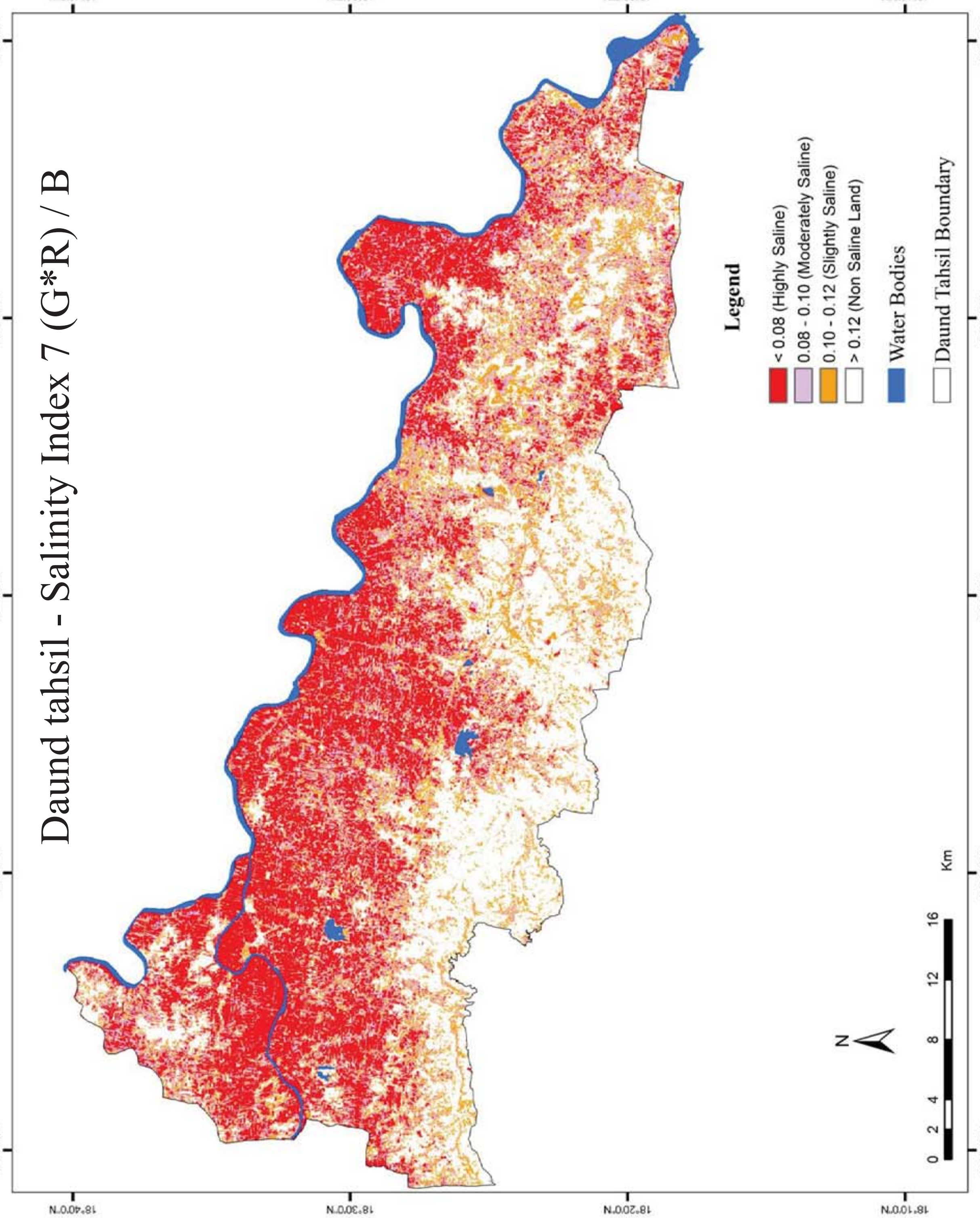

Daund tahsil - Salinity Index 7 (G*R) / B
Legend
< 0.08 (Highly Saline)
0.08 - 0.10 (Moderately Saline)
0.10 - 0.12 (Slightly Saline)
> 0.12 (Non Saline Land)
Water Bodies
Daund Tahsil Boundary
N
0 2 4 8 12 16
Km
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°10'0"N
18°20'0"N
18°30'0"N
18°40'0"N

Fig: 4.9

4.3.9 Salinity Index 8:

Salinity index 8 is the ratio of the product of blue and red bands to the green spectral band. The formula for Salinity Index 8 is as follows:

SI8 = (B*R) / G - Abbas and Khan, 2007

Where:
B = the reflectance value of the blue band of Landsat 8 image.
R = the reflectance value of the red band Landsat 8 image.
G = the reflectance value of the green band of Landsat 8 image.

Table 4.9 : Area under various classes of soil salinity according to Salinity Index 8

Classes	Area in ha	Area in sq. km	Area in %
Highly Saline (< 0.1)	42008.83	420.09	30.88
Moderately Saline (0.10 to 0.12)	30789.71	307.90	22.63
Slightly Saline (0.12 to 0.14)	35211.59	352.12	25.88
Non Saline Land (> 0.14)	20363.82	203.64	14.97
Water bodies	7665.40	76.65	05.63
Total	136039.35	1360.39	100.00

Salinity index 8 map (Fig. 4.10) shows four classes viz. highly saline (< 0.10), moderately saline (0.10 to 0.12), slightly saline (0.12 to 0.14), and non saline land (> 0.14). Highly saline area covers 30.88 %, moderately saline 22.63 %, slightly saline 25.88 %, non saline land 14.97%. Highly saline land covers a major part of the study area. Highly saline lands are observed mainly over northern part of the region which covers a large portion of the study area. Moderately saline lands are scattered all over the study area in association with the highly saline lands. Slightly saline lands are found over valleys in southern part and in patches over northern part of Daund tahsil in association with highly saline lands, indicating the spread of saline lands.

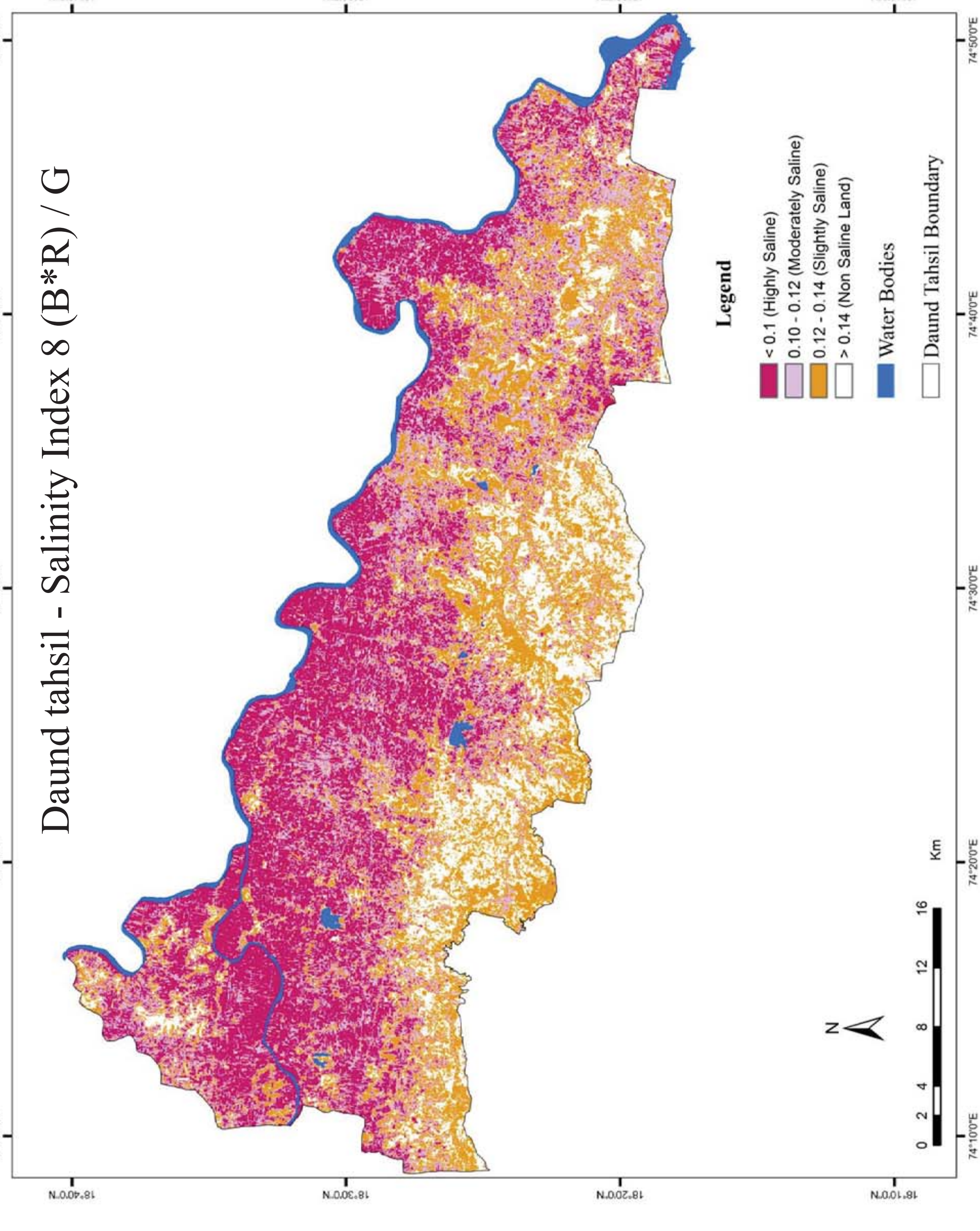

Daund tahsil - Salinity Index 8 (B*R) / G
Legend
< 0.1 (Highly Saline)
0.10 - 0.12 (Moderately Saline)
0.12 - 0.14 (Slightly Saline)
> 0.14 (Non Saline Land)
Water Bodies
Daund Tahsil Boundary
N
0 2 4 8 12 16
Km
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°40'0"N
18°30'0"N
18°20'0"N
18°10'0"N

Fig: 4.10

4.3.10 Salinity Index 9:

Salinity index 9 depends on the growing conditions of vegetation. It is the ratio of the product of red and near infra red bands to the green spectral band. The formula for Salinity Index 9 is as follows:

SI9 = (R*NIR) / G - Abbas and Khan, 2007

Where:
R = the reflectance value of the red band Landsat 8 image.
NIR = the reflectance value of the near infrared band Landsat 8 image. G = the reflectance value of the green band of Landsat 8 image.

Table 4.10 : Area under various classes of soil salinity according to Salinity Index 9

Classes	Area in ha	Area in sq. km	Area in %
Highly Saline (< 0.18)	24345.45	243.45	17.90
Moderately Saline (0.18 to 0.20)	29526.17	295.26	21.70
Slightly Saline (0.20 to 0.22)	36271.39	362.71	26.66
Non Saline Land (> 0.22)	38230.94	382.31	28.10
Water bodies	7665.40	76.65	05.63
Total	136039.35	1360.39	100.00

The map of salinity index 9 (Fig. 4.11) shows four classes viz. highly saline (< 0.18), moderately saline (0.18 – 0.20), slightly saline (0.20 – 0.22), and non saline land (>0.22). Highly saline area covers 17.90 %, moderately saline 21.70 %, slightly saline 26.66 %, non saline land 28.10%. A major part of the area is slightly saline land which covers entire region staring from northern, central, eastern and southern part. Highly saline land covers area along the canal and a few patches over the eastern and southern parts of the Daund tahsil. Moderately saline lands are scattered over northern, central and southeastern parts and also in patches in the western part.

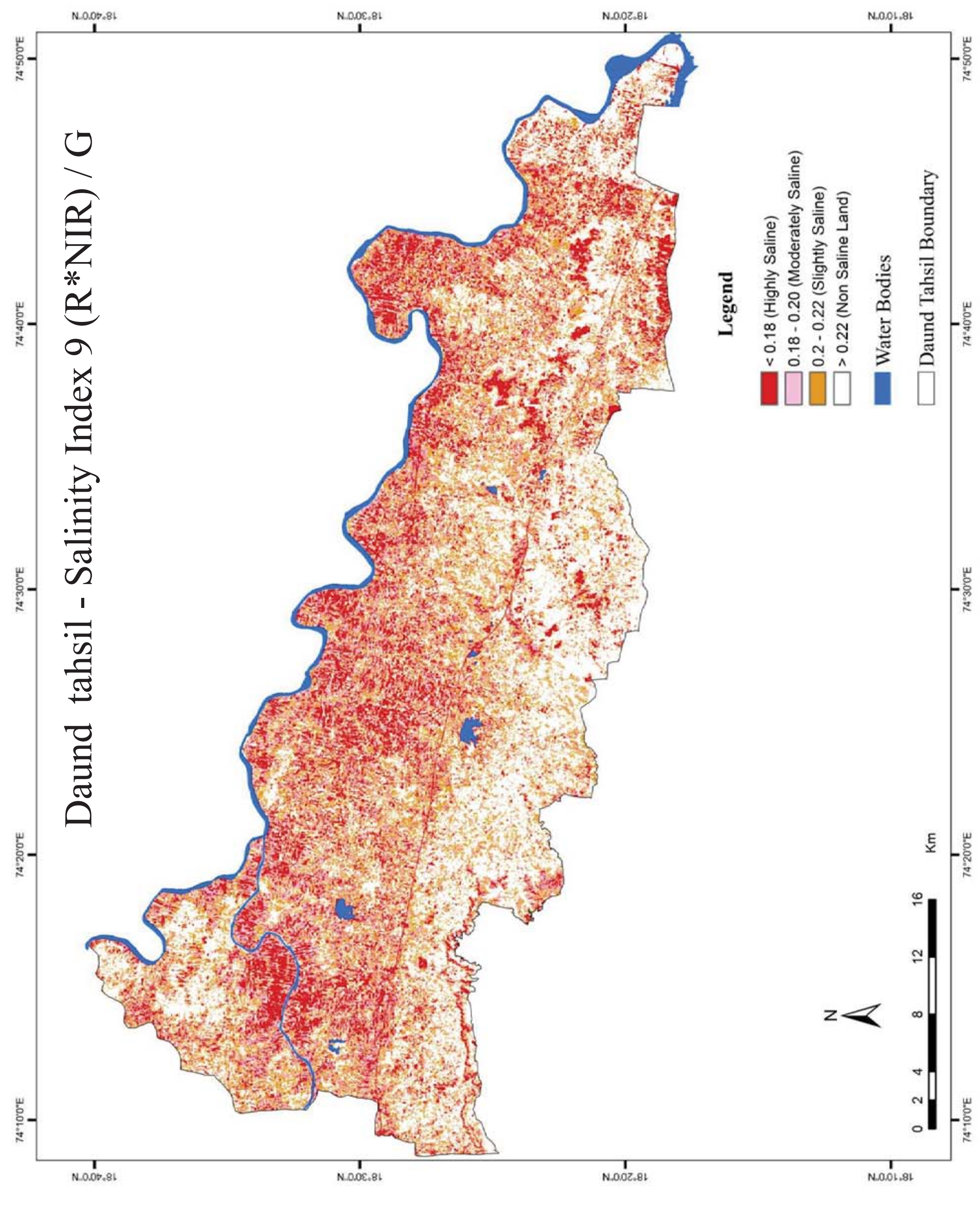

Daund tahsil - Salinity Index 9 (R*NIR) / G
Legend
< 0.18 (Highly Saline)
0.18 - 0.20 (Moderately Saline)
0.2 - 0.22 (Slightly Saline)
> 0.22 (Non Saline Land)
Water Bodies
Daund Tahsil Boundary
N
0 2 4 8 12 16
Km
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°40'0"N
18°30'0"N
18°20'0"N
18°10'0"N

Fig: 4.11

4.3.11 Soil Adjusted Vegetation Index (SAVI):

Halophytic plants have the ability of growing in saline soils, and they are adapted to high salinity of soil. Therefore, halophytic vegetation can be used as an indirect indicator for estimating and mapping of soil salinity. Hence, the spectral reflectance of halophytic plants can be taken into consideration for the purpose of detecting and mapping of soil salinity, more specifically in areas of high salinity.

Many scholars and researchers have mapped soil salinity using different spectral vegetation indices such as NDVI (Normalized Difference Vegetation Index), SAVI (Soil Adjusted Vegetation Index) etc. The presence of halophytic plants can cause errors in soil salinity detection based on the NDVI as there is a great mixing with the spectral signature of salts, which ultimately leads to errors in classification of soil salinity. In order to overcome this issue of NDVI and remove errors of classification to some extent, the SAVI index was formulated to help to separate soil and vegetation spectral reflectance signals.

Soil Adjusted Vegetation Index (SAVI) was developed by Huete to eliminate soil-induced variation and for using it in regions where soil backgrounds differed and the low canopy cover was present. Depending on the density of crops, the L factor generally ranges from 0 for higher densities and 1 for lower densities. The resulting SAVI values in the classified image are either positive, negative or zero. A positive SAVI value indicates that there is a decrease in the vegetation, while a negative value indicates an increase in vegetation. A zero value indicates no change in vegetation.

The soil adjusted vegetation index reduces the influence of soil for obtaining 100% reflectance from the vegetation cover. This index is highly effective in examining the vegetation and soil condition by including the correction factor ‘L’ as an improvement over NDVI. The structure of SAVI is similar to that of NDVI, except the inclusion of ‘L’ i.e. correction factor for soil brightness. When L equals to zero, then NDVI is equal to SAVI.

The formula for Soil Adjusted Vegetation Index (SAVI) is as follows:

$$SAVI = [(NIR - R)*(1+L)] / (NIR+R+L)$$ - Huete A.R., 1988

Where,

NIR = the reflectance of the near infrared band of Landsat 8 image,

R = the reflectance value of the red band of Landsat 8 image, and

L = the correction factor for soil brightness.

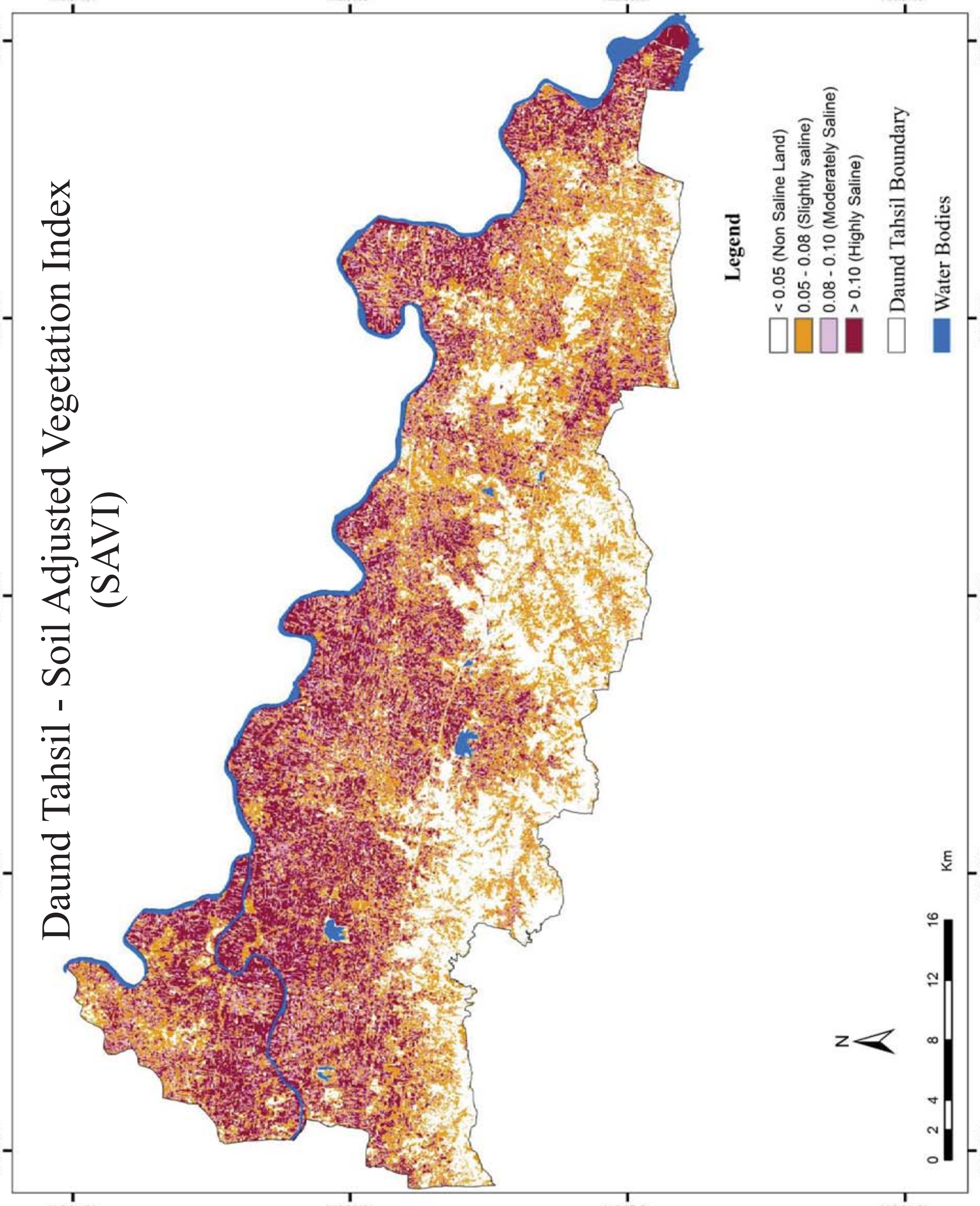
The soil adjusted vegetation index was formulated as an alteration of the normalized difference vegetation index to account for the effect of soil brightness when the amount of vegetation cover is low. The value of L changes according to the amount of green vegetation cover. In areas covered with very high amount of vegetation, L=0; and in areas without green vegetation cover, L=1. In most of the conditions, the default value of L is taken to be 0.5 which gives proper results.

