ASSESSMENT AND MANAGEMENT OF WATERLOGGED AND SALT AFFECTED AREA IN NORTH WESTERN HARYANA USING GEO-SPATIAL TECHNOLOGY

A Thesis

Submitted in partial fulfillment of the requirements for the award of the degree of

DOCTOR OF PHILOSOPHY

in

Geography

By

Manoj

Registration No. 41800064

Supervised By

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Transforming Education Transforming India

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DECLARATION

I hereby declare that the thesis entitled **"Assessment and Management of Waterlogged and Salt Affected area in North Western Haryana using Geo-Spatial Technology"** prepared and submitted by me under the supervision and guidance of Dr. Sahab Deen, Assistant Professor in Geography, School of Arts and Languages, Lovely Professional University, Jalandhar, Punjab (India) as per the full requirement for the award of the degree of Doctor of Philosophy (Ph.D.) in Geography is entirely my original work and all ideas and references have been duly acknowledged. It does not contain any work that has been submitted for award of any other degree or diploma of any other University.

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CERTIFICATE

This is to certify that the thesis titled **"Assessment and Management of Waterlogged and Salt Affected area in North Western Haryana using Geo-Spatial Technology"** which is submitted by **Mr. Manoj** for the award of degree of Doctor of Philosophy (Ph.D.) in Geography to the Lovely Professional University, Jalandhar, Punjab (India) has been carried out under my supervision and guidance. To the best of my knowledge, the present work is the result of his original investigation and study. No part of the thesis has ever been submitted for any other degree or diploma to any other university. The thesis is fit for the award of Doctor of Philosophy (Ph.D.) degree.

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ABSTRACT

Soil salinity probably won't be as sensational and harming as tremors or enormous scope avalanches; however it is absolutely an extreme ecological danger with expanding sway on crop yields and farming creation in together dry and inundated zones, owing to helpless land and water the board and development of the farming outskirts into negligible dry terrains. To monitor the adjustments in salinity and foresee further monitoring is required with the goal that appropriate and convenient choices can be made to change the administration rehearses or embrace recovery and restoration. Estimating soil salinity implies first distinguishing the spots wherever salts deliberate and besides; identifying the adjustments in this focus. Both generally rely upon the particular way of the ability of the remote sensing devices to recognize salts from the soil surface.

Land and water are critically most important natural resources on which agricultural production depends and whose efficient management is vital for sustainable development of rural areas. Like any other place, the study area is also not free from problem related to natural resources. The area is facing the problem of soil salinity and waterlogging, floods, improper use of canal for irrigation, declining trend of per capita availability of land productivity, absence of natural forest and problems caused by green revolution agricultural system. This causes the concern and to combat these problems, the integrated natural resources management holds key to sustainable development of natural resources of the area. To increase the foodgrain production for increasing population, land and water resources have been subjected to great stress.

The accumulation of excessive salts in the root region, resulting in a half- or total loss of soil quality, is a marvel in and of itself. Soil salinity problems are typical in parched and semi-arid areas but salt-affected soils often occur commonly in wet and sticky habitats, especially in beachfront areas where ocean water enters through estuaries and streams, as well as through groundwater, causing widespread salinization. Soil salinity is also a concern in this region, where groundwater with a high salt content is used for the water supply. The water supply is always expensive, sometimes unpredictably so and it necessitates skilled management. Inability to implement competent water board standards can result in water wastage by leakage; over-watering and lack of seepage cause waterlogging and salinity problems, which reduce soil efficiency, resulting in the loss of cultivable land.

It is generally accepted that the future food requirements of an expanding population can be addressed by integrating the efforts of all interested parties toward: improving the degree of the executives of soils effectively under cultivation and putting potentially arable soils that are actually crude under waterlogging. The current conceptualizing issue identified with soil salinity and waterlogging was profoundly featured in ranchers, media and diverse association since a decade ago. Geo spatial technology gives arising instruments to mapping, monitoring and the board of waterlogged and salt influenced zone. The focus of this research was to achieve objectives mapping and management of waterlogged and salinity territories in Fatehabad and Sirsa districts alongside their administration and the advancement of activity plan of the current investigation.

Sustainable development may be defined as that meets the needs of present generation without compromising the ability of future generation to meet their own needs. Sustainable development requires a simultaneous progress in the environmental dimension, economic dimension and social dimension. That is, it is improve economic efficiency, protect and restore economical balance and enhance the well being of people. There is often quoted fourth dimension too, the technological dimension. It has been needed new technologies that are more efficient and have lesser impact on environment.

Now a day there is a need of integrated planning and management of land and water resources for sustainable development of natural resources. Modern technologies such as remote sensing, GIS and computing capabilities can be effectively used to improve the efficiency of resources, models their outputs spatially. Existing agricultural production system focuses on intensifying crops yields while ignoring wider implication of changes in agricultural practices on quality of natural resources. Environmental issues including soil and land degradation, damage to water quality and quantity have not been given sufficient prominence. The continuous progress would depend upon more holistic approach that would have focus on health of natural resources base. Remote sensing and GIS has developed into a fast & reliable technology for mapping and management of natural resources and to formulate action plans for their judicious and sustainable use.

This prime objective has motivated me to take up this research work and I hope this work will be useful for micro-level planning of waterlogged and salt affected area and implementation of the suggested plan as suggested, which will improve the man-ecological relationship and socio-economic conditions of the area. The current work is based on qualitative and quantitative data for sustainable management of waterlogged and salt affected area such as water and soil with the aims to utilize the authentication of present land use in the context of sustainability of agriculture. Thus the novelty of the present research is that the productivity level of different crops is showing a declining trend, despite manifolds increase in fertilizer use and plant protection chemicals. Sustainable agricultural practices fulfil the demand of coming generation and increasing population in respect to the sustainability of natural resources.

The present study has been based on primary as well as secondary source of data. There are secondary source of data which are readily available from the government and private or non-governmental organizations. Such as district census handbook provides detailed information about demographic attributes apart from that state statistical abstract report for economic data.

Based upon visual interpretation of Indian Remote Sensing satellite data, the maps of various themes were prepared and ground truth verifications and soil sampling of waterlogged and salt affected area were done during field visit. The data on drainage and canal network have been derived from Survey of India topographical maps. The data on depth to water level, ground water quality and socio-economic aspects collected from available sources. All the thematic maps with other ancillary data integrated in a GIS environment to generate locally specific action plan for both land and water resources for sustainable development of area. Apart from all these, the satellite imageries were used to digitize present land use. For analyzing physical landscape SOI toposheet, Three season (Rabi, Kharif and Zaid) IRS-P6 1D LISS – III, LISS IV and Sentinel -2A (2018 & 2020) satellite images were used for mapping of present salt affected and waterlogged area. These maps were digitize and demarcated in the GIS environment and after due correction and attributes attachment, final digital maps of different themes were prepared. The land and water resources development plan for waterlogged and salt affected area (DSIS) have been prepared using integration techniques various thematic maps in GIS environment.

The study is mainly concerned to develop Decision Support Information System for salt affected and waterlogged area based on interpretation of high resolution satellite data. After image rectification and effective image enhancement techniques, satellite images can be used to help in the delineation and visualization of various thematic data. The pre-field interpreted map was created using the visual analysis tool. Final maps would be created based on the pre-field interpretation, ground truth checking, and available secondary knowledge.

An extensive use of GIS and remote sensing software's (Arc GIS, ERDAS Imagine) will be used for analyzing the spatial distribution of the various aspects taken up for study. GIS techniques will be used in order to create layers of waterlogged, salt affected area, soils, slope analysis and land use/ land cover. These layers were put in GIS format to create the database. On the basis of above database drainage network plan maps and action plan map for waterlogged and salt affected area were prepared in Arc map software.

Sirsa and Fatehabad districts are the leading agriculture districts of the state situated in the northwest, whereas 6.31 sq. km area of the study area is under salt affected and 20.30 sq. km area of the study area is under waterlogging. It is also the most intensively cultivated with 189.8% of Sirsa and 195.9% of Fatehabad district (Statistical Abstract of Haryana, 2017-18) cropping intensity. The population of study area is 2237200 persons (Census of India, 2011). Farmers here continue to grow rice-wheat and cotton - wheat as dominant crops due to government incentives and market price ignoring the suitability of soil, water and climatic conditions. The inappropriate land use and introduction of canal irrigation have resulted in soil degradation, soil erosion, salinity / alkalinity and waterlogging and nutrient losses at an alarming rate. The problems of salinity, sodicity and waterlogging have been attributed to irrigation without providing drainage. Excess soluble salts (saline soil), high exchangeable sodium (sodic soil) or both soluble salts and exchangeable sodium (saline sodic) soil all have negative effects on the development of most plants. Total area under salt affected is 6.31 sq. km. from which sodic soil covers 1.48 sq. km. area i.e. 23.45% of total salt affected area. Other class like saline covers 1.34 sq. km area which is 21.24% and saline -sodic soil covers 3.49 sq. km area i.e. 55.31% of total salt affected area. The area under seasonal waterlogged is 12.20 sq. km. i.e. 0.18% of total geographical area and the area under permanent waterlogged category is 8.10 sq. km. i.e. 0.12% of the total geographical area of the study area. Mostly seasonal waterlogged area is distributed in the western and southern side of the study area. This waterlogged area is near the canals. Most of the waterlogged area is resulted into secondary salinization and salinity is developed in this area.

Water table is falling in the north east zone due to over exploitation of ground water where rice –wheat crop rotation is practiced. It has gone down by of 6.0-7.5 metre in a short span of 10 years and thus, has increased the cost of irrigation. Soil fertility has also been declined here due the constant growing of nutrients exhaustive rice and wheat crops. The above situations, thus, pose serious threats to sustainability of agriculture in this high productive zone of the study area.

The overall ground water prospects of the study area are varying from poor to excellent. The units of alluvial origin have very good to excellent underground water scenarios but on the other hand, ground water prospects in aeolian plain and sand dunal areas are moderate and poor respectively. Alluvial plain with sand have good ground water potential. The ground water quality found in area is good to saline. These include fresh water (54.24 %), sub marginal (31.28%) marginal (11.60%) and saline (2.89%). It was observed that adjacent to water body like canal, ponds and river, the sub surface water quality is good. The depth of water table in the study area is 3 to 20 meters below ground level (BGL) in various parts. Maximum area having lowest water table class is found in southern part of the study area.

Surface water resources of the area are available in form of ephemeral river Ghaggar, Bhakhra Canal Network and village ponds. Ghaggar River is main seasonal stream flowing along northern boundary of the study area. In normal condition water flow is very less in this river but during monsoon it becomes very active and many time adjoining areas are flooded by water over flowing the embankments.

The map of land use and land cover was created by visual analysis of October 2018 and March 2019 satellite images. The land use of the study area has been narrowly divided into constructed land, agriculture, wastelands, and bodies of water. The landuse statistics reveals that major land use in this area is agriculture which covers 6407sq. km including double harvest, only rabi, only kharif and existing fallow-class. While double cropped area under agriculture land use constitute 90.94 percent of total area.

Geomorphologically, the study area were divided into mainly aeolian plain, dune complex, stabilized sand dunes, flood plain deep and alluvial plain. As per the soil texture the study area is established mainly consist of fine, loamy and sandy. The soils of the salt affected patches of study area have been evaluated on the basis of collected soil samples from the study area. The suitability and sustainability of waterlogged and salt affected soils for main agriculture crops and agricultural plantation of land evaluation and soil sustainability status of different crops along with their varieties are also discussed. It is concluded that area under input intensive crops of green revolution has increased at the cost of traditional crops and desi cotton, gram, pulses and millets cropped area have declined significantly.

The chief objective of present study is to generate Decision Support Information System (DSIS) for the study area which is optimally suitable to the topography, climate and creative potential of local resources then the production level will be maintained without decay over time. Current technology of agricultural engineering, resource capacity, terrain and environment criteria have been taken into account in the resource plan recommendations.

The Decision Support Information System (DSIS) and proper drainage network have been prepared for waterlogged and salt affected area by integrating different thematic maps such as landuse / land cover, geomorphology, lithology, soil texture, ground water quality, underground water table depth, rainfall and surface water irrigation facilities. These thematic maps were evaluated individually and jointly for preparation of management plan. For recommending land and water resource action plan various decision rules have been formulated related to the causes of waterlogging and soil salinity in the study area. Consequences of the Problem of waterlogging and soil salinity were also discussed in action plan. These consequences were discussed from farm to national level. For management of waterlogged and salt affected area different strategies for combating menace of waterlogging and salinity was suggested. The suggested strategies are Short term preventive and curative measures as well as Long term measures. Different cropping practices with their varieties for shallow water table and flood affected areas were suggested for rabi and khraif season.

Horizontal drainage system, Vertical drainage system, Bio-drainage system, Sub Surface vertical Drainage (Network of Tubwell), Link drain (Subsurface field drainage system) and Ditch drain (Subsurface field drainage system) were the major recommendation those are suggested for the management of waterlogged and salt affected area. Decision Support Information System for management of waterlogged and salt affected area plan map was prepared alongwith reclamation of alkali, saline and saline-sodic soils.

The appropriate suggested recommendation for management of waterlogged and salt affected area is based on agricultural engineering techniques of CCS HAU, Hisar, CSSRI and ICAR. The use of conventional methods for checking the rise in water table appears to be inadequate. The various measures suggested for controlling waterlogging includes surface drainage, sub surface vertical drainage, sub – surface horizontal drainage, conjunctive water use system, bio-drainage, water supply tube wells and sewerage development. In addition to the preventive measures of lining of canals and water courses as well as on farm water management could also be highly effective. There is a urgent need for improvement and upgradation of technology in waterlogged and salt affected areas.

The study is divided into seven chapters. The first chapter devoted to introduction part which covered the nature of problem, applicability of present research, objectives, database and methodology used in present study and about geographical background of study area which comprises of location and extent, administration, physiography, drainage & water bodies, slope, climate, soils, infrastructural development and flora & fauna.

Second chapter deals with review of literature and Third chapter deals with assessment of waterlogged and salt affected area. The fourth chapter described the water resources of study area including underground water quality, ground water table status and surface water resources and evaluation of soil resources including soil texture, geomorphological and lithological study of study area.

Fifth chapter discussed the types of land use, cropping pattern for rabi and kharif season and crop rotation with extent and evaluation of present land use pattern.

Sixth chapter deals with development of management plan for waterlogged and salt affected area. This chapter includes integration of different themes in GIS environment carried out and sustainable management of waterlogged and salt affected area plan map with different recommendations were formulated for sustainable development of land and water resources.

The last and seventh chapter consists of summary and conclusion of this research work and references have been cited in the end of thesis.

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(Manoj)

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LIST OF ABBREVIATIONS

APT	Aquifer Performance Test
ASTAC	Astronomy Supercomputer Time Allocation Committee
ASTER	Advanced Spaceborne Thermal Emission And Reflection Radiometer
Awifs	Advanced Wide Field Sensor
BGL	Below Ground Level
CBERS	China Brazil Earth Resources Satellite Programme
CCD	Charge Couple Device
CCSHAU	Chaudhary Charan Singh Haryana Agriculture University
CEC	Cation Exchange Capacity
CSSRI	Central Soil Salinity Institute
DBF	Digital Beam Forming
DEM	Digital Elevation Model
DGPS	Differential Global Positioning System
DN	Digital Numbers
DSIS	Decision Support Information System
EC	Electric Conductivity
EM	Electro Magnetic
ERDAS	Earth Resource Data Analysis System
ESP	Exchangeable Sodium Percentage
ESR	Electron Spin Resonance
ETM	Enhanced Thematic Mapper
FCC	False Colour Composition
FSI	Forest Survey of India
FYM	Farm Yard Manure
GCP	Ground Control Point
GIS	Geographical Information System
GLS	Global Land Survey
GPS	Global Positioning System
HARSAC	Haryana Space Application Centre
HOPP	Haryana Operational Pilot Project
HRV	High Resolution Visible
HSMITC	Haryana State Minor Irrigation and Tubewells

ICAR	Indian Council Of Agricultural Research
ICID	International Commission on Irrigation And Drainage
IGNP	Indira Gandhi Nahar Paryojona
IHS	Intensity Hue Saturation
ILWIS	Integrated Land and Water Information System
IMSD	Integrated Mission For Sustainable Development
INVI	investment vehicle
IR	Infrared
IRS	Indian Remote Sensing
LISS	Linear Imaging Self Scanning
LULC	Land Use Land Cover
M	Million
MRB	Manas River Basin
MRD	Ministry of Rural Development
MS	Microsoft
MSS	Multi Spectral Scanner
MT	Million Tonnes
NDC	National Defence Complex
NDSI	Normalized Difference Snow Index
NDVI	Normalized Difference Vegetation Index
NDWI	Normalized Difference Water Index
NGO	Non Governmental Organization
NIR	Near Infrared
NRSC	National Remote Sensing Centre
OLI	Operational Land Image
OLS	Ordinary Least Squares
PAN	Panchromatic Image
PCI	Personal Computer Interface
Ph	Potential of Hydrogen/ Power Of Hydrogen
PLSR	Partial Least Squares Regression
R	Red
RMSE	Root Mean Square Error
RS	Remote Sensing
RSC	Residual Sodium Carbonate

SAR	Sodium Absorption Ratio
SAT	Satellite
SAVI	Soil Adjusted Vegetation Index
SLAG	Spatial Log
SSC	Soil Salt Content
SSP	Soil Survey of Pakistan
SWIR	Short Wave Infrared
TDS	Total Dissolved Salt
TGA	Total Geographical Area
TIR	Total Indicator Runout
TIRS	Thermal Infrared Sensor
TM	Thematic Mapper
TSS	Total Suspended Solids
USDA	United States Department Of Agriculture
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
WGS	World Geodetic System
WI	Wetness Index
WPR	Work Participation Rate
WQI	Water Quality Index
WYC	Western Yamuna Canal

CHAPTER – 1

INTRODUCTION

1.1 Introduction of Waterlogging and Soil Salinity

Not long after commencement of Haryana in 1966, the Government decided the most prominent need to agriculture as the state was insufficient in food generation. The all around arranged and solid activities brought concerning a staggering progression which has stood Haryana a motto for improvement in partial capacity to focus fifty years of its reality. The dynamism and versatility of agricultural development has become a model for different states to emulate. The fantastic development of flooded agriculture and accomplishments of the state in different fields have immensely improved the overall economy and prosperity of its populace. Notwithstanding, during the time spent clarifying different assets particularly land and water, certain perplexing issues of declining in water table, water logging, soil salinity and different peculiarities are arising which shed some uncertainty on the maintainability of present day inundated agriculture in the state. The answer for these issues (influencing almost 50% territory of the state principally lying in central and western parts) is undoubtedly troublesome and complex because of negative geo-hydrological and agro-climatic conditions, for example, marginal or saline ground water in 65 percent of the state, geological structure of the central inland bowl and non accessibility of waste sources. It has been assessed that 50% zone encountering the ascent in water table, almost 4.0 Lac ha or 10% region of the state is as of now waterlogged as water table in this area during October stays inside 1.5 m. Additionally, it is likewise getting inclined to auxiliary soil salinization. The issue of waterlogging has been emphasized by continuous floods in these areas. Agriculture creation in such regions has been unfavorably influenced and extensive region stays crude even in Rabi season. Broad undertake have been made during the previous twenty years by different exploration associations and the improvements to grow techno-economically suitable answers for these issues.

Soil salinity probably won't be as sensational and harming as tremors or enormous scope avalanches; however it is absolutely an extreme ecological danger with expanding sway on crop yields and farming creation in together dry and inundated zones, owing to helpless land and water the board and development of the farming borders into negligible dry terrains. To monitor the adjustments in salinity and foresee further monitoring is required with the goal that appropriate and convenient choices can be made to change the administration rehearses or embrace recovery and restoration. Estimating soil salinity implies first distinguishing the spots wherever salts deliberate and besides; identifying the adjustments in this focus. Both generally rely upon the particular way of the ability of the remote sensing devices to recognize salts from the soil surface.

Amassing of large quantity salts in the origin zone bringing concerning an incomplete or complete defeat of soil efficiency is an largely marvel. The task of soil salinity are generally far reaching in the blasted as well as semi-dry locales however salt influenced soils likewise happen broadly in sub-moist and damp atmospheres, especially in the seaside areas in which the entrance of ocean water from end to end estuaries and streams and throughout groundwater resulted huge scope salinization. Salinity of soil is additionally a major issue in zones wherever underground water of fully salt substance is utilized for water system. The majority genuine soil salinity issues were being looked in the flooded bone-dry as well as semi-dry areas of the globe and it is in these very districts that water system is fundamental to increment agricultural creation to fulfill food prerequisites. In any case, water system is frequently exorbitant, in fact complex and requires gifted administration. Inability to apply effective standards of water the executives may bring about depletion of water by leakage; over irrigation and lacking seepage bring about waterlogging and salinity issues that decrease the soil efficiency, ultimately encouraging defeat of cultivable terrain.

Buringh (1979) determined from different accessible information at global level in general is trailing in any event 10 hectares (arable land) each moment, five as a result of soil disintegration, 3 from soil salinity, 1 from further soil debasement cycles and 1 from without cropped area employments. The issue of soil defacement is genuine danger to the government assistance of humankind. In spite; the fact that debasement of the land has consistently described man's orderly utilization of it, the cycle has quickened in late many years and accurately when populace development and rising desires have started to request colossal expansions in food creation. The issue is of overpowering desperation. As soil is dependent upon corruption, the expense of recovering it becomes upper, increasing pointedly until the limit is approved past that recovery is not, at this point financially attainable. Almost 50% of the flooded soil in dry and semi-bone-dry locales has a few levels of soil salinization issues. The figure discuss about the greatness of the difficult that must be handled to get together prospect worldwide food requirements.

It is commonly concurred that the prospect food requirements of expanding population resolve be met by coordinating the endeavors of every one worried towards:

- improving the degree of the executives of soils effectively below development and
- By bringing under groove the conceivably barren soils that are as of now crude.

Soil salinity is a major hurdle for both techniques in achieving increased harvest yields. It is also acknowledgment that the United Nations Conference on Desertification held in Nairobi in 1977 welcomed the accompanying proposals: "It is prescribed that dire measures be taken to battle desertification in the flooded grounds by anticipating and controlling waterlogging, salinization and sodification by adjusting cultivating strategies to build efficiency in a traditional and supported manner; by growing new water system and waste plans where proper continually utilizing a coordinated methodology and through progress of the social and monetary states of individuals subject to flooded agriculture" (United Nations 1977).

The issues related to soil salt-influenced soils are aged yet its extent and power had been expanding quickly because of huge scope endeavors to acquire extra territories under water system late many years. The issues have been inflamed by advancement of water system frameworks without sufficient arrangement for seepage and are being irritated by helpless water the board rehearses and shaky recovery methodology.

The overall qualities and essential standards engaged with the identification, recovery and the board of salt-influenced soils is the equivalent all through the world. In any case, contrasts here and there in soil attributes, atmosphere, water accessibility, ranch the board ability, money related assets, accessible sources of info and monetary motivating forces lead to contrasts in strategy, degree and velocity of soil recovery. Albeit specialized writing teems with sound data regarding the matter, in any case, there are extremely numerous halfway or inclusive disappointments of attempt to recover salt-influenced soils. These disappointments, due to a great extent to absence of appropriate recognizable proof and ensuing utilization of off base recovery strategies, bring about misfortunes of both cash and possible expansions in crop creation.

1.2 Background of the Study

1.2.1 Global and National Distribution

Salt affected soils are mostly found in desertic and semi-desertic climate region and they occupy 1,307 million hectares on a global scale. Australia has the most salt-affected soils, followed by Central and North Asia, South-West Asia and South America. India is expected to have 6.73 M hectares of salt-influenced soils, including 2.5 M hectares of Indo-Gangetic plain. The four regions of Jhajjar, Rohtak, Jind, Bhiwani, Panipat and Sonipat in central Haryana were the most significantly affected, with 52 percent of the geological zone (TGA) under salt-influenced soils. Older levees, relict downpour plains and ineffectively eroded bowl shaped pads are simple geological areas of salt invasion along the Gangetic alluvial plain, according to Landsat photos. During the 1950s, the introduction of a trench water grid from the Western Yamuna Canal in the state complemented the upward production of soil salinity caused by increasing water tables. Waterlogging with salinization appeared as a consequence of overuse of water system. Water in ineffectively degraded areas, causing crop losses in rice is 42 percent, in wheat is 38 percent and sugarcane is 61 percent. Auxiliary salt change in profiles of soil founded along the Ghaggar and Markanda stream fields as a result of the utilize of marginal ground water in 60 percent of total geographical area of study area for the water supply.

In 1966, the Haryana state was formed from the former Punjab. Irrigation services were only accessible in 1.29 million ha of the 3.9 million ha net cultivable land at the time, which has now risen to 2.657 million ha. Increases in irrigation capacity have helped improve agriculture productivity between 2.6 to 11.0 MT, converting a discrepancy state into excess, but they have also produced significant hydrological imbalances.

Water levels in canal-irrigated areas have risen at a rate of 10 to 30 cm per year over the last four decades, with around 473,400 ha of land coming within 3 m of the ground surface in June 1996, resulting in land loss due to waterlogging and secondary salinization. According to a report, critical problems in the region are expected to worsen over the next three decades.

1.2.2 Soil and Water Salinity Diagnostics

Soils are viewed as salt-influenced, on the off chance that they have salt focuses over the limits of harmfulness that incorporate the accompanying:

A. A convergence of salts in the soil arrangement of 3-5 g/L.

B. An amount of poisonous salts estimated in water concentrates of 0,0-5,15%

C. Direct electrical conductivity of immersed soil-glue concentrates of 2-4 mSm/cm (USDA Agriculture Handbook, 1954).

The reasonableness of such soils for various harvests is read out by ascribing them to direct soil bunches separated by their saltiness levels and particular degrees of the resilience of various yields. Salt-influenced soils are partitioned into two gatherings:

1) Saline soils without Natric/ Solonetzic/ Sodic skyline.

2) Alkaline soils with an all around created Natric/ Solonetzic/ Sodic skyline, which is the demonstrative skyline of this gathering.

The previous gathering incorporates Solonchaks and other saline soils without the solonetzic skyline, the last mentioned – Solonetz and solonetzized soils. Solonchaks are soils that contain high centralizations of harmful (dissolvable) salts inside their surface layer: over 0-5% for the situation if soft drink submerged saltiness and over 1% on account of chloride-sulfate saltiness. Such focuses forestall the development and advancement of most agricultural yields. The surface layer suggests an entire furrow layer (15-30 cm) of arable soils and the main 15-cm-thick layer of virgin soils. The surface salt outside that is generally present in Solonchaks has a normal salt substance of 10 - 20% and frequently higher.

1.2.3 Tools and Procedures Utilized for Finding and Appraisal of Salt-Influenced Soils

Due to huge unearthly inclusion and watchful parties, remotely sensed data has been used to prepare and check soil salinty and waterlogging in a timely and efficient way. To distinguish infertile, salt-influenced soils, Mougenot, Pouget and Epema (1993) used visible spectrum having a lot of reflection, while wet, ultraviolet and microwave ranges were used to represent the salts and vegetation's hygroscopic characteristics covered soils, respectively. Howari (2003) and Howari, Goodell, and Miyamoto (2002) test phantom reaches for salt-influenced soils with varying salt formation, researchers used spectro-radiometry as a distant detecting instrument in the visible and NIR classes. To plan hydro-saline land corruption in the Indus cup, Khan, Rastoskuev, Sato and Shiozawa (2005) used proportion charts, unearthly properties and computerised figure structure.

1.2.4 Traditional Methods for Ground Estimation of Degraded Soils

Metternicht and Zinck (1997) suggested a variety of methods for mapping sodium and salt-affected soils that combine computerised analysis with field observations and research centre inspection. The form and quantity of salt-tolerant plant cover, upper soil surface, and additional ground properties, they reasoned, were the primary drivers of ghostly disarrays that concealed differing soil saltiness alkalinity degrees. Using far-off detecting, ground facts, and soil investigative information, Joshi and Sahai (1993), Sharma, Saxena & Verma (2000) and Verma, Saxena, Barthwal, and Deshmukh (1994) used a similar technique to map waterfront salt-influenced soils in Saurashtra (Gujarat State) and inland salt-influenced soils in Uttar Pradesh State. Such techniques are time saving and entail concentrated efforts to combine image investigation, ground truth compilation and testing facility soil and water examinations for mapping however they provide more precise outcomes and structured yields of salt-influenced soils. The classification of soils according to their saltiness/alkalinity levels, such as mild, moderate and solid, aids in the selection of precise soil recovery and board options.

1.2.5 Waterlogging and Soil Salinity in Irrigated Agriculture

Water system is one of the basic parts of the green revolution that has kept up moderately predictable food creation to satisfy the regularly developing needs for food. Waterlogging and salinization pose a major threat to the viability of flooded terrains and the livelihoods of ranchers, especially smallholders, in influenced areas across the country. These problems are the result of a variety of factors, including leaks from unlined earthen trenches, insufficient surface and subsurface seepage, powerless water executives, insufficient water sources and the utilize of low-quality groundwater for the water supply.