Table 4.11: Area under various classes of soil salinity according to Soil Adjusted Vegetation Index (SAVI)

Classes	Area in ha	Area in sq. km	Area in %
Highly Saline (> 0.10)	33011.82	330.12	24.27
Moderately saline (0.08 to 0.10)	20774.79	207.75	15.27
Slightly saline (0.05 to 0.08)	38807.55	388.08	28.53
Non saline land (< 0.05)	35779.50	357.80	26.30
Water bodies	7665.40	76.65	05.63
Total	136039.06	1360.39	100.00

The Soil Adjusted Vegetation Index (SAVI) classified the image (Fig. 4.12) into four classes viz. highly saline (> 0.10), moderately saline (0.08 – 0.10), slightly saline (0.05 – 0.08), and non saline land (< 0.05). The analysis of this index shows that highly saline area covers 24.27 %, moderately saline 15.27 %, slightly saline 28.53 %, non saline land 26.30% and water bodies cover 5.63% of total area.

Highly saline land covers a major part of the study area under saline land class. Highly saline lands are observed almost over the entire region including western, northern, central, eastern and south eastern parts of the study area. Moderately saline lands are present in patches over the western, northern, central, and eastern parts of the study area in association with the highly saline lands. Slightly saline lands are mainly found over valleys in southern part of the study area and also in patches over northern, western and eastern parts of Daund tahsil in association with highly saline lands. This category of land indicates severity of salinization problem because land coming under this category indicates that salinization problem has just started over this zone.



Daund Tahsil - Soil Adjusted Vegetation Index
(SAVI)
Legend
< 0.05 (Non Saline Land)
0.05 - 0.08 (Slightly saline)
0.08 - 0.10 (Moderately Saline)
> 0.10 (Highly Saline)
Daund Tahsil Boundary
Water Bodies
N
0 2 4 8 12 16
Km
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°40'0"N
18°30'0"N
18°20'0"N
18°10'0"N

Fig: 4.12

4.4 Canal Irrigation and Soil Salinization in Daund Tahsil:

The most widely used source of irrigation in the study area is canal irrigation. Maximum irrigated area in Daund tahsil is irrigated by canal irrigation (Fig 4.13). After the development of Khadakwasla Canal in the study area, no repair work of the canal has been undertaken. Due to this, there is lot of leakage of water from the canal in the surrounding agricultural fields. There has been excessive water logging and increase in water level in the fields as there is continuous supply of water from the canal. As a result of this, the problem of salinization has been intensified and the area under saline lands has been increasing in Daund tahsil. The comparison of canal map and soil salinity indices maps shows that highly and moderately saline lands are present in most of the parts of Daund tahsil which are irrigated with the help of canal irrigation. These are the western, northern, central, eastern and south eastern parts of the study area. In the southern and southwestern parts of Daund tahsil which have hilly physiography, slightly saline lands are present which can be attributed to the absence of canal in these parts. In the context of problems related to agriculture being experienced in the study area, there is a need to shift from canal irrigation to drip irrigation so as to control soil salinity.

-x-x-x-

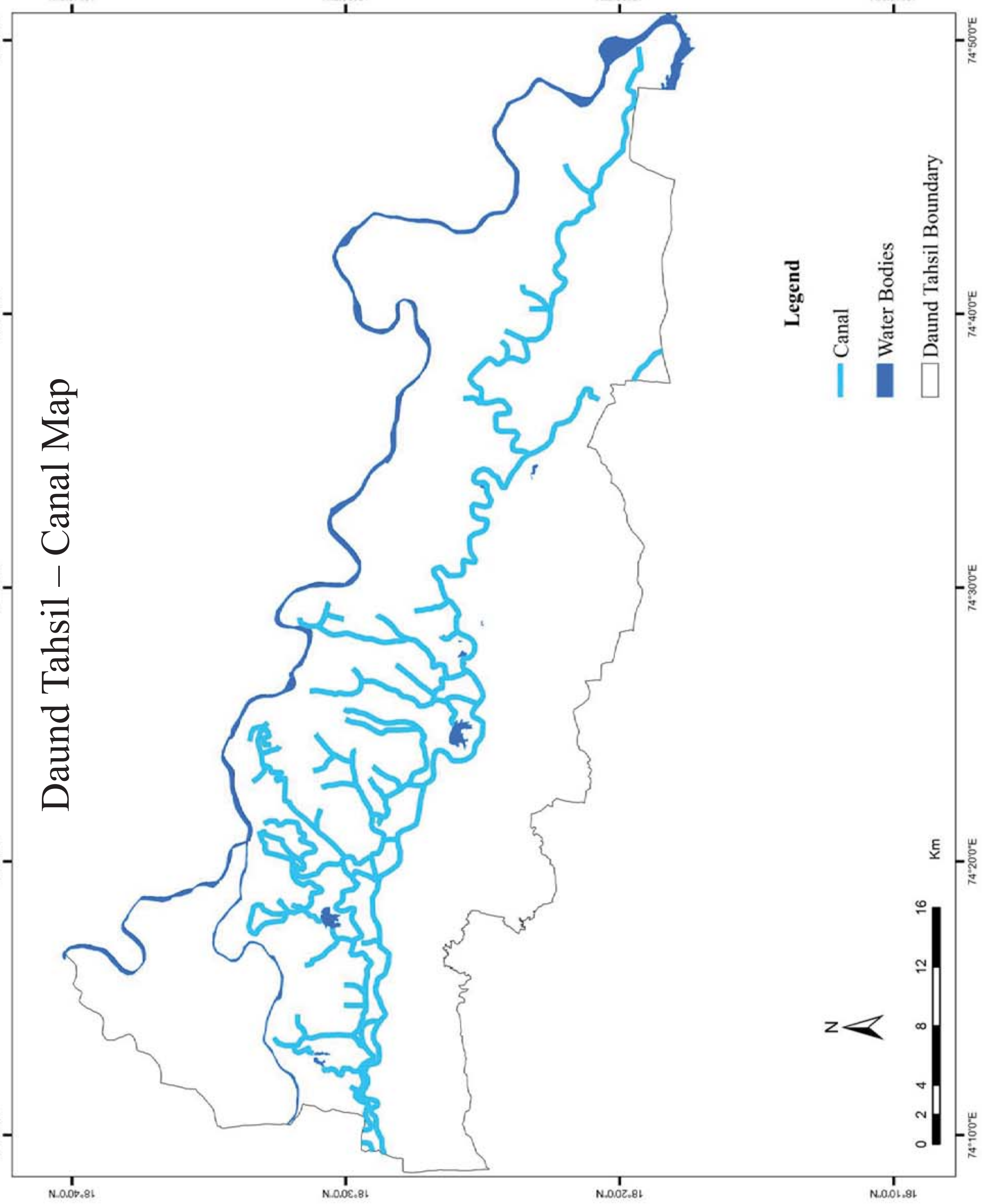

Daund Tahsil – Canal Map
Legend
Canal
Water Bodies
Daund Tahsil Boundary
N
0 2 4 8 12 16
Km
18°40'0"N
18°30'0"N
18°20'0"N
18°10'0"N
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E

Fig: 4.13

CHAPTER V

SOIL PRODUCTIVITY ASSESSMENT USING STORIE INDEX

5.1 Introduction:

Soils are the product of chemical, bio-chemical, and physical processes acting upon the earth's materials under various topographic and climatic conditions. The study of soil properties viz. physical, hydrological and chemical properties is highly significant in various fields.

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

The soils are mostly fine textured and well drained black soils and medium textured in some patches.

5.2 Soil Characteristics of Daund tahsil:

In order to analyze various soil characteristics, soil data from Mati Parikshan has been utilized. Various locations of soil samples in Daund tahsil of Pune District were selected village wise.

(Fig. 5.1)

The locations of salt encrustations in the study region have been mapped with the help of GPS instrument.

(Fig. 5.2)

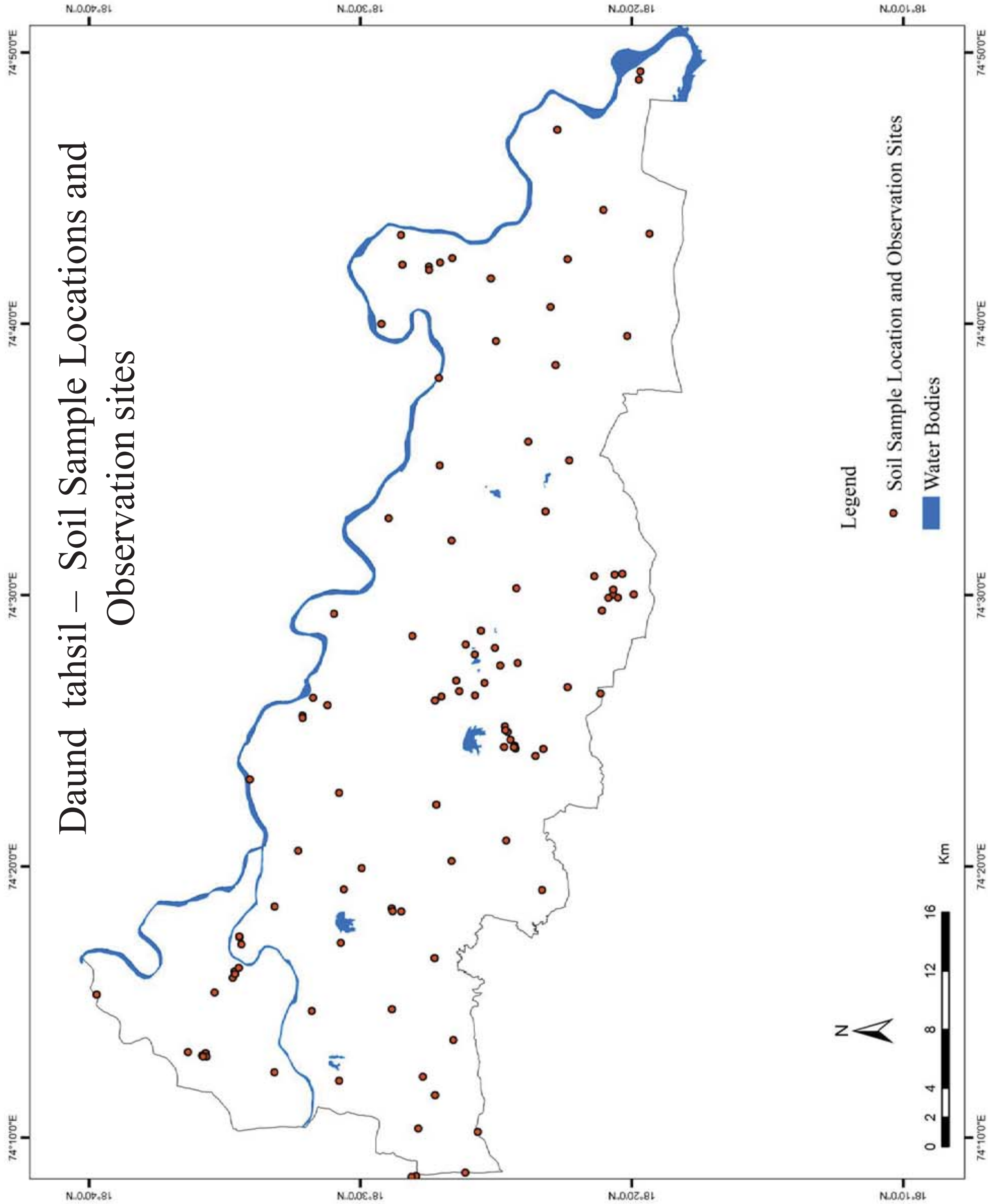
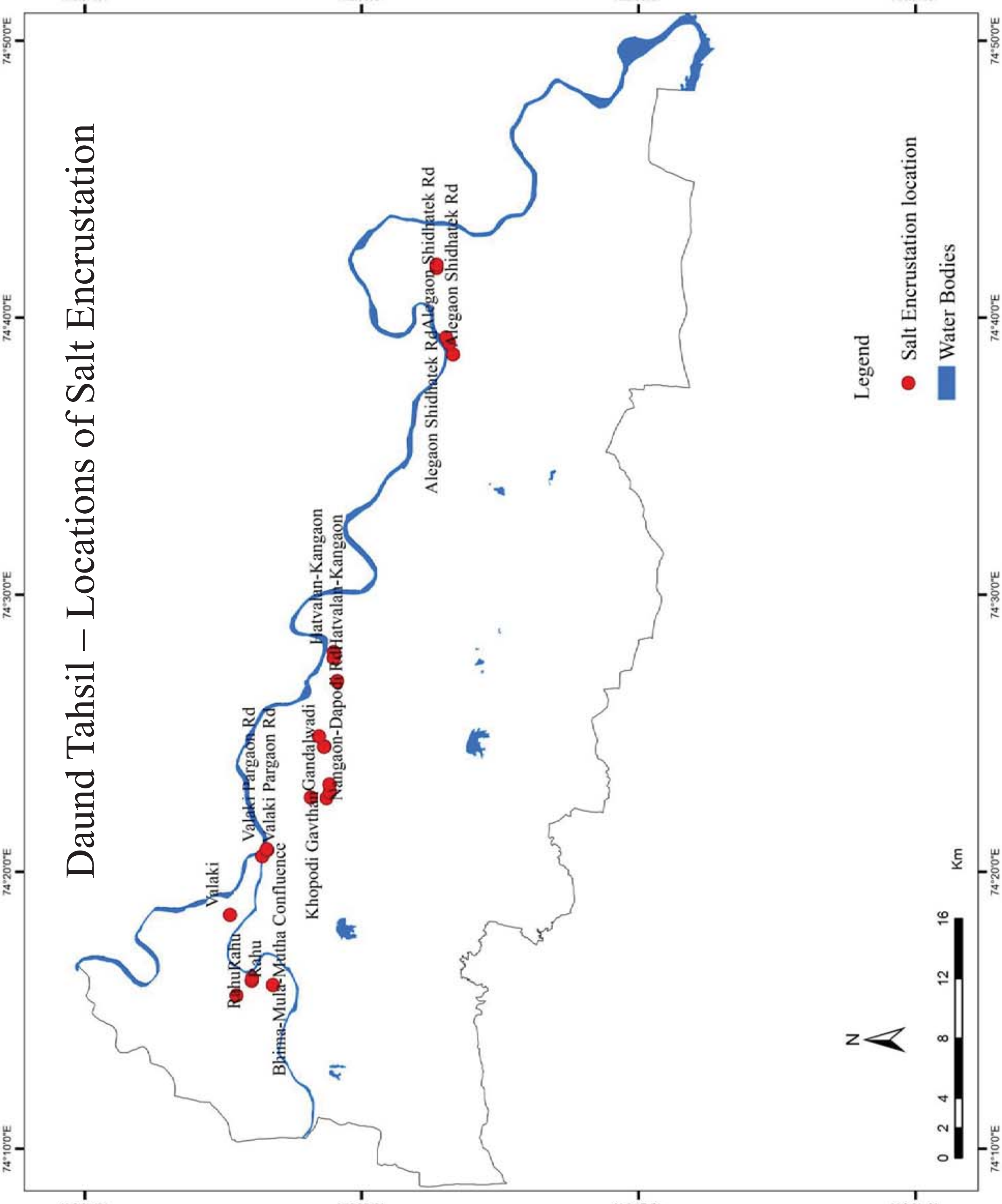

Daund tahsil – Soil Sample Locations and Observation sites
Legend
Soil Sample Location and Observation Sites
Water Bodies
N
0 2 4 8 12 16
Km
18°40'0"N
18°30'0"N
18°20'0"N
18°10'0"N
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E

Fig: 5.1



Daund Tahsil – Locations of Salt Encrustation
Legend
Salt Encrustation location
Water Bodies
Km
0 2 4 8 12 16
N
Valaki
Valaki Pargaon Rd
Rahu
Bhima-Mula-Mutha Confluence
Khopodi Gavthan
Gandalwadi
Kangaon-Dapodi Rd
Hatvalan-Kangaon
Alegaon Shidhatek Rd
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°40'0"N
18°30'0"N
18°20'0"N
18°10'0"N

Fig: 5.2

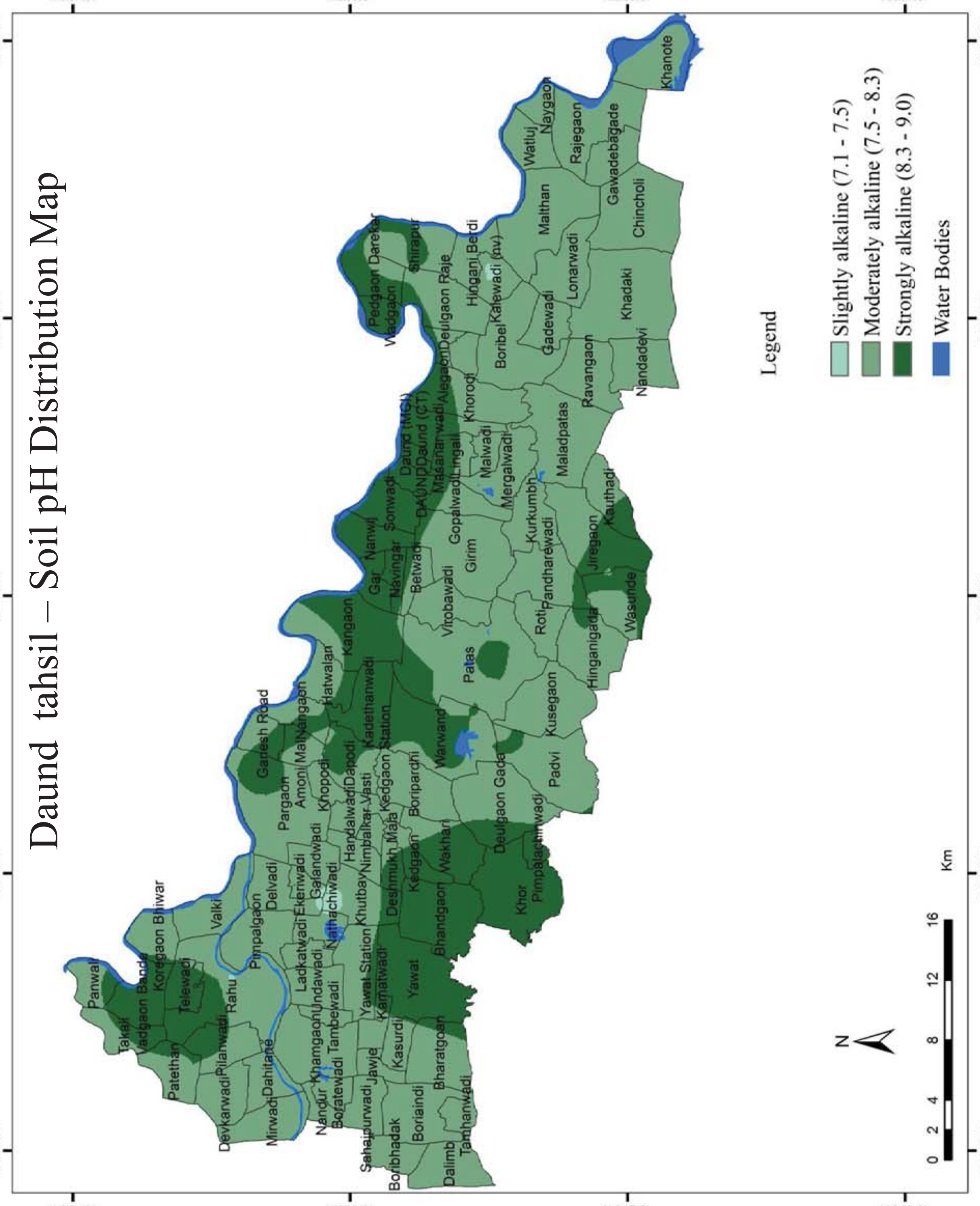
Soil pH:

Soil pH values conveniently express the degree of alkalinity in soil. The pH scale is divided into14 divisions or pH units numbered from 1 to 14. Soils with a pH of 7 are neutral. Soils with pH values below 7 are acid or "sour" and soils with pH values above 7 are alkaline or "sweet".