Around 6.7 million hectares of land in India are magnified by various amounts and salinity type, with nearly half of it under watered agriculture. Seriously waterlogged saline soils happen in around 2 million ha region in bone-dry/semi-parched north western conditions of Punjab, Haryana, Rajasthan and Gujarat and 1 MH each in the seaside and dark cotton produced districts. Waterlogging and soil saltiness are projected to affect about 13 million hectares of land in India's water system orders by 2025, with the use of saline/soluble base groundwater and climate change contributing to the risks.

Several efforts have been made in the country to improve the management of salt-influenced and waterlogged soils since the mid 1960s. Groundwater volumes can be reduced using tube wells and subsurface seepage systems, salts can be filtered using an abundance water system, compound revisions (such as gypsum, acids and natural issue) can be used and biological and real methods can be used.

Subsurface waste schemes have been introduced in 50000 ha of waterlogged freshwater soils in Rajasthan, Haryana, Gujarat, Andhra Pradesh, Punjab, Maharashtra and Karnataka over the previous two decades. Despite the fact that very compelling in bringing down water table, lessening soil saltiness and improving harvest yields, helpless activity and upkeep and non arrangement of satisfactory offices for the removal of saline seepage gushing have brought about restricted in general achievement of various such progress. This idea note presents a layout of a Workshop to be coordinated to assess the issues identified with waterlogging and soil saltiness in flooded agriculture.

1.3 Statement of Problem

Since the formation of Haryana in 1966, the government has recognized agriculture as having the highest priority because the state's food production capacity was inadequate. Haryana has become a pinnacle for improvement in limited capacity to focus fifty years of its reality as a result of well-organized and strong attempts. The dynamism and strength of agricultural development of Haryana has become a model for different states to copy. The way toward clarifying different assets particularly land and water, certain intricate issues of ascend in water table, water logging, soil salinity and different oddities are arising which shed some uncertainty on the manageability of present day flooded agriculture in the state.

According to the report of The Tribune Haryana version dated 7th January 2019, around 10% of cultivable place that is known for Haryana will waste because of the soil salinity and alkalinity. Agriculture creation in such zones has been antagonistically influenced and extensive zone stays crude even in Rabi or the two seasons. Broad endeavors have been made during the previous twenty years by different examination associations like CSSRI (Central Soil Salinity Institute, Karnal), CCSHAU (Chaudhary Charan Singh Haryana agricultural University, Hisar), ICAR (Indian Council for Agricultural Institute, New Delhi) and HOPP (Haryana Operational Pilot Project) to create techno-monetarily suitable answers for these issues.

Soil salinity probably won't be as emotional and harming as quakes or huge scope and slides, yet it is absolutely as ever natural danger with expanding sway on crop yield sand agricultural creation in both dry and flooded zones, in view of helpless land /water the board and extension of the crop fringes into minor dry grounds.

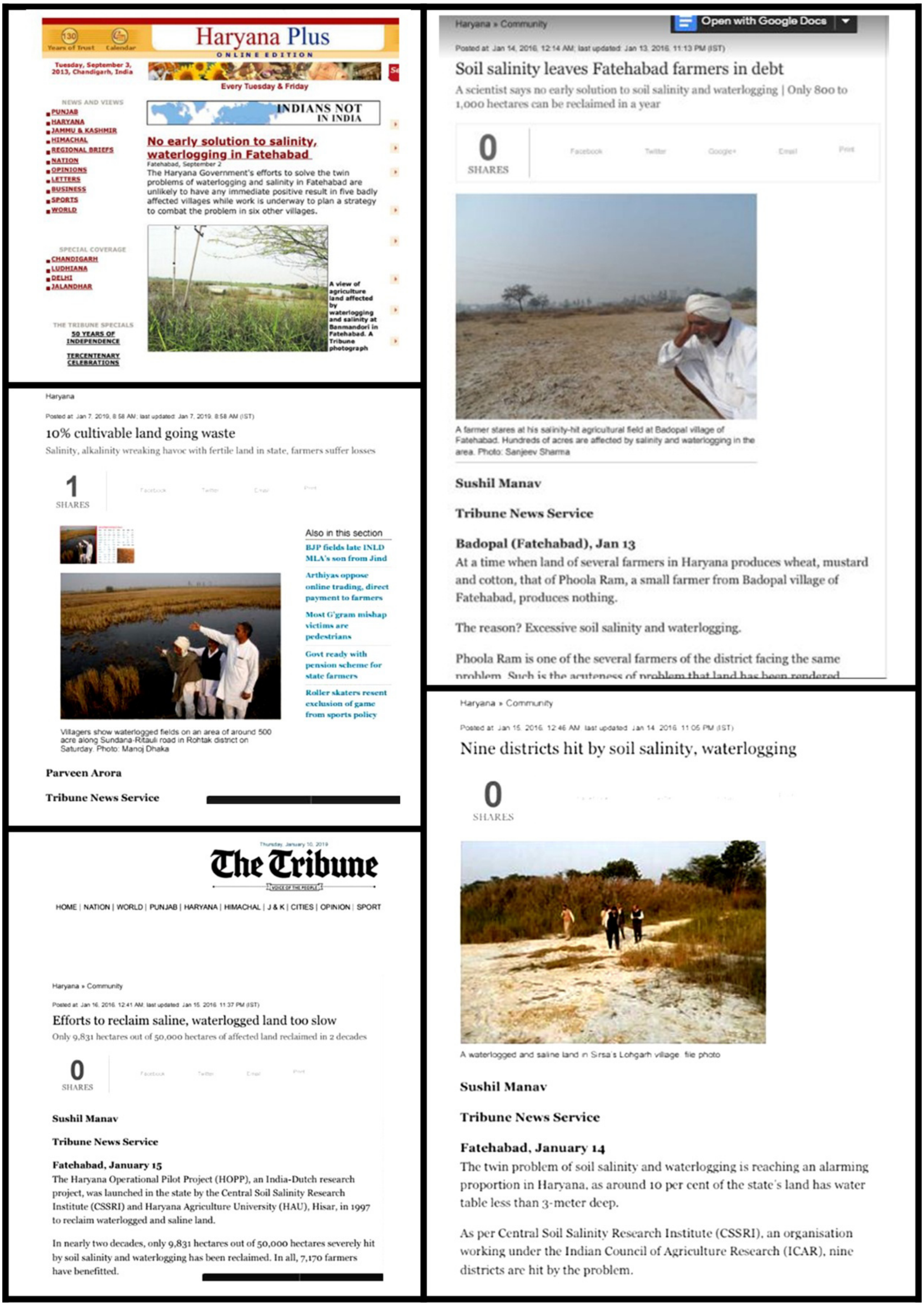
Mapping salinity entails initial identifying the areas wherever salts accumulate and then identifying changes in this concentration. Both generally rely upon the impossible to approach salts circulate at the soil exterior and on the capacity of the remote sensing equipments to recognize salts.

1.3.1 Justification of selection of study area and title:

As per the report of The Tribune Chandigarh, Haryana Plus dated 3rd September 2013, in excess of 4000 Acres of land of agriculture place that is known for 11 towns of Waterlogging and soil salinity are major problems in Fatehabad and Sirsa. Badlands cover 62.06 square kilometers of the study area, or 2.45% of the district's total geographical area. It is usually accepted that the prospect food requirements of an expanding population can be addressed by integrating the hard work of all interested parties toward: civilizing the degree of the executives of soils effectively over farming and putting potentially arable soils that are actually crude under waterlogging.

The natural drainage of the region is being restricted by development activities and the ground water being largely salt laden, the introduction of canal irrigation and inefficient water management practices have contributed the spread of serious waterlogging and salinity problems. Underground water quality is also marginally saline to saline in the study area that creates the problems of secondary salinization as well as overuse of water creates the problem of waterlogging and soil salinity /alkalinity in Fatehabad and Sirsa districts. The present topic related to waterlogging and salt affected area is highly discussed by various print and electronic media (Figure -1.1) as well as different institutions are also working on to resolve the issues of waterlogging and soil salinity in Fatehabad & Sirsa district.

The current conceptualizing issue identified with soil salinity and waterlogging was profoundly featured in ranchers, media and diverse association since a decade ago. Geo spatial technology provides new tools for mapping, monitoring, and management of waterlogged and salt-affected areas. Development of sustainable land use management plan of study area by integrating of soil characteristics including fertility status, salinity/sodicity, physiography, use of underground & surface water, wastelands and present land use was prepared. Keeping this in see, huge scope mapping of waterlogged and salinity territories in Fatehabad and Sirsa districts alongside their administration and the advancement of activity plan of the current investigation entitled "**Assessment and Management of Waterlogged and Salt Affected area in North Western Haryana using Geo-Spatial Technology**" was taken out.



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No early solution to salinity, waterlogging in Fatehabad

Fatehabad, September 2

The Haryana Government's efforts to solve the twin problems of waterlogging and salinity in Fatehabad are unlikely to have any immediate positive result in five badly affected villages while work is underway to plan a strategy to combat the problem in six other villages.

A view of agriculture land affected by waterlogging and salinity at Banmandori in Fatehabad. A Tribune photograph

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Haryana

Posted at: Jan 7, 2019, 8:58 AM; last updated: Jan 7, 2019, 8:58 AM (IST)

10% cultivable land going waste

Salinity, alkalinity wreaking havoc with fertile land in state, farmers suffer losses

1 SHARES

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Villagers show waterlogged fields on an area of around 500 acre along Sundana-Ritauli road in Rohtak district on Saturday. Photo: Manoj Dhaka

Parveen Arora

Tribune News Service

Thursday, January 10, 2019

The Tribune

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Haryana » Community

Posted at: Jan 16, 2016, 12:41 AM; last updated: Jan 15, 2016, 11:37 PM (IST)

Efforts to reclaim saline, waterlogged land too slow

Only 9,831 hectares out of 50,000 hectares of affected land reclaimed in 2 decades

0 SHARES

Sushil Manav

Tribune News Service

Fatehabad, January 15

The Haryana Operational Pilot Project (HOPP), an India-Dutch research project, was launched in the state by the Central Soil Salinity Research Institute (CSSRI) and Haryana Agriculture University (HAU), Hisar, in 1997 to reclaim waterlogged and saline land.

In nearly two decades, only 9,831 hectares out of 50,000 hectares severely hit by soil salinity and waterlogging has been reclaimed. In all, 7,170 farmers have benefitted.

Haryana » Community

Open with Google Docs

Posted at: Jan 14, 2016, 12:14 AM; last updated: Jan 13, 2016, 11:13 PM (IST)

Soil salinity leaves Fatehabad farmers in debt

A scientist says no early solution to soil salinity and waterlogging | Only 800 to 1,000 hectares can be reclaimed in a year

0 SHARES

A farmer stares at his salinity-hit agricultural field at Badopal village of Fatehabad. Hundreds of acres are affected by salinity and waterlogging in the area. Photo: Sanjeev Sharma

Sushil Manav

Tribune News Service

Badopal (Fatehabad), Jan 13

At a time when land of several farmers in Haryana produces wheat, mustard and cotton, that of Phoola Ram, a small farmer from Badopal village of Fatehabad, produces nothing.

The reason? Excessive soil salinity and waterlogging.

Phoola Ram is one of the several farmers of the district facing the same problem. Such is the acuteness of problem that land has been rendered

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Haryana » Community

Posted at: Jan 15, 2016, 12:46 AM; last updated: Jan 14, 2016, 11:05 PM (IST)

Nine districts hit by soil salinity, waterlogging

0 SHARES

A waterlogged and saline land in Sirsa's Lohgarh village. file photo

Sushil Manav

Tribune News Service

Fatehabad, January 14

The twin problem of soil salinity and waterlogging is reaching an alarming proportion in Haryana, as around 10 per cent of the state's land has water table less than 3-meter deep.

As per Central Soil Salinity Research Institute (CSSRI), an organisation working under the Indian Council of Agriculture Research (ICAR), nine districts are hit by the problem.

Figure 1.1 (Source: Print & Electronic Media)

1.4 Objectives

The following goals are being followed in this research:

1. Identification, delineation and mapping of different types of water logged and salt affected lands in the study using high resolution satellite data.
2. To suggest effective management strategies to the site specific land use plan, cropping system and proper drainage network to counter the problem in the study area.
3. To develop a Decision Support Information System (DSIS) to manage the water logged and salt affected soils in the area.

1.5 Research Questions

In the light of above objectives, subsequent research questions were framed.

- Does the present waterlogged and salt affected area will be delineated?
- Does the existing salt affected and waterlogged land will be utilized for agricultural practices under environmentally sound agricultural practices or not? If not how it will be made useable?
- What are the Decision Support Information systems for waterlogged and salt affected area of the district for sustainable agricultural practices?

1.6 Role of Geo Spatial Technology for Mapping and Management of Waterlogging and Soil Salinity

Because of its negative effects on the climate, agro-environments, agricultural efficiency, and supportability, soil salinity is a major global issue. Salinity degrades soil quality, destroying the asset base. Soil asset utilisation and the board both require a rational understanding of soil salinization. It is significant in the areas wherever salinity happens, to produce soil salinity data to decide degree and danger of salinity, of which salinity mapping and customary monitoring has an incredible task to carry out. Salinity data at territorial, public and neighborhood levels, just as in watered fields, consequently, turns out to be critical for dynamic and dealing with these assets. The treatment of saline soils is extremely site dependent, depending on factors like the composition of the soils, solvent salts and hydrological conditions in the area. Helpless vegetation cover may be a sign of salinity in the region and RS symbolism is sufficient to chart the surface articulation of salinity. At large scales and small scales, diverse methodologies combining GIS and remote sensing can be utilised to cultivate salinity mapping. Though groundwater depth and vegetation cover are generally recognised as the most fundamental determinants of salinity patterns and dangers, the aim of such an work out is to survey and drawing soil salinity in order to better appreciate the issue, give evidence for taking a critical step to prevent its global spread and deal with the creation and efficient use of a solution. Salinized and trimmed zones may be connected to a greenness and splendor-based salinity file that displays leaf dampness as a feature of salinity, to old-style fake shading composites of isolated units or to a PC-assisted land-surface structure. A splendor file recognizes brilliance showing up at elevated levels of salinity. A complete audit of advancements for mapping and monitoring of salinity is given in the individual areas.

1.6.1 Soil Salinity Mapping and Monitoring Using Remote Sensing Imagery and GIS

Monitoring of salinity and mapping throughout utilizing remote sensed data and GIS have been regular in numerous nations; such systems have as of late been utilized in Abu Dhabi Emirate and Kuwait as a feature of public inventories of soil; at the territorial and public levels. RS technologies for soil salinity, demarcation of salt-affected soils using Remote Sensing and GIS; Salinity evaluation utilising RS techniques; mapping salt-affected soils using Landsat satellite data; soil salinity study using airborne remote sensing and spectroscopy; salinity appraisal through integrating Remote Sensing and GIS; multispectral remote sensing of saline leaks; Remote sensing in salt biomass and anxiety finding; salinity management using Remote Sensing and GIS; outline of salt-influenced soils by advanced investigations of Landsat MSS data; use of multi-temporal Landsat data for salinity discriminating proof; salinity monitoring using RS and GIS; Salt-affected soils: remote sensing Landsat symbolism for saline soil mapping; Landsat symbolism for measuring soil salinity patterns; RS and conventional data reconciliation The TM groups five and seven are commonly used to find out soil salinity or waste lands; wide-scale soil salinity monitoring using satellite-based remote sensing.

1.6.2 Impact of Waterlogging and Salinity on Agriculture and Environment

The concentration of dissolved salts in the groundwater rises in lockstep with the level of groundwater. Salinization may occur if the upward flow is not stopped by percolating irrigation water moving downhill. The soil gets waterlogged when the water table falls below 1.5 m below the surface, indicating that the water holding potential is insufficient to withstand the monsoon rains. As a result, a destructive period of floods throughout the raining season and intense salinization throughout the waterless season has begun. It has a far-reaching effect on agricultural development. The field floods during the monsoon if the level of water table is too elevated and the farmer is unable to cultivate the kharif crop. If the upper layer of water is fresh or brackish, the Rabi crop will benefit, especially if irrigation water is short, but in most circumstances, the Rabi crop will not compensate for the loss of the kharif crop. Both crops are destroyed as the salinity level rises. Salts pushed out by irrigation from adjacent fields are absorbed in some regions. Farmers would naturally lose some of their land; as a result, a patchwork of lush irrigated fields and salty plains has emerged that have been lost. Irrigation in a different area has a ripple impact that enhances socioeconomic, ecological, hydrological and environmental conditions. Our failure to anticipate the effects of canal irrigation, particularly in dry and semi-arid areas, has resulted in significant environmental damage, as well as our failure to take appropriate measures to minimize the changes wrought by irrigation, has eventually resulted in a slew of problems. Salinity and waterlogging are the products of extensive agriculture in semi-arid and arid areas. There are more than 250 M hectares of irrigated land in the nation, with nearly 30 million hectares destroyed due to salinity and waterlogging. Per year, salinization kills approximately 1.5 million hectares of cropland. In Pakistan, Egypt and India, salinity and waterlogging have lowered large crop yields by approximately 30%.

Soil salinity and waterlogging are two examples of land erosion that pose a danger to the long-term consumption of soil and water supplies. In the long term, these concerns contribute to land abandonment, according to historical facts. There are negative growth effects in the short to medium term. There isn't any detail on the losses experienced as a result of these issues. Three major problems must be addressed: (i) the economic implications of soil salinity and waterlogging, (ii) the possibility of farm level disposal as a way of crisis management and (iii) the limitations to successful agricultural land drainage implementation.

1.7 Scope of the Study

The estimating and monitoring of EMR emitted or absorbed by the surface is at the heart of remote sensing. Ponded water, high water table zones, salty water, sandy soil and salt-affected plants represent light differently from other landscape features, making them easy to discern in waterlogging and soil salinity investigations.

Black and white and FCC satellite data were the first remote sensing tools used to survey and map waterlogged and salt-affected soils. Waterlogging is shown by the dark appearance, while salinity is shown by the light appearance caused by salt crust efflorescence. Waterlogging and salinity have an indirect effect on crops, which offers knowledge on waterlogging and salinity. Units are identified using satellite data based on a number of geomorphological variations. It was also attempted to connect the variations in the various tones to the salt material.

The scope of the present study of management of waterlogged and salt affected area using Geo-informatics is briefly given below.

- To demarcate salt affected and waterlogged area.
- To find out the causes for waterlogging and soil salinity.
- Management of waterlogged and salt affected area.
- Waterlogging and salinity have an effect on agriculture and the climate.
- Irrigation in an unrelated region results in a sequential reaction of socio-agricultural, hydrological and ecological changes.
- Suggestions to control over exploitation of sub surface water and land resources particularly in waterlogged and salt affected area.
- To improve of water table depth and brackish water.

- To improve decreasing agricultural productivity on the basis of environmentally sound agricultural practices with available natural resources in salt affected and waterlogged area.
- To Improve faulty cropping pattern from monoculture to crop diversification.
- To the management of cropping activities for flood-prone regions with a shallow water level.

1.8 Database and Methodology

1.8.1 Database

1.8.1.1 Satellite Data

IRS-IC/ID LISS-III, LISS-IV and Sentinel digital data of various years were used to analyze the waterlogged and salt-affected areas. The satellite data's datum and prediction method were WGS 84 and UTM, respectively. The info collected from the Haryana Space Applications Centre (HARSAC), Haryana Government's Department of Science and Technology and Sentinel data was retrieved via the Sentinel Open Access Hub. With the help of an on-screen interpreter, satellite data was analyzed. Detail of satellite data used is shown in Table-1.1.

Table-1.1 Detail of satellite data used

Satellite	Sensor	Date of Acquisition	Spatial Resolution
IRS-P6	LISS-IV	05December, 2017	5.8 M
		11 March, 2017	
IRS-P6	LISS-III	10 June, 2018	23.5 M
		12 January, 2018	
Sentinel-2A		28 April, 2018	2.5 M
		27 May, 2020	

1.8.1.2 Ancillary Data

Toposheets from the SOI were used to locate settlements, major transportation networks, cultural characteristics and interpreted major towns and cities. Climatic data and information related ground water quality, water table fluctuations etc, published literature, maps and reports were collected, consulted and used suitable.

1.8.1.3 Soil and Underground Water Data

Data related to soil were collected from ground and analyzed at CCS HAU University, Hisar with their physical and chemical properties. Data related to underground water depth and quality is collected from Central Ground Water Board, Ministry of Water Resources, Government of India.

1.8.2 Software Used

1.8.2.1 ERDAS Imagine

ERDAS Imagine is a remote sensing and raster graphics editor developed by ERDAS, Inc. In addition, to make the analysis easier, this programme was used to prepare final photographs. 9.2 is the version number. It helps the user to plan, view and improve digital images for use with GIS applications. It is mainly targeted at geospatial raster data processing. It's a toolbox that lets you run a variety of operations on a picture and get answers to basic geographic questions. Layer piling, cropping, geo-referencing and mosaicing of satellite data is all done with this programme.

1.8.2.2 Arc/Map (9.3)

The most widely used ArcGIS desktop software for mapping. This app makes it simple to create maps that relay a post. Arc Map comes with all of the resources you'll need to place data on a map and show it effectively. The software was used to build a database for mapping the research area's waterlogged and salt-affected patches.

1.8.2.3 Arc Info

Arc Info Workstation used for Topogrid Maps like water quality, water depth, Slope Analysis maps using interpolation or kriging command.

1.8.2.4 Geometica-10.3

PCI is an acronym for Personal Computer Interface. After a signal optimized environment for remote sensing, GIS, Photogrammetry, Cartography, Internet and production tools, Geomatica has developed Geomatica software. For image processing, the Geomatica10.3V package is used. Geomatica10.3 has a range of features, including IRS-P6 CBERS and format support, as well as ortho rectification.
For all of your computing needs, Geomatica has absolute raster and vector integration, as well as support for over 100 solutions, all while ensuring complete interoperability with outside device technologies. Because of the software's good classification tools and improved interpretability, it was chosen for this analysis.

1.8.2.5 Microsoft Office 2010

MS - Office was used to construct records, charts and diagrams.

i. Microsoft word – was mostly used in the current study's research drafting.
ii. Microsoft Excel – was used to calculate different figures for change analysis, graph planning and excel sheets.
iii. Microsoft Access – When loading and uploading GPS points to the device, it was used to organize a .dbf list of points of global positioning system.

1.8.2.6 Garmin Hand Held GPS

Garmin hand held GPS was used for GPS collection during the ground truth.

1.8.3 Methodology

1.8.3.1 Rectification and Geo-Referencing

In order to generate spatial data that can be used in a GIS environment, raster satellite data must be georeferenced using a coordinate scheme. Georeferencing involves conveying a coordinate scheme and translating a raster data to input these coordinates so that spatial data can be viewed, queried and interpreted. Geometric correction of satellite digital data was performed using a geo-referenced master image (Cartosat-1 ortho-rectified image) as a reference, with uniformly spaced Ground Control Points (GCPs) and an RMS error of pixels at 0.5. The collected images were geo-referenced and the image was resampled using the nearest neighbor technique.

1.8.3.2 Base Map Preparation

Base maps were prepared by using the toposheets. All line information and other important control points were traced from the toposheets. Village settlements and other places were identified using 1:50,000 scale SOI toposheet of the area. These base maps are used to establish the landuse & land cover maps for the research field.

1.8.3.3 Interpretation of Satellite Data

Onscreen visual analysis of remotely sensed data was carried out using a hybrid approach based on typical image uniqueness that are color, texture, pattern, form, scale, position and involvement among others. "Keys" to understanding were produced for a number of salt-affected and flooded locations. The "keys" for interpreting satellite data were developed from these "keys." These interpretation keys are used to divide satellite data into three salinity and two waterlogged groups according on their frequency in the study area. The most prevalent sites for these classes include low-lying areas, impermeable infrastructure, and canal/river banks.

1.8.3.4 Approach & Methods

1.8.3.4.1 Visual Image Interpretation

On the basis of satellite images properties such as tone, texture, shape, color, associations etc interpretation key were developed; (Table 1.3) The various waterlogged and salt-affected sites were marked out. In order to elevate the geomorphological information, the accessible geological maps and information were also studied. During the interpretation of satellite data somewhere some doubtful objects were demarcated and the same were noted for field verification published literature and other relevant. The ground verification was completed based on encoded pre-field interpretation cross plan and unsure units were verified in the field at the time of soil sample collection. The corrections were incorporated while finalizing the salt affected and waterlogged area map. Every effort was made for verification of all the geomorphic units during field visit in order to improve the correctness. After digitization and error removal, attributes were attached to various land use units. For the various actions stated in the project work goal, standard procedures developed by HARSAC and the Indian Space Research Organization (ISRO) for agricultural system analysis were applied (Panigrahy et. al., 2008). ERDAS 9.1, GEOMATICA 10.3, and ARCMAP 9.3 software programmes were used to analyze digital images at HARSAC in Hisar. Figure 1.2 shows the steps required in digital investigation, which are detailed elsewhere (Anonymous, 1990 and Patel et al., 1993, Yadav et al., 2008, and Hooda et al., 2008). To geo-reference multi-date and multi-season digital satellite data with the master images, GCPs were gathered using a second polynomial order and nearest neighbour resampling technique.

1.8.3.4.2 Development of classification scheme:

A classification scheme was constructed based on earlier knowledge about the study region, a quick exploration & investigation, and additional information from past research in the subject area, as shown in Table 1.2.

Table 1.2 Land use/Land cover classification scheme

Level-I	Level-II	Level-III
Built up	Rural	Village
		Single/ Group Building
Agricultural Land	Crop land	Crop land
	Fallow land	Current Fallow
	Plantation	Field plantation
		Strip Plantation along the Road
		Bund plantation
Waste Land	Scrub land	Land with dense scrub
		Land with open scrub
	Grazing land	Degraded grazing land
		Dense grazing land
	waterlogged	Seasonal waterlogged
	Salt affected area	Salt affected area
	Brick kilns	Brick kilns
Water body	Pond/River	Pond/River Channel/lake

1.8.3.4.3 Digital Image Interpretation

For the various actions stated in the project work goal, standard procedures developed by HARSAC and the Indian Space Research Organization (ISRO) for agricultural system analysis were applied (Panigrahy et. al., 2008). ERDAS 9.1, GEOMATICA 10.3, and ARCMAP 9.3 software programmes were used to analyse digital images at HARSAC in Hisar. Figure 1.2 shows the steps required in digital analysis, which are detailed elsewhere (Anonymous, 1990 and Patel et al., 1993, Yadav et al., 2008, and Hooda et al., 2008). To geo-reference multi-date and multi-season digital satellite data with the master images, GCPs were gathered using a second polynomial order and closest neighbour resampling technique. The geo-referenced images were employed in a comprehensive enumeration approach for additional analysis. The administrative boundaries of the districts were digitized, a mask created, and superimposed on the geo-referenced image in the complete enumeration approach. All of the data items (pixels) were extracted for further classification and analysis. The Iso-Data Clustering classifier was utilised in an unsupervised classification technique, and the class of concentration was determined. The cropping pattern maps for kharif, rabi and zaid were created using categorized images and logical grouping. Cropping pattern maps for kharif, rabi and summer were used to create crop rotation maps.

Table 1.3 Image interpretation key for waterlogged and salt affected area and landuse/land cover

Land use/ Land cover	Tone	Size	Shape	Texture	Association
Settlement					
Buildup land	Bluish Grey	Varying	Definite	Coarse	Streets
Agricultural Land					
Crop land	Red/Greenish	Varying	Rectangular	Fine to medium coarse	Outskirts of settlement
Fallow Land	Yellowish white to Reddish white	Varying	Rectangular	Medium to Fine coarse	Outskirts of settlement
Plantations	Dark red	Varying	Irregular	Coarse with mottling	Agricultural land
Strip plantation	Dark red to dark gray	Defined	Linear	Coarse	Along roads/railway line/canals
Forest					
Dense	Dark red	Varying	Irregular	Coarse with mottling	Notified forest areas, hills
Open Forest	Dark grey	Varying	Irregular	Coarse with dark mottling	Hills
Wastelands					
Scrub land	Dull red / brown / greenish	Varying	Irregular	Coarse	Foothills, Rocky slopes
Sandy areas	Dull white, light yellow	Varying	Irregular	Fine to medium	Scrubs, Foothills
Degraded grazing land	Dull red / brown	Varying	Irregular	Coarse to mottled	Village peripheries
Waterlogged	Black	Varying	Irregular	Coarse	Agricultural Land
Salt affected	White to light blue	Varying	Irregular	Smooth to mottled	Waterlogged areas
Water body					
Pond / River	Light blue/Dark blue	Defined	Regular	Smooth	Build up areas

1.8.3.4.4 Development of Decision Support Information System for waterlogged & salt affected area

The study is mainly concerned to develop Decision Support Information System for salt affected and waterlogged area based on interpretation of high resolution satellite data. After image rectification and effective image enhancement techniques, satellite images can be used to help in the delineation and visualization of various thematic data. The pre-field interpreted map was created using the visual analysis tool. Final maps would be created based on the pre-field interpretation, ground truth checking and available secondary knowledge.

An extensive use of GIS and remote sensing software's (Arc GIS, ERDAS Imagine) will be used for analyzing the spatial distribution of the various aspects taken up for study. GIS techniques will be used in order to create layers of waterlogged, salt affected area, soils, slope analysis and land use/ land cover. These layers were put in GIS format to create the database. On the basis of above database drainage network plan maps and action plan map for waterlogged and salt affected area were prepared in Arc map software. The methodology flow chart (Figure 1.3) shows the details of used methodology.