A pH of 9 is ten times more alkaline than a pH of 8 and a pH of 10 is ten times more alkaline than a pH of 9. Thus, a soil with a pH of 10 is 100 times more alkaline than a soil with a pH of 8. The pH value of most soils falls in the range between 4 and 8. Most crop plants grow and produce best on slightly acid or neutral soils.

Soil pH distribution map of Daund tahsil shows three classes viz. slightly alkaline (7.1 to 7.5), moderately alkaline (7.5 to 8.3) and strongly alkaline (8.3 to 9.0). It is observed that slightly alkaline soils cover very less area and are in patches.

Majority of Daund tahsil has moderately alkaline soil category of pH, whereas strongly alkaline category occupies the northern and southern parts of Daund tahsil. Villages like Hatwalan, Gar, Kangaon, Daund (CT), Pedgaon, Wadgaon, Shirapur, Dapodi, etc. are having strongly alkaline soil.
(Fig. 5.3)



Daund tahsil – Soil pH Distribution Map
Legend
Slightly alkaline (7.1 - 7.5)
Moderately alkaline (7.5 - 8.3)
Strongly alkaline (8.3 - 9.0)
Water Bodies
N
0 2 4 8 12 16
Km
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°40'0"N
18°30'0"N
18°20'0"N
18°10'0"N

Fig: 5.3

Electric Conductivity (EC):

Electrical conductivity indicates the soluble salts in the soil. The EC range varies between <1.0 to >3.0. Majority of the study area is under average EC i.e. <1.0. The central part of Daund tahsil shows high EC value of >3.0 which indicates soils that affect all crops types. Under high EC (i.e.>3.0) villages like Dapodi, Kedgaon, Deshmukh Mala, Boripardhi, Nimbarkar Vasti, etc. are coming.
(Fig. 5.4)

Nitrogen (N):

Nitrogen (N) is an essential element for plant growth. The amount of nitrogen over Daund tahsil is calculated in Kg/ha. Nitrogen distribution map shows five classes viz. <200, 200-400, 400-600, 600-800 and >800 kg/ha. Nitrogen is in high proportion over the north-western and northern parts i.e. over 800 kg/ha. Major part of the study area is under 200-400 kg/ha Nitrogen. Villages like Rahu, Pilanwadi, Hatwalan, Nangaon, Kangaon, etc. are coming under high Nitrogen content (i.e.>800 kg/ha).
(Fig. 5.5)

Phosphorus (P):

Phosphorus (P) has a great influence on both natural and agricultural ecosystems than any other essential element. Phosphorus deficient plants are often severely stunted. Phosphorus is calculated in kg/ha. Phosphorus range in the study area is between < 200 Kg/ha and > 1,100 Kg/ha. The highest phosphorus amount is observed over northwestern part of the study area and the lowest range is observed over central and western parts of the study area. Villeges like Valki, Delvadi, Pimpalgaon, Koregaon Bhiwar, etc. are coming under high Phosphorus content (i.e. >1100 kg/ha).
(Fig. 5.6)

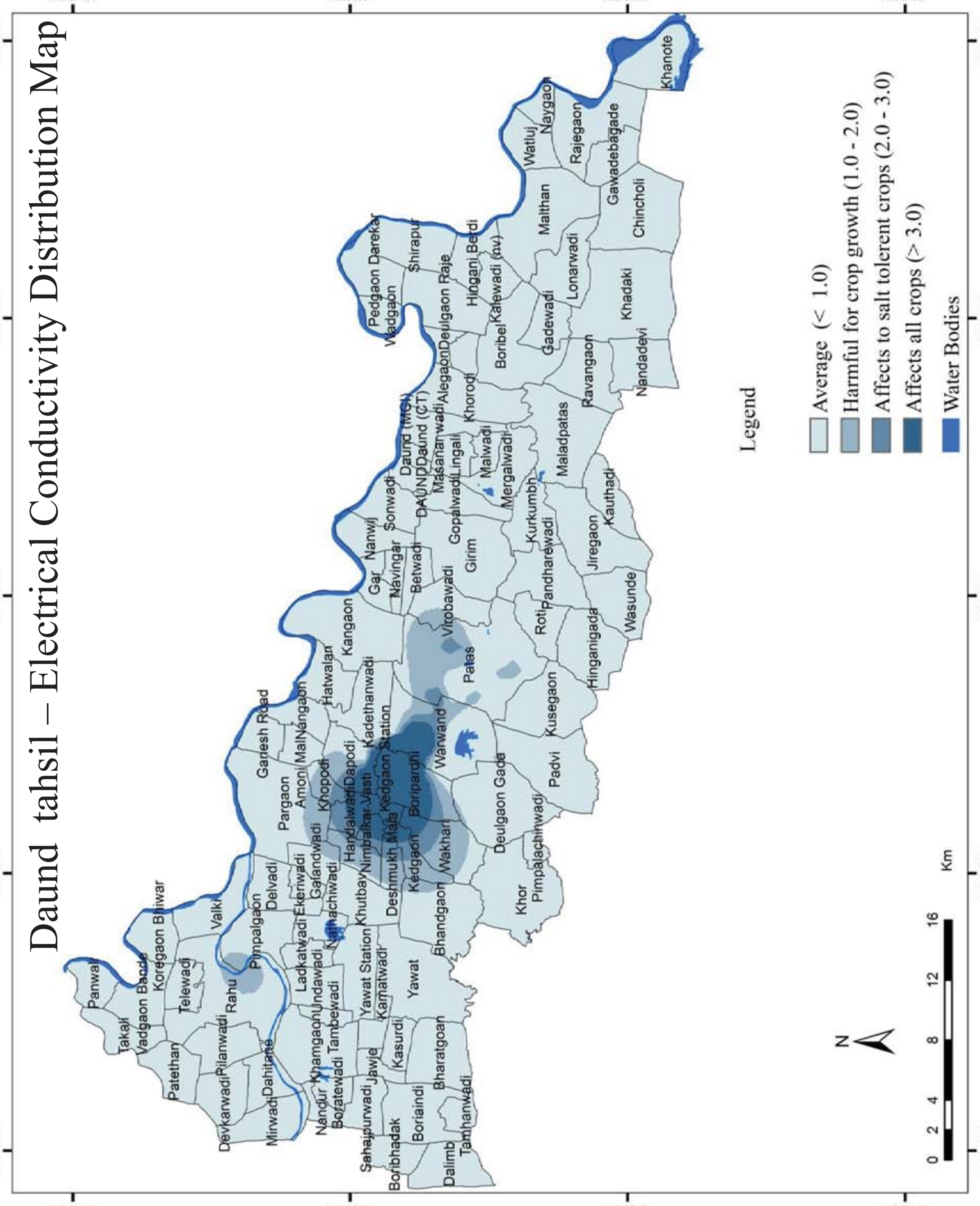

Daund tahsil – Electrical Conductivity Distribution Map
Legend
Average (< 1.0)
Harmful for crop growth (1.0 - 2.0)
Affects to salt tolerent crops (2.0 - 3.0)
Affects all crops (> 3.0)
Water Bodies
N
0 2 4 8 12 16
Km
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°10'0"N
18°20'0"N
18°30'0"N
18°40'0"N

Fig: 5.4

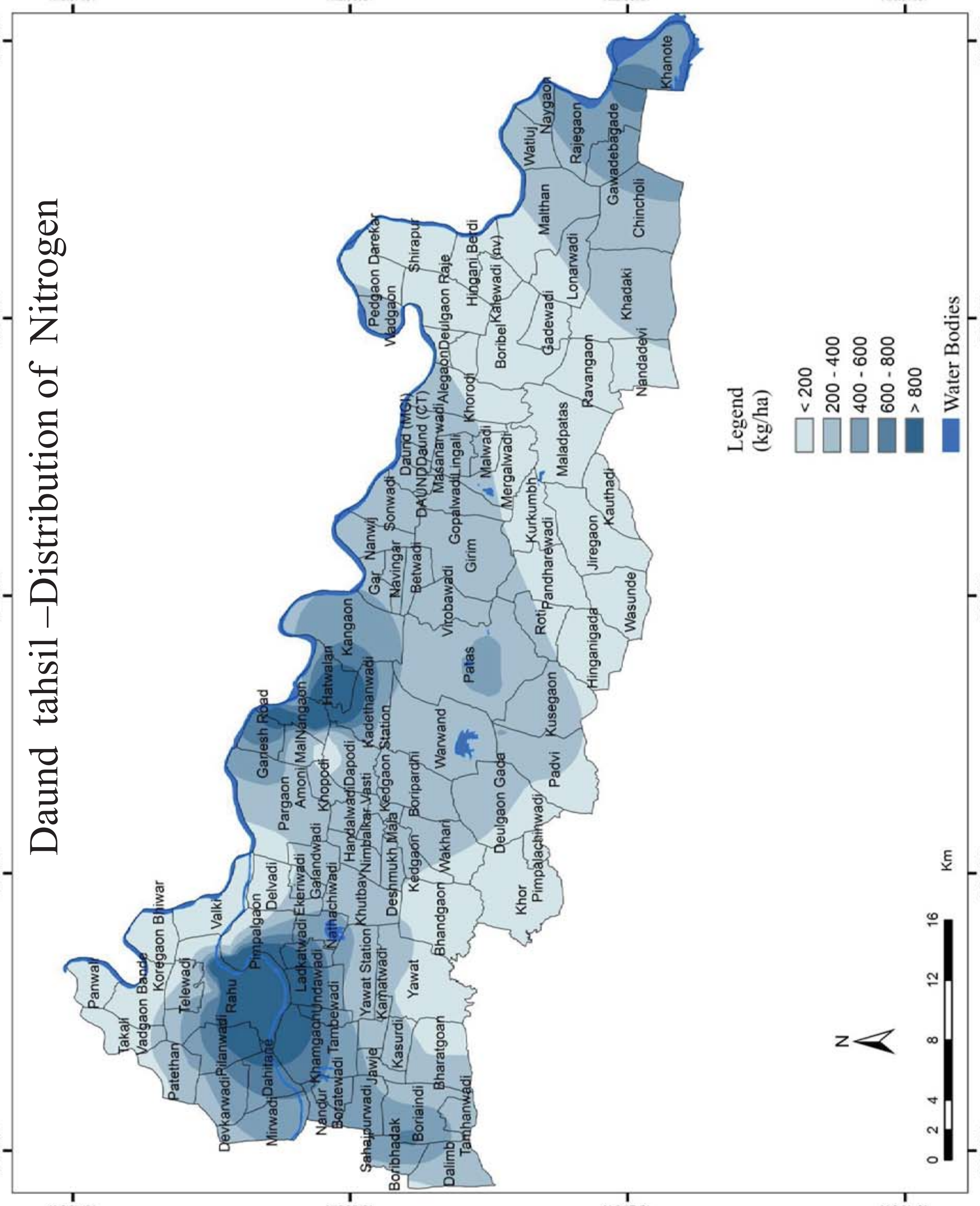

Daund tahsil –Distribution of Nitrogen
Legend
(kg/ha)
< 200
200 - 400
400 - 600
600 - 800
> 800
Water Bodies
N
Km
0 2 4 8 12 16

Fig: 5.5

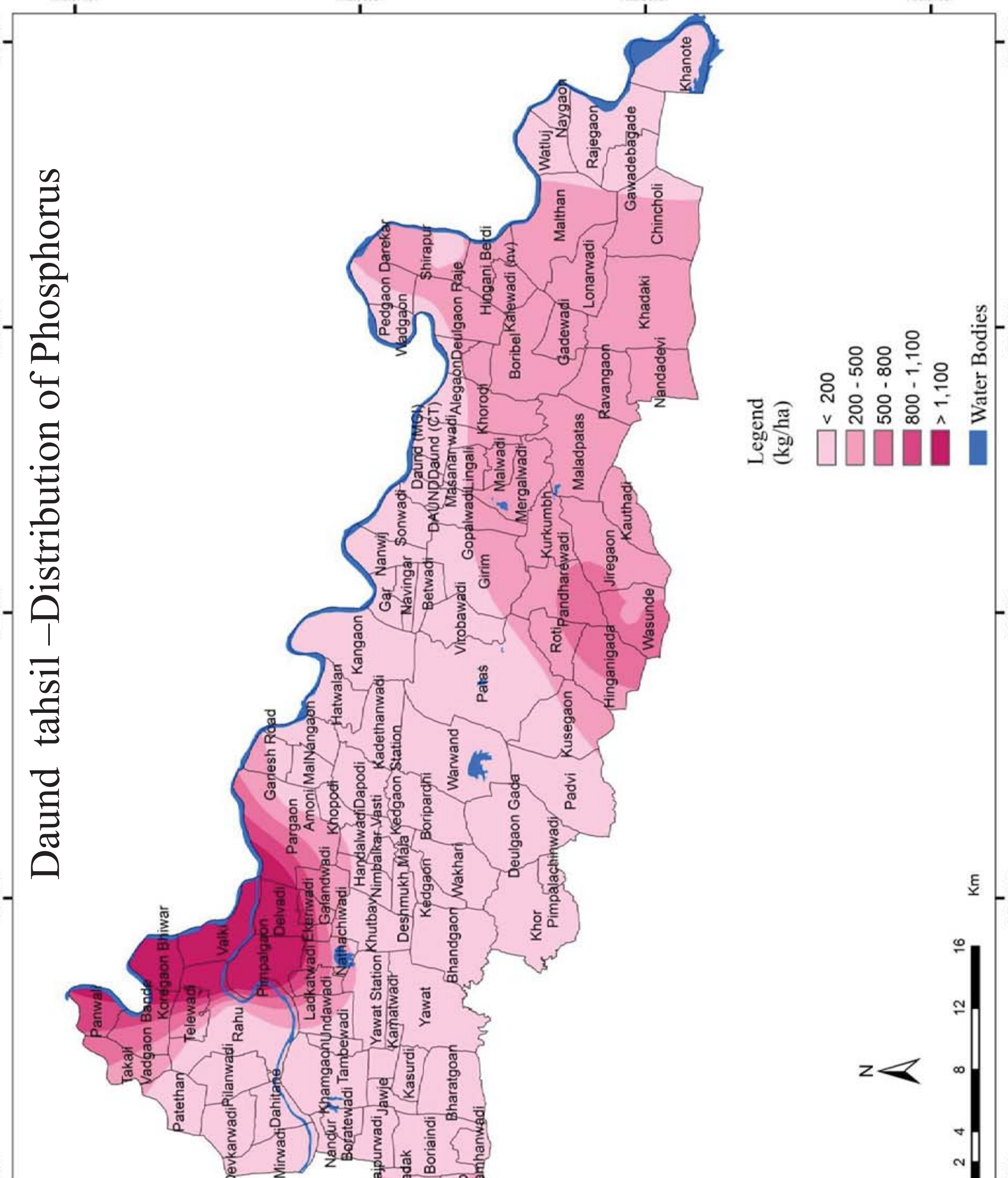

Daund tahsil –Distribution of Phosphorus
Legend
(kg/ha)
< 200
200 - 500
500 - 800
800 - 1,100
> 1,100
Water Bodies
N
0 2 4 8 12 16
Km
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°10'0"N
18°20'0"N
18°30'0"N
18°40'0"N

Fig: 5.6

Potassium (K):

Potassium has a role of essential element in plants. When potassium is sufficient in the soil, it helps for the growth of crops. Excess of potassium in the soil is not harmful. The range of Potassium varies from < 300 kg/ha to >900 kg/ha. The highest amount of K is over the central part and lowest amount is over the eastern part of the study region. Villages like Rahu, Kedgaon, Hatwalan, Deshmukh Mala, Nimbalkar vasti, Patas, etc. are coming under high Potassium content (i.e.>900 kg/ha).
(Fig. 5.7)

Iron (Fe):

The iron distribution map shows high iron content in the soil over northern part i.e. above 2.0 ppm and lowest i.e. <0.5 ppm over the eastern and western parts of the study area. Villages like Patas, Boripardhi, Dapodi, Amonimal, Nangaon, Pargaon, etc. are coming under high Iron content (i.e.>2.0 ppm).
(Fig. 5.8)

Manganese (Mn):

The manganese distribution map shows highest manganese content in soil over south-western and northern parts i.e. above 1.2 ppm and lowest value of less than 0.3 ppm is observed over south western part of the study area. Villages like Boriandi, Yawat, Pargaon, Dapodi, Amonimal, Patas, Nangaon, Khopodi, etc. are coming under high Manganese content (i.e.>1.2 ppm).
(Fig. 5.9)