1.8.3.5 Ground Verification, Water & Soil Sample Collection

Land truth was obtained in the study area, along with ground photos and GPS points, due to the variations of salinity and landscape characteristics in the study area. During the ground reality, the pre-field interpreted maps' suspicious areas were reviewed and the pre-field maps were updated by adding field observations, if any. Water & Soil samples from various locations were gathered and analyzed for their chemical characteristics in the laboratory as follows.

Soil Properties

Electric Conductivity (EC)
pH
Sodium (Na)
Calcium (Ca)
Magnesium (Mg)
Exchangeable Sodium Percentage (ESP)
Cation Exchange Capacity (CEC)
Electric Conductivity (EC)
pH

Water Properties

Sodium (Na)
Calcium (Ca)
Magnesium (Mg)
Carbonate (CO_3)
Bicarbonate (HCO_3)
Residual Sodium Carbonate (RSC)
Sodium Absorption Ratio (SAR)
Chlorine (Cl)
Total Suspended Solids (TSS)
TH

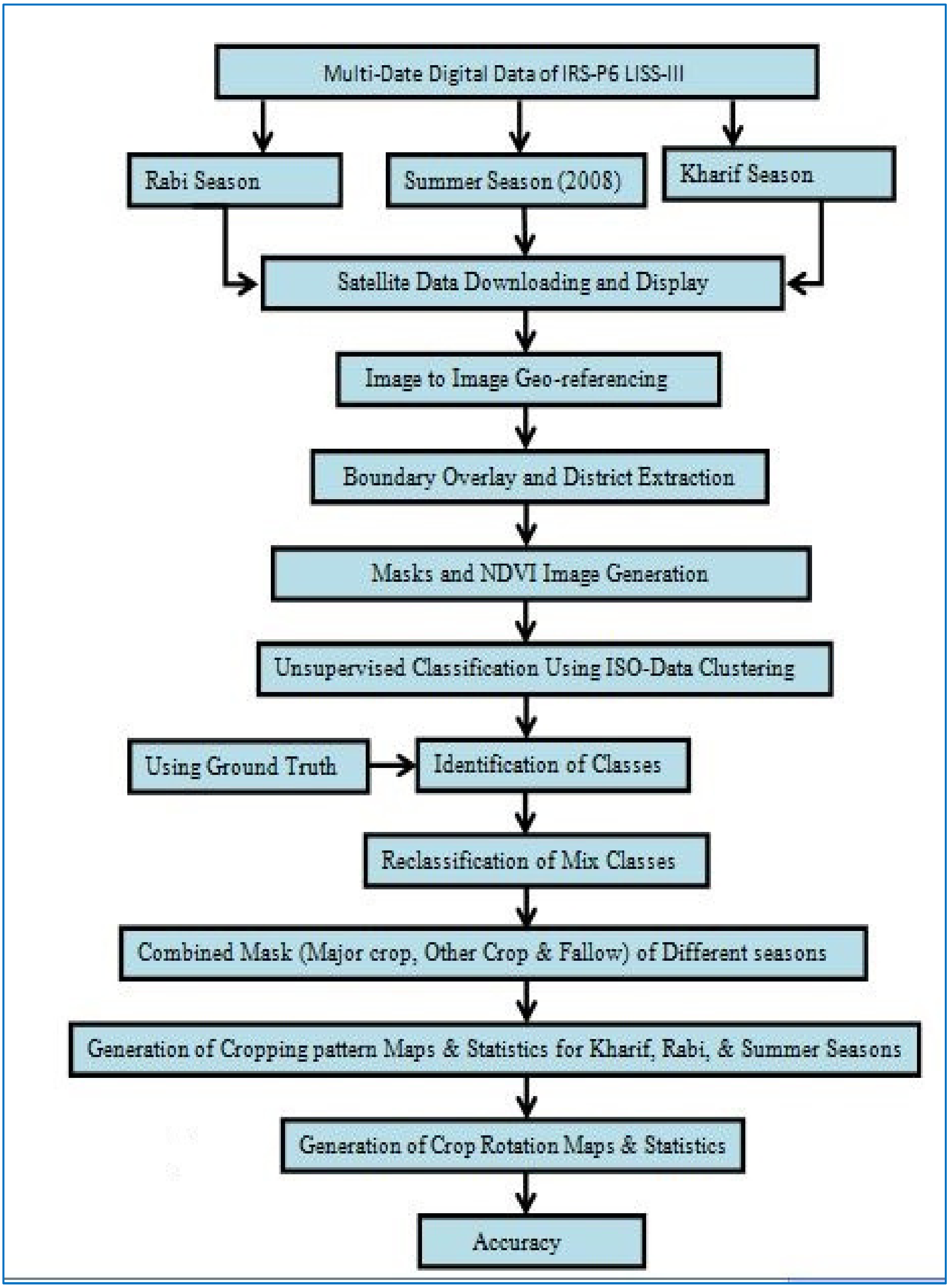


Figure 1.2 Methodology flow chart for cropping system analysis

1.8.3.6 Preparation of Final Maps

Final maps for waterlogged & salt affected areas, soil texture maps, geomorphology maps, lithology maps, rabi & kharif cropping pattern and crop rotation maps, ground water quality maps, water depth maps, slope analysis maps, water & soil sample location maps, settlements & Infrastructure maps and drainage network plan was prepared.

1.8.3.7 Generation of hard copy maps and report writing

Hard copy of reports and all thematic maps were generated.

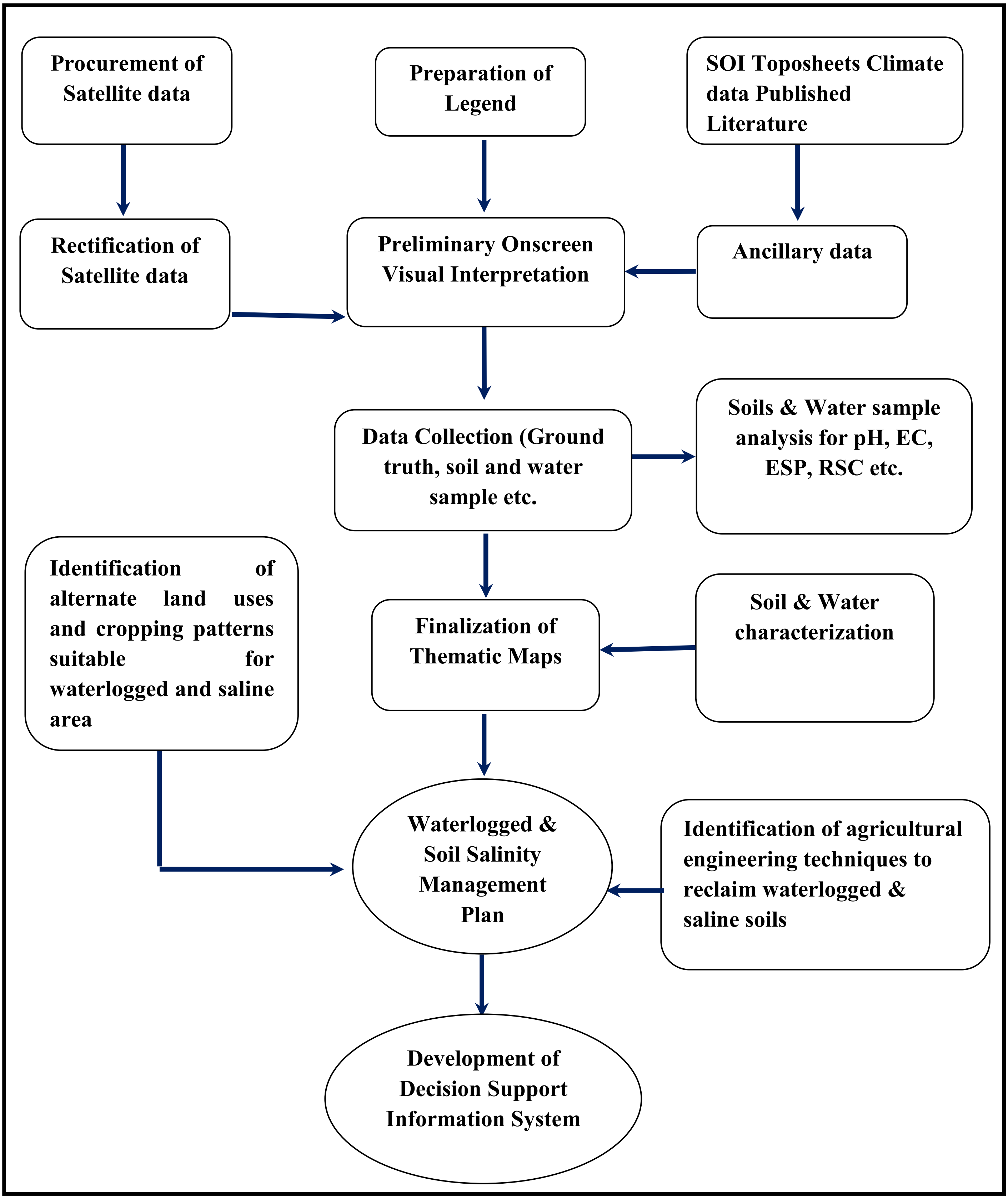


Figure 1.3 Methodology Flow Chart

1.9 Description of Study Area

The study suggests the management of waterlogging and soil salinity in North western Haryana state and its management. The study area comprises of Fatehabad and Sirsa districts of the state.

1.9.1 About Haryana

Haryana is a landlocked Indian state in the north. Haryana is a tiny state that spans the latitudes of 27^{o}29' to 30^{o}56' N and the longitudes of 74^{o}27' to 77^{o}36' E, covering an area of 44,212 square kilometers. It covers 1.35 percent of the country's total area. The Yamuna River forms the state's eastern boundary with Uttar Pradesh. Haryana also surrounds Delhi on three sides, establishing its northern, western and southern borders. As a result, the NCR encompasses a significant portion of Haryana. Chandigarh is the state's capital. Haryana is one of India's richest states. Haryana has four distinct geographical characteristics.

- The entirety of the state is overlayed by the Yamuna-Ghaggar plain.
- To the northeast, the Shiwalik Hills.
- To the southwest, a semi-desert sandy plain.
- To the south, the Aravali Range.

1.9.2 Study Area

The districts of Sirsa and Fatehabad are located in northwestern Haryana. Sirsa district was formed on September 1, 1975, while Fatehabad was formed on July 15, 1997, from Hisar district. Sirsa is said to be one of North India's oldest cities, with an ancient name of Sairishaka that appears in the Mahabharata. The root of the town's name is the subject of many stories. Its original name was Sairishaka, which has since been corrupted to Sirsa. According to legend, in the 7th century A.D., an unnamed king called Saras founded the town and constructed a fort. Another legend says that the name Sarasvati derives from the holy river Sarasvati. The district's administrative headquarters is in Sirsa. It is located 259 kilometers on National Highway-09 from the national capital New Delhi and 250 kilometers on National Highway-64 from the state capital Chandigarh.

1.9.3 Location and Extend

The state's far western part is where Haryana's northwestern area is found. On the north and north-east, the Punjab (Faridkot and Bhatinda districts), the Rajasthan districts of Ganganagar and Hanumangarh on the west and south, and the Haryana districts of Hisar and Jind on the east, it is surrounded by the Punjab (Faridkot and Bhatinda districts). As a result, it is surrounded on three sides by interstates and barely links to its possess state on the eastern region. The study area covers 28°48' to 30°North latitudes and 74°29' to 77°12' East longitudes, spanning 6692.44 square kilometers in total. Figure 1.5 depicts the research area's position in the province, while Figure 1.4 depicts the Survey of India toposheet index map.

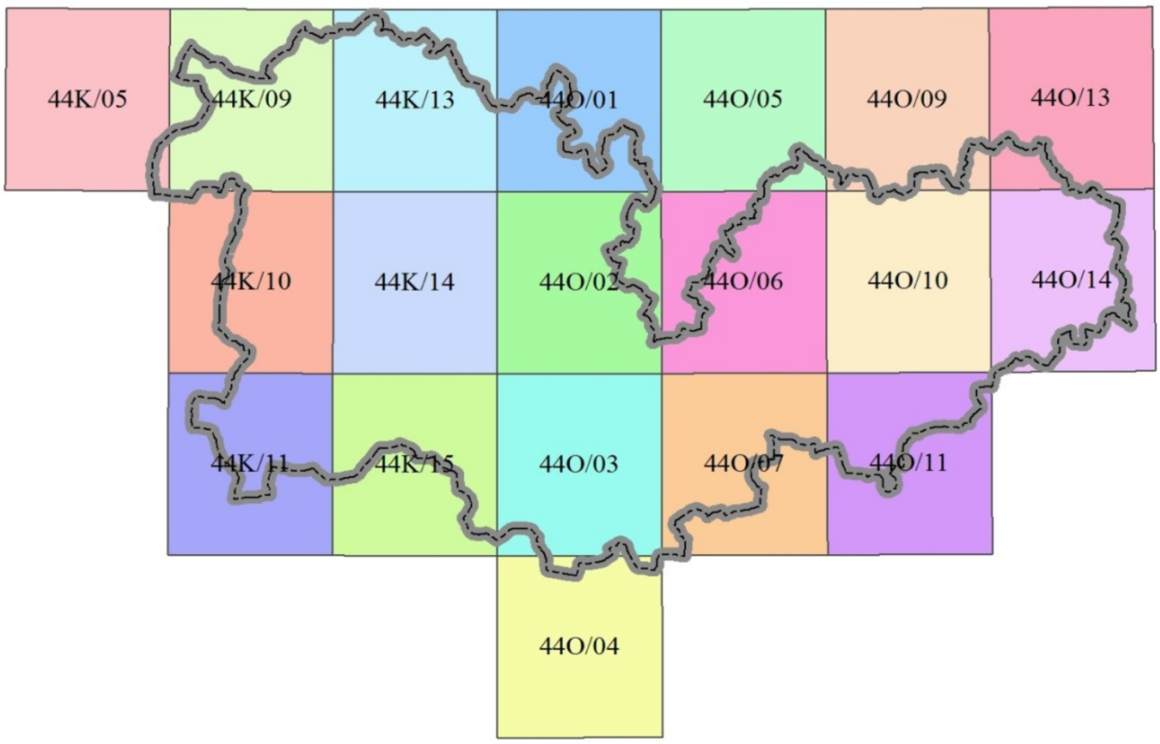


Figure 1.4 Survey of India Toposheet Index Map

1.9.4 Climate

Aridity, temperature extremes and a lack of rainfall characterize the climate of the studied region. Subtropical, semi-arid, continental, and monsoon climates are the four types of climate. The winter season lasts from November to March. The summer season runs from April to June 30. From July to September and September to October, respectively, are the south-west monsoon and post-monsoon seasons.

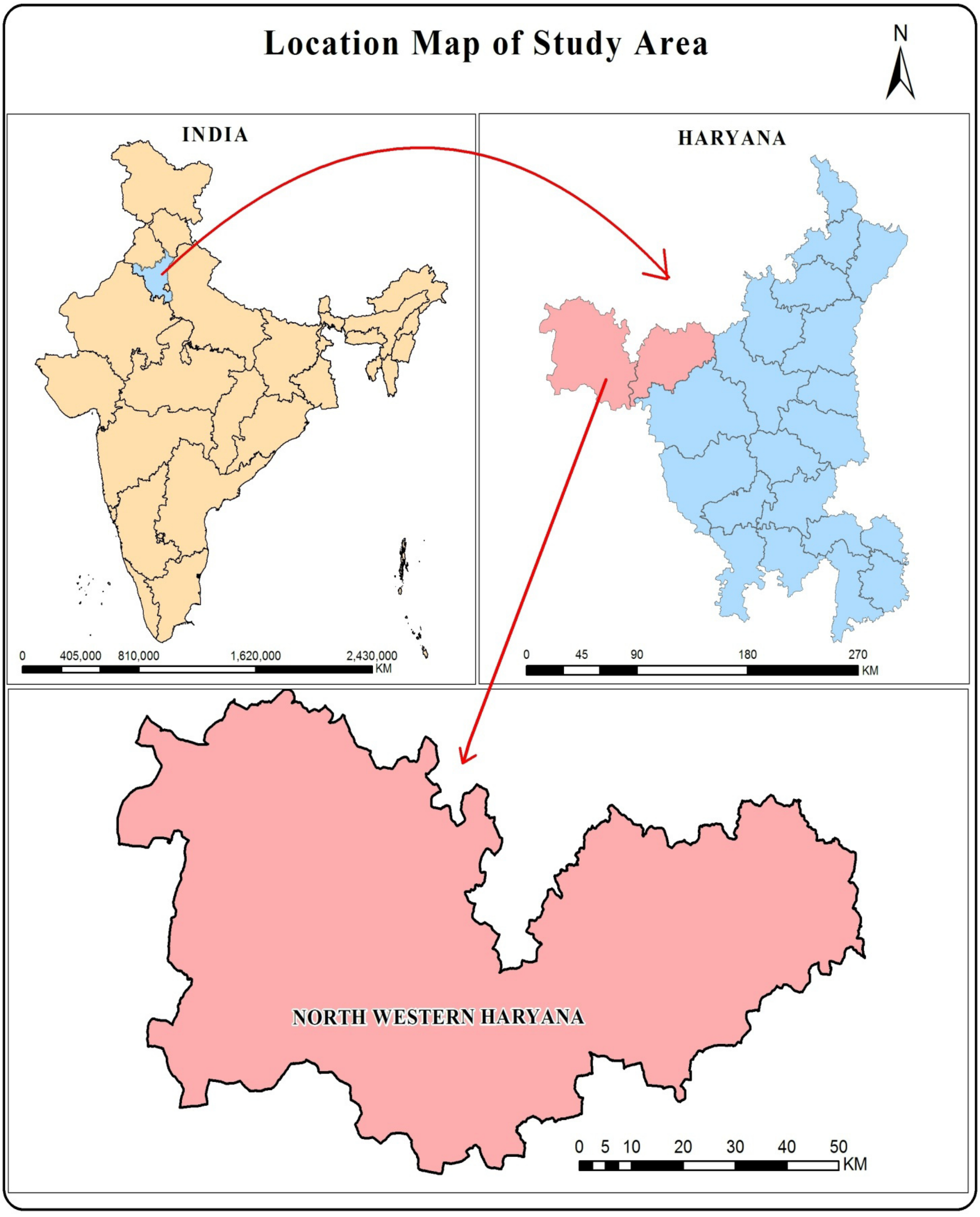

Location Map of Study Area
N
INDIA
HARYANA
0 405,000 810,000 1,620,000 2,430,000
KM
0 45 90 180 270
KM
NORTH WESTERN HARYANA
0 5 10 20 30 40 50
KM

Figure 1.5

.

1.9.4.1 Rainfall

The average monthly rainfall in the district is 186.3 mm. More than 60% of the yearly rainfall falls between the months of July through September. (Table 1.4 & Figure 1.4). During the winter months of December to February, some rainfall is often obtained as a result of western disturbances that move through the district or its neighborhood from west to east, impacting the weather in the district.

1.9.4.2 Temperature

The months of March to June are the hottest with temperatures rising. The typical daily high temperature is 41 to 46 degrees Celsius, with a daily minimum of roughly 27 degrees Celsius. Temperatures can reach up to 48 degrees Celsius temperatures begin to decline as the monsoon approaches and the monsoon continues to be unpleasant due to increased humidity and warm nights. The temperature decreases after October, both during the day and at night and the decline becomes steeper after the middle of November.

1.9.4.3 Humidity

During the monsoon season, which lasts from December to February, the relative humidity in the mornings is normally around 75% or higher. The rest of the year has lower humidity, with the summer season being the driest, with relative humidity hanging near 30% in the afternoons.

1.9.4.4 Cloudiness

The sky was mildly to strongly clouded during the monsoon season. The clouds are often dark or lightly clouded the majority of the year. Over the cold season, cloudy skies reign for one or two days in conjunction with moving western turbulence.

1.9.4.5 Winds

Winds in the study region are normally light, but they can get stronger in the late summer and monsoon seasons. Winds from the west and south are more common during the south-west monsoon season, but easterlies and south-easterlies also blow. During the post-monsoon and winter seasons, southerly or westerly winds are more common in the mornings, whereas northerlies and north-westerlies are more common in the afternoons. Morning winds from the west or south-west are more common during the season. They often come in the afternoons from the west and north-west.

Table-1.4 Average Monthly Rainfall (2005-06 and 2018-19)

Month	Average Monthly rainfall (2005-06) in mm	Average Monthly rainfall (2018-19) in mm
January	0	3
February	23.5	23.15
March	16.8	3.72
April	7.6	1.1
May	37.4	1.3
June	10.7	36.1
July	69.9	115.1
August	146.1	112.7
September	80.6	112.9
October	0	0
November	2.5	0.2
December	0	7.15
Total	395.1	416.42

Source- Statistical abstract of Haryana-2018-2019

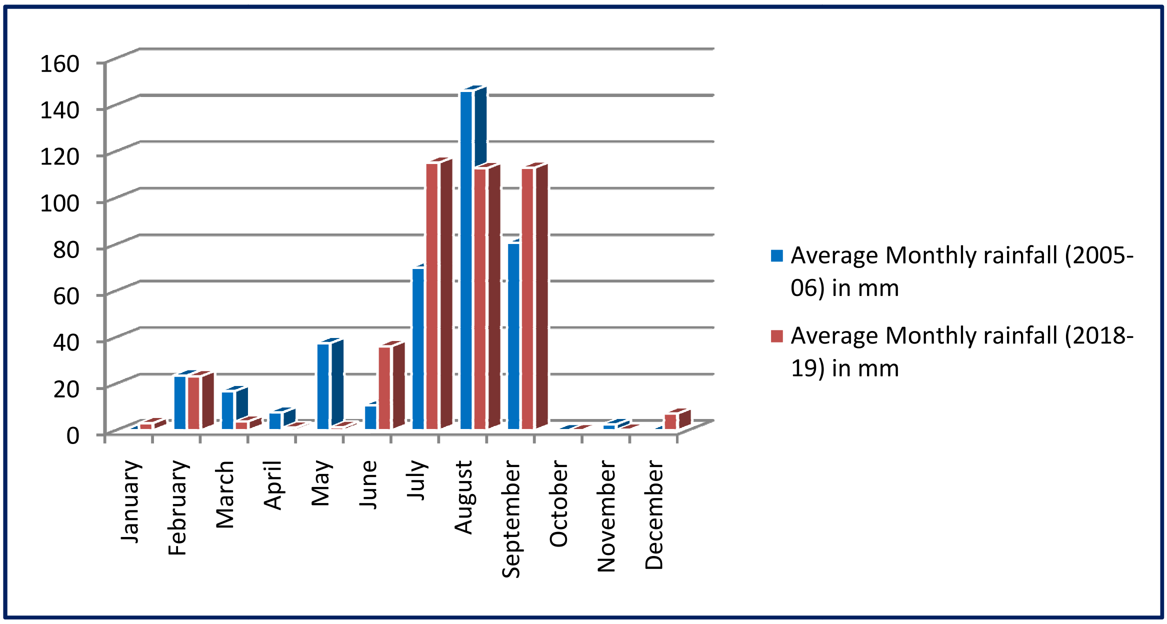


Figure 1.6

1.9.5 Administration

The study area is under Hisar division and having four sub-divisions namely Sirsa, Dabwali, Kalanwali and Ellenabad of Sirsa district and three sub-divisions namely

Fatehabad, Tohana and Ratia of Fatehabad district. Administrative set up of study area is presented in Table-1.5.

Table: 1.5 Administrative Division of Study area

Sirsa District				Fatehabad District			
Sub-Division	**Tehsil**	**Block**	**Sub-Tehsil**	**Sub-Division**	**Tehsil**	**Block**	**Sub-Tehsil**
Sirsa	Sirsa	Sirsa	Gauriwala	Fatehabad	Fatehabad	Fatehabad	Bhuna
Dabwali	Dabwali	Dabwali		Tohana	Tohana	Tohana	BhattuKalan
Ellenabad	Rania	Baragudha		Ratia	Ratia	Ratia	Jakhal
Kalanwali	Ellenabad	Rania				Bhuna	Kulah
	Kalanwali	Odhan				BhattuKalan	
	Nathusari Chopta	Ellenabad				Jakhal	
		Nathusari Chopta					

1.9.6 Physiography

The research region's landscape can be divided into three major categories from north to south: Haryana Plain, Ghaggar or Nali alluvial bed and Sand dune tract. The Haryana Plain lies from south to the north frontier of the Ghaggar's alluvial bed. It is a huge expanse of level to rolling land. It takes up more than 65 percent of the district's total territory. From east to west, the elevation of the soil ranges between 190 and 210 metres above mean sea level. The alluvial field of Ghaggar The clayey, featureless plain of Nali. The Haryana plain runs across it on the north and west, and the sound dune tract runs through it on the south. The Haryana plain runs across it on the north and west, and the sound dune tract runs through it on the south. In some areas of this flat surface of impervious clay of considerable thickness, waterlogging is a severe issue. The district's southernmost portion is covered by a sand dune tract. The region is a northward continuation of the sand dunes of Rajasthan's Hisar and Ganga Nagar districts. Tibbas are the local name for the sand dunes. The tibbas around Ellenabad block will reach a height of 9 meters.

1.9.7 Drainage

During the monsoon season, Ghaggar, Haryana's most powerful seasonal river and the only river that passes through the district, transports water. Its water was partly used for irrigation during these months through Ottu feeder. In a southwesterly direction, it flows in a narrow meandering path. Near Mallewala, the river bed widens dramatically and it continues to widen downstream. Because of Ottu's damming, the river channel south of Saha develops into a long finger-like wide lake. Three canals, the Bhakra main line in the north, the Sukchain distributary in the centre and the Fatehabad distributaries in the south, all use canal water in the region.

1.9.8 Geology

The whole research area is filled by a Quaternary formation made up of fluvial and aeolian deposits. The Aeolian deposits, which are characterized by sand dunes, are restricted to the district's southern and western areas. The alluvial deposits are divided into two categories: newer and older. In the northern part of the study area, newer alluvium is found in the active flood plains of the Ghaggar river. Calcareous concretions are found combined with other constituents of different amounts. The character of the alluvial sediments is heterogeneous. The quaternary alluvium is deposited on a Pre-Cambrian basement of metamorphic and igneous rocks.

1.9.9 Soils

In any region, the type of soil has a major effect on the growth of plants and crops. The soil classification scheme uses a number of factors to classify a region's soils, including geology, temperature, rainfall patterns, soil composition and soil salinity. In the study area, there are two types of soils: Sierozem and Desert soils. Desert soils are found in a smaller portion of the district, particularly in the south, while sierozem soils are found in a greater portion of the district. Sierozem soil can be found in regions with annual rainfall ranging from 300 to 500 millimetres. These soils have a range of textures, from sandy loam to loamy sands and are only mildly fertile. While salinity poses a major challenge, the degree of salinity and alkali hazard varies greatly. These soils are primarily present in the district's northern zones, such as the Odhan, Baragudha and Sirsa blocks, as well as portions of the Dabwali, Nathusari Choupta, Bhattu Kalan and Rania, Bhuna blocks. Desertic soils are typically present in regions of less than 300 mm of average rainfall. These sandy soils cover most of the district's southern sections, including Ellenabad block and parts of Dabwali, Rania & Nathusari Choupta and Bhattu Kalan blocks. The research area's soils are sandy to sandy loam as per texture.

1.9.10 Slope

Slope is an important parameter from land utilization point of view. Overall runoff, land irritation, and land capability are all determined by it. The effect of the slope is perceived as a restriction on cultivation and accessibility. It is critical for plant growth as it does not only affect the soil formation but also the amount of infiltration. The knowledge and database of slope is of primary concern for land use planning and policy making. Drainage pattern, density, and length immediately reflect slope in every area, determining locational suitability of settlement, dams, and reservoirs of all sizes, as well as watershed characteristics.

For slope analysis of study area, the Survey of India toposheets on 1:50000 scales with 20-meters contour interval were used. The method adopted is taken from the guidelines given by NRSA, Department of Space, Govt. of India, Hyderabad for Integrated Mission for Sustainable Development (IMSD, 1995) project. The vertical decrease was calculated by multiplying the map distance by the scale factor and the horizontal distance between the contours was calculated by multiplying the map distance by the scale factor. By comparing widely spaced contours to sparsely spaced contours, the region of closely spaced contours has a higher percentage of slope. As a result, the thickness of contours will be used to make a slope map.

The study areas was divided as per slope into seven classes from 190-195, 195-200, 200-205, 205-210, 210-215, 215-220 and 220-225. The major division of the study area falls under almost plane. In this category, land is almost flat and geomorphologically comprises of alluvial plain, fluvio-aeolian plain and aeolian plain. This nearly level slope provides ideal condition for any type of farming, provides other agronomic conditions are favourable. Almost all arable lands fall under this category. The slope of the research area is generally from north east to south west. Figure 1.7 shows a slope diagram of the sample area.

1.9.11 Natural Vegetation

The Rajasthan desert extends into the western part of the study area. Forests are highly degraded dominated by the tree species of tropical thorn forest. The natural vegetation of the selected region is conquered by tree species like Acacia Arabica/ senegal/tortillas, Prosopisjuliflora and Salvadoraoleoides etc. and shrub species Salvadora (jal), Prosopisspecigera (jand). The main perennial grass species found in the district are Cenchrusciliaris (anjan), Cenchrussetigerus (dhaman), Lasiurussindicus (karad) etc.

1.9.11.1 Flora: The study area is situated in semi-arid zone and comprises of xerophytic type of flora. According to recent classification of Forest Survey of India (FSI), the forest type in the area comes under tropical thorn forest category. The flora is sparse and varies depending on the location and soil type. Shisham and Tut are common trees in moist and irrigated areas. Jand, Jal, Rohera and Kikar are all popular in sandy areas. In sandy areas, Sarkanda and Khip are also popular. Bansa, Indirain, Aswagandha, Kharnthi, Aok, Bhakra and Datura are some of the medicinal plants found in the region. Hins, Karaunda, Puthanda, Bansa, Babool, Karir and other shrubs can be found in this area. The lack of natural forest in village common lands and uncultivated fields is a problem in the district and tree species are sparse and of low commercial value. These fields were once protected by social forestry but they have since deteriorated due to overgrazing and unregulated tree cutting for fodder and timber. The rate of grazing is very high in these areas as a result of increased irrigation and land hungriness and they are in the final stages of retrogression. With the active participation of local rural people, the village common lands and other lands can be taken under silvipasture. The social forestry plantation areas are limited to rail, road, canal and drain strips. The area's essential grasses include Dabh, Anjan, Dhaman and Dub. These are tasty fodder grasses that are becoming sparse due to unregulated grazing. The grasses in common lands and wastelands are of low quality and they are insufficient in quantity to satisfy the demand for fuel. As a result, these lands are being transformed to agriculture.

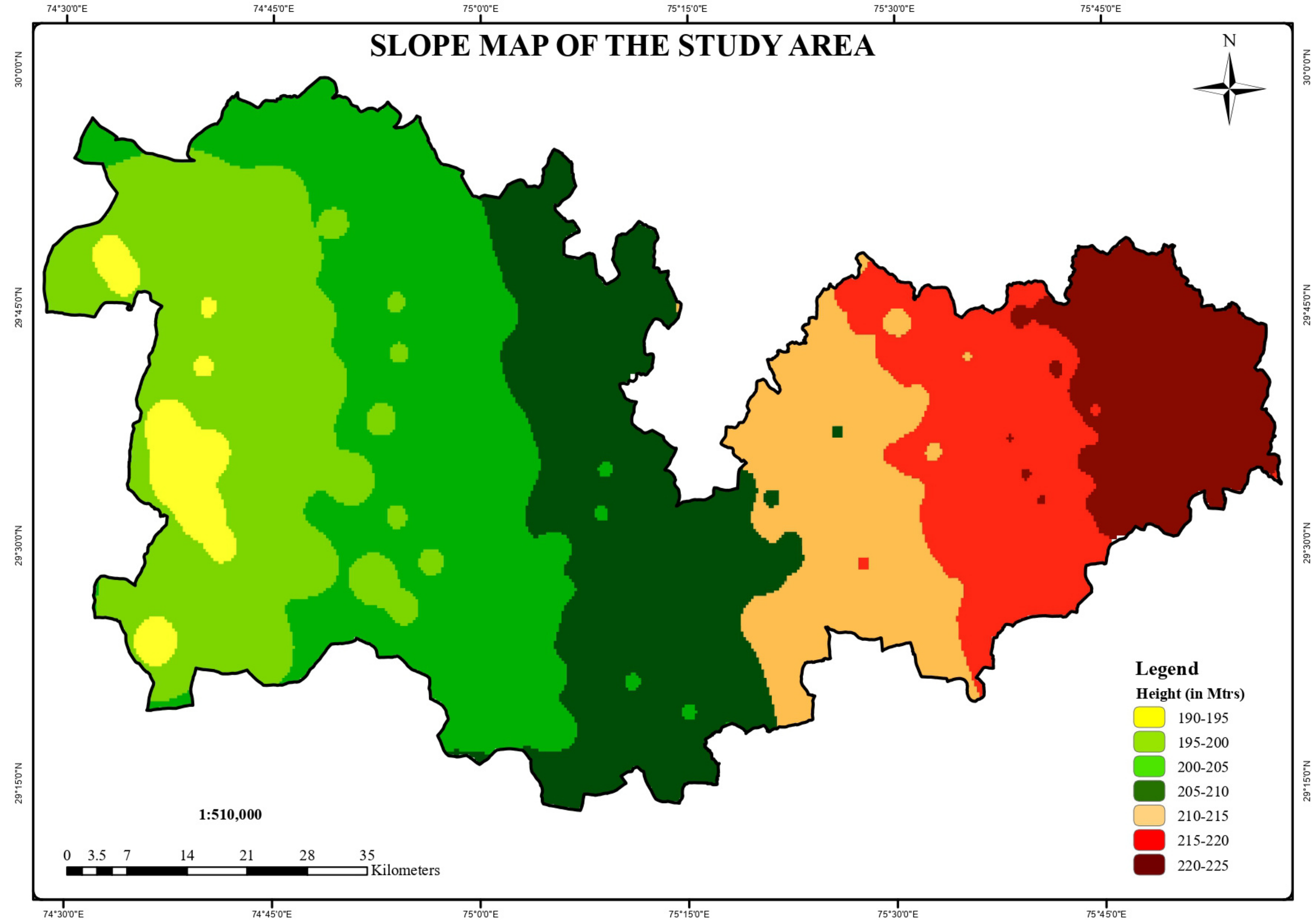


Figure 1.7 (Source: SOI toposheets)

1.9.11.2 Fauna: The area is inhabited by varied group of animals, mammals, birds and reptiles. Bander and common Languor, Jungle cat, the small Indian cinet, the common goose and Indian fox represent the primates. Other small mammals found in the area are Chuchunder, bats, Gilheri, common house rats and Indian hare Chinkara and Black Buck are seen in the area but the number is very small. Nilgai are common in sandy areas. A large number of game birds, birds of economic importance and colourful birds are found which are year-round residents and others are only there during the winter. There are several various varieties of ducks and geese, as well as Indian Black Patridges (the state bird), Grey Patridges and quails. The Bengal Green Pigeon, Blue Black Pigeon and a number of doves can be found in the villages among the pigeons and doves. Dabchik is a native bird as well. Scavenger birds such as kites, vultures, eagles and crows prey on dead animals to keep the environment free of them. The diverse wildlife of the study area is enriched by a wide number of colorful birds. The common peafowl, India's national bird, is very common. Besides, the mammals and birds, the reptiles like a number of snake types, lizards, tortoise, frogs and fishes reside in the area (Sirsa District Gazetteer, 2016).

1.9.12 Demography

As per Census of India, 2011 the total people of the Sirsa & Fatehabad district are 2237200 persons. Males account for 1177942 of the total population, while females account for 1059258. The rural population in both districts is concentrated in 575 villages, while the remainder of the population is concentrated in eleven towns in the study region.

In terms of density Sirsa ranks at last position with a density of 303 and Fatehabad which was 897 in 2011 and Fatehabad district were 902 females per 1000 males population. The rural population of study area is 1738364 persons during 2011 Census. In terms of Child Sex Ratio (0-6 year) the Sirsa district stands at fourth place with a Child Sex Ratio of 862 while Fatehabad district have 854. The proportion of Child Population (0-6 years) is 12.17 percent in Sirsa district. The percentage of scheduled caste population to total population in the Sirsa district is 29.9 percent and it ranks at second position after Fatehabad (30.19%). In terms of literacy Sirsa stands at nineteenth place. The literacy rate of Sirsa district in 2011 is 68.8 percent whereas it was 60.6 percent during 2001 Census while the literacy rate of Fatehabad district (2011) is 66.03 percent whereas it was 58 percent during 2001.

The research area's Work Participation Rate (WPR) is 38.8%, compared to 35.2 percent for the entire state. Males in the research region have a work participation rate of 54.1 percent, while females have a work participation rate of 21.6 percent. Cultivators account for 32.7 percent of total staff in the research region in 2011, compared to 37.4 percent in 2001. In the study region, the proportion of agricultural labourer to total workers was 29.3 percent in 2011, compared to 23.8 percent in 2001. In the study region, the proportion of household industry workers to total workers is 2.4 percent, compared to 2.9 percent in Haryana. In the study region, the ratio of other employees to total workers is 35.6 percent, compared to 52.1 percent in Haryana.

1.9.13 Hydrogeology

Unconsolidated Quaternary alluvial deposits make up the volcanic formations. Sand, silt and clay are found in alluvial soils along with kankar. A fine to medium grained sand horizon forms the possible aquifer in the area. The main sources of ground water recharge in the area are inflow of ground water from the north eastern and northern parts of the territory, runoff, seepage from canals, return seepage by drainage, and percolation from surface water bodies. In the region, aquifers are both unconfined and sealed. In the testing field, unconfined aquifers can be located down to 60 metres below ground level. The main aquifer content is fine to medium sand and sand mixed with kankar, with alluvium serving as a groundwater source. In nature, isolated sand lenses embedded in clay beds or well-connected granular areas with pinching and swelling disposition can be seen. Ground water is obtained using hand pumps and shallow tubewells in an unconfined aquifer, while ground water is captured using medium and deep tubewells in a deep and sealed aquifer. The alluvium deposit varies in thickness from 200 to 300 meters.

The thickness of the alluvial formation increases as we pass northwest. Tubewells tapping the water bearing area at a depth of 100 to 200 m yield 1500 to 3000 lpm for a drawdown of 5 to 17 m, according to data from an exploratory tubewell drilled in the Ghaggar Basin. On exploratory wells, the Aquifer Performance Measure (APT) was used to evaluate aquifer parameters such as transmissivity (T), storability (S), hydraulic conductivity (K) and yield (discharge). To test aquifer parameters, 11 exploratory boreholes were drilled down to a maximum depth of 306.71m in the area. The test well's yield (discharge) ranges from 120 to 3000 lpm, with a drawdown of 3.66 to 17.47 meters. The aquifers' transmissivity ranged from 327 to 2600 M^2 per day. Hydraulic conductivity fluctuated between 5.83 and 83 metres a day. The storage coefficient was determined to be between 0.638 and $27x10^{-3}$. Shallow tubewells in the district have a discharge rate of 300 to 1000 lpm and a drawdown of 1.0 to 3.5 meters. In contrast, deeper tubewells/borewells drilled in the Ghaggar basin and tapping the water bearing area at depths ranging from 100 to 260 meters yield 1500 to 3000 lpm with a drawdown of 5 to 17 meters yield 1500 to 3000 lpm with a drawdown of 5 to 17 metres. As a result, tubewells built along the Ghaggar River have tremendous groundwater capacity.

1.9.14 Infrastructural Development

Base map of study area with village boundary with settlements was prepared by collecting the available information from various sources. Most of the linear features were extracted from the satellite data. State, district boundaries were collected from HARSAC to incorporate in the database. The major infrastructure facilities like transport network, settlements, canals & drain network are described below. Study area is a small and relatively isolated residential community. It is commuter settlement with good road & rail links. Settlement location point map of study area with major village name and transport network are displayed in Figure 1.8.

Transport network is very necessary for linkages to other destination. Expansion of transport facilities helps industrialization and hence enriches social, cultural & political outlook of people of that region. Roads constitute the prime mode of transport besides rail transport in the state. The total road length in study area was 8478 km out of which 123 km is under National Highway, 239 km is under State, 322 km is under Major District road and rest of road is under village roads or other district roads. There is two National Highway passing through the state (NH No 9 & 1). The study area has a good transport network to its adjoining location and to the other state through rail also. All towns and villages are linked to each other and to district headquarter with metalled road. The study area enjoys a good transport system with a quite high frequency of bushes at each location.

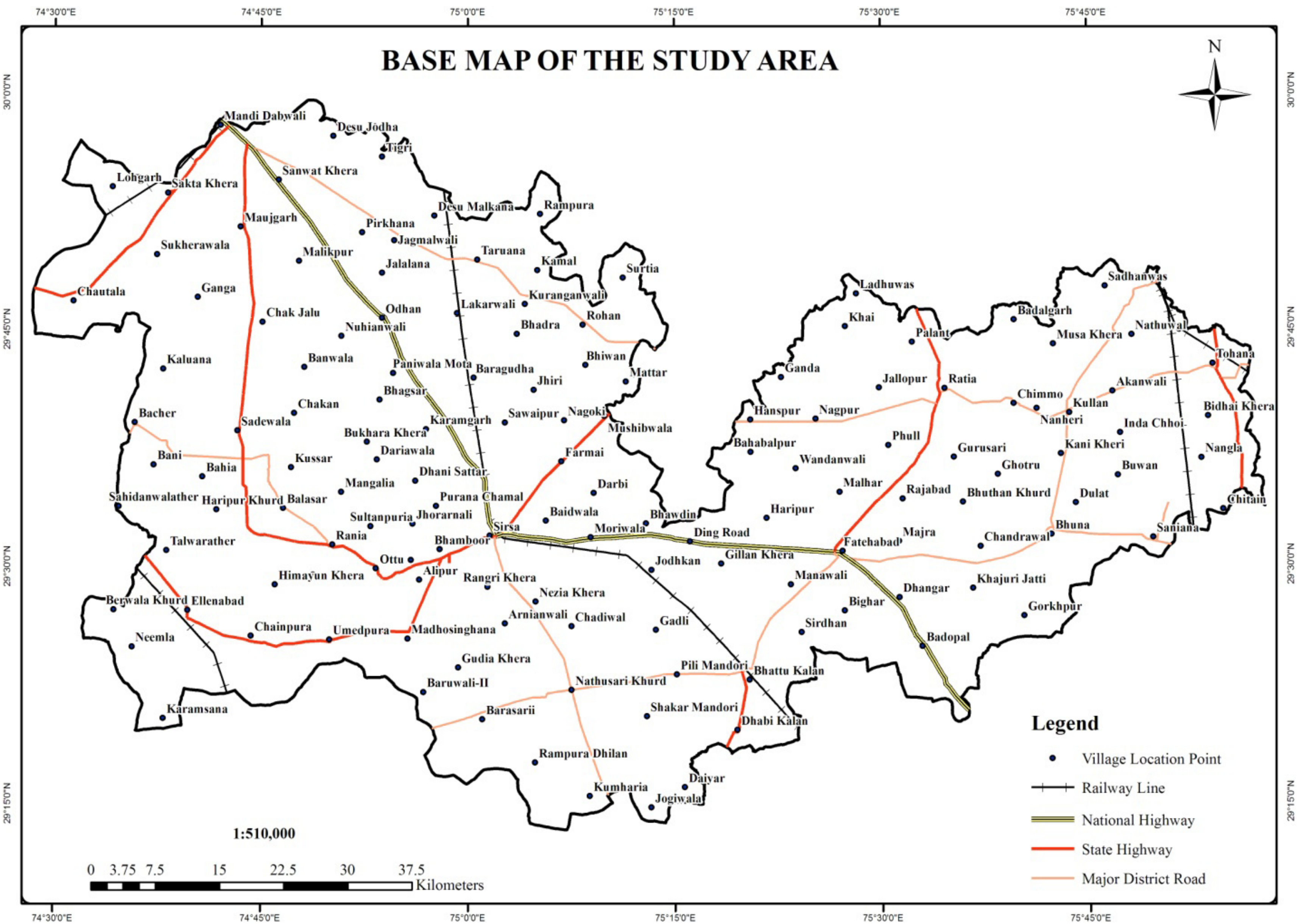


Figure 1.8 (Source: SOI toposheets)

CHAPTER – 2
REVIEW OF LITERATURE

Land is our most precious resource, which is vital for well-being sustainable development without distributing soil erosion and degradation. Over irrigation and problems of floods causes a change to the soil salinity, which has adverse effect to the environment and agricultural production. In recent years, the mapping, monitoring and planning of waterlogged and salt affected area can be studied through accurately by adopting remote sensing and GIS methods. The technology of geoi-informatics has emerged as important tools in recent times for spatial analysis and Development of Decision Support System. In relation to the issue of waterlogging and soil salinity, the analysis also discusses evidence sources, appropriate image processing and GIS methods and accuracy evaluation procedures.

Review literature related to soil salinity

Mousavi, Habibnejad, Kavian, Solaimani and Khormali (2020) identified digital mapping of topsoil salinity using RS indices in Agh-Ghala plain, Iran. The most common land use of Agh-Ghala plain is farmland that is mostly under wheat, rapeseed and barley. The multi-spectral Landsat 8 (OLI-TIRS) satellite image was acquired on 10th July; 2014. Landsat 8 data was used to precisely geolocate the sample point coordinates, which were then geometrically corrected using a corrected map. Salinity in the Agh-Ghala plain was extremely variable, according to a descriptive statistical study of soil salinity.

Walker, Kumar and Biswas (2019) used to assessment of different indices and salt affected area trend analysis using Shannon entropy approach. The principal supply of water in Churu district of Rajasthan is the Indira Gandhi Canal Project and deep wells. The eastern part of Churu is bounded of the Shekhawati river basin which possesses a well-developed drainage system. The Landsat TM/ETM^{+} data was used to monitor the spatio-temporal change in vegetation condition and soil salinity. The Shannon entropy index was used to understand and quantify the salt affected growth and trend. The difference between the red and near infra red bands has become beneficial for analyzing, monitoring and measuring extent of soil salinity. It have been perceived from ground truth verification and satellite image that scanty vegetation cover is the main decisive factor towards the being there of salt in the soil. The increasing trend in the salinity was computed and assessed using three Landsat images.

Al-Khakani and Yousif (2019) used RS data was to assess changes in soil salinity and plants wrap in a section of the governorate of An-Najaf. The province of An-Najaf encompasses agricultural fields with unreliable plants densities, urban areas and bare lands. Images from 2001, 2009 and 2015 were taken during the day in the spring season to detect land cover changes. According to the results, soil salinity and vegetation regions have an opposite relationship, with most areas seeing a rise in salinity in the saline map followed by a decline in vegetation and vice versa.

Nouri, Borujeni, Alaghmand, Anderson, Sutton, Parvazian and Beecham (2018) studied Veale gardens in the Adelaide parklands was used to chart soil salinity in town vegetation using RS and nearest sensing techniques. Since Mt. Lofty is prominent topographic element, Adelaide's climate is considered unique. To translate the EM 38 measurements to soil salinity, the calibration approach used spatial regression methods. The Soil Adjusted Vegetation Index (SAVI), according to the research, is the only salinity index that can estimate soil salinity in urban greenery using high-resolution images.

Aredehey, Libsekal, Brhane, Welde and Giday (2018) evaluated soil salinity of the Timuga irrigation scheme in South Tigray, Ethiopia, was mapped using a geo-statistical method. Alluvial soils deposited from mountain sediments dominate the Timuga irrigation system. Using the Arc GIS 10.2 fishnet, a 33.5 km^2 area was delineated and a regularly spaced grid of sampling points was developed. Strongly alkaline soils account for 85.70 percent of overall irrigated fields, while mildly alkaline soils account for 14.30 percent, according to the geospatial study.

Asfaw, Suryabhagavan and Argaw (2018) remotely sensed and GIS were discussed to map soil salinity simulation. The climate in the field, Ethopia's Wnzi sugarcane irrigation type, is semi-arid. The analysis used Landsat TM data from 2012, route 168 and row 0.54. The picture was analyzed with Arc GIS 10.2, IRDAS imaging 11, INVI

4.7 and JNP statistical software version 11 salinity models was developed by overlying factor layer that contributes directly or indirectly to the occurrence of spoil salinity. Due to the model's salinity's validity, the combined EC value and salinity produced from the remote sensing index model had a higher connection (63 percent). In the red and near-infrared bands, saline soil with a smooth and light salty-crust foundation displayed a high spectral reflectance.

Solafa, Elbasri and Hamid (2018) used RS indices and a geo-statistical approach improved the spatial inconsistency of salinity indicators of soil. The site is in Sudanese state of White Nile. Soil samples were obtained at two depths: 0 to 20 cm and 20 to 40 cm. To achieve the condition of the plants and the salinity of the soil, the Normalized Discrepancy Vegetation Index (NDVI) and the Salinity Index are used. The method was found to have a high level of accuracy based on RMSE and it improves the assessment of soil spatial variability and provides significant interaction of different variables and indices in the landscape.

Zhang, Wang and Han (2017) evaluated the Manas River basin; the ecosystem's vulnerability to soil salinization has been studied. The research area is part of the Manas River delta, which is situated in northwestern China in the Eurasian continents' hinterland. They tracked soil salinization through seven habitats in the Manas River basin using Landsat 8 photos and field surveys. The kriging tool in Arc GIS software was used to interpolate the spatial distribution of each eco system's susceptibility to salinity of soil. The primary reason of land corrosion in arid and semi-arid areas is soil salinization, which may occur spontaneously. According to the evidence currently available, the area under from land in MRB has significantly decreased in recent years, groundwater has been over-extracted and water supply collection has been inequitable, componding the issue of soil salinity in MRB.

Ivushkin, Bartholomeus, Bregt and Pulatov (2017) carried out in Uzbekistan, satellite thermography was used to findout soil salinity in agricultural regions. Syrdarya Province in Uzbekistan is a semi-arid area with a lot of salt. Both of data were estimated using the WGS 1984 UTM Zone 42N coordinate scheme. The authors used the MOD13A2 vegetation index and an NDVI threshold of O-3 to differentiate between vegetated and non-vegetated pixels. Cotton was found to be the most affected by soil salinity while wheat was found to be less so.

Jadhav and Sasane (2016) carried out for saline land reclamation, use locally accessible admixtures. The research area is the Ahmednagar district in the Indian state of Maharashtra. The study used an entirely randomized block method for seven different treatments. The author looked at salt-affected land that was reclaimed using admixtures such as coal fuel, wheat straw and cow dung from the soil. Soil samples were taken at depths of 0-10 cm, 10-20 cm, and 20-30 cm at random; it was discovered that the application of different organic materials lowered pH values due to the formation of organic and inorganic acids as organic matter decomposed.

Scudiero, Corwin. Anderson and Skaggs (2016) used RS for soil salinity at a geographic scale has progressed. The ground truth data is used to establish a mathematical equation with chosen co-variates in order to quantify soil salinity in un-sampled regions. NDVI ratings from relatively high resolution imagery are often unrealistically poor. To ensure crop productivity and soil quality, water supplies must be used carefully. Salinity maps and updates on land use and agronomic management will help monitor improvement and prevent unnecessary soil degradation by correcting adverse salinization trends.

Bhat, Sheoran, Dar, Dahiya, Wani, Singh and Singh (2015) discussed geo-informatics was tested as a method for assessing salt-affected soil. Microwave radio metres working in the L-band can detect salt-affected and waterlogged areas, according to the authors. They also quoted Dwivedi as saying that fertile land is increasingly becoming unproductive due to waterlogging and eventual salinization. In the visible and NIR regions of the electromagnetic spectrum, saline and saline-sodic soils display comparatively more incident light energy than regular soils, according to Rao et al. Traditional methods for studying salt-affected soils are insufficient due to the high cost and labour involved and the use of a broadband sensor for studying soils affected by salts is insufficient owing to the minimal spectral information available.

Sharma and Singh (2015) established salinity studies, achievements, obstacles and potential prospects given that terrestrial habitats provide 99.7% of all food eaten worldwide, with ocean and other marine environments accounting for the remaining 0.3 percent. The parameters used to identify salt-affected soils include soil reaction and electrical conductivity of soil saturation extract, exchangeable sodium percentage (ESP) and sodium absorption ratio (SAR). Plants developing in salt-affected soils go through two distinct phases: osmotic (water) stress and growth-inhibiting salt stress. The ICAR-CSSRI was established in 1969 to conduct basic and applied research in the field of agricultural salinity control. Around 2.0 million hectares of barren sodic soil have been planted with crops, demonstrating the tremendous success of gypsum-based alkali land reclamation in the region. More powerful technologies, such as detailed characterization of salt-affected areas in the near future, solute transport modeling and the use of airborne geophysical sensors should be prioritized.

Scudiero, Skaggs and Corwin (2015) used Landsat ETM^+ canopy reflection was analyzed to review regional scale salinity of soil. The author's research area is the San Joaquin Valley in California. For assessing the output of models with additional explanatory variables, the CRSI with soil salinity linear association (R2=0.564) is discuss as a benchmark. Extremely accurate salinity maps for 22 fields measuring 542 ha were used for ground-truthing. The findings suggested that if high resolution auxiliary data on soil texture were available, the prediction capacity of salinity assessment models may be improved even more.

Mehrjardi, Minasny, Sarmadian and Malone (2014) studied Ardakan region of central Iran, digital mapping of soil salinity was completed. Pistachio nuts, wheat and madder are the most common crops grown in the Ardakan plain. The spectral bands 3, 4, 5, and 7 of the Landsat ETM^+ (2002) satellite were used, as were geomorphologic units and data from the satellite. Salinization and alkalinization are the two most important soil erosion cycles in central Iran.

Shah and Thivakaran (2014) assessed GIS study on chemical characteristics of salt affected of coastal Kachh, Gujarat, India. Soil samples were collected from 20km inland to coastline at 10cm depth. ESR was used to characterize the sodicity of soils. The results of soil texture at all the locations were sandy loam to loamy. The results indicate that the quality of soil significantly uniquely from location to location.

Singh, Pandey and Rathore (2014) emphasis on waterlogging, researchers looked into the reasons that contributed to the contrasting signatures of wasteland growth in the northern and southern Gangetic Plains. Cereal crops are the most common in the region, with rice, maize and wheat being the most common. For the years 2005-2006, the NRSC provided cloud-free data for the area. A few hydrological stations provided data on pre-monsoon and post-monsoon ground water levels.

Arya et al. (2014) carried out change analysis of wastelands in arid zone (Bhiwani, Rewari, Mahendergarh & Mewat district) of Haryana. Area under waterlogged and marshy land- permanent class is 9.07 sq. km & area under waterlogged and marshy land- permanent is 5.92 sq. km in arid zone of Haryana.

Wu, Al-Shafie, Mhaimeed, Ziadat, Nangia and Payne (2014) identified soil salinity and mapping it using RS in Mesopotamia, Iraq. Mesopotamia, the land between rivers is a typical flood terrain between Euphrates and Tigris rivers. The researchers used a multiyear, from 2009 to 2012, a multi-resolution and multi-sensor dataset was created, principally using Landsat ETM+ and MODIS data. According to the findings, salinity has a significant impact on approximately 60% of the refined land in Iraq's Mesopotamian plain.

Mhaimeed, Wu, Al-Shafie, Ziadat, Al-Musawi and Saliem (2013) studied the Musaib area of central Iraq, RS is being used to map soil salinity. Between the Tigris and the Euphrates rivers is the Musaib region. Soil sampling, EM 38-MK2 measurement and landuse/landcover investigation were all done in the field between September 2011 and Jul y 2012. Around 60 percent of agricultural area has been severely exaggerated by salinity, with 20-30 percent discarded.

Singh, Kumar and Mathur (2013) used IRS P6 LISS-III and LISS-IV data and GIS techniques; a comparative analysis of sodic wastelands and waterlogged areas was carried out. Sandila block is situated in Uttar Pradesh's Hordoi district. For delineation and visualization on-screen, geo-corrected IRS P6 LISS-III & LISS-IV images received between December 2004 (Rabi season) and February 2006 was used. 7.6 percent of the region was sodic according to LISS data, while 7.24 percent was sodic according to LISS-IV data. According to LISS-III results, a 2.4 km^2 area was flooded.

Dehni and Lounis (2012) carried out in Algeria's Oran area; a remote sensing technique was utilized for mapping of salts. Oran is surrounded by the huge alluvial plains identified as the Es-Senia plains. Image processing and salt delineation were done using Landsat multispectral and multi-data photographs. During interpretation and field work, written soil survey reports, soil maps, the Oran atlas, Census reports and water quality reports for the research area were used. The findings show that the Oran region is impaired by waterlogging caused by canal seepage and salinity caused by salts on the soil, which appears as a white salt encrustation.

Mandal and Sharma (2011) discussed characterization of waterlogged salt-affected soils in Indira Gandhi Nahar Paryojona using remote sensing and GIS techniques. Sand hills, sand dunes, flood plain depressions and interdunal flats abound in the study region. To identify waterlogged and salt impacted areas, the Survey of India used topomaps, pre-processed IRS LISS II geocoded imagery on a 1:50000 scales, and other ancillary material. The waterlogged area occupied 22268 ha (5.4%) of the total area, and the future waterlogging field enclosed 3342 ha (0.8%) and 18029 ha (4.4%), correspondingly, according to the estimates. Standard crops, ponded water and the possible waterlogging region all demonstrated similar reflectance patterns in B-1, B-2 and B-3 but not in B-4 (INR).

Zhang and Zhao (2010) in the Yellow River Delta, researchers investigated the effect of anthropogenic land use on salinization. Three sub-region models were developed using the RS-GIS framework to normalize salinity heterogeneity. The salt contented of the soil outside (0-15cm) ranges from 0.4 percent to 1.5 percent and salty ground occupies more than 70% of the total area. For decades, the Yellow River delta has seen substantial and rapid industrial and agricultural growth. Using the standard kriging interpolation technique, a distribution map of saline soil was developed. The findings suggest that the cumulative effects of non-anthropogenic causes must be normalized. Several important anthropogenic determinants have been identified using SAR sub-regions models. Large-scale oil production and saline aquaculture policies, it is proposed, should be cautiously considered in heavily saline regions.