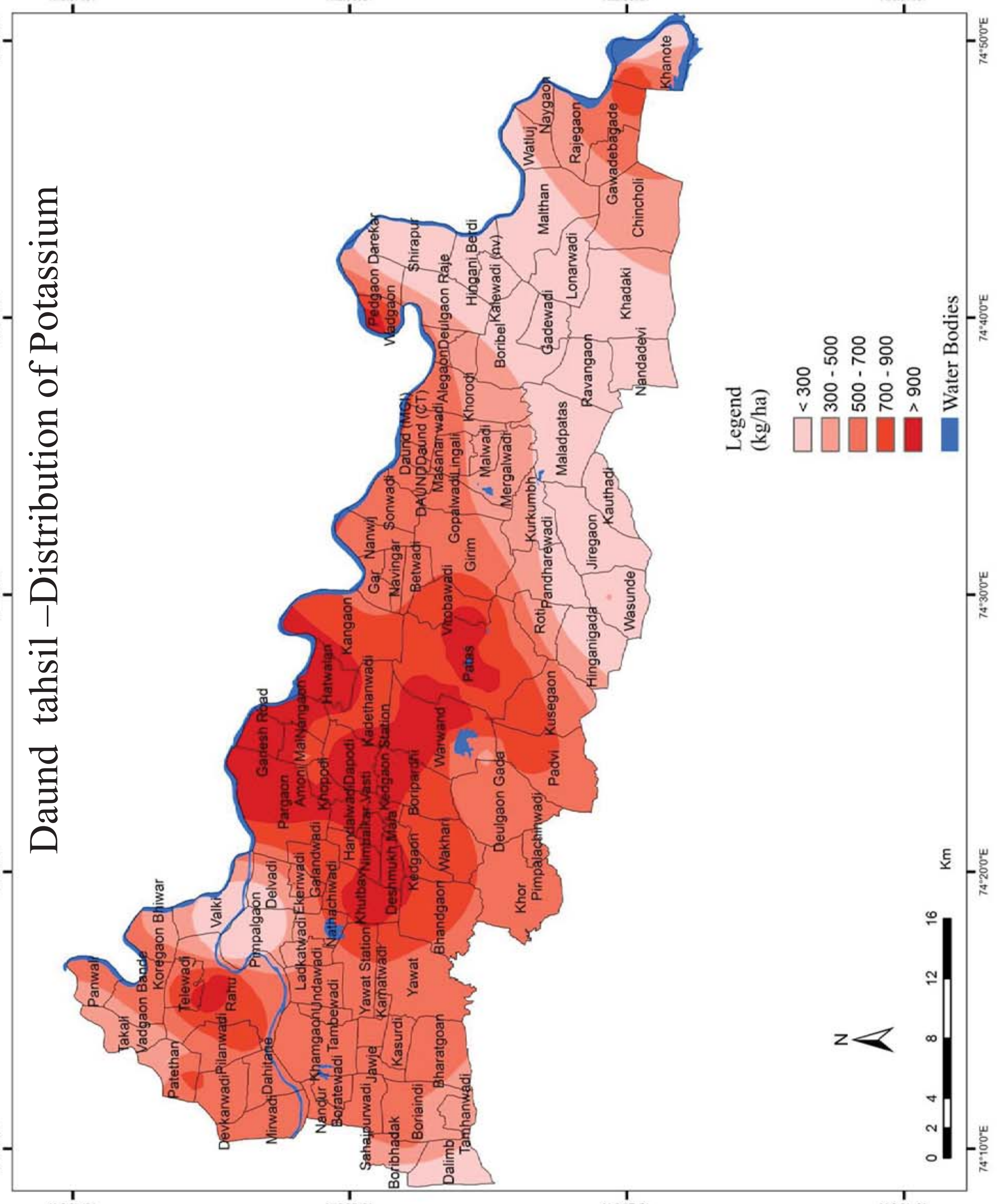
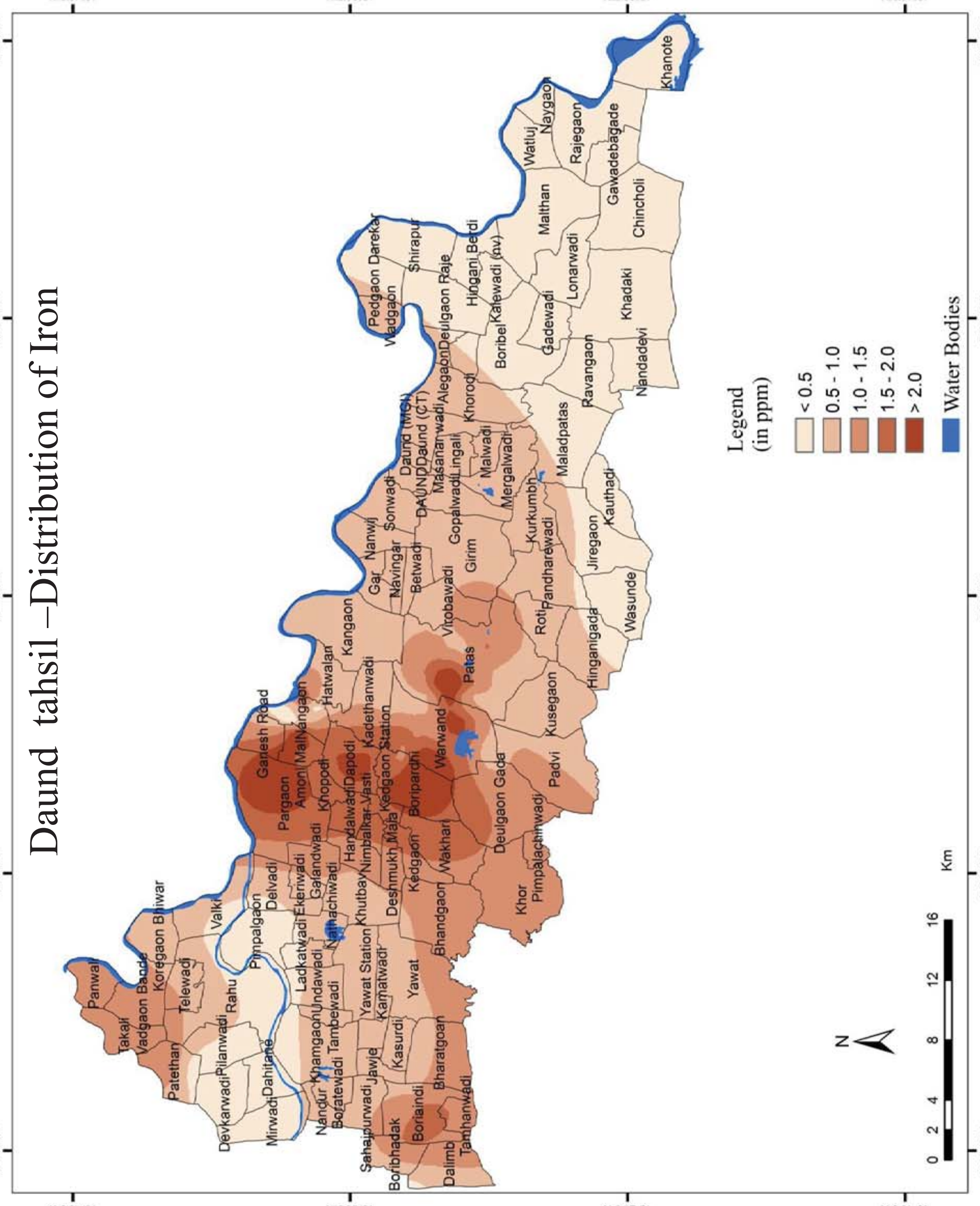

Daund tahsil –Distribution of Potassium
Legend
(kg/ha)
< 300
300 - 500
500 - 700
700 - 900
> 900
Water Bodies
N
0 2 4 8 12 16
Km
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°40'0"N
18°30'0"N
18°20'0"N
18°10'0"N
Panwali
Takali
Vadgaon Bande
Koregaon Bhiwar
Telewadi
Rahu
Patethan
Pilanwadi
Dahitane
Devkarwadi
Mirwadi
Valki
Pimpalgaon
Delvadi
Ladkatwadi
Ekeriwadi
Galandwadi
Nathachiwadi
Khamgaon
Undawadi
Tambewadi
Nandur
Boratewadi
Sahajpurwadi
Boribhadak
Boriaindi
Dalimb
Tamhanwadi
Bharatgoan
Kasurdi
Jawje
Yawat
Yawat Station
Kamatwadi
Khutbav
Deshmukh Mala
Kedgaon
Bhandgaon
Wakhari
Handalwadi
Dapodi
Khopodi
Pargaon
Amoni Mal
Mathwangaon
Gadesh Road
Hatwalan
Kangaon
Kadethanwadi
Kedgaon Station
Boripardhi
Warwand
Deulgaon Gada
Pimpalachiwadi
Khor
Padvi
Kusegaon
Patas
Vitobawadi
Hinganigada
Roti
Pandharewadi
Wasunde
Jiregaon
Kurkumbh
Kauthadi
Maladpatas
Ravangaon
Nandadevi
Girim
Gopalwadi
Ingali
Malwadi
Mergalwadi
Betwadi
Navingar
Gar
Nanwij
Sonwadi
DAUND
Daund (MCl)
Daund (CT)
Masanarwadi
Alegaon
Khorodi
Boribel
Deulgaon Raje
Pedgaon
Darekar
Wadgaon
Shirapur
Hingani Berdi
Katewadi (nv)
Gadewadi
Lonarwadi
Khadaki
Malthan
Watluj
Naygaon
Rajegaon
Gawadebagade
Chincholi
Khanote

Fig: 5.7



Daund tahsil –Distribution of Iron
Legend
(in ppm)
< 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
> 2.0
Water Bodies
N
0 2 4 8 12 16
Km
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°40'0"N
18°30'0"N
18°20'0"N
18°10'0"N
Panwali
Takali
Vadgaon Bande
Koregaon Bhiwar
Telewadi
Patethan
Rahu
Pilanwadi
Devkarwadi
Dahitane
Mirwadi
Valki
Pimpalgaon
Delvadi
Ekeriwadi
Ladkatwadi
Galandwadi
Undawadi
Khamgaon
Tambewadi
Nandur
Boratewadi
Jawje
Sahajpurwadi
Boribhadak
Boriaindi
Dalimb
Tamhanwadi
Bharatgoan
Kasurdi
Kamatwadi
Yawat Station
Yawat
Nathachiwadi
Khutbav
Bhandgaon
Deshmukh Mala
Kedgaon
Nimbalkar Vasti
Handalwadi
Wakhari
Khor
Pimpalachiwadi
Deulgaon Gada
Padvi
Boripardhi
Kedgaon Station
Dapodi
Khopodi
Amoni Mal
Pargaon
Ganesh Road
Nangaon
Kadethanwadi
Warwand
Hatwalan
Kangaon
Patas
Kusegaon
Hinganigada
Vitobawadi
Roti
Pandharewadi
Wasunde
Gar
Navingar
Betwadi
Nanwij
Sonwadi
Girim
Kurkumbh
Jiregaon
Kauthadi
Gopalwadi
Ingali
Mergalwadi
Malwadi
DAUND
Daund (CT)
Daund (MCI)
Masanarwadi
Khorodi
Maladpatas
Alegaon
Ravangaon
Nandadevi
Deulgaon Raje
Boribel
Gadewadi
Khadaki
Vadgaon
Pedgaon Darekar
Shirapur
Hingani Berdi
Katewadi
Lonarwadi
Malthan
Chincholi
Watluj
Rajegaon
Gawadebagade
Naygaon
Khanote

Fig: 5.8

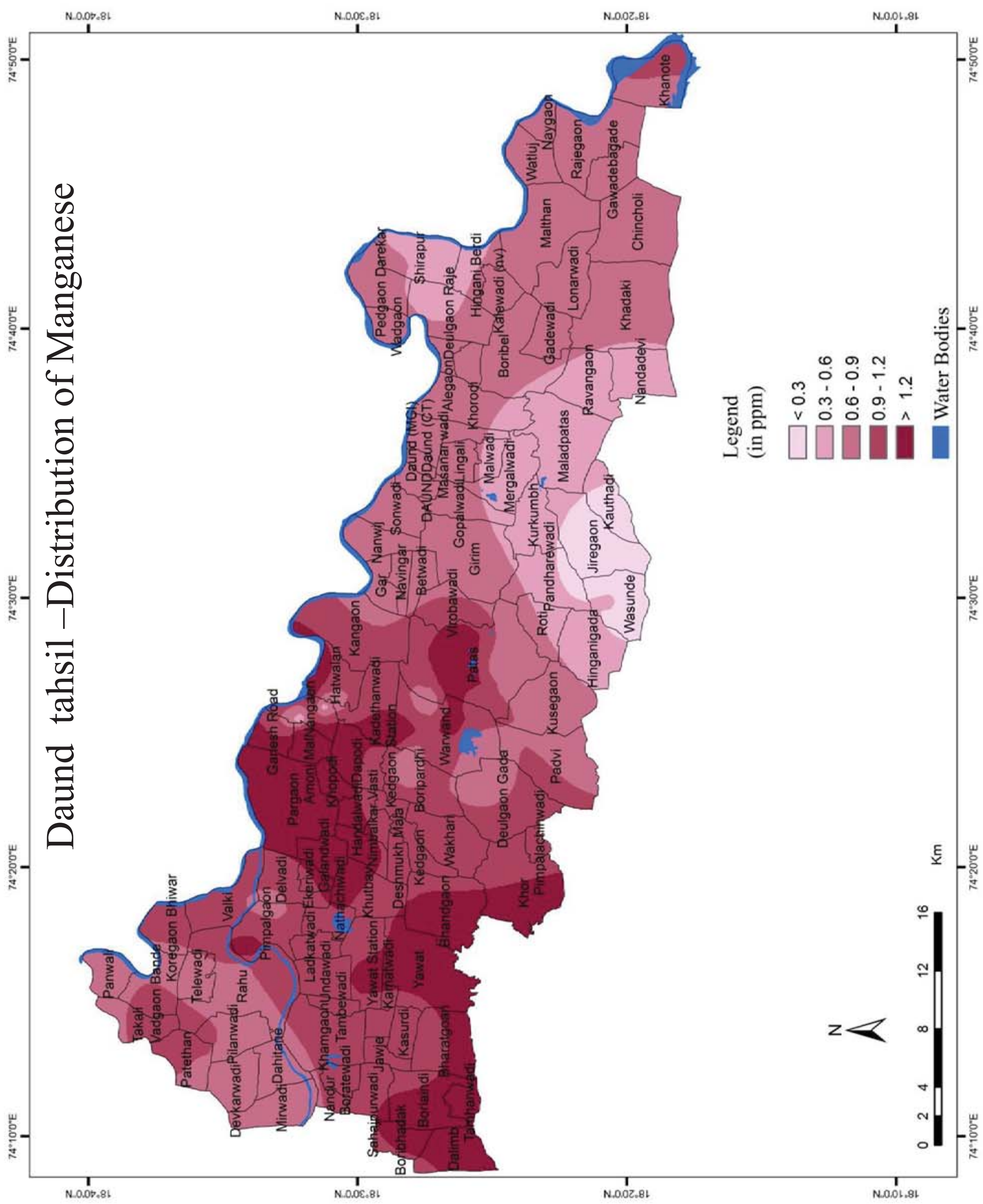

Daund tahsil –Distribution of Manganese
Legend
(in ppm)
< 0.3
0.3 - 0.6
0.6 - 0.9
0.9 - 1.2
> 1.2
Water Bodies
Km

Fig: 5.9

Zinc (Zn):

The zinc distribution map shows highest range of > 0.8 ppm over north-western part and lowest amount of < 0.2 ppm over the southern part in patches. Majority of the study area has 0.2 to 0.4 ppm zinc. Villages like Valki, Delvadi, Pimpalgaon, etc. are coming under high Zinc content (i.e.>0.8 ppm).
(Fig. 5.10)

Copper (Cu):

The copper distribution map shows four classes viz. < 0.20, 0.20 to 0.40, 0.40 to 0.60 and > 0.60 ppm. The highest range is over the north-western part of the study area. The maximum part of the study area is having 0.20 to 0.40 ppm copper content. Villages like Delvadi, Pimpalgaon, Wasunde, etc. are coming under high Copper content (i.e.>0.60 ppm).
(Fig. 5.11)

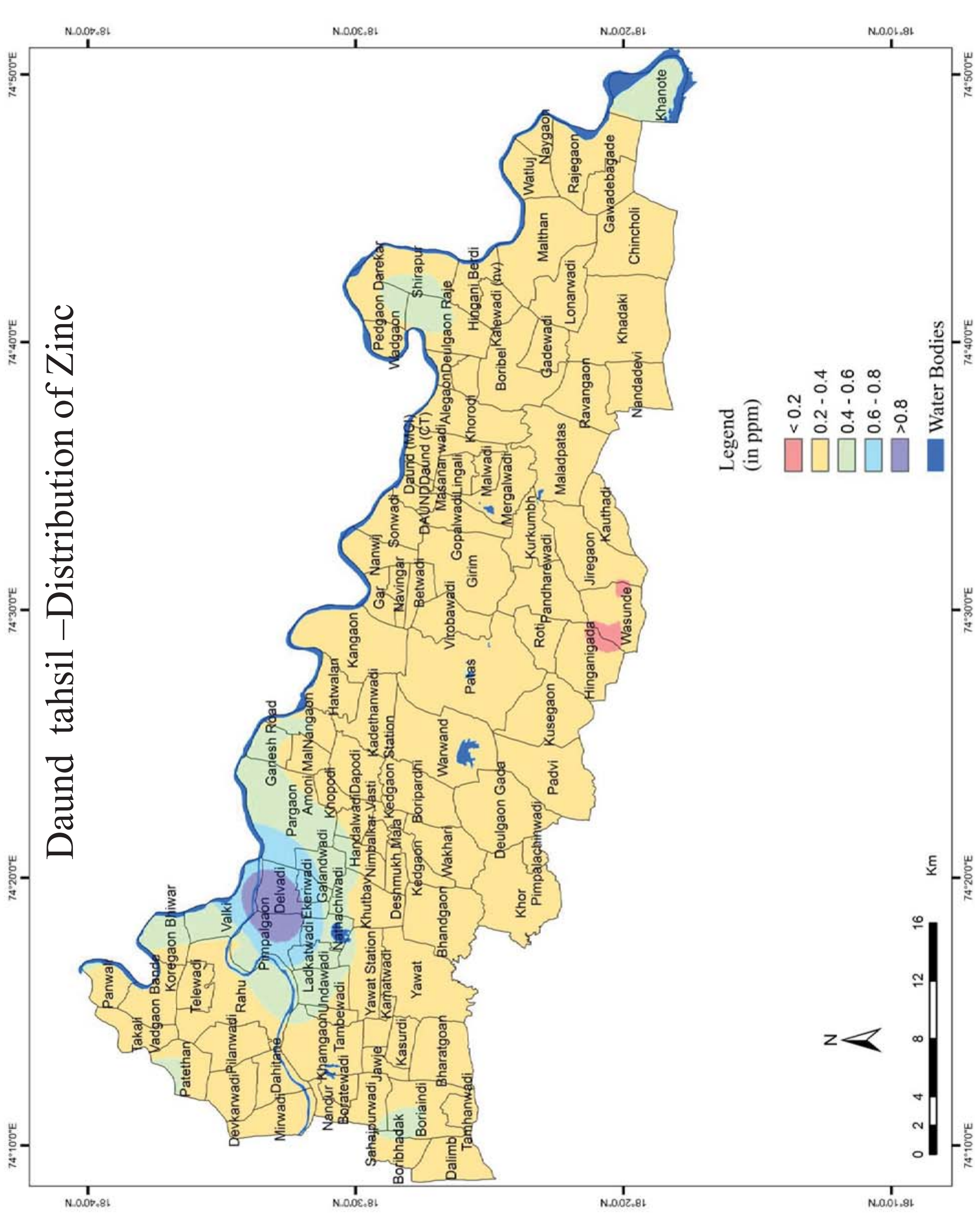

Daund tahsil –Distribution of Zinc
Legend
(in ppm)
< 0.2
0.2 - 0.4
0.4 - 0.6
0.6 - 0.8
>0.8
Water Bodies
N
0
2
4
8
12
16
Km
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°10'0"N
18°20'0"N
18°30'0"N
18°40'0"N

Fig: 5.10

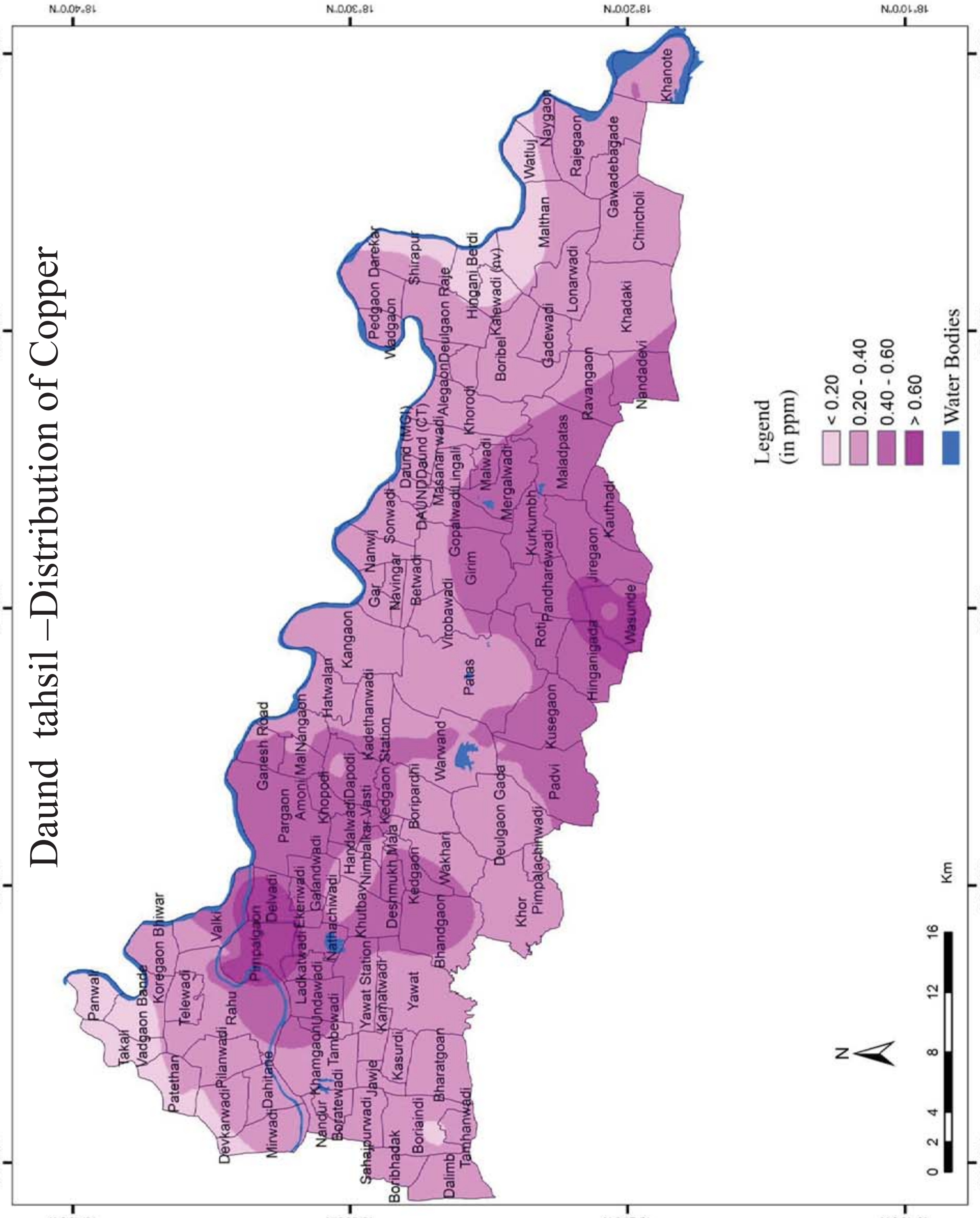

Daund tahsil –Distribution of Copper
Legend
(in ppm)
< 0.20
0.20 - 0.40
0.40 - 0.60
> 0.60
Water Bodies
N
Km
0 2 4 8 12 16

Fig: 5.11

5.3 ESTIMATION OF STORIE INDEX:

The Storie index is a widely used index and accepted method for estimating potential productivity of soil. It is soil-based system of classification of land productivity. The method of Storie Index has been used mainly for irrigated soils in California, U.S.A., North America.