Nawar, Reda, Farag and El-Nahry (2010) mapped soil salinity in El-Tinaplain in Egypt using geo-statistical approach. The northwestern part of Sinai Peninsula, Egypt is located under arid conditions. Grid sampling scheme with 800m*800m spacing was developed to explore spatial variability of the soils and satellite image ETM^+ acquired in June 2006. Quantitative evaluation showed that the mean soil salinity was high across El-Tina plain, generally pertaining to heavy salinized soil types.

Yan, Huang, Gao, Shan, Kuang, Hang and Shi (2008) described remote sensing study of the dynamic shift in soil salinization in the Tarim river's upper drain. The Tarim river basin has an arid, dry climate in the warm temperate region, with little rainfall and heavy evaporation. They discovered that in the spring, the test area has a high salt-return and the surface of a salty soil format smooth with salt-crusting or salt-skin is much higher than that of other soils. The data of TM/ETM^+ image spectro bands 5,4 and 3 are selected to make FCC which reflect soil salinization better the other the research of TRM showed that the research areas total areas of saline soil had been continuing to increase but the salinization intensity has been dropping distinctly, soil deterioration and improvement coexisted.

Wu, Vincent, Yang, Bouarfa and Vidal (2008) developed soil salinity changing by remote sensing monitoring. Hectao irrigation district, the study city, is located in China's Inner Mongolia autonomous region. Since Landsat was chosen as the major data source because it has the world's largest continuous collection of space-based terrestrial remote sensing data. Data from the IRS and the CBERS (China-Brazil Earth Assets Satellite) are also used. The findings showed that remote sensing was 90.2 percent accurate in finding soil salinity and 98 percent accurate in finding cultivated area, suggesting that remote sensing is a helpful instrument for detecting and tracking soil salinity shifts.

Sharma and Mondal (2006) developed in the Indo-Gangetic terrain, digital data processing and GIS were used to chart soil salinity and sodicity. ILWIS programme was used to assign sample strip dependent training sets to Landsat TM data for supervised classification. The research used Landsat TM data from seven bands. The salt-affected soils of the sample region rank as salty and sodic soils due to the nature of salts. Although saline and sodic soils reflect similarly in TM band 3, saline soils reflect substantially higher than sodic soils in TM band 4. During the dry season, the analysis found that exterior accumulating white salt crystals were a superior predictor for detecting and correlating salinity.

Sonkar, Sinha, Gupta, Shukla and Singh (2006) studied soil salinity using remotely sensed and GIS technique in Jaunpur branch sub-basin. In this study, total waterlogged area was observed 1890 square kilometers that constitutes 35% of the total region. The bulk of the salt-affected lands were located close to the drainage grid. The current drainage scheme, together with the use of groundwater for irrigation, limits the amount of waterlogged soils, according to the report.

Bhatt, Singh, Litoria and Sharma (2004) in the Muktsar district of Punjab, researchers used remotely sensed images and GIS to determine waterlogged and salt-affected areas for tehsils-by-tehsils study. IRS 1D (LISS III) satellite data and PAN merged data were used in this analysis. In Muktsar district, data validated by ground truth was used to delineate pre and post monsoon waterlogged zones, as well as pre monsoon salt impacted soils. Except for the high dunes, the landscape is extensively planted and irrigated. However, paddy is increasingly replacing cotton as a crop. There are two types of salinity impacted areas: salt affected and salty soil with patchy crop. Waterlogging was observed to be more prevalent on the western side of the twin canals (Sirhind and Rajasthan Feeder), flowing in a specific pattern, namely north-east to south-west. Canal seepage, brackish ground water, poor canal alignment, insufficient drainage and defective irrigation methods are the most common causes of waterlogging and salinity. The step that area needed to be taken up are prevention of canal seepage, conjunctive use of saline/sodic groundwater, adequate surface drainage, efficient form management practice and use of remotely sensed data and GIS.

Garcia, Eldeiry and Elhaddad (2000) estimated soil salinity using RS data. The authors concentrated their initial research in the La Junta area of Colorado's Arkansas Valley. To correlate the variable, regression models such as ordinary least squares (OLS), spatial autoregressive (SAR) and spatial log (SLAG) are used. Additional water produced by human actions like irrigation mobilises salt deposited in the soil profile, resulting in human-induced salinization.

Abbas and Khan (1998) studied appraisal of irrigated soil salinity using RS techniques. The Faisalabad district is situated in Rechna Doad's south-western corner. With a spatial resolution of 36.25 M, the IRS-1B LISS-II images were geo-referenced to UTM projection in four spectral bands. Standard and salt-affected soils have different land surface conditions. Salt-affected soils are described by the accumulation of various accumulated salts in the soil profile.

Choubey (1997) studied land use and drainage pattern to define waterlogged area and areas vulnerable to waterlogging in the command area of Tawa river in Madhya Pradesh, using IRS-IA-LISS-I FCC data from 1988. Water table data was used to confirm the findings, which revealed that about 80 square kilometers were affected by waterlogging and 140 square kilometers were vulnerable to waterlogging. Crop stress induced by a high water table may be the greatest integrative predictor since the water level cannot be measured directly by satellite measurements.

Kalra and Joshi (1996) the Indian arid region, salt-affected soils are identified using satellite imagery from Landsat, SPOT and IRS. It is either saline or sodic land water that can be used for irrigation. Sodic soils, standard salt-affected saline soils Landsat-MSS band 2, Landsat-MSS and TM, IRS LISS I, LISS II, and SPOT HRV2 were used to identify some natural salt-affected soils. The multi-dated imagery was used to differentiate between naturally sandy soils, freshwater sodic soils and sodic soils. Because of their higher resolution, the TM FCC provided greater contrast than the MSS FCC. The picture characteristics of remote sensing images are directly influenced by the scale of imaging, sensor resolution and data acquisition season. The IRS LISS II programme helped in the exploration of salt-affected land in all forms.

Metternicht and Zinck (1996) concluded the amount of salts, as well as soil wetness, colour and landscape smoothness, all of that are determined by various salt combinations and the form of soil surface, shape and organic matter, are the key factors influencing reflectance in visible and near-infrared wavelengths. Surface characteristics affected by salts include soil crusts that have little or no signs of salt presence.

Singh (1994) used aerial photos and Landsat-TM images to map improvements in the condition of saline soils (U.P.). Synoptic views at a scale of 1:40,000 and a regular FCC picture at a scale of 1:50,000 with a minimum delineation of 2 hectares. To delineate salt-affected soils, FCC is visually analyzed on a 1:50,000 scale using image representation components as guides. Two types of salt-affected soils could be distinguished by colour variation: strongly and mildly salt-affected soils. Severely these soils present as white spots of dense salt efflorescence on the surface, while mildly salt-affected soils appear light bluish grey. The Landsat-based salt-affected maps were transferred using toposheets from the Survey of India.

Oster (1993) evaluated sodic soil reclamation. Sodic soil reclamation normally involves applying gypsum to the soil and incorporating it, as well as leaching. The rate of water use determines the rate of reclamation. The high-salt dilution process' water requirement can be reduced to around 1.7 cm of water per cm of soil. In most situations, the infiltration rate of gypsiferous, sodic soils is adequate to ensure efficient reclamation using low electrolyte irrigation waters.

Cannon, McKenzie and Lachapelle (1993) carried out electromagnetic induction and satellite-based navigation technologies were used to map soil salinity. In three ha, a 30 hectares site near Brooks and a 100 hectare in Canada, were surveyed, yielding 600 salinity measurements. Using field portable PCs, a DGPS system and an EM 38 meters with analogue output were assembled. A survey was conducted in May of 1992.

Rao and Venkataraman (1991) used sodic soils were classified as bright white patches having fine texture using the Landsat-TM standard FCC, whereas moderately sodic soils were identified as dull white to strong brown using the Landsat-TM standard FCC. Remote sensing underestimated salt-covered surfaces due to a mix-up of mildly sandy and non-saline soils.

Johnston and Barson (1990) studied peak vegetation growth; researchers in Australia discovered that distinguishing saline areas was most successful. The poor fractional vegetation cover of the salinized region made it difficult to distinguish areas that had become barren due to overgrazing, drought, or ploughing. When the plots are dry at the end of the irrigation or rainy season, Siderius (1991) discovered that salinity is better visible.

Narayan et al. (1989) studied using Landsat-MSS FCC at a scale of 1:10,00,000, wasteland was described as salt-affected, gullied or ravined, waterlogged or marshy, undulating highland with or without brush, jhum or woodland void, sandy areas (coastal or desert), barren hill ridge or rock outcrops, and snow-covered/glacial areas. Land evidence and geographical knowledge from the field is used to help the interpretation technique. When opposed to a field survey, the identification and mapping of wastelands achieved an accuracy of 80 to 90%.

Review literature related to waterlogging

Tran, Xu, Dang and Alwah (2020) predicted regression algorithms and open data repositories on the internet are used to determine the risks of urban waterlogging. Hanoi is situated in the Red River Delta's core. Hanoi is a major player in the growth of the country's most important economic region. Resolution of 30 m, The United States Geological Survey (USGS) used Landsat 8 OLI/TIRS data from the 7th of June 2018. In the study of urban waterlogging risk, waterlogged spots were deemed the most valuable resource. The authors investigated the effect of urban surface elevation on the possibility of urban waterlogging using DEM.

Kaushik, Dhote and Thakur (2019) identified waterlogged areas in Rohtak district using satellite imageries. Bajra/Jawar/Guar, Paddy, Cotton and Sugarcane are the main crops in the Kharif season while Maize, Mustard and Sugarcane are the main crops in the Rabi season. Sentinal-2 MSS level 1C data was employed in the investigation, which gave high spatial resolution images with good coverage. The surface flooded area of Rohtak district during the post-monsoon season is 17.86 sq km. According to the data, waterlogging is a serious issue in Rohtak district, especially during the post-monsoon months.

Chowdhury, Nayak, Brahmanand, Mohanty, Chakraborty, Kumar and Ambast (2018) identified waterlogged areas in Eastern India are being delineated using spatial approaches for better crop management. The population pressure in Eastern India is very intense. Landuse/landcover data at 1:50000 scale based on LISS-III for the year 2005-2006 were collected. Waterlogged soil changes its physical, chemical, and microbiological properties as a result of excess water. Waterlogged soils cover roughly 11.6 million hectares (8.3% of India's net sown area).

Sahu (2018) deducted waterlogged areas using geo-informatics technique and relationship study in Panskura-Tamluk flood plain, India. USGS Landsat 8 images of the pre- rainy seasons (26 April 2013 and 22 April 2014) and during rainy season (4 November 2013) were used. After dividing each range into three classes with equal width, it is observed that the areas extended over map containing extreme positive side of every WI (wetness Index) range more or less akin to the waterlogged areas .The amount of waterlogged areas is around 1.53 km^2.

Singh (2017) discussed the normalized difference water map, described waterlogged regions in the Vaishali district (Bihar). The Ganga, Gandak and Burhi Gandak rivers carry alluvial to the Vaishali district, which forms a vast plain. Geo-referencing is the method of converting an uncorrected raw image from an arbitrary coordinate system to a map projection coordinate system. Between 1988 and 2006, Landsat TM satellite images were used to delineate areas affected by waterlogging. Strong NDWI values indicate high water quality, while low NDWI values indicate low vegetation.

Singh and Kanga (2017) studied using geospatial techniques, salt-affected and waterlogged areas may be identified. The study area, Muzaffarpur district, Bihar, is predominantly drained by the Burhi Gandak, Baghmati and Baya rivers, all of which flow in a south-easterly direction. Thematic layers of salt impacted and waterlogged areas were delineated using satellite images retrieved from the IRS P-6, LISS-III sensor at a scale of 1:50000. With the aid of previous knowledge of the research area, visual analysis techniques of multi temporal satellite images were used to delineate salt impacted and waterlogged areas in the current study. They discovered that areas with a high frequency of waterlogging and salt contamination, as well as areas with a high average rainfall, show a favorable association between the two phenomena of waterlogging and rainfall.

Mandal (2016) measured the description of soil salinity and waterlogged soil in central Haryana's Gangetic plain. To delineate and characterize salt-affected and waterlogged soils, IRS LISS III resource satellite data is combined with ground reality and soil analyses. The Yamuna, Ghaggar and other seasonal streams that source in the Arawali hills drain the study region. The seasonal data revealed that saturated salt impacted soils and waterlogged areas were more prevalent in March and October and dry salt was more prevalent in June. Sodic soils in central Haryana's Gangetic plain are high in sodium carbonate and bicarbonate salts, have a varied soil composition, and have a high ESP. Through the use of suitable amendments such as gypsum or pyrite, sodic soil and water may be recycled.

Gu, Zhang, Xu, Dong and Dong (2016) detected of paddy waterlogging was carried out using a shift vector analysis model. The Huaihe River basin is located in eastern China, in the transition region between semi-humid and humid climates. Three mid-resolution HJ-1/2 CCD images were used. The change vector analysis model and two HJ CCD pictures obtained around flood were used to define the spatial distribution of paddy waterlogging. The findings revealed that waterlogged paddy was found in the basin of Huaihe river mostly in the Huaihe river basin. In shouxian County, the waterlogging was especially heavy.

Mistry, Dholakia and Prakash (2015) used remote sensing to analyse waterlogged areas in the Kheda district of Gujarat, India.. The Kheda district has over 600 villages. Panchromatic satellite images and IRS P6 LISS III 2006 data was used. Based on the 2014 LISS III data, supervised classification and NDVI calculations suggest that a total of 1844 hectares is covered by wetland mapping, with waterlogging accounting for 12.81 percent of the total wetland area. Waterlogging is caused by seepage from unlined or ruined canals, insufficient drainage, and intensive irrigation.

Kumar (2015) identified Jhajjar district has waterlogged salinity zones. Jhajjar is located in the Ganga basin's Yamuna sub-basin and is mostly drained by an underwater drain. The IRS-ID LISS-III satellite data (10 October 2006) was used. The flooded region was split into two groups: pre-monsoon and post-monsoon. Waterlogging was found to be most prevalent on the canal's western shore.

Arnous and Green (2015) used remotely sensed multi temporal data & GIS and monitored and assessed waterlogged and salt-affected region of Egypt's eastern-Nile delta. The Mediterranean Sea and Lake Manzal surround Egypt to the north, while the desert rolling plain borders Egypt to the south. The TM and ETM $^{+7}$ and Landsat 8 OLI data sets were compiled and analyzed using tools like ERDAS imagine, Arc GIS and PC Arc Details to track and assess waterlogged and salt affected areas. The TM, ETM and OLI imagery had a spatial resolution of 30m by 30m. In the expanded desert fringes and waterlogging zones, the findings show a strong association between appropriate cultivation practices and land reclamation.

Sahu (2014) carried out a study on Moyan basin's waterlogged area using RS and GIS method and their contemporary economic significance. The Kasai and Chandia rivers pass through the Moyna basin, which is located in West Bengal. Topographical sheets from the USGS Landsat TM data (2009), the USGS Spatial Visualization Viewer and Specialized Spaceborne Thermal Emission and Reflection data were included in the thesis (2009). The findings revealed that heavy rain causes land waterlogging and that the period of waterlogging varies depending on the quantity of precipitation, evapotranspiration and soil composition.

Arya et al. (2014) studied supervision of waterlogging and soil salinity in Central Haryana using Geo-informatics and carried out wet and salt affected region of Central Haryana using LISS IV, Carto Sat and Radarsat satellite data for the year 2010-11for Rabi and Kharif season. Area under waterlogged and salt affected is 109.55 and 63.21 square kilometer respectively. They also developed action plan map and Decision Support System for waterlogged and soil salinity area in relation to the sustainability of environmentally sound agricultural practices.

Sahu (2014) used RS and GIS methods were discussed waterlogged regions in the Purba Medinipur section of the basin of Keleghai river in India were identified and mapped. The Purba Medinipur district of West Bengal is well-known for its flood-prone areas and low-lying areas. Landsat-8 imagery and topographical sheets from the

USGS (4 November 2013) were used, with Arc GIS 9.3 and ERDAS Imaging 9.1 processing and field observations. According to the findings, waterlogged areas account for about 80 km^2 of the overall study area of 145 $km^{2.}$

Hassan and Mohmud-ul-Islam (2014) studied waterlogged areas were detected using remotely sensed data in Bangladesh's Jessore of Khulna division. Ganges-tidal flood plains define the entire region's ground surface. The majority of the land is virtually level and badly drained. Landsat imageries from 1972, 1989 and 2014 were used to identify waterlogged areas and measure affected agricultural crops using temporal RS. Bangladesh's south-western coastal region has been experiencing severe waterlogging.

Kaiser, Rayes, Ghodeif and Geriesh (2013) studied waterlogging crisis in Egypt's eastern Nile delta was managed using GIS data integration. Flood muddy and silty sand mats characterize the Wadi El-Tumilate basin geologically. Three collections of satellite data were used to map and track the waterlogging issues in the Wadi basin. We used a 1984 Thematic Mapper image, a 2000 Improved Landsat Thematic mapper image and a 2008 SPOT-4 image. Waterlogged regions increased in size from 9.1 km^2 in 1984 to 18.8 km^2 in 2000 and 25.3 km^2 in 2008.

Yu, Liu, Du, Wang, Hu and Zhang (2012) carried out semi-arid west Jilin Province, China, Landsat OLI data and the PLSR Algorithm was used to map soil salinity/sodicity. The west Jilin region has the highest saline-alkali and sodic soil allocation in north east China. Satellite images provided by Landsat 8 OLI were used to cover the study region. Sodicity, rather than salinity, influenced the majority of the soil in the sample region.

Koshal (2012) used GPS, RS and GIS, satellite images of salinity areas were analyzed. The Indo-Gangetic plateau, a vast alluvial plain, includes Punjab. Sandy soil can be found in Punjab and Haryana's southwestern regions. IRS 1D LISS III satellite images from March and May 2000 were used to visually interpret salinity areas. Waterlogged areas emerged in a dark grey red mixed tone consistent with saline surfaces and the appearance of salt resistant weeds when the improved FCC picture was shown on 1:50000.

Singh, Bundela, Sethi, Lal and Kamra (2010) used in a remote sensing and GIS system was used to assess salt-affected soils. Salt-affected soil can be present on all continents and in a range of habitats, posing a significant threat to agriculture. Most of the Indo-Gangetic plains in north India, like the states of Uttar Pradesh, Haryana, Punjab, Bihar and Delhi have salt-affected soils. India's reclamation classification system, in comparison to the USDA classification, splits salt-affected soils into two categories: saline and alkali. In 1902, a traditional survey of soil salinity in India was undertaken to delineate some patches of alkali soils in Uttar Pradesh. Remote sensing can be used to detect salt-affected soils directly from salt-incrusted surfaces with different salt mineralogy or indirectly from vegetation/crop conditions. We don't use a single agency approach in India; instead, we use a project approach, in which different agencies are assigned to different projects at different times.

Chowdary at el. (2008) discussed RS and GIS were used to assess surface and sub-surface waterlogged regions in irrigation command areas in Bihar state. Bihar is in the eastern Gangetic plain and is now known as South Asia's breadbasket. Digital data from the IRS-1D LISS III sensor was used to define before and after monsoon terrain waterlogged zones in the years 2002-2003. The results show that 90.20 percent of the waterlogged region is affected by seasonal waterlogging, which involves surface inundation which flooded soil, which is mostly caused by heavy rains and inadequate drainage during the rainy season.

Rai and Kumar (2007) evaluated classification techniques for identification of waterlogged area using RS data. Darbanga and Samastipur districts of Bihar were selected for the study by the authors. Geo-rectified IRS-1C LISS-III data acquired in 2005-06 is used to delineate and chart the waterlogged area. This area covered by water bodies are 54sq km. The area covered by waterlogged class is 122.00 sq km. The overall accuracy for whole classified image was 92.70%.

Review literature related to Land use / land cover

Sonu and Kumar (2020) evaluated landcover variations in Musi River basin, a part of Rangareddy and Hyderabad districts, Telangana. Telangana was carved out as a separate state from Andhra Pradesh in 2014 as the 29th state of the Union of India.

Two time periods were chosen on the basis of availability of imagery for the year 2000 and 2019. The ASTER, Landsat 7 and 8 satellite images have been obtained from United States Geological Survey (USGS) Earth explorer site. The Musi River acts a carrier of domestic and industrial waste generated in Hyderabad affecting the river ecology.

Thakkar, Desai, Patel and Potdar (2017) studied Arjuni watershed in Gujarat, India was analyzed for enhancing the categorization of land use / landcover in desertic regions using geo-informatics after post-classification corrections. The 14th December 2001 area LISS-III satellite data was geometrically corrected with 100 GCPs and mosaiced together in ERDAS IMAGINE 9.2 to fit the lower small portion of the watershed. In 2001 and 2011, the average categorization accuracies of LU/LC maps were 67.84 percent and 71.93 percent, respectively, without post-classification changes but after post- categorization, they climbed to 82.75 percent and 87.43 percent, correspondingly.

Debneth, Dass, Ahmed and Bhowmik (2017) evaluated channel migration and its power analysis of LU/LC with the help of RS and GIS on the Khowai River in Tripura. The authors employed the SOI topography map (1975) and satellite data (2014, landsat TM, Landsat MSS) with RS and GIS tools to depict channel migration. The thesis made extensive use of Geomatica 2012 for channel migration, ARC GIS 10.1 for LULC research, and ERDAS 9.1 for image radiometric correction. Agricultural land, populated territory, dry land, dense forests, and open forest have been converted in amounts of 66.23 percent, 18.53 percent, 4.57 percent, 3.77 percent and 1.78 percent, respectively from water supplies.

Kumar, Kumar and Shekhar (2016) conducted study based in the Ellenabad block of Sirsa district, RS and GIS techniques were used to track land resources and their temporal use. Ellenabad's climate is arid and humid, with very hot summers and cool winters even during the monsoon season. ERDAS Imagine 9.3, ARCGIS Desktop 9.3 and MS 2007 were included. On a 1:50000 scales, the latest transition mapping was generated to track improvements in land use and landcover from 2007 to 2009. The main LU/LC groups observed in both 2007 and 2009/10 were built-up area, agriculture crops, plantation, wasteland and water body. At that time, the gross agricultural area shrank by 5.50 square kilometers.

Kumar, Kumar, Kumar and Bansal (2015) carried out analysis of Dabawali block of Sirsa district to determine the spatial structure, temporal composition and likelihood of transition in LU/LC mapping using geospatial technology. The dry lands of Sandy fields, rolling sand dunes, consolidated sand dunes and dissected upland tracts dominate Dabawali. On a 1:50000 scale, the percent change mapping was created to chart changes in landuse and landcover from 2006-2007 to 2009-2010. The gross agricultural area declined 15.48 sq km from 2006-07 to 2009-2010, according to the findings. This is because the built-up area and strip plantation groups have increased. In the waste land categories, there were also minor changes.

Kumar, Kumar, Kumar and Singh (2015) carried out a pilot study of Rania block (Sirsa, Haryana) was used to track and analyse landuse / land cover with the help multi temporal AWiFS data. In the Sirsa district as a whole, the annual rainfall is 186.3 mm. Data from the Indian remote sensing satellite P-6 AWiFS was used for both Rabi and Kharif seasons. Thematic layer was prepared using satellite data from Bhuvan for both seasons and years (2006-2007 and 2009-2010). In both 2006-07 and 2009-10, the built environment, agricultural crops, plantation, wasteland and water body were classified as major LU/LC groups.

Singh, Kumar and Kumar (2015) used geo spatial technology to test in the Nathusari Chopta block (Haryana), land use/land cover mapping and shift analysis were conducted. On the Rajasthan border, Nathusari is located. Fatehabad district borders it on the east, Sirsa block on the north, Ellenabad on the west and Rajasthan's Hanumangarh district on the south. For both Rabi and kharif seasons, data from the Indian remote sensing satellite P6-AWiFS was used. Agriculture crops class occupied 693.22 square kilometers in 2007 and 669.65 square kilometers in 2009-2010, according to the author's research.

Arya, Singh, Kumar (2015) carried out geo-informatics was used to identify potential Jatropha plantation sites in Haryana. On a 1:250,000 scales, SOI toposheets no.44K, 440, 44P, 53C, 53D, 53F, 53G, 53H and 54E cover Haryana state. The lands were classified using IRS-IC/ID, LISS-III satellite images for the months of February 2003. Most Haryana villages have depleted pasture grounds and waterlogged areas can be found in Mewat, Jhajjar and Bhiwani districts.

Arya, Arya, Kumar, Singh and Hooda (2015) used Space technology to track wastelands in the Hisar district of Haryana. Banawali, Rakhi Garhi and Siswal in Hisar district are pre-Harappan sites that date from the 1st semi of the 3rd Millennium B.C., if not earlier. Using the WGS-84 datum and UTM projection system, digital satellite data were interpreted in the district for the 2008-2009 year. The district has 107.58 acres of degraded pasture ground, followed by open scrub. According to the change analysis matrix, the wastelands decreased from 138.91 to 132.89 square kilometers during the study period.

Taj, Bukahari and Iqbal (2015) identified spatio-temporal modeling and simulation of LU/LC temporal examination using RS and GIS through a pilot study of Lahore district. In modern World, the most important factors that cause remarkable change in LU/LC are urbanization, Industrialization, large scale cultivation technique and other infrastructure development. Population census, growth rate and density data for 1981, 1992 and 1998-2009 were obtained from the Punjab development statistics report (2011). The results showed that the land consumption per person was 0.0042 ha in 1992, 0.0041 ha per person in 2000 and 0.0038 ha per person in 2009.

Arya, Kumar, Kumar, Singh, Arya and Hooda (2014) used multi-temporal satellite data in a GIS environment, wasteland change analysis was carried out in six districts of northern Haryana. Northern Haryana's climate is expressed by a scorching and arid summer and a chilly winter. The LISS III (Linear Image Self Scanning) data from the Indian Remote Sensing Satellite was used. The result showed that the wasteland cover 322.46 sq km area that is 0.8 percentage total graphical area.

Kumar, Kumar, Kumar and Hooda (2014) used Geo-informatics techniques to map trees outside of the forest in Kalesar block (Yamuna Nagar district, Haryana). The Shivalik Hills, which run north-west to south-east, run along Yamuna Nagar's northern border. Cartosat-I (Panchromatic) digital data from October 2009, as well as IRS LISS IV data, were included. The total area measured for the underline categories was 30582.8 meters. The block plantation was discovered to be 233.2 ha in size, covering the majority of the land.

Kumar, Arya, Hooda, Singh and Kumar (2013) carried out studies of a micro-watershed were established using RS and GIS in the Bhiwani district of Haryana. The temperature in Bhiwani is exceptionally warm in the summer and extremely cold in the winter. Geo-referenced satellite images were used as the study's satellite data. The micro-watershed boundary vector layer was overlaid on satellite images of the region under investigation. In the micro-watershed, the double crop group was found to be the most widespread land use, with a notable rise of 90.49 ha from 2007-2008 to 2011-2012.

Sheoran, Sharma, Yadav and Sharma (2013) carried out land use / land cover improvements in Haryana's Jind district over a 1.5-decade span using an RS and GIS strategy. Multi-date satellite data utilized for establish landuse & landcover maps for two separate years, 1992-93 and 2007-08. For the years 1992-1993, IRS-IA/IB, LISS-I data with 72m resolution was used. The findings found that as the human population expanded, so did the volume of built up. To satisfy the growing demand for food, the man has restored some wasteland and turned it to farm land.

Damilola (2012) discussed use of remote sensing for wasteland mapping was investigated. Wasteland is property that is actually not being used to its maximum extent due to different restrictions. For identification of temporal variations in the wasteland, geo-coded FCC images on a 1:50000 scales are combined with visual image analysis techniques. Two time data sets, IRS, LISS-III are used. The data derived from the satellite and topographic studies have brought out the factor that wasteland should be managed properly.

Hooda et al. (2012) generated Wastelands Atlas of Haryana November, 2012. They carried out all wastelands of Haryana including waterlogged area using LISS III satellite data of 2008-09 (both Rabi & Kharif season). Area under waterlogged and marshy land- permanent class is 18.35 sq. km & area under waterlogged and marshy land- permanent is 30.46 sq. km in Haryana.

Hooda et al. (2011) identified wastelands atlas of India. National Wastelands Development Board, under ministry of rural development (MRD), Government of India formed in 1985 and vested with the overall responsibility of planning and implementation of various wasteland development programmes in the country, approached Department of space, Government of India to provide large scale maps(1:50000scale) showing the spatial distribution of wastelands. Wasteland vector layer created with 2005-2006 multi-temporal satellite data. For the years 2005-2006, Resourcesat data was collected for all three cropping pattern of India. During the years 2008-2009, a cumulative area of 32340 sq km of various wasteland types was found to be converted to non-wasteland status.

Todkari, Suryawanshi, Suryawanshi and Patil (2010) carried out agriculture land use pattern in Solapur district of Maharastra. The soil of Solapur district is mainly of Deccan Trap Volcanic origin. The crop data has been computed with Weaver's technique of crop combination. Solapur district has listed ten crop combinations by computing crop ranks and crop combinations. This style of research reflects the current state of cropping patterns and aids agriculture scientists, planners and researchers.