The Storie index is obtained by multiplying ratings for individual soil parameters viz. factor A, factor B, factor C and factor X.

The rated parameters include the degree of soil profile development in terms of soil depth and gravel content (factor A), the textural characteristics of the surface soil (factor B), the slope in percent (factor C), and other important properties of the soil and landscape conditions such as drainage class e.g. well drained or poorly drained, alkali content, degree of acidity, fertility status or content of nutrients, degree of soil erosion i.e. wind and water erosion, and micro-relief features (factor X or “dynamic factor” which can be modified by management).

The most ideal settings or favourable conditions with respect to each attribute are rated at 100 percent. A value ranging from 0 to 100% is given for each factor, and the ratings are then multiplied together to generate the Storie index. Each factor is given a percentage score but decimal values are taken while multiplying the factors. The final Storie index is given as a percentage.

Formula:

Storie Soil Index rating

= [(Factor A/100) × (Factor B/100) × (Factor C/100) × (Factor X/100)] × 100

The soil profile groups have been classified on the basis of the degree of development of soil profile and the nature of the parent material. The soils in the study area can be classified in the group of soils on upland areas underlain by hard igneous bedrock or soils derived from hard igneous bedrock i.e. basalt rock on the Deccan Plateau of Maharashtra.

The rating of factor A i.e. the character of physical profile of soils is based on the soil depth to a lithic (hard rock) contact. The scores become higher with the increasing depth of soil.

The rating of factor B is based on the texture of the surface soil. Soils with medium texture i.e. loamy soils have been given the highest ratings, while heavy or fine-textured soils have been given lesser ratings. Clay-rich and sandy soils are given lower ratings.

The rating of factor C is based on the slope of land surface. High ratings have been given to nearly level to gently sloping lands (0% to 8% slope). Lower ratings have been given to land areas having slopes greater than 30%.

The rating of factor X is based on dynamic properties of soil and landscape which require particular attention. These properties can be grouped into soil chemical and fertility properties such as alkalinity, acidity, content of nutrients etc. and hydrologic and physical properties of soil such as drainage class, soil erosion etc.

An assessment of nutrient status was not attempted because fertility can be a very dynamic property in agricultural settings, depending on fertilization practices and other variables.

Table 5.1: Storie Soil-Rating Chart

Factor A - Rating on character of physical profile	
Soils on upland areas underlain by hard igneous bedrock:	
at less than 1 foot	10-30
at 1 to 2 feet	30-50
at 2 to 3 feet	50-70
at 3 to 4 feet	70-80
at 4 to 6 feet	80-100
at more than 6 feet	100
Factor B - Rating on basis of surface texture	
Medium textured:	
fine sandy loam	100
Loam	100
silt loam	100
sandy loam	95
silty clay loam, calcareous	95
silty clay loam, non-calcareous	90
clay loam, calcareous	95
clay loam, non-calcareous	85-90
Heavy or fine-textured:	
silty clay, highly calcareous	70-90
silty clay, non-calcareous	60-70
clay, highly calcareous	70-80
clay, non-calcareous	50-70

Table 5.1: Storie Soil-Rating Chart

Factor C - Rating on basis of slope	
A-Nearly level (0 to 2%)	100
AA-Gently undulating (0 to 2%)	95-100
B-Gently sloping (3 to 8%)	95-100
BB-Undulating (3 to 8%)	85-100
C-Moderately sloping (9-15%)	80-95
CC-Rolling (9 to 15%)	80-95
D-Strongly sloping (16 to 30%)	70-80
DD-Hilly (16 to 30%)	70-80
E-Steep (30 to 45%)	30-50
F-Very steep (45% and over)	5-30
Factor X - Rating of conditions other than those in factors A, B, and C	
Alkali:	
alkali-free	100
slightly affected	60-95
moderately affected	30-60
moderately to strongly affected	15-30
strongly affected	5-15

Table 5.1: Storie Soil-Rating Chart

Erosion:	
100 none to slight	100
detrimental deposition	75-95
80 moderate sheet erosion	80-95
occasional shallow gullies	70-90
moderate sheet erosion with: shallow gullies	60-80
deep gullies	10-70
moderate sheet erosion with: deep gullies	10-60
severe sheet erosion	50-80
severe sheet erosion with: shallow gullies	40-50
deep gullies	10-40
very severe erosion	10-40
moderate wind erosion	80-95
severe wind erosion	30-80

5.4 Analysis of Soil Productivity using Storie index:

The analysis of soil productivity using Storie index reveals that Daund tahsil has three classes of soil productivity viz. Fair Grade, Poor Grade and Very Poor Grade. (Fig. 5.12)

Three soil grades have been set up in Daund tahsil by combining soils having ranges in index rating as follows:

1. Fair Grade: Soils that rate between 40 to 59 percent and which are generally of fair quality, and may give good results with certain specialized crops. Mostly area having fair grade soils is confined along Mula-Mutha river banks in the northern region, a part in the central region and along banks of Bhima river in the eastern region.

2. Poor Grade: Soils that rate between 20 to 39 percent and which have a narrow range in their agricultural possibilities. The maximum part of Daund tahsil shows poor grade of soils.

3. Very Poor Grade: Soils that rate between 10 and 19 percent are of very limited use except for pasture, because of adverse conditions such as shallowness, roughness, and alkali content. There are few patches of very poor grade of soils in Daund tahsil in the north-western, northern and south-eastern parts of the study region.

-x-x-x-

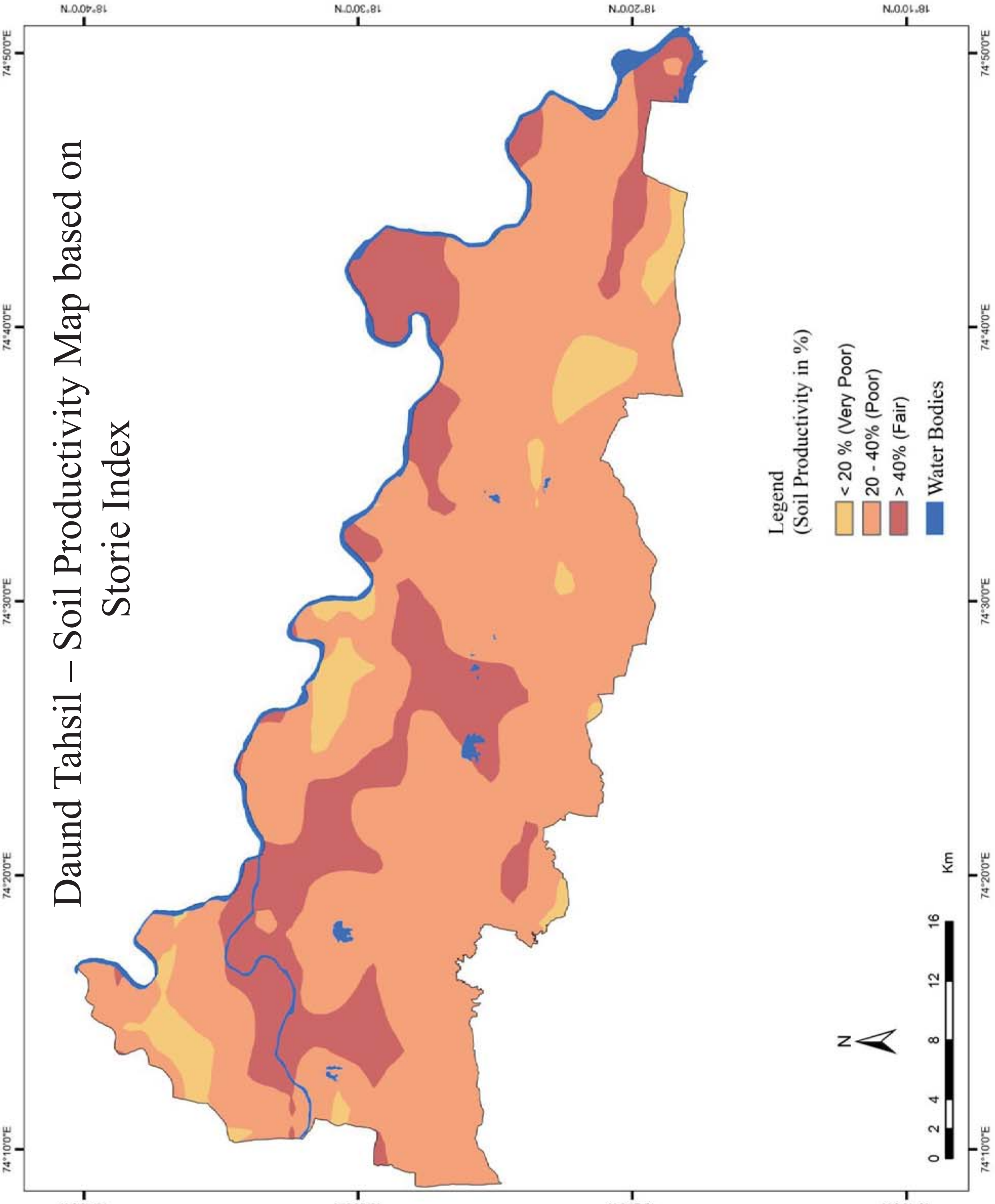

Daund Tahsil – Soil Productivity Map based on Storie Index
Legend
(Soil Productivity in %)
< 20 % (Very Poor)
20 - 40% (Poor)
> 40% (Fair)
Water Bodies
N
0 2 4 8 12 16
Km
74°10'0"E
74°20'0"E
74°30'0"E
74°40'0"E
74°50'0"E
18°40'0"N
18°30'0"N
18°20'0"N
18°10'0"N

Fig: 5.12

CHAPTER VI

FINDINGS, CONCLUSION AND RECOMMENDATIONS

6.1 Findings:

Land Use / Land Cover Analysis and Change Detection Analysis:

The LU / LC analysis of Daund tahsil for the years 2012 and 2015 and its subsequent change detection analysis revealed the extent of lands vulnerable to soil salinity in Daund tahsil.

The LU / LC map of Daund tahsil for the year 2012 shows that the proportion of saline land was significantly high i.e. 32.97% of the total study area in the year 2012. Also, the percentage of barren land was high i.e. 26.40% of the total area of Daund tahsil. Agricultural land covered about 16.40% of the study area, while agricultural fallow land covered 5.97% of the study area. The area of settlements was about 13.41% in Daund tahsil in the year 2012. The problem of soil salinization had started becoming a major serious concern in 2012.

The LU / LC map of Daund tahsil for the year 2015 shows that the proportion of saline land was significantly higher i.e. 37.61% of the total study area in 2015 as compared to 2012. Also, the percentage of barren land was high i.e. 22.37% of the total area of Daund tahsil. Agricultural land covered about 15.61% of the study area, while agricultural fallow land covered 6.20% of the study area. The area of settlements was about 13.62% in Daund tahsil in the year 2012. The problem of soil salinization had started becoming a major serious concern in 2012. These LU / LC statistics indicate that the problem of soil salinization has become worse and intensified from 2012 to 2015.

There have been significant changes in the extent of saline land in Daund tahsil within a short interval of time i.e. 3 years from 2012 to 2015.

The area under saline land, agricultural fallow land and settlements has increased, while the area under barren land, agricultural land and water bodies has decreased within a short period of 3 years from 2012 to 2015.

In Daund tahsil, the highest percentage change or increase from 2012 to 2015 is in the area under saline lands which is around 4.63%. The need for increasing land use for settlements has been fulfilled by converting barren land areas into built up areas. In the southern hilly part of Daund tahsil, the area under saline land has been slowly growing and replacing the barren land. There is a decrease of - 4.03% area from 2012 to 2015 in the area under barren land. The area of agricultural land is also showing a slight decrease of - 0.80% area from 2012 to 2015. This shrinking in the area under agriculture is attributed to the spread of saline land in 2015. During the field visit, it was observed that some agricultural fields are facing intense salinization problem. Over such fields, salt encrustation is not clearly visible at the surface but salts are clearly visible below it as the top soil is relatively thin. All such agricultural fields are classified under saline lands which are infertile for crop production. Agricultural fallow lands in Daund tahsil are attributed to the desertion or abandonment of the fields due to saline soils by the farmers. Such lands are mainly observed in the villages (Nangaon, Amonimal etc.) having severe problem of soil salinization. The proportion of area under agricultural fallow land is almost unaltered in Daund tahsil between 2012 and 2015.

In Daund tahsil, significantly larger and visible patches of salt encrustation are identified especially in the northern part of the tahsil which is having low lying physiography. The land on the hilly slopes in the southern part of the tahsil was mostly untouched by salinization during the year 2012, but patches of saline land spread in this region in the year 2015. Salt encrusted land, agricultural land and fallow land lie in proximity with each other. Farmers are not only misusing irrigation water but are using it unscientifically which has resulted into severe salinization problem which has been magnifying continuously.

In 2015, it was observed that in the valley areas in the southern part having hilly terrain, the process of salinization has become active. This is an indication that unscientific and inappropriate utilization of irrigation water is intensifying the soil salinization problem in the study area. As a result of which, the land areas which were unaffected by soil salinization process are also been converted into saline land. Ultimately, the salt affected land area in Daund tahsil has been growing day by day, mainly due to conditions of water logging in the fields due to unscientific irrigation practices by the farmers and their reluctant nature towards the condition.

Quantitative Analysis of Soil Salinity Indices:

According to the quantitative analysis of Normalized Difference Salinity Index (NDSI), highly saline land covers a major portion of Daund tahsil i.e. 23.79 % area as well as moderately saline land covers an area of around 20.0 %. Slightly saline land covers around 23.11 % of the total study area. Highly saline lands are found in the entire Daund tahsil covering a large portion of the study area.

The quantitative analysis of Salinity Index 1 shows that highly saline land covers a major portion of Daund tahsil i.e. 20.91 % area. Moderately saline land covers an area of around 16.46 %. Slightly saline land covers around 14.43 % of the total study area. Highly saline lands are found in the northern part of Daund tahsil especially along the canal.

According to the quantitative analysis of Salinity Index 2, highly saline land along with moderately saline land cover a major portion of Daund tahsil i.e. 13.81 % and 29.06 % area respectively. Slightly saline land covers around 26.27 % of the total study area. Highly saline lands are mostly found in the low lying areas in the northern part of the study area especially along the canal and river banks. A major part of the study area is moderately saline land.

The quantitative analysis of Salinity Index 3 indicates that highly saline land covers a major portion of Daund tahsil i.e. 29.63 % area whereas moderately saline land covers an area of around 12.84 %. Slightly saline land covers around 11.99 % of the total study area. Highly saline lands are found in most of the parts of Daund tahsil.

According to the quantitative analysis of Salinity Index 4, highly saline land covers a very large area of Daund tahsil i.e. 31.71 %. Moderately saline land covers an area of around 16.40 %. Slightly saline land covers around 16.69 % of the total study area. Highly saline lands are found almost in the entire region except hilly mountainous terrain in the southern part.

The quantitative analysis of Salinity Index 5 shows that highly saline land covers a major portion of Daund tahsil i.e. 18.45 % area whereas moderately saline land covers an area of around 11.93 %. Slightly saline land covers around 13.55 % of the total study area. Highly saline lands are found almost in the entire region except in the southern part.

According to the quantitative analysis of Salinity Index 6, highly saline land covers a very large area of Daund tahsil i.e. 32.03 %. Moderately saline land covers an area of around 11.82 %. Slightly saline land covers around 23.83 % of the total study area. Highly saline lands are found almost in the entire region except hilly mountainous terrain in the southern part.

The quantitative analysis of Salinity Index 7 shows that highly saline land covers a very large area of Daund tahsil i.e. 29.74 % along with moderately saline land which covers an area of around 19.80 %. Slightly saline land covers around 17.71 % of the study area. Highly saline land covers a major part of the study area.

According to the quantitative analysis of Salinity Index 8, highly saline land covers a very large area of Daund tahsil i.e. 30.88 %. Also, moderately saline land covers a large area of around 22.63 %. Slightly saline land covers around 25.88 % of the total study area. Highly saline lands are mainly found in the northern part of the tahsil which covers a large portion of the study area.

According to the quantitative analysis of Salinity Index 9, highly saline land covers an area of 17.90 % of Daund tahsil. Moderately saline land covers an area of around 21.70 %. Slightly saline land covers around 26.66 % of the total study area. A major part of the study area is slightly saline land. Highly saline land is found along the canal area and a few patches over the eastern and southern parts of Daund tahsil.

The quantitative analysis of the Soil Adjusted Vegetation Index (SAVI) shows that highly saline land covers an area of about 24.27 %. Moderately saline land covers an area of 15.27 %. While slightly saline land covers an area of 28.53 % which is a major part of the study area. Highly saline lands are found in most of the parts of the study area.

The quantitative analysis of all the eleven soil salinity indices shows that highly saline lands covers 24.8% of the total study area and they are found in all the major parts of Daund tahsil viz. western, northern, central, eastern and south eastern parts. The moderately saline lands account for 18.0% of the total study area and they are present in patches over the western, northern, central, and eastern parts in association with the highly saline lands. Also, the slightly saline lands are found in patches in association with highly saline lands and are mainly concentrated in the valleys in the southern part. The slightly saline lands highlight the severity of the soil salinization problem as these lands indicate that salinization process is becoming established over these patches of the study area.

Table 6.1: Area under Soil Salinity in Daund Tahsil

Sr. No.	**Classes**	**Area in sq. km**	**Area in %**
1	Highly Saline Land	337.8	24.83
2	Moderately Saline Land	244.7	17.99
3	Slightly Saline Land	288.1	20.79
4	Non Saline Land	418.5	30.76
5	Water bodies	76.6	05.63
	Total Area	1360.4	100.00

Analysis of Chemical Properties of Soil and Productivity using Storie Index:

Slightly alkaline soils (pH 7.1 to 7.5) cover very less area in Daund tahsil and are found in patches. In Daund tahsil, mostly strongly alkaline soils (pH 8.3 to 9.0) and moderately alkaline soils (pH 7.5 to 8.3) are dominant. In most of the parts of the study area, the EC (Electrical Conductivity) is below average EC i.e. less than 1.0. The soils in the central part of Daund tahsil shows high EC values of more than 3.0 which can affect the growth of all types of crops.

According to the analysis of soil productivity using Storie index technique, there are three grades of soil in Daund tahsil indicating the soil productivity. These are fair grade, poor grade and very poor grade soils. Area having fair grade soils is along the Mula-Mutha river banks in the northern part of Daund tahsil, a part in the central region and along banks of Bhima river in the eastern part of Daund tahsil. The poor grades of soils are found in most of the parts of Daund tahsil. The very poor grade soils are concentrated in few patches in Daund tahsil in the north-western, northern and south-eastern parts.

6.2 Conclusion:

The canal-irrigated sugarcane cultivating areas in the Daund tahsil of Western Maharashtra Plain region have become water logged and a great area of the agricultural land has been degraded by conversion of maximum area into saline land in Daund tahsil.

The excessive use of water for irrigation and chemical fertilizers for large scale sugarcane cultivation has degraded the soil in Daund tahsil. Unscientific practices of irrigation have made a great impact on the fertility levels of soils in the sugarcane cultivating belt of Daund tahsil.

Daund tahsil has the largest area under saline soils or alkali soils among all the tahsils in Pune district. Daund tahsil accounts for more than 14,000 hectares of saline land area in Pune district.

Remote sensing data based vegetation and soil salinity indices such as the Soil Adjusted Vegetation Index (SAVI), the Normalized Difference Salinity Index (NDSI), and nine other soil salinity indices formulated on the basis of combinations of spectral bands, have been implemented for the mapping of soil salinity in Daund tahsil. The salinity indices have been very useful to map the saline areas and the degree of salinity in the study area. The salinity indices and LULC change detection analysis have revealed the spread of saline soils in Daund tahsil.

Among all the soil salinity and vegetation indices calculated using remote sensing data, salinity indices NDSI and SAVI index shows close similarity in the result and also with the present situation of salinization in the study area. Both the images of NDSI and SAVI have been verified with the Google earth image of the same time of the year and the results reveal that these two indices can be used for analysis or delineation of salt affected areas as they provide accurate picture of the salinization problem in the study area.

If suitable remedial measures are not taken, the area under saline land will continue to grow every year.

6.3 Problems and Recommendations:

After the development of Khadakwasla Canal in the Daund region, no repair work of the canal has been undertaken. Due to this, there is lot of leakage of water from the canal in the surrounding agricultural region leading to water logging conditions as there is continuous supply of water from the canal. As a result of this, the problem of salinization has been magnified and the area under saline lands has been increasing in the study area. The leakages should be detected and repaired.

An excessive amount of water gets supplied to agricultural fields in Daund tahsil due to the problem of load shedding. Due to this, the areas of elongated fields which have already got water supply are again supplied with water, ultimately leading to water logging conditions. This problem should be prevented through proper planning by farmers in consultation with the concerned authorities.

There has been excessive water logging and increase in water level in the fields due to canal irrigation. As long as the canal has water, the fields are also supplied with water. The water from the wells should be lifted so that the excess water from the fields will infiltrate underground and the water level will be lowered in the field.

The farmers in Daund tahsil have converted the area of non perennial streams into agricultural land by widening them. As the streams are plugged by the farmers, it becomes a great obstacle for the excess water to flow out of the agricultural fields. Such practices should be totally curbed to control the problem of water logging and spread of saline soils.

Farmers in Daund tahsil lack knowledge regarding water use and requirements of different crops and proper technique of supplying irrigation water to the fields. This is intensifying the salinization problem in the Daund tahsil. So, the farmers need to be educated regarding water requirements of various crops, effects of over use of water and proper techniques of irrigation such as drip irrigation technique. The five sugar factories in Daund can take this initiative of training farmers by coming together. There should be application of proper principles of soil and water management to tackle against the water logging and soil salinization problems.

The lands in Daund tahsil have not only become saline but also there is a great increase in the salt content in the ground water. The underground water has a significant content of salts in it. Ground water from bore wells and wells has become saline. After using such water for irrigation, layer of salts is left behind in the soils after evaporation. Such saline ground water should not be used for cultivation. Filters should be fitted on wells to reduce the salts in the ground water. Water should be passed through filter or treated before using it for irrigation. The use of such water can be limited for agriculture purpose.

The excessive use of chemical fertilizers for higher yields by farmers has increased soil salinity in Daund tahsil. Injudicious use of fertilizers by the farmers can be controlled by giving proper knowledge to the farmers. Organic fertilizers can be used as the best alternative to chemical fertilizers.

Sugarcane crop needs a great quantity of water i.e. around 2000 mm per hectare annually. Also, sugarcane is a deep-rooted crop in the soil and can extract soil water from considerable depths such as well below one meter, throughout the year. Sugarcane is very well recognized crop for its capacity of high water consumption. The trend of sugarcane monoculture has increased because labourers are not available and cultivation of such cash crops is easier and requires less labour. The monoculture cropping pattern of sugarcane can be replaced with other alternatives such as crop rotation or inter cropping for better soil productivity.

The agricultural lands are not kept fallow in the study area. Crops are grown all round the year leading to increased watering frequency to the fields. Day by day the proportion of cash crops is increasing because they fetch good returns but such crops require a great amount of water. Agricultural lands should be kept fallow to restore fertility of the soil and to reduce watering of the fields.

After land has become saline in the study area, instead of treating such land it is has been used for other purposes or land uses such as jaggery factory, brick factory or poultry. Instead of changing the land use, saline land should be treated and reclaimed by planting crops which reduce salinity such as the sustainable variety of 265-sugarcane, jute etc.

The rate of spread of salinization is rapid in villages such as Nangaon, Amonimal, Hatavalan etc. Lands have become infertile. Government should provide special funds to treat and reclaim such saline lands.

x-x-x

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Appendix - A: Relief Parameters					
Longitude	**Latitude**	**Lowest Elevation (m)**	**Absolute Relief (m)**	**Relative Relief (m)**	**Dissection Index (%)**
74.27	18.65	520.00	560.00	40.00	7.14
74.22	18.61	540.00	560.00	20.00	3.57
74.27	18.61	520.00	560.00	40.00	7.14
74.31	18.61	520.00	560.00	40.00	7.14
74.17	18.56	540.00	560.00	20.00	3.57
74.22	18.56	520.00	560.00	40.00	7.14
74.27	18.56	520.00	550.00	30.00	5.45
74.31	18.56	510.00	550.00	40.00	7.27
74.36	18.56	510.00	540.00	30.00	5.56
74.41	18.56	510.00	540.00	30.00	5.56
74.17	18.52	520.00	550.00	30.00	5.45
74.22	18.52	530.00	550.00	20.00	3.64
74.27	18.52	530.00	550.00	20.00	3.64
74.31	18.52	530.00	560.00	30.00	5.36
74.36	18.52	530.00	550.00	20.00	3.64
74.41	18.52	520.00	530.00	10.00	1.89
74.46	18.52	510.00	520.00	10.00	1.92
74.50	18.52	500.00	520.00	20.00	3.85
74.55	18.52	500.00	510.00	10.00	1.96
74.60	18.52	490.00	510.00	20.00	3.92
74.17	18.47	550.00	610.00	60.00	9.84
74.22	18.47	550.00	640.00	90.00	14.06
74.27	18.47	550.00	630.00	80.00	12.70
74.31	18.47	560.00	600.00	40.00	6.67
74.36	18.47	540.00	580.00	40.00	6.90
74.41	18.47	530.00	550.00	20.00	3.64
74.46	18.47	520.00	540.00	20.00	3.70
74.50	18.47	520.00	540.00	20.00	3.70
74.55	18.47	500.00	530.00	30.00	5.66
74.60	18.47	500.00	540.00	40.00	7.41
74.65	18.47	490.00	510.00	20.00	3.92
74.69	18.47	480.00	510.00	30.00	5.88
74.74	18.47	480.00	500.00	20.00	4.00
74.17	18.43	600.00	860.00	260.00	30.23
74.22	18.43	610.00	780.00	170.00	21.79
74.27	18.43	620.00	740.00	120.00	16.22
74.31	18.43	590.00	720.00	130.00	18.06

Longitude	Latitude	Lowest Elevation (m)	Absolute Relief (m)	Relative Relief (m)	Dissection Index (%)
74.36	18.43	570.00	680.00	110.00	16.18
74.41	18.43	550.00	570.00	20.00	3.51
74.46	18.43	540.00	580.00	40.00	6.90
74.50	18.43	540.00	660.00	120.00	18.18
74.55	18.43	520.00	620.00	100.00	16.13
74.60	18.43	510.00	600.00	90.00	15.00
74.64	18.43	500.00	600.00	100.00	16.67
74.69	18.43	490.00	540.00	50.00	9.26
74.74	18.43	470.00	510.00	40.00	7.84
74.31	18.38	620.00	710.00	90.00	12.68
74.36	18.38	590.00	680.00	90.00	13.24
74.41	18.38	570.00	670.00	100.00	14.93
74.46	18.38	580.00	670.00	90.00	13.43
74.50	18.38	600.00	650.00	50.00	7.69
74.55	18.38	550.00	640.00	90.00	14.06
74.60	18.38	530.00	570.00	40.00	7.02
74.64	18.38	510.00	600.00	90.00	15.00
74.69	18.38	510.00	590.00	80.00	13.56
74.74	18.38	480.00	580.00	100.00	17.24
74.79	18.38	480.00	530.00	50.00	9.43
74.36	18.34	630.00	670.00	40.00	5.97
74.41	18.34	630.00	660.00	30.00	4.55
74.46	18.34	630.00	680.00	50.00	7.35
74.50	18.34	600.00	640.00	40.00	6.25
74.55	18.34	580.00	640.00	60.00	9.38
74.60	18.34	550.00	600.00	50.00	8.33
74.64	18.34	530.00	570.00	40.00	7.02
74.69	18.34	510.00	580.00	70.00	12.07
74.74	18.34	480.00	570.00	90.00	15.79
74.79	18.34	490.00	550.00	60.00	10.91
74.83	18.34	480.00	500.00	20.00	4.00
74.64	18.29	550.00	580.00	30.00	5.17
74.69	18.29	540.00	570.00	30.00	5.26
74.74	18.29	500.00	550.00	50.00	9.09
74.79	18.29	480.00	490.00	10.00	2.04
74.83	18.29	410.00	510.00	100.00	19.61

Appendix - B: Soil Chemical Properties

Soil Sample No.	Longitude (°)	Latitude (°)	PH	EC	N	P	P	Fe	Mn	Zn	Cu
1	74.41607	18.40949	8.1	0.35	560	50	345	0.41	0.72	0.56	0.22
2	74.40677	18.41168	8.2	1.6		105	343	0.14	0.44	0.32	0.24
3	74.40562	18.38754	8.21	0.25	264	32	810	0.86	0.79	0.22	0.33
4	74.40125	18.39243	8.1	0.21	215	35	745	1.55	1.18	0.24	0.39
5	74.41127	18.40772	8.6	0.35	296	50	825	0.74	0.81	0.19	0.55
6	74.4194	18.41116	8.15	0.27	328	47	946	0.94	1.105	0.26	0.51
7	74.40584	18.4046	8.25	0.73	256	38	886	0.91	0.77	0.22	0.29
8	74.40755	18.40534	8.25	0.73	256	38	886	0.91	0.77	0.22	0.29
9	74.40662	18.40573	8.25	0.73	256	38	886	0.91	0.77	0.22	0.29
10	74.41714	18.4109	7.91	0.2	400	40	900	0.94	0.85	0.25	0.29
11	74.21933	18.60582	8.2	0.23	260	39	250	1.6	1.2	0.36	0.25
12	74.21869	18.59496	8.3	0.854	480	35	485	0.26	1.06	0.26	0.28
13	74.2166	18.59443	8	0.68	304	49	700	0.22	0.72	0.34	0.24
14	74.21729	18.59717	7.8	0.666	320	38	995	0.18	0.84	0.28	0.28
15	74.21656	18.59658	7.8	0.666	320	38	995	0.18	0.84	0.28	0.28
16	74.25591	18.58948	8.6	0.73	577	26	1031	0.92	0.77	0.28	0.28
17	74.26886	18.5773	8.3	0.58	344	36	1044	0.85	0.92	0.32	0.28
18	74.26496	18.5783	8.4	0.35	416	38	900	0.85	0.87	0.29	0.27
19	74.26734	18.57686	7.9	0.72	344	45	980	0.92	1.19	0.25	0.35
20	74.27106	18.57466	7.4	1.718	4597	106	989	0.16	0.6	0.34	0.32
21	74.66676	18.487	8.9	0.82	320	45	1047	0.95	0.78	0.22	0.27
22	74.30759	18.48066	8.2	0.3	224	28	1238	0.87	0.9	0.2	0.55
23	74.30582	18.48009	8.3	0.47	408	37	880	0.89	1.07	0.24	0.39
24	74.30579	18.47476	8.82	0.63	216	31	821	0.92	1.22	0.23	0.42
25	74.31929	18.51009	7.3	0.75	376	54	870	0.96	1.25	0.37	0.29
26	74.33239	18.49917	8.1	0.52	320	72	860	0.96	1.25	0.36	0.29

Soil Sample No.	Longitude (°)	Latitude (°)	PH	EC	N	P	P	Fe	Mn	Zn	Cu
27	74.17241	18.46434	7.9	0.26	697	30	625	1.7	1.56	0.36	0.26
28	74.20421	18.46163	7.9	0.23	220	25	640	0.85	0.95	0.33	0.31
29	74.19287	18.45406	8.1	0.94	420	47	430	1.7	1.35	0.35	0.24
30	74.43697	18.52897	8.1	0.83	400	54	923	2.5	1.25	0.19	0.28
31	74.43208	18.54177	8.2	0.251	480	85	387	0.22	0.78	0.42	0.34
32	74.43334	18.54123	7.8	0.342	304	69	917	0.28	0.86	0.24	0.28
33	74.43292	18.5407	8	0.428	561	35	953	0.14	0.66	0.36	0.32
34	74.42609	18.53556	8.3	0.62	1922	90	1207	0.2	0.32	0.38	0.36
35	74.42888	18.51794	9.4	0.47	4020	59	1001	0.28	0.84	0.22	0.36
36	74.42458	18.53538	8.2	0.36	833	110	1238	0.2	0.32	0.38	0.36
37	74.43244	18.52011	7.6	0.582	1762	107	1431	0.26	0.38	0.3	0.28
38	74.42094	18.51519	8	0.58	264	57	607	1.55	1.18	0.24	0.39
39	74.42333	18.51531	8.1	0.5	336	54	700	1.61	1.25	0.23	0.38
40	74.4321	18.54289	8.1	0.785	961	69	1059	0.2	0.98	0.38	0.32
41	74.42907	18.5308	8.3	0.375	336	57	923	0.16	1.2	0.5	0.3
42	74.5002	18.34461	8.2	0.26	290	90	810	0.6	0.85	0.45	0.3
43	74.51321	18.33902	8.4	0.121	60	228	0.37	0.42	0.07	0.12	0.42
44	74.5035	18.34469	8.5	0.11	7	564	0.72	0.42	0.04	0.16	0.66
45	74.50053	18.332	8.5	0.111	50	653	0.67	0.44	0.02	0.2	0.66
46	74.51174	18.35627	8.3	0.75	57	712	0.65	0.46	0.01	0.21	0.6
47	74.51259	18.34371	8.2	0.64	63	310	0.34	0.46	0.02	0.24	0.56
48	74.49862	18.34174	7.6	0.64	37	302	0.09	0.44	0.02	0.13	0.56
49	74.49064	18.35163	8.3	0.96	34	813	0.56	0.44	0.26	0.13	0.6
50	74.49848	18.34772	8	0.67	22	608	0.64	0.38	0.4	0.22	0.58
51	74.44757	18.44102	8.25	0.31	250	42	831	3.24	1.44	0.25	0.36
52	74.43784	18.45019	8.15	4.5	210	70	1015	0.94	0.88	0.19	0.22
53	74.45688	18.41403	8.5	1.05	440	57	942	0.97	0.75	0.21	0.23

Soil Sample No.	Longitude (°)	Latitude (°)	PH	EC	N	P	P	Fe	Mn	Zn	Cu
54	74.46366	18.42971	8.1	0.973	464	23	1038	0.94	1.26	0.42	0.32
55	74.46973	18.4353	7.8	2.9	240	20	918	0.75	1.32	0.25	0.29
56	74.43845	18.42952	8.4	1.4	200	18	749	0.68	0.88	0.22	0.27
57	74.45842	18.40332	8.1	1.2	320	32	812	0.95	0.81	0.29	0.27
58	74.43532	18.45401	8.9	0.86	248	28	1191	0.75	0.62	0.35	0.27
59	74.46762	18.41722	8.6	0.37	488	23	702	1.62	0.95	0.28	0.26
60	74.44621	18.42368	7.94	0.95	545	47	945	1.42	1.19	0.25	0.35
61	74.47816	18.42589	7.5	0.16	360	50	1146	1.42	1.19	0.25	0.35
62	74.44112	18.4392	7.5	0.3	336	41	1074	2.65	1.56	0.32	0.33
63	74.46762	18.41722	7.64	1.3	296	33	1180	0.95	1.23	0.22	0.32
64	74.70438	18.45093	8	1.18	50	209	1.25	0.22	0.38	0.48	0.39
65	74.70315	18.47407	7.9	0.48	50	309	1.57	0.12	0.64	0.43	0.36
66	74.70715	18.44343	8.1	0.5	43	180	1.09	0.1	0.25	0.18	0.16
67	74.70198	18.45777	8.7	0.155	3	160	0.61	0.05	0.49	0.36	0.19
68	74.69985	18.45772	8.3	0.185	1	210	1.09	0.03	0.27	0.44	0.24
69	74.72131	18.47509	8.3	0.14	3	220	1.05	0.1	0.5	0.2	0.18
70	74.69456	18.41974	7.5	0.1	50	329	1.57	0.22	0.75	0.32	0.22
71	74.28555	18.57295	7.9	1.05	70	1624	0.39	0.5	1.69	0.43	0.84
72	74.30876	18.55266	8.2	0.42	80	2433	0.5	0.23	0.84	1.14	0.84
73	74.28997	18.57412	7.6	0.75	131	3522	0.42	0.22	0.87	0.18	0.24
74	74.29034	18.57424	7.5	0.56	145	3810	0.97	0.22	1.04	0.26	0.25
75	74.14324	18.46573	7.8	0.26	80	631	0.2	0.18	0.9	0.24	0.26
76	74.14273	18.46857	7.9	0.24	85	743	0.2	0.32	0.88	0.32	0.24
77	74.82192	18.32801	8.1	0.843	472	62	172	0.18	1.02	0.4	0.28
78	74.8168	18.32888	7.8	0.607	721	66	890	0.1	0.74	0.36	0.36
79	74.50743	18.48518	8.5	0.24	376	41	516	0.85	0.73	0.22	0.29
80	74.40828	18.46982	7.3	46	216	16	1079	0.45	0.56	0.18	0.29