Khaier (2003) carried out soil salinity detection using satellite RS. The Balikh basin is in Syria's northwestern corner. The location of sampling points was selected at random from a hard copy of the ASTER image taken on March 10, 2002. Cotton accounts for more than 80% of summer crops and cotton fields are known to be fallow in March. Low values of index 2 less than 0.0222 are clearly visible near the river in the south and in the upper right.

Hoeschele (2003) carried out intra-governmental communication and the application of GIS to improve wastelands in India.1:8000 to 1:10000 scale and many of other available data through satellite data was used. Wastelands divided into thirteen categories have been mapped at the scale for the entire nation based on satellite imagery. Government officials put an excessive of trust in the maps as compared to the actual ground reality.

Sharma (1999) reclaimed the salt-affected soil's suitability for wheat production. Singh and Sharma identified 2.2, 5.2 and 12.9 lakh ha of saline and alkali land in the three districts of Haryana, Punjab and U.P. correspondingly. Productivity of soil was evaluated using the parametric and limitation approaches. The wheat yield data from the CSSRI reclamation experiments in Karnal and Sampla were used. The most restrictive horizon in alkali soils is the surface horizon with the highest pH, ESP, sodium carbonate and bicarbonate concentration, and platy structure. The shallow water table depth, high salt content and lighter soil texture are all characteristics of salty soil.-affected soils with salty and sodic soil occupying 2.9 & 3.7 million ha, correspondingly.

Goossens and Van (1996) discussed in the western Nile Delta, researchers looked at the commencement, center and ending of the rising season and found that although a single image can detect severely salinized soils, temporal images can show more gradations.

Review literature related methodology & Techniques

Kaushik, Dhate, Thakur, Nikam and Aggarwal (2019) evaluated and integrated approach for identification of waterlogged areas using RS and GIS technique and ground water modeling. The northern portion of Jammu district is hilly, with low to relatively elevated linear ridges with a mild to steppe slope and sharp to grounded crested ridges. On November 1, 2002, and December 21, 2002, data from the Indian remote sensing satellite 1D Panchromatic+ Linear Imaging self scanner (LISS III) were integrated on hard and soft copy at 1:50000 and 1:25000 scales. A zone with high storability, shallow depth to water level, and strong water holding capacity is ideal for artificial groundwater recharge.

Saleh (2017) studied in Basrah, Iraq, different soil salinity mapping techniques were used, including RS indicators and regression techniques. Shatt-Al-Arab river which flows into the Arabian Gulf. Landsat's Operational Land Imager (OLI-8) satellite provided the images. With the help of UTM coordinate system, the images were geo-rectified. In Saleh's research area, ECe values range from highly saline (>16 ds m-1) to non-saline (0-2 ds m-1). On the spatial prediction plot, the spatial distribution of

ECe was seen, with lower values in alluvial soils. Rachna Doab was analysed by Mehmood, Khan, Amin and Ali (2017), who used RS and GIS to delineate surface and sub-surface waterlogged areas. The Chenab and Ravi rivers meet at Rachna Doab, which is situated in the heart of the Chenab Valley. Before and after monsoon exterior waterlogging regions were delineated and visualized using RS images of Landsat 8 (2014).

Mahdi Saghafi (2017) studies uses of remote sensing indices to map salt-affected areas using field data methods for the Kaji Playa Lake regions in Iran's South Khorasan province. The fieldwork of the studied area was carried out by soil sample analysis and multi-temporal analysis of Landsat ETM^+ data. The fieldwork included measuring the soil salinity and gathering the ground truth for image classification. Field investigations and 31 soil samples collections were carried out and analyzed the values of EC (Electric conductivity/ micromhos per cm) for the bare soil of the plain unit. Once the region with maximum reflectance rate were recognized, the level of the salinity was determined based on their reflectance value. In the NDSI data, the saline regions are founded in gray color and can roughly.

Elhag (2016) different soil salinity mapping strategies were tested in an arid environment in Saudi Arabia using RS techniques. The Saudi Arabian government subsidized agriculture from 1974 to 2006 in order to increase living conditions in urban areas and promote sustainability. High floating water tables, waterlogging, and soil salinization have occurred from excessive runoff of less developed drained soils. The analysis intends to construct a regression relationship between ground truth data and its related salinity index value using satellite image RS data received from Landsat operational land Image (OLI-S) on April 17th, 2014. According to the findings, higher soil salinity was caused by an inappropriate and intensive irrigation system layout, as well as a lack of an effective water supply management plan.

Arya et al. (2015) developed sustainable land use plan on 1:50000 scale for Jhajjar district of Haryana using LISS-III satellite data. Author used an integrated approach and remote sensing techniques for soils, physiography, ground water depth, ground water quality and land use.

Raut, Maji, Sarangi, Mukhopadhyay and Lama (2015) used RS and GIS were to investigate the effects of soil salinity on vegetation index, land use and irrigation scheduling productivity in separate blocks of coastal West Bengal. IRS P6 L3 data for the summer season 12 Apr.2013 was collected from NRSA. The EC value of soil for rice crop was 0.40-0.46. In general, salinity and finer texture of soil in the area are associated with impeded drainage.

Mariappan, Selvaraj and Vadivel (2014) evaluated perspectives methods and techniques for soil salinity in the perspective of India's reconnaissance soil map. For more precise mapping & tracking of saline and sodic soils, Landsat MSS and TM images were utilized. The IRS-IBB and LISS-II satellite data in all four bands (B1, B2, B3 and B4) were used for the study. The Indo-Gangetic alluvial plain in India has about 2.8 million hectares of salt-affected soils.

Nwer, Ali and Zurqani (2013) carried out soil salinity model was prepared adopting RS and GIS in Libya. The study area is in Libya's Ajdabia district, in the country's northwestern corner. The year 2000 Landsat-7 ETM satellite image (Enhanced Thematic Mapper) was used to detect coastal saline areas. The key GIS packages used to create the model and execute its functions were ERDAS imagine and Arc GIS. In the study area's coastal areas, salinization is the most important process. The model shows that remote sensing data were used to delineate 91.20 percent of the saline areas, as well as saline areas delineated using site observations data, showing that the model is reliable. As a result, saline deposits cover about 12% of Libya's northern area, 16.5 percent of its western region and 23.4 percent of its central region.

Pareta (2013) in Rajasthan's south Bharatpur district, the Kakund watershed was assessed for long-term groundwater conservation. The river Kakund is a small sub-feeder of the Ghambir river in the south. Using Arc GIS 10.2 software, different thematic maps such as LULC, geographical, hydrological, depth to water level and waterlogged fluctuation were developed. In the study, data layer/maps was topographical map, remote sensing data, geological map, geomorphological map, slope map, drainage map, land use/land cover map, soil map, ground water, climatic and demographic data. New wells, such as drilled well shallow tube wells, dug-cumbour wells and deep tube wells, may be contributed to the potential production of ground water. To stop the training of surface water resources from the basin, it will be important to renovate village reservoirs, contribute stop dams and enter shafts.

Kumar and Siwach (2012) used RS and GIS to investigate arithmetical examination of canal density and canal system analysis in the Hisar district. Between 2002 and 2006, the average rainfall in Hisar was 276.2mm, which is part of the Indo Gangetic alluvial plain. IRS satellite LISS-III data is used, which is downloaded via Bhuvan from the NRSC, Hyderabad website. The total length of all canals in Hisar district is 1413.63 kilometers, with a canal density of 0.338 per square kilometer.

Koshal (2012) used GPS, RS and GIS were used to test satellite image measurement of salinity regions. Punjab is located within the large alluvial plains known as the Indo Gangetic plains. The land in the south-western areas of Punjab and Haryana is sandy. On the camera, the improved FCC image was shown at a scale of 1:50000. LISS III data from March 2000 was used for vegetation crop inventory and crop parameters. The truth was gathered from 24 villages, with 120 samples drawn from both salt-affected and non-affected areas. Waterlogging caused by canal seepage and salinity caused by salts on soil emerged as a sallow salt encrustation in areas of south-west Punjab.

Sethi et al. (2012) used RS and GIS were used to study salt-affected and waterlogged soils in Haryana's Rohtak, Bhiwani, Jind and Jhajjar districts. To acquire location details of each sample sheet, GPS reading were acquired using the land-set Garmin Etrex GPS unit. Satellite image of IRS P6 dated Oct. 2006 and Feb. 2007 were acquired from NRSC. The global DEM derived from ASTER data tiles were directly downloaded the supervised robust and simpler for detecting degraded salt affected soil in other districts of Haryana. The accuracy of the classification of land-cover maps derived from LISS III data were found to be 87.25%.

Mandal (2012) studied salt-affected and waterlogged regions in Central Haryana's Indo-Gangetic plain were established and characterized for reclamation and management. The Yamuna, Ghaggar and their tributaries drain Kurukshetra, which is part of the former Gangetic alluvial plain. On a 1:50000 scales, the geo-coded FCC of

IRS LISS III for Mar, Jun and Oct 2006 were visually discussed to delineate salt impacted soils and waterlogged areas. With the right amount of modification like gypsum or pyrites and better maintenance techniques, the soils may be reclaimed.

Moayad, Izadi and Heidari (2012) studied lime and nano silica stabilization of salty silty sand. According to an Iranian analysis, saline soil covers around 15% of the region, causing substantial harm to civil engineering projects. Geotextile strengthening, soil removal, vibratory compaction, dense soil densification and lime and cement stabilization have all been used to improve the internal properties of salty soil. It was discovered that applying lime to the soil decreased the overall dry unit wait period and improved the optimal moisture content. When fine-grained soils are blended with water and lime, they undergo a caution exchange reaction in the short term and a pozzolanic reaction in the long term. The pozzolanic reaction increases the soil's resistance.

Rina, Singh, Datta, Singh and Mukherjee (2012) carried out Groundwater salinity was mapped using geochemical modeling, ionic ratio and GIS and governing processes were assessed in Northern Gujarat, India. The Sabarmati River and its tributaries were the primary origin of surface water in Northern Gujarat. The region's land use / land cover map were created using the IRS P6 LISS picture (LULC), which indicates that the majority of the area is cropland interspersed with fallow land.

Jabbar and Zhou (2012) accessed of RS and GIS techniques were used to determine the effect of soil salinity on agriculture in Iraq's Basras province. The province of Basras is a traditional salt affected area in Iraq's southern region and satellite imagery and thematic were used to detect vegetation cover and salinization. For research, Arc-info software was used in conjunction with field observation data. The result showed that 6579.1 km sq. saline area increased in last 13 years and vegetation covered has decreased 4595.9 km sq. The results of the spatial analysis approach revealed that 7894.9 km sq. (41.45) of land are free of the possibility of environmental destruction caused by soil salinity.

Iqbal (2011) used satellite image, we were able to detect salt-affected soil in the rice-wheat field. Rachna Doab is situated in the Gujranwala district of Punjab's central province. The identification of saline and sodic soils was done using Landsat satellite imagery and a map released by the SSP (Soil Survey of Pakistan). A majority filter of 8*8 was used to generalize the extracted salt affected region. Within a triangle formed by the Chenab river, the Qadrabad-Baluki link canal and the low Chenab canal, a greater patch of salt-affected land exists. About 75 percent of the triangle's territory is within 20 kilometers of the lower Chenab canal.

Iqbal and Mostorakis (2006) used remote sensing and GIS, build a chart of soil salinity and track it. The research was carried out in Pakistan's Punjab province's Mungi Bangla. A research to assess an irrigation scheme in Pakistan's cotton-wheat region. The near IR and thermal IR bands in NDSI tended to be salty, with some vegetation health difference. The NDSI of NIR and TIR have precise data but their confirmation requires further analysis. The thesis demonstrated the feasibility of accurately detecting salinity using Landsat imagery. For salt identification, the proposed salinity Index does not require complicated measurements or weather data.

Shrestha and Farshad (2004) mapped salinity hazard: an integration application of RS and modeling based techniques. A 7400-hectare study area was chosen in Thailand's Nakhon Ratchasima province's Nong Suang district. Landsat TM data from February 2003 were geo-referenced using the UTM coordinate system and the Indian 1975 datum. The contour lines on a 1:50000 scale topographic map were scanned and digitized on paper. Because of the deposition of salt on the terrain surface and the development of salt crusts, salty areas have higher reflectance values than non-saline areas on satellite images.

Pal, Srivastava, Durge and Bhattacharyya (2003) discussed the role of micro topography in the development of sodic soils was studied in the semi-desertic areas of India's Indo-Gangatic plains. The Indo-Gangatic alluvial plain contains a significant portion of India's seven M hectares of saline - sodic soils. Sodic soils occupy 2.32 million hectares in Punjab, Haryana and U.P. in the north-western region of the country. They have a high ISP value and a high pH (9.5-10.5), (80-95 percent). The picture factor was interpreted from a geo-coded FCC image obtained from the IRS series IV via the LISS II sensor (at 1:50000). The soils on the MH are usually unaffected by salt, while those on the rim and ML are highly sodic. The soil on the ML position is close to the soil on the MH position. That has a subtle colour, consistency and calcareousness distinction. The ESP in MH soils decreases with depth but increases with depth in ML soils.

Venkataratnam and Rao (1991) studied the spectral behavior of salt-affected soils in the Indo-Gangetic Alluvial Plain and discovered that salt-affected soils showed a larger spectral response in the visible and near-infrared regions than normal cultivated soils. Furthermore, spectral response was higher in extremely saline-sodic soils than in moderately saline-sodic soils. Vegetation cover changes the overall spectral response pattern of salt-affected soils, especially in the green and red spectral bands. Changes in the Sun's elevation angle and moisture content were found to determine the reported spectral reactivity of salt-affected soils.

Moulders (1987) used bands in the near and middle infrared ranges, he said, offer valuableknowledge on soil wetness and salinity in general. This result was supported by Steven et al. (1992), who showed that the NIR index is a greater pointer of chlorosis in harassed plants. The sum of water in the leaves is implied by this current ratio, which is unchanged by colour variations.

Venkataratnam (1983) used temporal Landsat-MSS images from the before monsoon, after monsoon and harvest seasons to map saline soil in Punjab, India. The spectral curves of extremely and reasonably salt affected soils shift dramatically over the yearly period, complicating the time composition technique, they discovered.

Barret and Curtis (1976) used Landsat-MSS data to chart watercourse channel formation and system, watercourse volume and the position of waterbodies, according to the researchers. By identifying the drainage network and its properties in a basin, as well as information on the presence of a high water table, high morphology, soil colour, plant strain, and drainage water collection in lower locations, GIS aids in evaluating the waterlogging and drainage problem.

Review literature related to cropping pattern

Kumar and Hassan (2018) carried out the sustainability of agriculture in Haryana using primary and secondary data of the land use, cropping pattern, irrigation, crop production and inputs for the year 1970-73, 1980-83, 1990-93, 2003-04 and 2013-14. Stratified random sampling method was used for data collection during the survey. Agricultural transformation in Haryana at regional dimension and issue pertaining to agricultural sustainability was studied on the basis of database used.

Prawasi, Sharma, Babu, Ompal, Saroj, Yadav and Hooda (2015) studied landuse & landcover for mapped and investigation of change detection through RS and GIS, block level study, Jind district, Haryana. Jind has tropical steppe, semi-arid and hot monsoon type of climate. The LISS-III data from the IRS Resourcesat-2 were utilized for the kharif, rabi and zaid seasons in October 2011, March 2012 and June 2012, respectively. As a result of the same territory being changed to built up, farmland or water sources, pasture land has decreased by 0.98 percent from 3.48 percent in 2005-2006 to 2.51 percent in 2011-2012.

Satyawan, Yadav and Hooda (2012) carried out a pilot study of Sirsa, Haryana, India, was used to analyse crop systems using a geospatial approach. The Sirsa region is surrounded by the Indo-Gangetic alluvial plain. For classification and crop rotation, Geomatica 10.3 was used, while Arc GIS 9.3 was used for clipping and map composition. According to RS data analysis, cotton is the most important crop during the monsoon season, followed by Paddy, Guar, Bajra and horticulture fruit crops.

Singh, Kudrat, Jain and Pandey (2011) studied UP crop pattern was investigated using IRS-P6 data. Up is fed by five main rivers that flow into the Bay of Bengal: the Ganga, the Yamuna, the Gomati, the Ramganga and the Ghaghra. AWiFS data has a ground resolution of 56 meters and four spectral channels, as well as a 5-day temporal resolution and a 740-kilometer swath radius. According to Kharif season analysis rice was the single most dominant crop in the research area of U.P. Sugarcane is the main cash crop, which is predominantly grown in the western part of the country.

Review literature related to soil resources

Kumar, Deen, Sonu and Manoj (2019) identified an assessment of soil resource of Hisar district using Geospatial technology. The annual rainfall in Hisar district is 307.7mm. Toposheets of Survey of India (440/7,8,11,12,14,15,16,44 p/9, 13 and 53 c/3, 4) were used. The software used: ArcGIS Desktop 9.3, MS Office 2007. The result showed that the potential benefit of soil resources assessment in the form of increased production of food grains and agriculture production.

Arya, Kumar, Singh, Singh, Kumar and Hooda (2015) carried out Palaeochannels- a promising option for archeological and ground water exploration sites in Haryana. The study area of the author's form a division of Indo-Gangetic flood plain of Haryana. Landsat TM digital data for the year 1995 of 30m spatial resolution and Radarsat microwave data for 1998(resolution 12.5 m) were used to identified and delineate the Palaeochannels on 1:50000 scale. Palaeochannels are drainage/rivers/streams that flowed either ephemerally or perennially in the past but are now extinct due to internal (tectonic) and external (human) activities.

Lhissou, Harti and Chokmani (2014) mapped soil salinity in irrigated land using optical RS data. The Anmed El-Hansali dam gathers water to irrigate the Tadla-Azilal region in central Morocco. Soil samples were taken by the ground survey and their electrical conductivity was measured in the laboratory using physiochemical analysis. The most affected areas by the high salinity are located in the hydraulically down gradient following a recycling of salty ground water by pumping.

Mandal, Reddy and Ravisankar (2011) digitized a series of salt-affected soils. Salt impacted areas were mapped on a 1:250000 and the understanding of RS data, field fact and laboratory analysis for pH, ECe and ESP. To create a compound map of saline soils in India, saline soil maps from fifteen states were combined in a GIS. Saline soils measured in 2956809 ha area in twelve states and in Andaman & Nicobar island. According to state-level figures, India has 6.7 million ha of salt.

Abdelfattah, Shahid and Othman (2009) developed soil salinity map model adopting remote sensing and GIS study of Abu Dhabi, UAE. Nearly 80% of the Abu Dhabi Emirate is desert, with a large region of coastal salt flats to the north and west and no

“Sabkha” in the area. Salinity detection using satellite data, site inspection, correlation and verification and model validation are all phases of model creation. Coastal saline areas were detected using multi temporal Landsat ITM images taken in 2000 and 2002. X-ray diffraction analysis revealed halite to be the most abundant salt mineral, followed by gypsum, anhydrite and measure. According to the findings, 63.34 percent of the sample region is categorized as strongly to highly saline, while 36.66 percent is classified as minor to moderately saline. 91.2 percent of the salty area demarcated with the help of RS data compared to 91.2 percent of the saline area demarcated with the help of side observation data, according to the simulations.

Verma, Litoria, Sood, Sharma and Singh (2003) evaluated sensitivity to secondary, an assessment using RS and GIS. The division of Indo-Gangetic flood plain is located in south-western zone of Punjab state. The area qualifies for aridic moisture regime according to the criteria laid in soil taxonomy. The soil map was finalized on 1:150000 scales. Aerial photographs of March 1998 and IRS-1D LISS III geo coded FCC of Mar. 2001 were used. The area has been divided into four categories viz. good, saline to highly saline, sodic and poor.

Karale, Bali and Rao (1983) identified soil mapping using RS techniques. The beginning of soil surveys in India dates back to early twenties when sporadic attempts were made to characterize and classify soils. RS, in a stricter sense connotes a technology of acquisition and interpretation of data about the terrestrial and atmospheric objects and processes. In the saline soil studies conducted in Haryana and Punjab, three levels of soil salinity could be identified and mapped by photo interpretation techniques.

Review literature related to water resources

Mehra, Oinam and Singh (2016) studied in Mewat district of Haryana, India, GIS was used to perform an integrated evaluation of groundwater for agricultural use. The district's groundwater reservoirs are mostly made up of quaternary alluvium with hard rock fractures, joints and crevices. The weighted index approach was used to model groundwater efficiency. The crop yield, soil fertility and irrigation source were all used to confirm the result. The integrated evaluation of Mewat's groundwater resource provides policy makers with valuable knowledge for adopting steps for long-term groundwater resource management.

Subramani, Krishnan and Kumarsan (2012) studied groundwater quality with GIS utilities Coonoor Taluk of Nilgiri district. Groundwater, the chosen option, is under pressure in India as a result of anthropogenic practices, which has resulted in decline in ground water quality. GIS makes data collection and retrieval easier, as well as providing efficient statistical methods for multi-map integration. Using Arc View 9.3 the spatial interpolation was done on the basis of attribute values. The ground water superiority in Coonoor Taluk would reduce because of pollution.

Sharma and Kansal (2011) studied the national capital region of India, described water quality study of River Yamuna using water quality index (2000-2009). The river system's catchment area comprises portions of U.P., H.P., Haryana, Rajasthan, M.P. and Delhi. WQIs (Water Quality Indices) are a statistical instrument that can include a single number of vast amounts of water quality data in a systematic way. The study described the toxins that have important impact on the quality of river's water as it flows through the region.

Jothivenkatachalam, Nithya and Mohan (2010) studied Perur block of Coimbatore district, Tamil Nadu, India, a correlation study of drinking water quality was conducted. Because of the rapid growth in population, rapid industrialization, unplanned urbanization, waste flow from upland to lowland and excessive usage of fertilizers and pesticides in agriculture, groundwater quality has become a significant water management problem. Both seven samples have a high calcium and magnesium content that exceeds allowable levels. The explanation for the deteriorating water quality in this region may be due to the high population density and the presence of large and ancillary industrial units in the area.

Jasrotia, Kumar and Saraf (2007) studied land water recharge sites in Jammu district, India, were delineated using integrated RS and GIS. The northern part of Jammu district is hilly, with a moderate to steppe slope and low to medium high linear ridges. On November 1, 2002, and December 21, 2002, remote sensing data from India's 1D Panchromatic and Linear Imaging self scanner (LISS III) was blended on hard and soft copy at 1:50000 and 1:25000 scales. A zone with high storability, shallow depth to water level, and adequate water holding capacity is the optimal zone for artificial ground water recharge.

Manchanda and Kumar (1999) studied Mewat region of Haryana adopting IRS (LISS II) remotely sensed images and GIS techniques were used to investigate soil and water resource management issues. Soils, hydro-geomorphology, ground water, soil salinity and waterlogging were all included in the resource diagram. A final site-specific action plan was created for the creation and maintenance of productive land and water supplies.

Review literature related to planning and management

Kumar, Deen and Sonu (2020) integrated resource supervision for environmentally sound agricultural landuse plan in Hisar with the help of remote sensing & GIS. The climate of Hisar is famous for its waterlessness and boundaries of hotness with insufficient rainfall and varies arid to semi arid type. IRS satellite series (LISS-III) images for the year 2017-2018 was used for explanation of the present landuse & land cover, cropping pattern and crop rotation. The study suggested 700.83, 18.57, 123.92 square kilometer is suggested for agri-horticultural, agro forestry and for dual crop with clone eucalyptus plantation on field boundary.

Negi, Arya, Kathota, Patel, Singh, Garg and Kaluborme (2019) carried out in Gujarat, India, Geo-informatics technology was used to determine the effect of canal irrigation on waterlogged areas and the environment. The major irrigation sources in Gujarat are tube wells, Narmada branch canal and natural drains of river Mahi and Dhadhar. Multi dates satellite data of LISS-IV, LISS-III and Landsat-8 TM data of different dates were used for monitoring and demarcation waterlogged and saline and sodic lands. The results showed that the water table in same of the villages were slightly come up throughout the period of last 15 years.

Rawat and Kumar (2019) evaluated the impact of overpopulation of land use pattern, a contextual analysis of sustainable natural resources. The average population density in India is 382 persons per sq km according to census of India 2011. The data for the last six decades 1951, 1961, 1971, 1981, 1991, 2001 & 2011 for analysis were considered. Intensive cropping kills beneficial insects and plants, degrades and depletes soil, pollutes drainage and water systems and increases flooding susceptibility.

Sar, Chatterjee and Adhikari (2015) discussed watererlogging hazard susceptibility and risk evaluation using combined geo-informatics based spatial simulation using an empirical hierarchy framework. The research is taking place in the Kelghi River basin in India's West Bengal province. The study's main goal is to classify the waterlogged region in terms of its hazard susceptibility and danger of entering the Kelghi River basin using multi-temporal Landsat imageries, groundwater table, irrigation networks, topography variation, demographic dispersion, and socio-economic features. The study area's 80 percent population is largely dependent on agriculture, which is the most impacted by waterlogging. Landsat multi-temporal imageries from the post-monsoon season. The intensity level of waterlogged area was calculated using ASTAC automated alleviation groundwater table and population data. The findings revealed that the highest spatial extent of waterlogging areas was more covered in the eastern part of the basin.

Kalra and Joshi (1997) used SPOT, MSS & TM and the Internal Revenue Service (LISS-I & II). During the Zaid season (April, May), Rabi crop (January/February), and rained crop (March/April), FCC pictures were utilized to assess the capabilities of multi-sensor data for distinguishing salt-affected soils in desert Rajasthan. According to the findings, moderately and severely salt-affected soils could be mapped using any season's FCC of Land Sat, Place, and IRS LISS-II. In comparison, photos taken during the summer season showed the most saline soils. Using irrigated crop season (January) photos enhanced by knowledge of the irrigation water content used, saline soils due to saline water irrigation and sodic soils owing to RSC (Residual Sodium Carbonate) water irrigation can be displayed independently based on uneven tone and sequence. The only way to tell the difference between saline and sodic soils was to use multi-date imagery (October and January) and the indicator provided by the cropping pattern.

Baber (1982) pointed out that soil moisture concentration or plant stress may signify drainage issues in colour infrared photography. Surface moisture levels in shallow water tables rise, as measured by visible reflectance and microwave emissivity.

Research Gap

The main explanation for choosing this study field is that wheat, mustard and cotton are grown on the property of many farmers in Haryana. Farmers in Fatehabad's salt-affected area yield little, despite spending a lot of money on inputs, only to see their crops ruined due to high soil salinity. On the other hand HARSAC (Haryana Space Applications Centre, Hisar) had completed the study regarding the problems of waterlogging and soil salinity in Central Haryana adopting remote sensing and GIS techniques on 1:10000 scales using LISS IV satellite images. But brackish ground water table is constantly rising due to seepage of water through canals, irrigation channels and irrigated fields in the internal drainage sink in the saucer shaped topography of the Fatehabad district that create the problems of flooding and secondary soil salinization. But the problem of Fatehabad district is not taken up by any institute or agencies. Keeping this research gap in mentality the current study area was taken up to increase the foodgrain production for increasing population. Land and water resources have been subjected to great stress and inappropriate land use which has resulted to soils degradation in the district.

CHAPTER 3
ASSESSMENT OF WATERLOGGED AND SALT AFFTECTED AREA

3.1 Concept of Waterlogging & Soil Salinity

Agriculture structures major monetary action of Haryana. The central western district strongly relies upon water system from waterway sources. The interpenetrate misfortunes from the transport and conveyance framework and leakage from overloaded fields are bringing about quick ascent of the water table. Waterlogging and salinity are two troubles which occur as a result of the harsh nature of freshwater and the consequent restrictions on its use. As the water stand exceeds the root area, the air supply in this area is disturbed, ensuing in a substantial decline in agricultural productivity and the field is referred to as waterlogged. During October, the areas with a submerged table depth between 0 to 1.5 m were found totally waterlogged.

Low-lying land that has water at/near the surface for the majority of the year is known as waterlogged land. Permanent waterlogged areas and seasonal waterlogged areas can be split into two groups depending on the term of water logging irregularity.

- **Permanently Waterlogged:** Permanently waterlogged regions in which water logging conditions triumph for the majority of the year. Low-lying fields, inaccesible foundations along canal/waterway channels, seaside inlands and so on are examples of these districts.
- **Seasonally waterlogged:** Seasonally waterlogged region in which the waterlogging situation induce most often throughout the rainy season. These properties have mainly in nearly level areas where there is a lot of drainage blockage.

Water logging and soil salinity have different definitions according to different organizations. Waterlogged/fundamentally waterlogged territories are described by the National Commission of Agriculture (1976) and the Ministry of Water Resources as areas where the water table is under 2 meters of the surface (Table 3.1).