Soil Sample No.	Longitude (°)	Latitude (°)	PH	EC	N	P	P	Fe	Mn	Zn	Cu
81	74.42757	18.47563	8.8	0.43	240	18	750	0.96	1.2	0.33	0.26
82	74.41636	18.44016	8.37	0.37	304	35	607	1.75	1.18	0.18	0.35
83	74.41686	18.44295	8.81	0.73	256	35	1173	0.94	1.19	0.24	0.39
84	74.41079	18.47126	8.75	0.26	248	55	1220	2.68	1.56	0.31	0.55
85	74.42141	18.44059	8.42	0.78	320	41	1400	2.58	1.49	0.35	0.42
86	74.40534	18.50459	8.6	1.4	200	50	1124	2.1	1.32	0.21	0.32
87	74.40267	18.48962	8.07	0.495	400	63	933	2.1	1.05	0.29	0.45
88	74.39991	18.45632	8.15	0.678	356	65	950	3.25	1.05	0.15	0.33
89	74.42013	18.43796	8.41	0.7	336	55	1079	2.89	1.19	0.25	0.35
90	74.44394	18.52996	7.9	0.85	272	30	1078	1.38	1.55	0.17	0.35
91	74.28772	18.48438	8.3	0.47	312	45	781	0.98	1.14	0.29	0.33
92	74.26098	18.49852	8.23	0.29	248	49	542	0.89	1.18	0.28	0.33
93	74.39267	18.54352	8.34	0.25	456	57	1378	2.87	1.57	0.38	0.41
94	74.40163	18.52779	8	0.58	264	57	607	1.55	1.18	0.24	0.39
95	74.41724	18.53214	8.41	0.625	300	55	1100	2.75	1.65	0.23	0.32
96	74.19	18.69	7.88	0.2	100	285	413	0.73	0.61	0.34	0.21
97	74.86	18.16	8.45	0.4	164	249	410	0.43	1.5	0.23	0.18
98	74.85	18.28	8.09	0.8	524	65	210	0.14	1.02	0.39	0.32
99	74.13	18.28	8.07	0.2	97	347	102	0.82	2.3	0.23	0.3

Appendix - C: Storie Index Ratings

Longitude	Latitude	Soil Depth	Soil Depth (A)	Soil Texture	Soil Texture (B)	Slope	Slope (C)	Storie Index
74.25833333	18.67510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.27500000	18.67510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.29166667	18.65843874	30.00	0.30	90.00	0.90	100.00	1.00	27.00
74.22500000	18.65843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.24166667	18.65843874	33.00	0.33	90.00	0.90	100.00	1.00	29.70
74.25833333	18.65843874	33.00	0.33	90.00	0.90	100.00	1.00	29.70
74.27500000	18.65843874	38.00	0.38	90.00	0.90	100.00	1.00	34.20
74.29166667	18.64177207	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.30833333	18.64177207	49.00	0.49	90.00	0.90	100.00	1.00	44.10
74.22500000	18.64177207	48.00	0.48	90.00	0.90	100.00	1.00	43.20
74.24166667	18.64177207	17.00	0.17	90.00	0.90	100.00	1.00	15.30
74.25833333	18.64177207	48.00	0.48	90.00	0.90	100.00	1.00	43.20
74.27500000	18.64177207	48.00	0.48	90.00	0.90	100.00	1.00	43.20
74.29166667	18.62510540	27.00	0.27	90.00	0.90	100.00	1.00	24.30
74.30833333	18.62510540	40.00	0.40	90.00	0.90	100.00	1.00	36.00
74.20833333	18.62510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.22500000	18.62510540	24.00	0.24	90.00	0.90	100.00	1.00	21.60
74.24166667	18.62510540	20.00	0.20	93.00	0.93	100.00	1.00	18.60
74.25833333	18.62510540	21.00	0.21	97.00	0.97	100.00	1.00	20.37
74.27500000	18.62510540	19.00	0.19	90.00	0.90	100.00	1.00	17.10
74.29166667	18.60843874	22.00	0.22	90.00	0.90	100.00	1.00	19.80
74.30833333	18.60843874	18.00	0.18	90.00	0.90	100.00	1.00	16.20
74.32500000	18.60843874	17.00	0.17	90.00	0.90	100.00	1.00	15.30
74.19166667	18.60843874	23.00	0.23	90.00	0.90	100.00	1.00	20.70
74.20833333	18.60843874	23.00	0.23	90.00	0.90	100.00	1.00	20.70
74.22500000	18.60843874	17.00	0.17	90.00	0.90	100.00	1.00	15.30
74.24166667	18.60843874	18.00	0.18	90.00	0.90	100.00	1.00	16.20
74.25833333	18.60843874	23.00	0.23	100.00	1.00	100.00	1.00	23.00
74.27500000	18.60843874	22.00	0.22	100.00	1.00	100.00	1.00	22.00
74.29166667	18.59177207	33.00	0.33	90.00	0.90	100.00	1.00	29.70
74.30833333	18.59177207	42.00	0.42	90.00	0.90	100.00	1.00	37.80
74.32500000	18.59177207	19.00	0.19	90.00	0.90	100.00	1.00	17.10
74.17500000	18.59177207	17.00	0.17	90.00	0.90	100.00	1.00	15.30
74.19166667	18.59177207	20.00	0.20	90.00	0.90	100.00	1.00	18.00
74.20833333	18.59177207	19.00	0.19	90.00	0.90	100.00	1.00	17.10
74.22500000	18.59177207	18.00	0.18	90.00	0.90	100.00	1.00	16.20
74.24166667	18.59177207	28.00	0.28	90.00	0.90	100.00	1.00	25.20
74.25833333	18.59177207	43.00	0.43	90.00	0.90	100.00	1.00	38.70
74.27500000	18.59177207	33.00	0.33	90.00	0.90	100.00	1.00	29.70
74.29166667	18.57510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00

Longitude	Latitude	Soil Depth	Soil Depth (A)	Soil Texture	Soil Texture (B)	Slope	Slope (C)	Storie Index
74.30833333	18.57510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.32500000	18.57510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.34166667	18.57510540	48.00	0.48	90.00	0.90	100.00	1.00	43.20
74.37500000	18.57510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.39166667	18.57510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.40833333	18.57510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.15833333	18.57510540	38.00	0.38	90.00	0.90	100.00	1.00	34.20
74.17500000	18.57510540	18.00	0.18	90.00	0.90	100.00	1.00	16.20
74.19166667	18.57510540	40.00	0.40	90.00	0.90	100.00	1.00	36.00
74.20833333	18.57510540	41.00	0.41	90.00	0.90	100.00	1.00	36.90
74.22500000	18.57510540	35.00	0.35	90.00	0.90	100.00	1.00	31.50
74.24166667	18.57510540	24.00	0.24	90.00	0.90	100.00	1.00	21.60
74.25833333	18.57510540	39.00	0.39	90.00	0.90	100.00	1.00	35.10
74.27500000	18.57510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.29166667	18.55843874	44.00	0.44	93.00	0.93	100.00	1.00	40.92
74.30833333	18.55843874	38.00	0.38	97.00	0.97	100.00	1.00	36.86
74.32500000	18.55843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.34166667	18.55843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.35833333	18.55843874	43.00	0.43	90.00	0.90	100.00	1.00	38.70
74.37500000	18.55843874	30.00	0.30	90.00	0.90	100.00	1.00	27.00
74.39166667	18.55843874	27.00	0.27	90.00	0.90	100.00	1.00	24.30
74.40833333	18.55843874	36.00	0.36	90.00	0.90	100.00	1.00	32.40
74.42500000	18.55843874	43.00	0.43	90.00	0.90	100.00	1.00	38.70
74.44166667	18.55843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.15833333	18.55843874	27.00	0.27	90.00	0.90	100.00	1.00	24.30
74.17500000	18.55843874	24.00	0.24	90.00	0.90	100.00	1.00	21.60
74.19166667	18.55843874	18.00	0.18	90.00	0.90	100.00	1.00	16.20
74.20833333	18.55843874	48.00	0.48	90.00	0.90	100.00	1.00	43.20
74.22500000	18.55843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.24166667	18.55843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.25833333	18.55843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.27500000	18.55843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.29166667	18.54177207	42.00	0.42	97.00	0.97	100.00	1.00	40.74
74.30833333	18.54177207	45.00	0.45	93.00	0.93	100.00	1.00	41.85
74.32500000	18.54177207	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.34166667	18.54177207	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.35833333	18.54177207	40.00	0.40	90.00	0.90	100.00	1.00	36.00
74.37500000	18.54177207	37.00	0.37	90.00	0.90	100.00	1.00	33.30
74.39166667	18.54177207	38.00	0.38	90.00	0.90	100.00	1.00	34.20
74.40833333	18.54177207	40.00	0.40	90.00	0.90	100.00	1.00	36.00
74.42500000	18.54177207	43.00	0.43	90.00	0.90	100.00	1.00	38.70
74.44166667	18.54177207	50.00	0.50	90.00	0.90	100.00	1.00	45.00

Longitude	Latitude	Soil Depth	Soil Depth (A)	Soil Texture	Soil Texture (B)	Slope	Slope (C)	Storie Index
74.15833333	18.54177207	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.47500000	18.54177207	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.49166667	18.54177207	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.17500000	18.54177207	48.00	0.48	90.00	0.90	100.00	1.00	43.20
74.19166667	18.54177207	47.00	0.47	90.00	0.90	100.00	1.00	42.30
74.20833333	18.54177207	49.00	0.49	90.00	0.90	100.00	1.00	44.10
74.22500000	18.54177207	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.24166667	18.54177207	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.25833333	18.54177207	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.27500000	18.54177207	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.29166667	18.52510540	28.00	0.28	100.00	1.00	100.00	1.00	28.00
74.30833333	18.52510540	38.00	0.38	97.00	0.97	100.00	1.00	36.86
74.32500000	18.52510540	40.00	0.40	93.00	0.93	100.00	1.00	37.20
74.34166667	18.52510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.35833333	18.52510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.37500000	18.52510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.39166667	18.52510540	47.00	0.47	90.00	0.90	100.00	1.00	42.30
74.40833333	18.52510540	17.00	0.17	90.00	0.90	100.00	1.00	15.30
74.42500000	18.52510540	17.00	0.17	90.00	0.90	100.00	1.00	15.30
74.44166667	18.52510540	17.00	0.17	90.00	0.90	100.00	1.00	15.30
74.45833333	18.52510540	17.00	0.17	90.00	0.90	100.00	1.00	15.30
74.47500000	18.52510540	38.00	0.38	90.00	0.90	100.00	1.00	34.20
74.49166667	18.52510540	17.00	0.17	90.00	0.90	100.00	1.00	15.30
74.50833333	18.52510540	17.00	0.17	90.00	0.90	100.00	1.00	15.30
74.17500000	18.52510540	27.00	0.27	90.00	0.90	100.00	1.00	24.30
74.19166667	18.52510540	35.00	0.35	90.00	0.90	100.00	1.00	31.50
74.20833333	18.52510540	25.00	0.25	90.00	0.90	100.00	1.00	22.50
74.22500000	18.52510540	41.00	0.41	90.00	0.90	100.00	1.00	36.90
74.24166667	18.52510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.25833333	18.52510540	31.00	0.31	100.00	1.00	100.00	1.00	31.00
74.27500000	18.52510540	40.00	0.40	93.00	0.93	100.00	1.00	37.20
74.29166667	18.50843874	30.00	0.30	100.00	1.00	100.00	1.00	30.00
74.30833333	18.50843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.32500000	18.50843874	30.00	0.30	97.00	0.97	100.00	1.00	29.10
74.34166667	18.50843874	48.00	0.48	93.00	0.93	100.00	1.00	44.64
74.35833333	18.50843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.37500000	18.50843874	48.00	0.48	90.00	0.90	100.00	1.00	43.20
74.39166667	18.50843874	47.00	0.47	90.00	0.90	100.00	1.00	42.30
74.40833333	18.50843874	34.00	0.34	90.00	0.90	100.00	1.00	30.60
74.42500000	18.50843874	24.00	0.24	90.00	0.90	100.00	1.00	21.60
74.44166667	18.50843874	19.00	0.19	90.00	0.90	100.00	1.00	17.10
74.45833333	18.50843874	18.00	0.18	90.00	0.90	100.00	1.00	16.20

Longitude	Latitude	Soil Depth	Soil Depth (A)	Soil Texture	Soil Texture (B)	Slope	Slope (C)	Storie Index
74.47500000	18.50843874	19.00	0.19	90.00	0.90	100.00	1.00	17.10
74.49166667	18.50843874	27.00	0.27	90.00	0.90	100.00	1.00	24.30
74.50833333	18.50843874	18.00	0.18	90.00	0.90	100.00	1.00	16.20
74.52500000	18.50843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.54166667	18.50843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.55833333	18.50843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.17500000	18.50843874	17.00	0.17	90.00	0.90	100.00	1.00	15.30
74.67500000	18.50843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.69166667	18.50843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.70833333	18.50843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.19166667	18.50843874	17.00	0.17	90.00	0.90	100.00	1.00	15.30
74.20833333	18.50843874	24.00	0.24	90.00	0.90	100.00	1.00	21.60
74.22500000	18.50843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.24166667	18.50843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.25833333	18.50843874	40.00	0.40	97.00	0.97	100.00	1.00	38.80
74.27500000	18.50843874	35.00	0.35	97.00	0.97	100.00	1.00	33.95
74.29166667	18.49177207	40.00	0.40	97.00	0.97	100.00	1.00	38.80
74.30833333	18.49177207	30.00	0.30	100.00	1.00	100.00	1.00	30.00
74.32500000	18.49177207	35.00	0.35	97.00	0.97	100.00	1.00	33.95
74.34166667	18.49177207	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.35833333	18.49177207	35.00	0.35	97.00	0.97	100.00	1.00	33.95
74.37500000	18.49177207	28.00	0.28	100.00	1.00	100.00	1.00	28.00
74.39166667	18.49177207	48.00	0.48	93.00	0.93	100.00	1.00	44.64
74.40833333	18.49177207	47.00	0.47	90.00	0.90	100.00	1.00	42.30
74.42500000	18.49177207	20.00	0.20	90.00	0.90	100.00	1.00	18.00
74.44166667	18.49177207	45.00	0.45	90.00	0.90	100.00	1.00	40.50
74.15833333	18.49177207	47.00	0.47	93.00	0.93	100.00	1.00	43.71
74.45833333	18.49177207	17.00	0.17	90.00	0.90	100.00	1.00	15.30
74.47500000	18.49177207	37.00	0.37	90.00	0.90	100.00	1.00	33.30
74.49166667	18.49177207	18.00	0.18	90.00	0.90	100.00	1.00	16.20
74.50833333	18.49177207	17.00	0.17	90.00	0.90	100.00	1.00	15.30
74.52500000	18.49177207	47.00	0.47	90.00	0.90	100.00	1.00	42.30
74.54166667	18.49177207	45.00	0.45	90.00	0.90	100.00	1.00	40.50
74.55833333	18.49177207	20.00	0.20	90.00	0.90	100.00	1.00	18.00
74.57500000	18.49177207	47.00	0.47	90.00	0.90	100.00	1.00	42.30
74.17500000	18.49177207	48.00	0.48	90.00	0.90	100.00	1.00	43.20
74.65833333	18.49177207	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.67500000	18.49177207	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.69166667	18.49177207	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.70833333	18.49177207	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.72500000	18.49177207	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.19166667	18.49177207	38.00	0.38	97.00	0.97	100.00	1.00	36.86

Longitude	Latitude	Soil Depth	Soil Depth (A)	Soil Texture	Soil Texture (B)	Slope	Slope (C)	Storie Index
74.20833333	18.49177207	49.00	0.49	90.00	0.90	100.00	1.00	44.10
74.22500000	18.49177207	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.24166667	18.49177207	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.25833333	18.49177207	47.00	0.47	93.00	0.93	100.00	1.00	43.71
74.27500000	18.49177207	45.00	0.45	93.00	0.93	100.00	1.00	41.85
74.14166667	18.47510540	47.00	0.47	93.00	0.93	100.00	1.00	43.71
74.29166667	18.47510540	37.00	0.37	97.00	0.97	100.00	1.00	35.89
74.30833333	18.47510540	40.00	0.40	93.00	0.93	100.00	1.00	37.20
74.32500000	18.47510540	43.00	0.43	93.00	0.93	100.00	1.00	39.99
74.34166667	18.47510540	37.00	0.37	93.00	0.93	100.00	1.00	34.41
74.35833333	18.47510540	33.00	0.33	100.00	1.00	100.00	1.00	33.00
74.37500000	18.47510540	30.00	0.30	100.00	1.00	100.00	1.00	30.00
74.39166667	18.47510540	49.00	0.49	90.00	0.90	100.00	1.00	44.10
74.40833333	18.47510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.42500000	18.47510540	49.00	0.49	90.00	0.90	100.00	1.00	44.10
74.44166667	18.47510540	43.00	0.43	90.00	0.90	100.00	1.00	38.70
74.15833333	18.47510540	37.00	0.37	97.00	0.97	100.00	1.00	35.89
74.45833333	18.47510540	37.00	0.37	90.00	0.90	100.00	1.00	33.30
74.47500000	18.47510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.49166667	18.47510540	49.00	0.49	90.00	0.90	100.00	1.00	44.10
74.50833333	18.47510540	47.00	0.47	90.00	0.90	100.00	1.00	42.30
74.52500000	18.47510540	38.00	0.38	97.00	0.97	100.00	1.00	36.86
74.54166667	18.47510540	37.00	0.37	93.00	0.93	100.00	1.00	34.41
74.55833333	18.47510540	23.00	0.23	90.00	0.90	100.00	1.00	20.70
74.57500000	18.47510540	24.00	0.24	90.00	0.90	100.00	1.00	21.60
74.59166667	18.47510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.60833333	18.47510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.17500000	18.47510540	37.00	0.37	93.00	0.93	100.00	1.00	34.41
74.62500000	18.47510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.64166667	18.47510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.65833333	18.47510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.67500000	18.47510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.69166667	18.47510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.70833333	18.47510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.72500000	18.47510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.19166667	18.47510540	32.00	0.32	97.00	0.97	100.00	1.00	31.04
74.20833333	18.47510540	30.00	0.30	100.00	1.00	100.00	1.00	30.00
74.22500000	18.47510540	45.00	0.45	93.00	0.93	100.00	1.00	41.85
74.24166667	18.47510540	40.00	0.40	93.00	0.93	100.00	1.00	37.20
74.25833333	18.47510540	33.00	0.33	97.00	0.97	100.00	1.00	32.01
74.27500000	18.47510540	30.00	0.30	100.00	1.00	100.00	1.00	30.00
74.14166667	18.45843874	40.00	0.40	97.00	0.97	100.00	1.00	38.80

Longitude	Latitude	Soil Depth	Soil Depth (A)	Soil Texture	Soil Texture (B)	Slope	Slope (C)	Storie Index
74.29166667	18.45843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.30833333	18.45843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.32500000	18.45843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.34166667	18.45843874	35.00	0.35	100.00	1.00	100.00	1.00	35.00
74.35833333	18.45843874	38.00	0.38	100.00	1.00	100.00	1.00	38.00
74.37500000	18.45843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.39166667	18.45843874	27.00	0.27	100.00	1.00	100.00	1.00	27.00
74.40833333	18.45843874	30.00	0.30	100.00	1.00	100.00	1.00	30.00
74.42500000	18.45843874	32.00	0.32	100.00	1.00	100.00	1.00	32.00
74.44166667	18.45843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.15833333	18.45843874	37.00	0.37	97.00	0.97	100.00	1.00	35.89
74.45833333	18.45843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.47500000	18.45843874	49.00	0.49	90.00	0.90	100.00	1.00	44.10
74.49166667	18.45843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.50833333	18.45843874	40.00	0.40	93.00	0.93	100.00	1.00	37.20
74.52500000	18.45843874	37.00	0.37	97.00	0.97	100.00	1.00	35.89
74.54166667	18.45843874	28.00	0.28	100.00	1.00	100.00	1.00	28.00
74.55833333	18.45843874	45.00	0.45	93.00	0.93	100.00	1.00	41.85
74.57500000	18.45843874	49.00	0.49	90.00	0.90	100.00	1.00	44.10
74.59166667	18.45843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.60833333	18.45843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.17500000	18.45843874	31.00	0.31	100.00	1.00	100.00	1.00	31.00
74.62500000	18.45843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.64166667	18.45843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.65833333	18.45843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.67500000	18.45843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.69166667	18.45843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.70833333	18.45843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.72500000	18.45843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.19166667	18.45843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.20833333	18.45843874	28.00	0.28	97.00	0.97	100.00	1.00	27.16
74.22500000	18.45843874	38.00	0.38	100.00	1.00	100.00	1.00	38.00
74.24166667	18.45843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.25833333	18.45843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.27500000	18.45843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.14166667	18.44177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.29166667	18.44177207	37.00	0.37	90.00	0.90	100.00	1.00	33.30
74.30833333	18.44177207	36.00	0.36	93.00	0.93	100.00	1.00	33.48
74.32500000	18.44177207	35.00	0.35	97.00	0.97	100.00	1.00	33.95
74.34166667	18.44177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.35833333	18.44177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.37500000	18.44177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00

Longitude	Latitude	Soil Depth	Soil Depth (A)	Soil Texture	Soil Texture (B)	Slope	Slope (C)	Storie Index
74.39166667	18.44177207	30.00	0.30	100.00	1.00	100.00	1.00	30.00
74.40833333	18.44177207	37.00	0.37	97.00	0.97	100.00	1.00	35.89
74.42500000	18.44177207	49.00	0.49	90.00	0.90	100.00	1.00	44.10
74.44166667	18.44177207	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.15833333	18.44177207	27.00	0.27	100.00	1.00	100.00	1.00	27.00
74.45833333	18.44177207	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.47500000	18.44177207	38.00	0.38	97.00	0.97	100.00	1.00	36.86
74.49166667	18.44177207	35.00	0.35	100.00	1.00	100.00	1.00	35.00
74.50833333	18.44177207	27.00	0.27	100.00	1.00	80.00	0.80	21.60
74.52500000	18.44177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.54166667	18.44177207	40.00	0.40	97.00	0.97	100.00	1.00	38.80
74.55833333	18.44177207	45.00	0.45	93.00	0.93	100.00	1.00	41.85
74.57500000	18.44177207	30.00	0.30	100.00	1.00	100.00	1.00	30.00
74.59166667	18.44177207	42.00	0.42	97.00	0.97	100.00	1.00	40.74
74.60833333	18.44177207	40.00	0.40	93.00	0.93	100.00	1.00	37.20
74.17500000	18.44177207	32.00	0.32	97.00	0.97	80.00	0.80	24.83
74.62500000	18.44177207	49.00	0.49	90.00	0.90	100.00	1.00	44.10
74.64166667	18.44177207	26.00	0.26	100.00	1.00	100.00	1.00	26.00
74.65833333	18.44177207	40.00	0.40	93.00	0.93	100.00	1.00	37.20
74.67500000	18.44177207	49.00	0.49	90.00	0.90	100.00	1.00	44.10
74.69166667	18.44177207	48.00	0.48	93.00	0.93	100.00	1.00	44.64
74.70833333	18.44177207	37.00	0.37	97.00	0.97	100.00	1.00	35.89
74.72500000	18.44177207	42.00	0.42	93.00	0.93	100.00	1.00	39.06
74.19166667	18.44177207	35.00	0.35	93.00	0.93	80.00	0.80	26.04
74.20833333	18.44177207	37.00	0.37	90.00	0.90	100.00	1.00	33.30
74.22500000	18.44177207	38.00	0.38	90.00	0.90	80.00	0.80	27.36
74.24166667	18.44177207	38.00	0.38	90.00	0.90	75.00	0.75	25.65
74.25833333	18.44177207	38.00	0.38	90.00	0.90	75.00	0.75	25.65
74.27500000	18.44177207	37.00	0.37	90.00	0.90	70.00	0.70	23.31
74.14166667	18.42510540	38.00	0.38	90.00	0.90	70.00	0.70	23.94
74.29166667	18.42510540	28.00	0.28	100.00	1.00	70.00	0.70	19.60
74.30833333	18.42510540	27.00	0.27	100.00	1.00	70.00	0.70	18.90
74.32500000	18.42510540	32.00	0.32	97.00	0.97	100.00	1.00	31.04
74.34166667	18.42510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.35833333	18.42510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.37500000	18.42510540	40.00	0.40	97.00	0.97	100.00	1.00	38.80
74.39166667	18.42510540	43.00	0.43	93.00	0.93	100.00	1.00	39.99
74.40833333	18.42510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.42500000	18.42510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.44166667	18.42510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.15833333	18.42510540	35.00	0.35	90.00	0.90	70.00	0.70	22.05
74.45833333	18.42510540	49.00	0.49	90.00	0.90	100.00	1.00	44.10

Longitude	Latitude	Soil Depth	Soil Depth (A)	Soil Texture	Soil Texture (B)	Slope	Slope (C)	Storie Index
74.47500000	18.42510540	30.00	0.30	100.00	1.00	100.00	1.00	30.00
74.49166667	18.42510540	25.00	0.25	100.00	1.00	75.00	0.75	18.75
74.50833333	18.42510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.52500000	18.42510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.54166667	18.42510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.55833333	18.42510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.57500000	18.42510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.59166667	18.42510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.60833333	18.42510540	28.00	0.28	100.00	1.00	100.00	1.00	28.00
74.17500000	18.42510540	35.00	0.35	90.00	0.90	70.00	0.70	22.05
74.62500000	18.42510540	43.00	0.43	93.00	0.93	80.00	0.80	31.99
74.64166667	18.42510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.65833333	18.42510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.67500000	18.42510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.69166667	18.42510540	26.00	0.26	100.00	1.00	100.00	1.00	26.00
74.70833333	18.42510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.72500000	18.42510540	45.00	0.45	93.00	0.93	100.00	1.00	41.85
74.19166667	18.42510540	36.00	0.36	90.00	0.90	70.00	0.70	22.68
74.20833333	18.42510540	36.00	0.36	90.00	0.90	70.00	0.70	22.68
74.22500000	18.42510540	38.00	0.38	90.00	0.90	70.00	0.70	23.94
74.24166667	18.42510540	38.00	0.38	90.00	0.90	70.00	0.70	23.94
74.25833333	18.42510540	34.00	0.34	90.00	0.90	70.00	0.70	21.42
74.27500000	18.42510540	31.00	0.31	97.00	0.97	80.00	0.80	24.06
74.14166667	18.40843874	19.00	0.19	90.00	0.90	100.00	1.00	17.10
74.29166667	18.40843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.30833333	18.40843874	45.00	0.45	93.00	0.93	100.00	1.00	41.85
74.32500000	18.40843874	47.00	0.47	93.00	0.93	100.00	1.00	43.71
74.34166667	18.40843874	48.00	0.48	93.00	0.93	100.00	1.00	44.64
74.35833333	18.40843874	37.00	0.37	97.00	0.97	100.00	1.00	35.89
74.37500000	18.40843874	38.00	0.38	97.00	0.97	100.00	1.00	36.86
74.39166667	18.40843874	40.00	0.40	97.00	0.97	100.00	1.00	38.80
74.40833333	18.40843874	40.00	0.40	93.00	0.93	100.00	1.00	37.20
74.42500000	18.40843874	37.00	0.37	97.00	0.97	100.00	1.00	35.89
74.44166667	18.40843874	49.00	0.49	90.00	0.90	100.00	1.00	44.10
74.15833333	18.40843874	23.00	0.23	90.00	0.90	100.00	1.00	20.70
74.45833333	18.40843874	48.00	0.48	93.00	0.93	100.00	1.00	44.64
74.47500000	18.40843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.49166667	18.40843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.50833333	18.40843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.52500000	18.40843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.54166667	18.40843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.55833333	18.40843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00

Longitude	Latitude	Soil Depth	Soil Depth (A)	Soil Texture	Soil Texture (B)	Slope	Slope (C)	Storie Index
74.57500000	18.40843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.59166667	18.40843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.60833333	18.40843874	25.00	0.25	100.00	1.00	80.00	0.80	20.00
74.62500000	18.40843874	25.00	0.25	100.00	1.00	80.00	0.80	20.00
74.64166667	18.40843874	25.00	0.25	100.00	1.00	80.00	0.80	20.00
74.65833333	18.40843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.67500000	18.40843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.69166667	18.40843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.70833333	18.40843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.72500000	18.40843874	26.00	0.26	100.00	1.00	100.00	1.00	26.00
74.74166667	18.40843874	37.00	0.37	97.00	0.97	100.00	1.00	35.89
74.75833333	18.40843874	49.00	0.49	90.00	0.90	100.00	1.00	44.10
74.77500000	18.40843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.79166667	18.40843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.25833333	18.40843874	23.00	0.23	90.00	0.90	100.00	1.00	20.70
74.29166667	18.39177207	23.00	0.23	100.00	1.00	100.00	1.00	23.00
74.30833333	18.39177207	25.00	0.25	100.00	1.00	75.00	0.75	18.75
74.32500000	18.39177207	38.00	0.38	97.00	0.97	100.00	1.00	36.86
74.34166667	18.39177207	40.00	0.40	93.00	0.93	100.00	1.00	37.20
74.35833333	18.39177207	45.00	0.45	93.00	0.93	100.00	1.00	41.85
74.37500000	18.39177207	43.00	0.43	93.00	0.93	100.00	1.00	39.99
74.39166667	18.39177207	30.00	0.30	100.00	1.00	100.00	1.00	30.00
74.40833333	18.39177207	47.00	0.47	90.00	0.90	100.00	1.00	42.30
74.42500000	18.39177207	28.00	0.28	100.00	1.00	100.00	1.00	28.00
74.44166667	18.39177207	45.00	0.45	93.00	0.93	100.00	1.00	41.85
74.45833333	18.39177207	33.00	0.33	100.00	1.00	75.00	0.75	24.75
74.47500000	18.39177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.49166667	18.39177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.50833333	18.39177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.52500000	18.39177207	23.00	0.23	100.00	1.00	100.00	1.00	23.00
74.54166667	18.39177207	21.00	0.21	97.00	0.97	100.00	1.00	20.37
74.55833333	18.39177207	21.00	0.21	93.00	0.93	100.00	1.00	19.53
74.57500000	18.39177207	20.00	0.20	93.00	0.93	100.00	1.00	18.60
74.59166667	18.39177207	19.00	0.19	93.00	0.93	100.00	1.00	17.67
74.60833333	18.39177207	23.00	0.23	97.00	0.97	100.00	1.00	22.31
74.62500000	18.39177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.64166667	18.39177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.65833333	18.39177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.67500000	18.39177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.69166667	18.39177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.70833333	18.39177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.72500000	18.39177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00

Longitude	Latitude	Soil Depth	Soil Depth (A)	Soil Texture	Soil Texture (B)	Slope	Slope (C)	Storie Index
74.74166667	18.39177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.75833333	18.39177207	30.00	0.30	97.00	0.97	100.00	1.00	29.10
74.77500000	18.39177207	49.00	0.49	90.00	0.90	100.00	1.00	44.10
74.79166667	18.39177207	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.80833333	18.39177207	48.00	0.48	93.00	0.93	100.00	1.00	44.64
74.29166667	18.37510540	19.00	0.19	93.00	0.93	100.00	1.00	17.67
74.30833333	18.37510540	20.00	0.20	93.00	0.93	100.00	1.00	18.60
74.32500000	18.37510540	17.00	0.17	90.00	0.90	100.00	1.00	15.30
74.34166667	18.37510540	21.00	0.21	97.00	0.97	100.00	1.00	20.37
74.35833333	18.37510540	26.00	0.26	100.00	1.00	100.00	1.00	26.00
74.37500000	18.37510540	27.00	0.27	100.00	1.00	100.00	1.00	27.00
74.39166667	18.37510540	28.00	0.28	100.00	1.00	100.00	1.00	28.00
74.40833333	18.37510540	30.00	0.30	100.00	1.00	80.00	0.80	24.00
74.42500000	18.37510540	28.00	0.28	100.00	1.00	100.00	1.00	28.00
74.44166667	18.37510540	25.00	0.25	100.00	1.00	85.00	0.85	21.25
74.45833333	18.37510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.47500000	18.37510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.49166667	18.37510540	23.00	0.23	100.00	1.00	100.00	1.00	23.00
74.50833333	18.37510540	19.00	0.19	93.00	0.93	100.00	1.00	17.67
74.52500000	18.37510540	21.00	0.21	93.00	0.93	100.00	1.00	19.53
74.54166667	18.37510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.55833333	18.37510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.57500000	18.37510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.59166667	18.37510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.60833333	18.37510540	21.00	0.21	93.00	0.93	100.00	1.00	19.53
74.62500000	18.37510540	18.00	0.18	90.00	0.90	100.00	1.00	16.20
74.64166667	18.37510540	20.00	0.20	93.00	0.93	100.00	1.00	18.60
74.65833333	18.37510540	23.00	0.23	97.00	0.97	100.00	1.00	22.31
74.67500000	18.37510540	24.00	0.24	100.00	1.00	100.00	1.00	24.00
74.69166667	18.37510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.70833333	18.37510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.72500000	18.37510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.74166667	18.37510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.75833333	18.37510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.77500000	18.37510540	26.00	0.26	100.00	1.00	100.00	1.00	26.00
74.79166667	18.37510540	27.00	0.27	100.00	1.00	100.00	1.00	27.00
74.80833333	18.37510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.30833333	18.35843874	17.00	0.17	90.00	0.90	100.00	1.00	15.30
74.32500000	18.35843874	18.00	0.18	90.00	0.90	100.00	1.00	16.20
74.35833333	18.35843874	24.00	0.24	93.00	0.93	100.00	1.00	22.32
74.37500000	18.35843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.39166667	18.35843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00

Longitude	Latitude	Soil Depth	Soil Depth (A)	Soil Texture	Soil Texture (B)	Slope	Slope (C)	Storie Index
74.40833333	18.35843874	24.00	0.24	100.00	1.00	100.00	1.00	24.00
74.42500000	18.35843874	23.00	0.23	97.00	0.97	85.00	0.85	18.96
74.44166667	18.35843874	24.00	0.24	100.00	1.00	85.00	0.85	20.40
74.45833333	18.35843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.47500000	18.35843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.49166667	18.35843874	24.00	0.24	100.00	1.00	100.00	1.00	24.00
74.50833333	18.35843874	23.00	0.23	100.00	1.00	100.00	1.00	23.00
74.52500000	18.35843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.54166667	18.35843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.55833333	18.35843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.57500000	18.35843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.59166667	18.35843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.60833333	18.35843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.62500000	18.35843874	20.00	0.20	93.00	0.93	100.00	1.00	18.60
74.64166667	18.35843874	17.00	0.17	90.00	0.90	100.00	1.00	15.30
74.65833333	18.35843874	17.00	0.17	90.00	0.90	100.00	1.00	15.30
74.67500000	18.35843874	35.00	0.35	93.00	0.93	100.00	1.00	32.55
74.69166667	18.35843874	40.00	0.40	97.00	0.97	100.00	1.00	38.80
74.70833333	18.35843874	30.00	0.30	100.00	1.00	100.00	1.00	30.00
74.72500000	18.35843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.74166667	18.35843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.75833333	18.35843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.77500000	18.35843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.79166667	18.35843874	25.00	0.25	100.00	1.00	85.00	0.85	21.25
74.80833333	18.35843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.37500000	18.34177207	19.00	0.19	97.00	0.97	100.00	1.00	18.43
74.39166667	18.34177207	23.00	0.23	100.00	1.00	100.00	1.00	23.00
74.40833333	18.34177207	18.00	0.18	93.00	0.93	100.00	1.00	16.74
74.42500000	18.34177207	17.00	0.17	90.00	0.90	100.00	1.00	15.30
74.44166667	18.34177207	23.00	0.23	97.00	0.97	100.00	1.00	22.31
74.45833333	18.34177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.47500000	18.34177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.49166667	18.34177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.50833333	18.34177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.52500000	18.34177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.54166667	18.34177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.55833333	18.34177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.57500000	18.34177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.59166667	18.34177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.60833333	18.34177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.62500000	18.34177207	23.00	0.23	100.00	1.00	100.00	1.00	23.00
74.64166667	18.34177207	17.00	0.17	90.00	0.90	100.00	1.00	15.30

Longitude	Latitude	Soil Depth	Soil Depth (A)	Soil Texture	Soil Texture (B)	Slope	Slope (C)	Storie Index
74.65833333	18.34177207	24.00	0.24	90.00	0.90	100.00	1.00	21.60
74.67500000	18.34177207	43.00	0.43	90.00	0.90	100.00	1.00	38.70
74.69166667	18.34177207	47.00	0.47	90.00	0.90	100.00	1.00	42.30
74.70833333	18.34177207	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.72500000	18.34177207	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.74166667	18.34177207	49.00	0.49	90.00	0.90	100.00	1.00	44.10
74.75833333	18.34177207	43.00	0.43	93.00	0.93	100.00	1.00	39.99
74.77500000	18.34177207	32.00	0.32	97.00	0.97	100.00	1.00	31.04
74.79166667	18.34177207	27.00	0.27	100.00	1.00	100.00	1.00	27.00
74.80833333	18.34177207	38.00	0.38	97.00	0.97	100.00	1.00	36.86
74.82500000	18.34177207	35.00	0.35	97.00	0.97	100.00	1.00	33.95
74.84166667	18.34177207	48.00	0.48	90.00	0.90	100.00	1.00	43.20
74.45833333	18.32510540	32.00	0.32	100.00	1.00	100.00	1.00	32.00
74.47500000	18.32510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.49166667	18.32510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.50833333	18.32510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.52500000	18.32510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.54166667	18.32510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.55833333	18.32510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.57500000	18.32510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.60833333	18.32510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.62500000	18.32510540	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.64166667	18.32510540	23.00	0.23	97.00	0.97	100.00	1.00	22.31
74.65833333	18.32510540	21.00	0.21	97.00	0.97	100.00	1.00	20.37
74.67500000	18.32510540	21.00	0.21	97.00	0.97	100.00	1.00	20.37
74.69166667	18.32510540	17.00	0.17	90.00	0.90	100.00	1.00	15.30
74.70833333	18.32510540	20.00	0.20	90.00	0.90	100.00	1.00	18.00
74.72500000	18.32510540	43.00	0.43	90.00	0.90	100.00	1.00	38.70
74.74166667	18.32510540	48.00	0.48	90.00	0.90	100.00	1.00	43.20
74.75833333	18.32510540	48.00	0.48	90.00	0.90	100.00	1.00	43.20
74.77500000	18.32510540	49.00	0.49	90.00	0.90	100.00	1.00	44.10
74.79166667	18.32510540	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.80833333	18.32510540	45.00	0.45	93.00	0.93	100.00	1.00	41.85
74.82500000	18.32510540	48.00	0.48	93.00	0.93	100.00	1.00	44.64
74.84166667	18.32510540	45.00	0.45	93.00	0.93	100.00	1.00	41.85
74.47500000	18.30843874	20.00	0.20	93.00	0.93	100.00	1.00	18.60
74.49166667	18.30843874	22.00	0.22	97.00	0.97	100.00	1.00	21.34
74.50833333	18.30843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.52500000	18.30843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.62500000	18.30843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.64166667	18.30843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.65833333	18.30843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00

Longitude	Latitude	Soil Depth	Soil Depth (A)	Soil Texture	Soil Texture (B)	Slope	Slope (C)	Storie Index
74.67500000	18.30843874	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.69166667	18.30843874	23.00	0.23	97.00	0.97	100.00	1.00	22.31
74.70833333	18.30843874	17.00	0.17	90.00	0.90	100.00	1.00	15.30
74.72500000	18.30843874	18.00	0.18	90.00	0.90	100.00	1.00	16.20
74.74166667	18.30843874	17.00	0.17	90.00	0.90	100.00	1.00	15.30
74.75833333	18.30843874	17.00	0.17	90.00	0.90	100.00	1.00	15.30
74.79166667	18.30843874	44.00	0.44	90.00	0.90	100.00	1.00	39.60
74.80833333	18.30843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.82500000	18.30843874	50.00	0.50	90.00	0.90	80.00	0.80	36.00
74.84166667	18.30843874	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.62500000	18.29177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.64166667	18.29177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.65833333	18.29177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.67500000	18.29177207	25.00	0.25	100.00	1.00	100.00	1.00	25.00
74.69166667	18.29177207	22.00	0.22	97.00	0.97	100.00	1.00	21.34
74.70833333	18.29177207	24.00	0.24	100.00	1.00	100.00	1.00	24.00
74.72500000	18.29177207	24.00	0.24	100.00	1.00	100.00	1.00	24.00
74.74166667	18.29177207	18.00	0.18	90.00	0.90	100.00	1.00	16.20
74.80833333	18.29177207	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.82500000	18.29177207	50.00	0.50	90.00	0.90	100.00	1.00	45.00
74.84166667	18.29177207	50.00	0.50	90.00	0.90	100.00	1.00	45.00