Table 3.1: Criteria adopted by different agencies for waterlogging

Waterlogging	National Commission of Agriculture	Ministry of Water Resources, Govt. of India
Waterlogged/Critical	Water table <1.5 m	Water table <2 m
Potentially waterlogged		Water table 2-3 m
Safe area		Water table >3 m

Salinity is dissolvable salts accessible in the soil. The most generally acknowledged meaning of salt influenced soils is as characterized by the United States Department of Agriculture, USDA. The definition depends on pHs (pH of the soaked soil glue), EC (electrical conductivity of the immersion concentrate of soil, dS m1) and ESP (replaceable sodium level of the soil):

1. **Saline soils:** These soils have an ECe of more than 4 dS m-1 at 250°C, a pH of less than 8.2, an ESP of less than 15 and a high concentration of sodium, calcium and magnesium chlorides and sulphates.
2. **Sodic soils:** Sodic soils have a pH greater than 8.5, an ESP of 15 or greater and a high concentration of sodium carbonates and bicarbonates. If the salts are capable of alkali hydrolysis, the EC can be high; otherwise, it should be less than 4 dS m-1 at 250°C.
3. **Saline-sodic soils:** These soils have a pH of greater than 8.5 at 250°C, an EC of greater than 4 dS m-1 and an ESP of greater than 15. A mixture of salinization and sodication has resulted in the formation of these soils.

Table-3.2 provides a common guidance for the severity of soil salinity / sodicity but the severity which differ based on the kind of soil and yield.

Table-3.2: Criteria of soil salinity/alkalinity

Key to degree of salinity/sodicity	Salinity ECe (dS m^{-1})	Alkalinity/Sodicity	
		pH	ESP
Slight	4-8	8.2-9.0	<15
Moderate	8-25	9.0-9.8	15-40
Strong	>25	>9.8	>40

Salinity improves the permeable ability of soil solution, making it more hard for plant roots to consume wetness and nutrients. Table-3.3 shows a preliminary description based on crop growth and the findings of the US Salinity Laboratory.

Table-3.3: Soil Salinity and Crop growth

Salinity	Conductivity of saline extract, S/m^{-1}	Remarks
Non Saline	0-2	Salinity effect negligible
Slightly Saline	2-4	Yields of sensitive crops affected
Moderately Saline	4-8	Yields of several crops affected
Strongly Saline	8-16	Only salt tolerant crops survive
Very Strongly Saline	>16	Few salt tolerant crops survive

3.2 Soil Salinization

Soil salinization is a worldwide issue and influences practically all landmasses; it isn't static yet powerful. Salinization can influences biological system to a level where it can't offer ecological types of assistance to its maximum capacity. It is a world regional-public site level worry to us all. Numerous elements add to the advancement of saline soil setting. Notwithstanding, the majority of soils become saline throughout ocean water interruption (costal zones) and using saline/bitter ground water for water system purposes (agricultural ranches). Salt fixations in soil change broadly both vertically and evenly relying upon such conditions, variety in soil surface, plant development, nature of water system, water pressure driven conductivity and water system framework set up and so forth when it is said and done, a salinity mapping and control strategy should be part of every task including the utilize of water system water with salinity/sodicity. In farming homesteads, a powerful salinity-monitoring plan will be developed to track salt shifts, especially in the origin region and to guide the effect of the executives' decisions to survive or minimize salinity influences.

3.2.1 Salinity Mapping and Monitoring

The aim of soil salinity mapping is to locate minor salinity contrasts in a scene and construct salinity zones to help executives prepare for the most effective use of soil properties. Changes in soil salinity are monitored on a regular basis. Mapping of saline soil at the provincial, public and homestead level is getting progressively significant for asset getting, use and the board reasons. The soil salinity could be caused because of numerous reasons; catastrophic events (Tsunami), ocean water interruption, water system with saline and bitter waters and so forth last mentioned if not appropriately oversaw can cause salinization in agricultural homesteads and decay ranch gainful limit. In agricultural fields the water conveyance through flood water system and present day water system frameworks (dribbles and sprinklers) can't be applied consistently; hence, the conduct of salinity advancement would be heterogeneous. Under such saline conditions numerous plants either neglect to develop or their development is impeded altogether. Be that as it may, barely any plants develop well on saline soils; in this manner, salinization frequently confines alternatives (biosaline agriculture) for trimming in a given land region. The previews (mapping) of salinity at surface and subsoil layers everywhere (ranch level) and little scopes (provincial and public levels) can help comprehend the genuine issue and help create the board and use intend to get more an incentive from each real estate parcel.

Two seasons satellite data of LISS-IV, LISS-III and Sentinel were interpreted on 1:10,000 scale to generate various thematic maps like waterlogged & Salt affected area maps, Cropping pattern and Crop rotation, Ground water quality, Ground water depth, Soil texture, Soil moisture, Hydro geomorphology, canal & drainage and settlements & infrastructure maps etc. The description of various themes is given below.

3.3 Assessment of Salt Affected Area

Most plants are negatively affected by excess soluble salts (saline soil), high exchangeable sodium (sodic soil), or both (saline sodic soil). Sodic soil spans 1.48 square kilometers, or 23.45% of the entire salt-affected region, totaling 6.31 square kilometers. Other classes include saline, which accounts for 21.24 percent of total salt affected area, and saline-sodic soil, which accounts for 55.31 percent.

Total 24 soil samples from 12 various locations of salt affected area were taken from different depths i.e. from 0-15 and 15-30 cm. The chemical properties of these samples were studied in the lab. On the basis of their chemical characteristics (EC, pH & ESP), these soil samples were classified into various classes like saline soil, sodic soil & saline sodic. The location map of collected soil samples is shown in Figure 3.1. The Chemical personality of these soil samples are given in Table-3.4.

It was discovered that the majority of the saline areas are found around canals or drains. Near the villages of Lohgarh, Sakta Khera, Taruana, Rohan, and Kungrawali, there are large expanses of sodic soil. The *saline sodic* soils are distributed near the village Surtia, Nathusari Chopta, Darba Kalan, Dhabi Kalan and Gudia Khera. Patches of saline soil are distributed near the village Gorakhpur and Badopal village in Fatehabad district. Table 3.5 shows the areal extent of these soils by class and Figure 3.2 shows the salt impacted region map by class.

Table 3.4 Chemical characteristics of Soils

Sample No.	District	Village Name	Latitude	Longitude	Depth (cm)	pH	EC	ESP	Classification
1A	Fatehabad	Khabra Kalan	29.33742	75.35750	0-15	8.3	21.2	19.68	Saline-sodic
1B	Fatehabad	Khabra Kalan	29.33742	75.35750	15-30	8.5	5.4	25.76	Saline-sodic
2A	Sirsa	Makhu Sheorani	29.35345	75.18079	0-15	8.3	18.7	19.79	Saline-sodic
2B	Sirsa	Makhu Sheorani	29.35345	75.18079	15-30	8.7	5.6	32.49	Saline-sodic
3A	Sirsa	Ludesar	29.36006	75.08862	0-15	7.5	3.0	5.85	Normal
3B	Sirsa	Ludesar	29.36006	75.08862	15-30	8.4	4.9	22.73	Saline-sodic
4A	Sirsa	Ludesar	29.36410	75.08957	0-15	8.9	8.6	38.41	Saline-sodic
4B	Sirsa	Ludesar	29.36410	75.08957	15-30	8.2	3.5	13.53	Normal
5A	Sirsa	Nathusari Chopta	29.39649	75.12116	0-15	8.3	17.0	18.31	Saline-sodic
5B	Sirsa	Nathusari Chopta	29.39649	75.12116	15-30	8.3	7.3	16.53	Saline-sodic
6A	Sirsa	Nathusari Chopta	29.39744	75.11732	0-15	8.7	6.0	31.79	Saline-sodic
6B	Sirsa	Nathusari Chopta	29.39744	75.11732	15-30	8.8	19.5	35.82	Saline-sodic
7A	Sirsa	Surtia	29.77948	75.19858	0-15	8.7	9.5	32.08	Saline-sodic
7B	Sirsa	Surtia	29.77948	75.19858	15-30	8.7	6.1	31.97	Saline-sodic
8A	Sirsa	Surtia	29.81184	75.18567	0-15	8.7	12.1	30.55	Saline-sodic
8B	Sirsa	Surtia	29.81184	75.18567	15-30	8.6	8.0	27.93	Saline-sodic
9A	Sirsa	Phaggu	29.77243	75.12961	0-15	8.6	3.4	16.03	Sodic
9B	Sirsa	Phaggu	29.77243	75.12961	15-30	8.6	2.8	15.31	Sodic

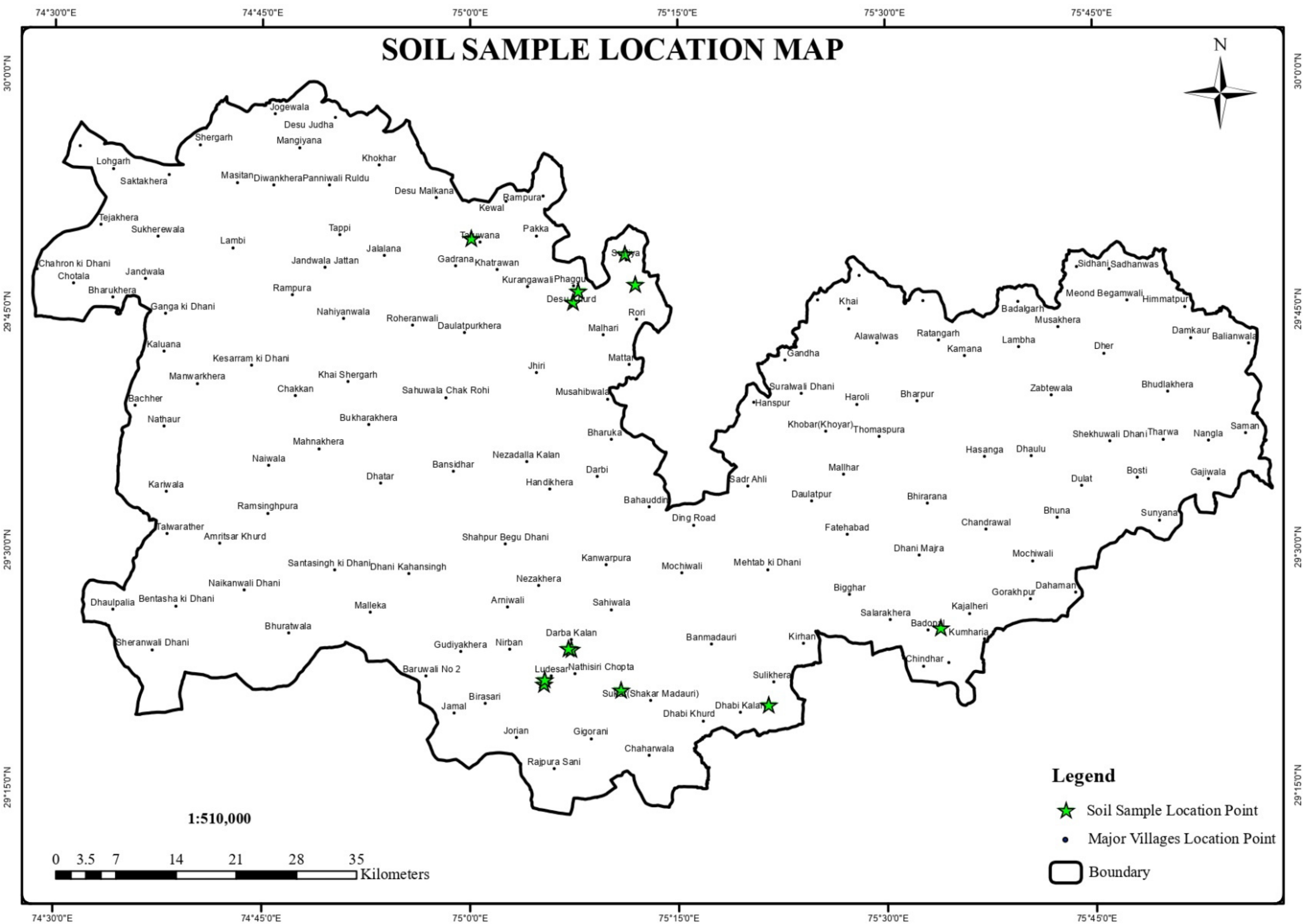
10A	Sirsa	Deshu Khurd	29.76115	75.12352	0-15	8.6	1.4	24.61	Sodic
10B	Sirsa	Deshu Khurd	29.76115	75.12352	15-30	8.5	1.4	17.12	Sodic
11A	Sirsa	Kalanwali	29.82832	75.00157	0-15	8.5	1.1	15.82	Sodic
11B	Sirsa	Kalanwali	29.82832	75.00157	15-30	8.1	1.3	12.27	Normal
12A	Fatehabad	Badopal	29.41746	75.56473	0-15	7.7	11.8	8.47	Saline
12B	Fatehabad	Badopal	29.41746	75.56473	15-30	8.0	6.5	10.93	Saline

Table 3.5 Areal extent of different soil salinity classes

Salinity classes	Area in Sq. km.	Percent of total salt affected area	Percent of total geographical area
Saline	1.34	21.24	0.020
Saline Sodic	3.49	55.31	0.052
Sodic	1.48	23.45	0.022
Total Area	6.31	100.00	0.094

3.4 Assessment of Waterlogged Area

Waterlogged patches can also be discovered in limited depressions or parallel to canals in the research region. Water collects in the depressions during the rainy season, producing flooding. Canal seepage along the banks also contributes to water logging. In the study area, seasonal and permanent waterlogged areas were identified. Seasonal waterlogged areas were defined as those that were only flooded during the Kharif season, whereas permanent waterlogged areas were defined as those that were flooded during both seasons. The seasonal waterlogged region of the research area is 12.20 sq km, or 0.18 percent of the whole geographical area, whereas the permanently waterlogged area is 8.10 sq km, or 0.12% of the total geographical area. The western and southern sides of the study region have mostly seasonal wet areas. This waterlogged area is near the canals. Most of the waterlogged area is resulted into secondary salinization and salinity is developed in this area. Table 3.6 shows the area that is seasonal and permanent waterlogged. Figure 3.3 shows a map of the waterlogged area.



SOIL SAMPLE LOCATION MAP
N
74°30'0"E
74°45'0"E
75°0'0"E
75°15'0"E
75°30'0"E
75°45'0"E
30°0'0"N
29°45'0"N
29°30'0"N
29°15'0"N
Jogewala
Desu Judha
Shergarh
Mangiyana
Lohgarh
Khokhar
Saktakhera
Masitan
Diwankhera
Panniwali Ruldu
Desu Malkana
Rampura
Kewal
Tejakhera
Sukherewala
Lambi
Tappi
Pakka
Jalalana
Chahron ki Dhani
Chotala
Jandwala
Jandwala Jattan
Gadrana
Khatrawan
Kurangawali
Phaggu
Bharukhera
Rampura
Desu Khurd
Ganga ki Dhani
Nahiyanwala
Roheranwali
Daulatpurkhera
Rori
Malhari
Kaluana
Kesarram ki Dhani
Matta
Manwarkhera
Khai Shergarh
Jhiri
Chakkan
Sahuwala Chak Rohi
Musahibwala
Bachher
Nathaur
Bukharakhera
Bharuka
Mahnakhera
Naiwala
Nezadalla Kalan
Bansidhar
Dhatar
Darbi
Kariwala
Handikhera
Bahauddin
Ramsinghpura
Ding Road
Talwarather
Amritsar Khurd
Shahpur Begu Dhani
Kanwarpura
Mochiwali
Mehtab ki Dhani
Santasingh ki Dhani
Dhani Kahansingh
Nezakhera
Naikanwali Dhani
Dhaulpalia
Bentasha ki Dhani
Malleka
Arniwali
Sahiwala
Bhuratwala
Darba Kalan
Banmadauri
Kirhan
Sheranwali Dhani
Gudiyakhera
Nirban
Baruwali No 2
Ludesar
Nathisiri Chopta
Sulikhera
Birasari
Sukhar(Shakar Madauri)
Jamal
Dhabi Kalan
Dhabi Khurd
Jorian
Gigorani
Chaharwala
Rajpura Sani
Khai
Sidhani
Sadhanwas
Meond Begamwali
Himmatpur
Badalgarh
Musakhera
Alawalwas
Ratangarh
Lambha
Damkaur
Balianwala
Kamana
Dher
Gandha
Suralwali Dhani
Haroli
Bharpur
Zabtewala
Bhudlakhera
Hanspur
Khobar(Khoyar)
Thomaspura
Shekhuwali Dhani
Tharwa
Nangla
Saman
Hasanga
Dhaulu
Mallhar
Dulat
Bosti
Gajiwala
Sadr Ahli
Daulatpur
Bhirarana
Bhuna
Sunyana
Fatehabad
Chandrawal
Dhani Majra
Mochiwali
Bigghar
Gorakhpur
Dahaman
Kajalheri
Salarakhera
Badopal
Kumharia
Chindhar
1:510,000
0 3.5 7 14 21 28 35
Kilometers
Legend
Soil Sample Location Point
Major Villages Location Point
Boundary

Figure 3.1

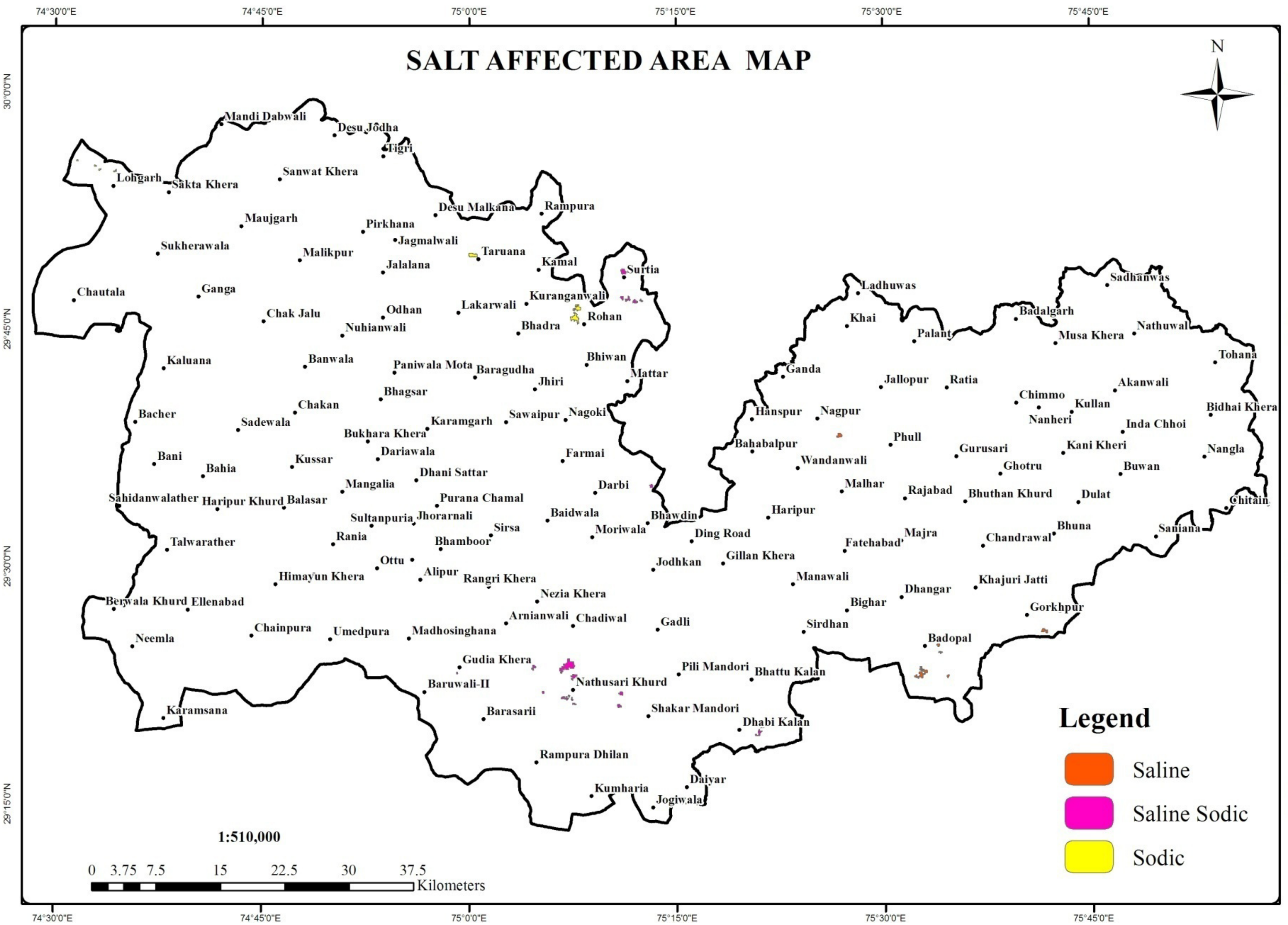


Figure 3.2 (Source: LISS III & LISS IV Satellite data)

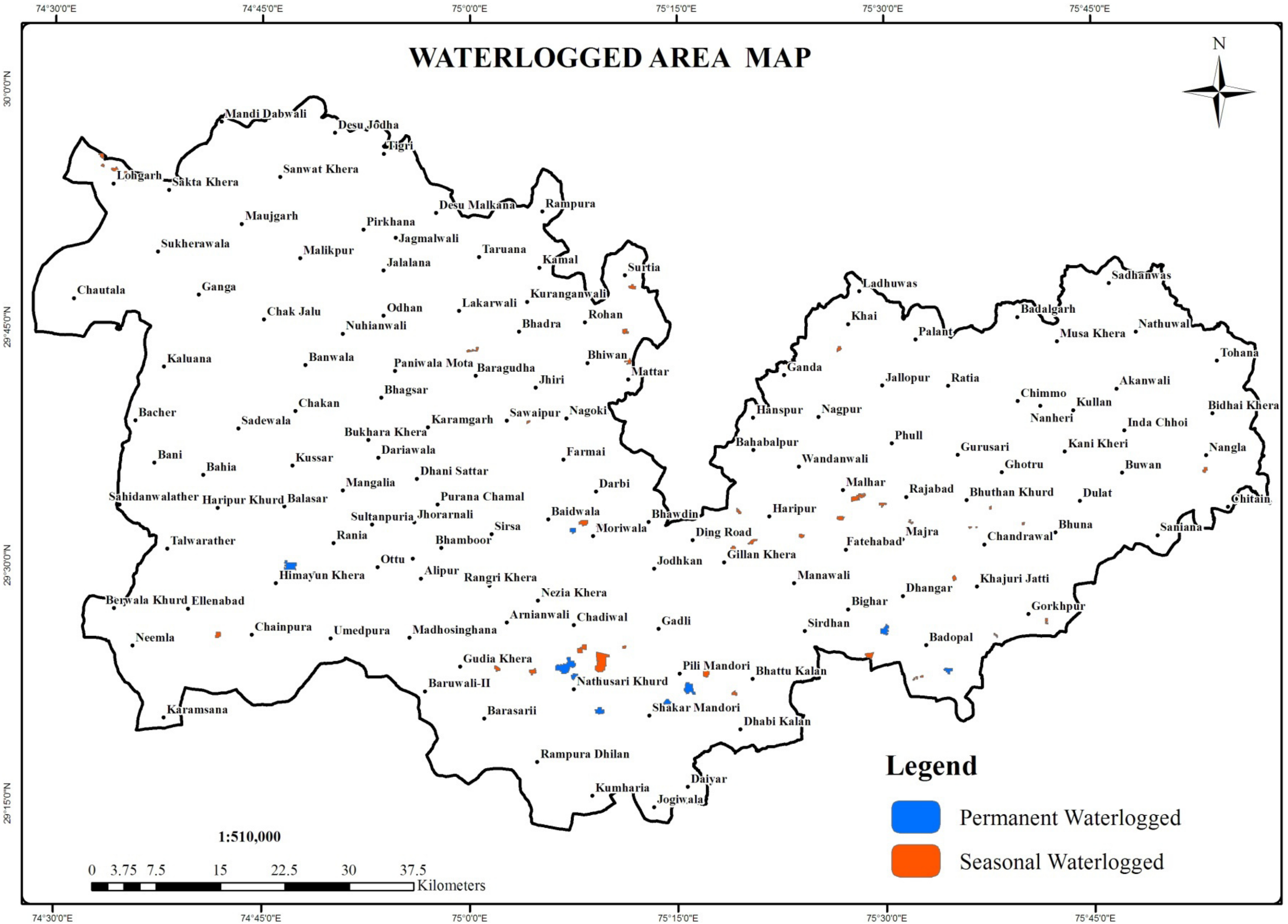


Figure 3.3 (Source: LISS III & LISS IV Satellite data)

Table 3.6 Areal extent of waterlogged areas

Waterlogged classes	Area in Sq. km.	Percent of total waterlogged area	Percent of total geographical area
Seasonal waterlogged	12.20	60.10	0.18
Permanent waterlogged	8.10	39.90	0.12
Total Area	20.30	100.00	0.30

3.5 Causes of Water Logging and Soil Salinity in study area

Water logging occurs as the top layers of the soil turn into completely soaked with water, denying plant roots access to oxygen. Water logging isn't generally because of ascending of water table; it could be because of exceptionally helpless seepage limit of the established region of the soil. Land and water the executives are vital for the maintainable cultivation biological system. There were numerous methods of overseeing waterlogging situation. One of the financially sharp models is agroforestry that seems, by all accounts, to be a response for both these issues. Agroforestry is a crop cycle in which trees grows alongside harvests, whichever at bunds or by intercropping. This fills some needs. One sided it is pointed toward getting crop creation on temporary premise and acquiring woodland items on extended haul premise. Alongside monetary advantages, there are numerous ecological advantages related with agro forestry.

The yields and trees are completely linked. It creates an ideal environment for the normal growth of soil miniature vegetation while minimizing nursery effect. It increases soil's natural, chemical and biological characteristics. One of the main problems to be discussed is the synergic durability of forests and yields in terms of their utilization of water and nutrients available in the land. By advancing soil supplements and preventing supplement filtering in the secret water table, agro-forestry will enhance soil quality. Other side is to be tended to is the issue of waterlogging. The provincial financial system and cultivation of Haryana is under danger because of fumble of water and land assets. Excessive water system and faulty editing designs have made a huge segment of land fruitless and unsuitable for agriculture reason. Because of overabundance water system and helpless characteristic seepage of water, the low lying lands are turning out to be waterlogged.

The study area is in parched and semi-desertic areas, where surface water, groundwater, or both are used to supplement the water system. Surface water was moved over long distances and spread to ranchers' fields using an unlined irrigation scheme during the early stages of its presentation. The groundwater body was energized by continuing with drainage and permeation through the essential/optional/tertiary phases of the water system framework. Even after being covered, the water system's framework has not improved significantly and leakage problems still exist. Ineffective land leveling, ineffective water application policies and informal water infrastructure practices all contribute to the problem of rising water tables. Groundwater production for water systems is limited due to the poor content of groundwater. As a result, the groundwater recharge has outpaced the release, causing hydrological irregularities and an increase in the water level in these regions. The ascent of water table has following impacts:-

1. The groundwater's salt content rises, indicating a moderately deeper encompassing water table.
2. Rising groundwater transports salts from lower soil layers to the surface or surface layers, which is a fine marvel.
3. As the water level rises, the natural seepage is limited and salt filtering is disrupted.

Around half of the state is affected by the rising water level. In certain places, the water table has hit the ground floor, creating severe waterlogging. The salt fixation in waterlogged areas is increasingly expanding as the region sinks into bone-dry and semi-dry locales with strong dissolution demands. Trench water has a salt centralization of 0.3-0.4 dS/m-1. The salts available in the soil profile are compounded by use of this water in the field without adequate drainage. When salt builds up in the root layer, the soil gradually becomes salt-affected. The harvest yield in such regions is imperceptibly reduced in the preceding years, but has a significant effect in the succeeding years, rendering them completely inefficient. The fundamental driver of soil salinity improvement is:-

i) Evidence related to salts on soil exterior because of upper water table.

ii) Seepage from water system/transport and relevance framework.

iii) Poor waste (surface or sub-surface) in the zone.

iv) Utilize of low excellence water system water.

v) Arid and Semi-parched atmosphere.

vi) Topographic melancholy.

vii) Geo-hydrological conditions.

Every one of these elements, either exclusively or in blend with different components, assumes a critical function in the advancement of salinity. However, basically, the water system prepares and geo-hydrology of the territory is liable for waterlogging and expansion in salinity of soil in enormous pieces of the Haryana. This cycle of auxiliary soil salinity is as aged as watered cultivation.

3.7 Summary

Waterlogged land is low-lying land with water adjacent to the surface for mainly of the year. Waterlogged and soil salinity are described by the National Commission of Agriculture (1976) and the Ministry of Water Resources as areas where the water table is under 2 meters of the ground. Globally, soil salinization affects practically all land masses. The amount of salt fixed in soils depends on a variety of conditions, including soil surface, plant development, water system, water pressure-driven conductivity, and water system framework. Ultimately, a salinity mapping and control strategy should be a part of every task, including the use of salinized water for irrigation and other purposes. A salinity-monitoring plan must be established in agricultural homesteads to track salinity shifts in the root zone, especially.

The research employed two seasons of satellite data from LISS-IV, LISS-III, and Sentinel to produce a variety of thematic maps, such as maps of salt affected areas and waterlogged areas. After this, total 24 soil samples from 12 various locations of salt affected area were taken from different depths i.e. from 0-15 and 15-30 cm. Mostly saline area are found near canal and drains. The total area affected by salt is 6.31 sq. km., including 23.45% sodic soil, 21.24% salinity, and 55.31% saline-sodic soil. Seasonally flooded areas account for approximately 12.20 sq km (0.18 percent) of the research area's geographical area, whereas permanently waterlogged areas account for 8.10 sq km (0.12 percent).

CHAPTER- 4
EVALUATION OF SOIL AND WATER RESOURCES

4.1 Evaluation of Soil Resources

The ability of the soil for most favourable utilization that is to obtain highest profit with minimal degradation—is assessed using a classification system called land evaluation. According to Van Diepen et al. (1991), this can be described as "any strategy to explain or predict the use potential of land." Because various types of soil have vastly diverse qualities, their responses to various uses vary. Land progression is founded on the premise that reaction was a result of all features, and that by understanding these properties, we could expect how the soil would behave in a given situation. From the assessment of such features, different degrees of soil appropriateness for each goal can be derived. These degrees are reflected on maps of use capacity or suitability, which are used to make suggestions for smart soil use planning. Because it is intended to provide practical results that can be plotted on territorial maps, land evaluation cannot be limited to the analysis of the physical medium of the earth; rather, it must be complemented by corresponding socio-economic studies that enable cost-benefit analyses of the profitability of the land used. As a result, land appraisal can predict the biophysical and economic behaviour of land for current and future uses.

The research area's irrigated agriculture's long-term viability is endangered by salinization of soil and water supplies. Seepage from unlined canals, insufficient surface and subsurface drainage, poor water management, and cultural practises like saline water irrigation are all contributing to these problems. The most salt-affected area is found in various irrigated areas, resulting in average output decreases as well as economic losses. Salinity and water logging are not just agricultural difficulties; they also affect the state as a whole, as well as society's social fabric and farmers. Communities with salt-prone land and water resources have serious social and economic effects, resulting in poor living circumstances. The local population has been compelled to quit their lands and migrate to other locations in order to make a life. Details of various thematic maps discussed in present chaper are presented in Figure 4.1.

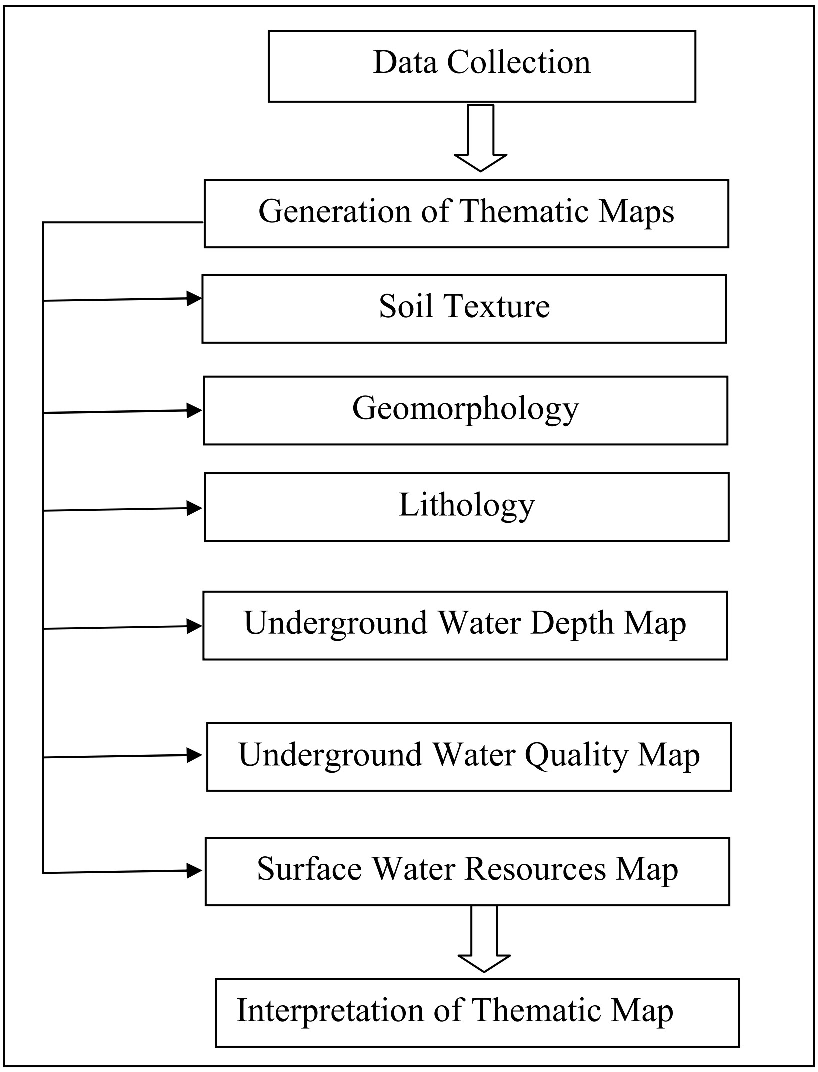


Figure 4.1 (Methodology of soil and water resourcres mapping)

4.1.1 Soil Texture

The texture of the soil is a significant factor in crop development and field management. A soil's textural class is measured by the percentages of silt, sand and clay. A soil texture map of the north western Haryana was prepared by analyzing the soil samples collected at 0-15cm & 15-30 cm depth from different physiographic units. It was found that various soil texture family classes like Fine loamy, Sandy, Fine and Coarse loamy. The fine loamy class occupies 5125.28 sq km or 76.58 percent of the study area's overall geographical area. The coarse loamy class encompasses 108.20 square kilometres or 1.62 percent of the study area. Mainly fine loamy class is distributed in whole of the study area and fine texture class was observed in Ghaggar river belt area. The second highest type is sandy, which occupies 686.44 square kilometres or 10.26% of the total area. This class is spread across the sample area. Fine is the third largest class, occupying 597.09 square kilometres or 8.92 percent of the sample area. Figure 4.2 indicates the spatial distribution of soil texture, while Table 4.1 shows the region under various classes of soil texture.

Table 4.1 Areal extent of soil texture classes

Soil Texture class	Area in sq km	Percentage to TGA
Coarse Loamy	108.2	1.62
Fine	597.09	8.92
Fine Loamy	5125.28	76.58
Habitation	158.56	2.37
Sandy	686.44	10.26
Waterbody Mask	16.87	0.25
Total	6692.44	100.00

Heavy textured salt-affected soil with substantial percentages of clay is difficult to rehabilitate due to the issues connected with water movement throughout the soil profile. Clay-rich soils can be found in the vicinity of the villages of Rajaband, Bhuthan Khurd, Malhar, Majra, and Fatehabad. If the clay fraction is dominated by swelling type clay mineral, in addition to high clay content, leaching of salt-prone soils is difficult. When water is used to leach clay minerals, they inflate quickly and damage macro pores, lowering the soil's hydraulic conductivity. Increasing the Ca (Calcium) concentration in the leaching water reduced swelling while simultaneously controlling clay particle dispersion and migration throughout the leaching process. Salinity, alkalinity, and waterlogging are major problems in the area due to the combined effects of climatic conditions, fine-textured soils, shallow water table, high salt concentration in groundwater, irrigation with highly saline water, inadequate drainage facilities, excessive and uncontrolled irrigation practices, windborne salt, and destruction of the native vegetation cover. Salt is carried in the drainage water from irrigated fields. As a result, proper drainage effluent disposal or reuse is critical for the long-term practicality of irrigated agriculture in the study area's arid and semi-arid regions.

4.2 Geomorphological & Lithological Studies

Geomorphology exercises tremendous control on the ground water regime. Relief, slope, weathering depth, type of weathered material, deposit thickness, deposit composition and the overall assemblage of various land types all play a role in determining the ground water regime, particularly in hard rocks and unconsolidated sediments.

Satellite images with their synoptic view facilitate better appreciation of geomorphology and help on identification and mapping of different land forms and their assemblage. Conventionally the relief information is taken from the satellite data & topographic map and the origin of land form and their material content are studied through field surveys. This is uninterestingly and time consuming exercise as it involves intensive field work. The imagery in combination with topographic maps and limited field checks at appropriate places help in accurate geomorphic analysis and mapping of landforms. While satellite multispectral data gives morphographic and morphometric detail of different land forms, the multi season temporal data provides information on time variant features that indirectly indicate the origin, composition and material content of these land forms.

Thus, with the aid of satellite imagery, a large number of erosional and depositional landforms can be identified and grouped into different types like fluvial, deltaic, marine, glacial, aeolian etc.

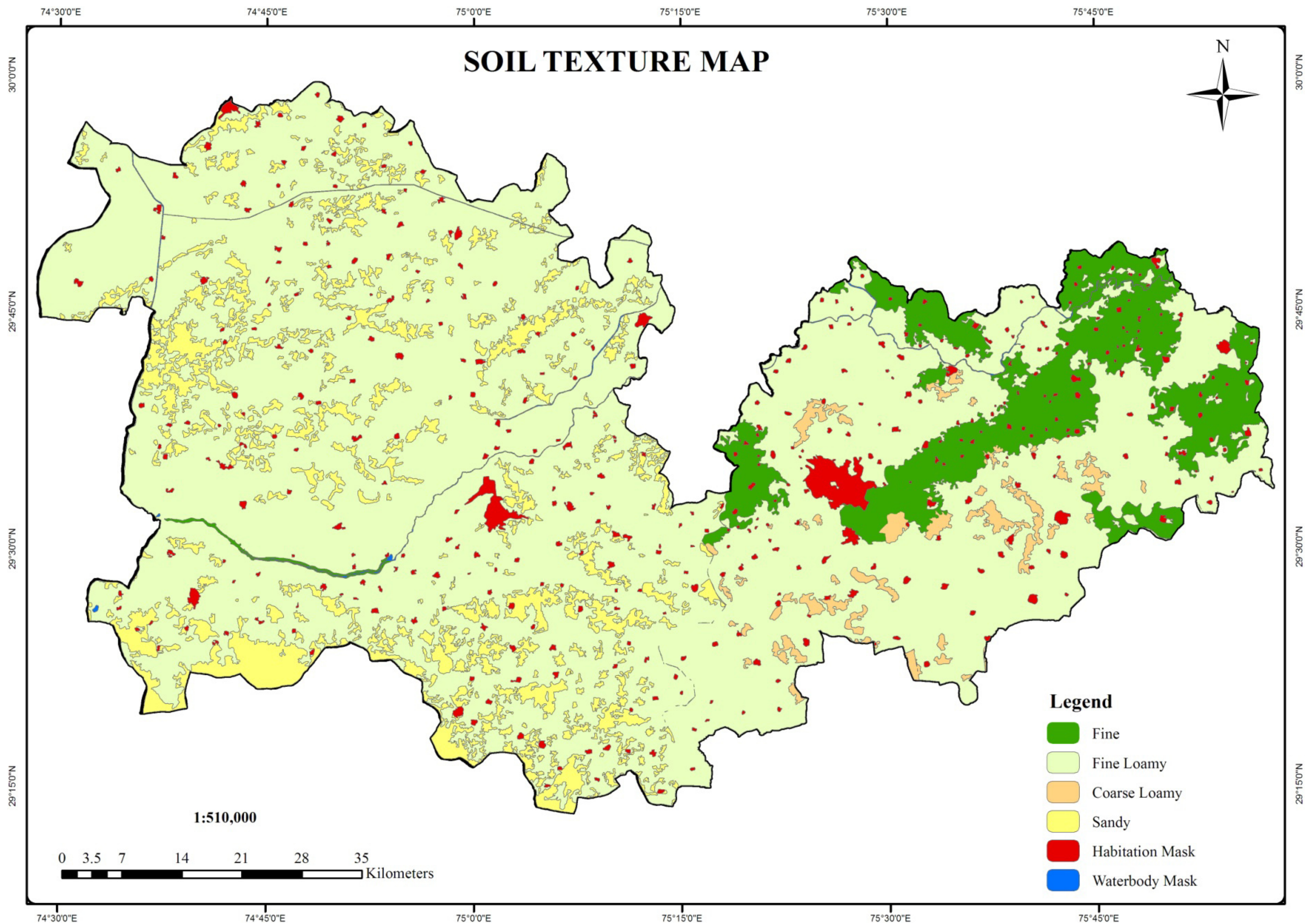


Figure 4.2 (Source: Haryana Space Applications Centre, Hisar)

Based on their genesis and characteristics, the region has been geomorphologically divided into four major units. They are largely fluvial in nature. Alluvial plain older deep, aeolian plain deeper, sand dune & dune complex are the geomorphological units mapped. The geomorphological & lithological maps of the study area have been exposed in Figure 4.3 & Figure 4.4 correspondingly. Geographical areas under different geomorphic units are given in Table 4.2 and lithological unit with their respective area is presented in Table 4.3. The landforms occurring in the study area under each of the geomorphic unit are stated below.

4.2.1 Alluvial Plain Younger Deep

About 4297.76 sq. km area of the study area is sheltered by flood plain younger deep, which is a division of the great Indo-Gangetic alluvium. Clay, silt and fine to coarse sand make up these flat or softly undulating plains. It comprises of gently sloping plain, nearly level plain and some scattered patchy depression. Medium to fine textured sandy soils make up the majority of this landform. Since the soil is rich and there are adequate irrigation facilities (Canal and Tube wells), these have been used extensively for a long time. This area constitutes about 64.22% of the total area.

4.2.2 Aeolian Plain Deep

These landforms are formed due to aeolian sand deposits. This class is found in southern part of study area. About 1067.84 sq.km area of the study area is covered by aeolian plain deep that is 15.96% of study area.

4.2.3 Dune complex

Dunes can also be comprised of smaller dunes of different types called complex dunes. Soils in this unit are excessively drained and have rapid permeability at some laces. These dunes are susceptible to wind erosion. This class covered 407.77 sq. km area that is 6.09 % of study area. Small patches of this class are scattered in whole study area.

4.2.4 Palaeochannels

Palaeochannels are the remnants of a once-active river or stream channel that has now been filled or buried by newer sediment. Unconsolidated, semi-consolidated, consolidated or lithified sediments can be cut into or submerged by the ancient channel.

These area were highly cultivated due to high nutrient availability and high irrigated agricultural practices. 513.73 sq. km area is covered that is 7.68 % of study area.

Table 4.2 Geomorphic units with their respective areas

Geomorphic unit	Area in sq km	Percentage to TGA
Alluvial Plain Older-Deep (Thickness >20m)	7.36	0.11
Alluvial Plain Younger-Deep (Thickness>20m)	4297.76	64.22
Dune Complex	407.77	6.09
Aeolian Plain Deep	1067.84	15.96
Flood Plain Deep (Thickness >20m)	169.67	2.54
Palaeochannel	513.73	7.68
Pediment	81	1.21
Stabilised Sand Dunes	147.31	2.20
Grand Total	6692.44	100.00

Table 4.3 Lithological units with their respective areas

Lithology Classes	Area in sq km	Percentage to TGA
Grey, Fine to Coarse Grained Sand with Pebble and Clay-Channel Alluvium-Newer Alluvium-Holocene	169.00	2.53
Loose Brown Fine Sand with minor Silt-Aeolian Deposit-Holocene	1703.62	25.46
Polycyclic Sequence of Sand, Silt, Clay with Kakar-Ambala Alluvium-Older Alluvium-Quaternary	4819.82	72.02
Grand Total	6692.44	100.00

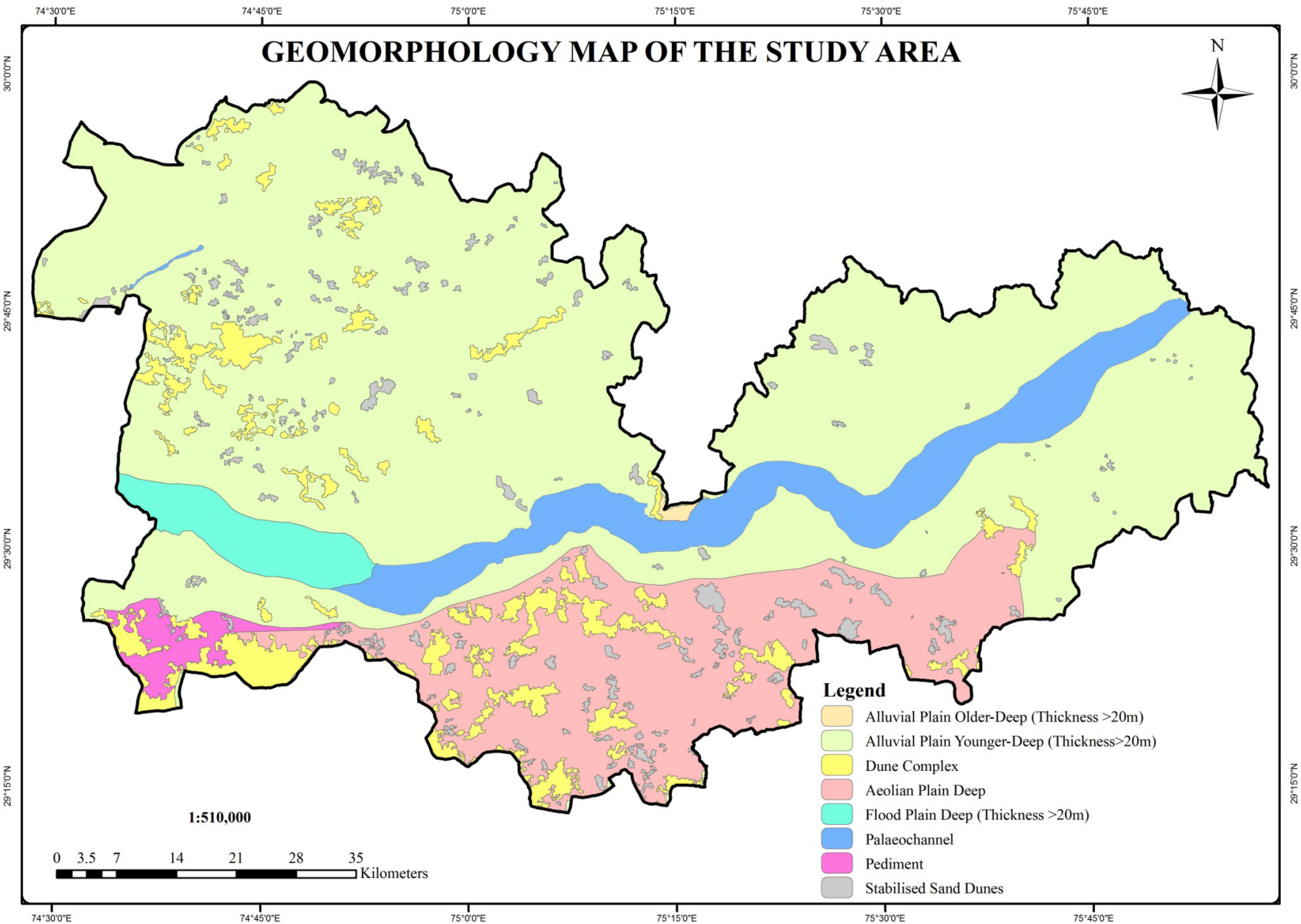


Figure 4.3 (Source: Haryana Space Applications Centre, Hisar)

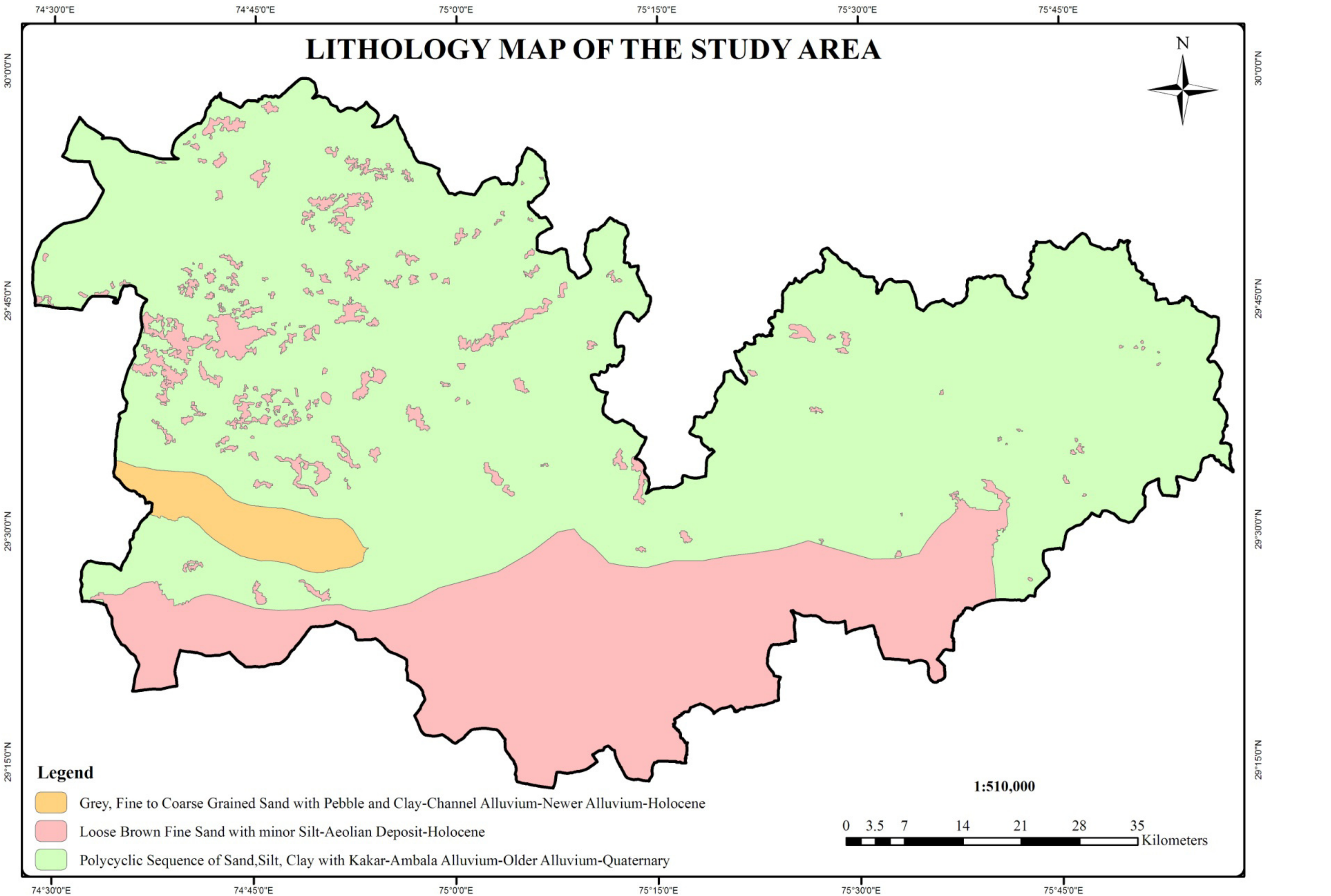


Figure 4.4 (Source: Haryana Space Applications Centre, Hisar)

4.3 Analysis of Underground Water Quality

There are three types of salinity in groundwater: (i) Natural/primary salinity is created by the breakdown of minerals from bedrocks (e.g. halite, anhydrite, carbonates, gypsum, fluoride-salts, and sulphate-salts) or the accumulation of salts from rainfall over time., and (ii) dry land/secondary salinity is created by rising water levels, which bring salt to the surface, or by clearing vegetation, which causes salt to accumulate in the soil. The salts are percolated down in heavy rainfall areas, while they remain on the surface in arid and semi-arid areas (iii) tertiary/irrigated salinity, which is created by salts stay after evaporation and accumulate over time as a result of repeated water irrigations. With rains, these stored salts leach down to the groundwater.

Soil salinization is the mainly noticeable risks to land desertification, and it occurs frequently in drought-prone locations. Soil evaporation is high, and surface water contains salts with a high solubility. Regional water and salt movements driven by climate, terrain, hydrogeology, and inappropriate human causes have resulted in these situations.

A high EC value indicates a high level of salinity. As a result, EC is regarded as a critical water quality criterion in the evaluation of both drinking and irrigation water. The EC is a commonly used indicator for salinity, and it has also been used to define water as medium, low, or high saline.

Water in the saturation region that is isolated from the earth's crust by a permeable aeration zone is referred to as underground water. The groundwater quality investigation in the study area included laboratory analysis of water samples. Total 291 water samples were collected from different locations of the study area by Central Ground water Board. These water samples of underground wells, tube wells & hand pumps were collected along with their GPS locations and analyzed for their chemical properties like EC (dS/m), pH, Ca^{+} ,Mg (me/L), Fe, F,No_3 Cl, So_4, HCO_3 (me/L) and Residual Sodium Carbonate (RSC) in the laboratory. The location sites of water samples are shown in Figure 4.6. The water samples with their chemical properties are given in Table 4.5.

Based on chemical properties of the collected water samples from Central Ground Water Board, the water quality maps were generated in Arc GIS as shown in Figure 4.7 (EC based). The samples were clubbed into four classes based on their Electrical Conductivity (E.C.) as 0-2000µS/m, 2001-4000µS/m, 4001-6000 µS/m and > 6000 µS/m. It was found that maximum area is covered by class 0-2000 that is 3629.65 square kilometers that is 54.24% of total region. Other major class is 2000-4000 that covers 2093.18 square kilometers area that is 31.28% of the study area while the classes 4001-6000 & > 6000 cover an area of 776.39 & 193.23 sq. km, respectively as shown in Table 4.4. Methodology adopted for collection and analysis of water samples is presented through methodology flow chart at Figure 4.5.

Table 4.4 Area under different classes of water quality based on EC

Electrical Conductivity (µS/m)	Area in sq km	Percentage to TGA
0-2000	3629.65	54.24
2001-4000	2093.18	31.28
4001-6000	776.39	11.60
>6000	193.23	2.89
Total	6692.44	100.00

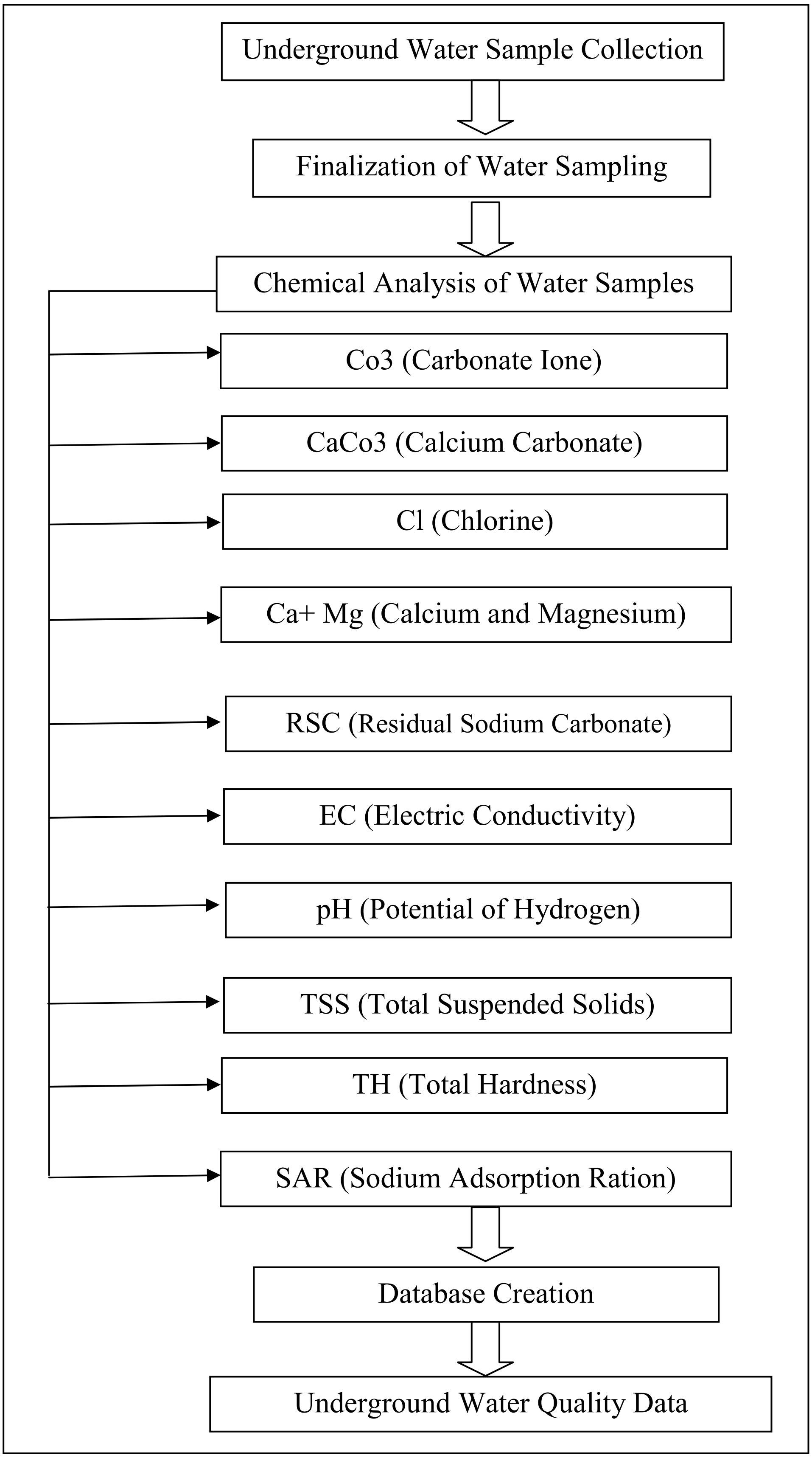


Figure 4.5 (Methodology Flow Chart for Water Sample Analysis)

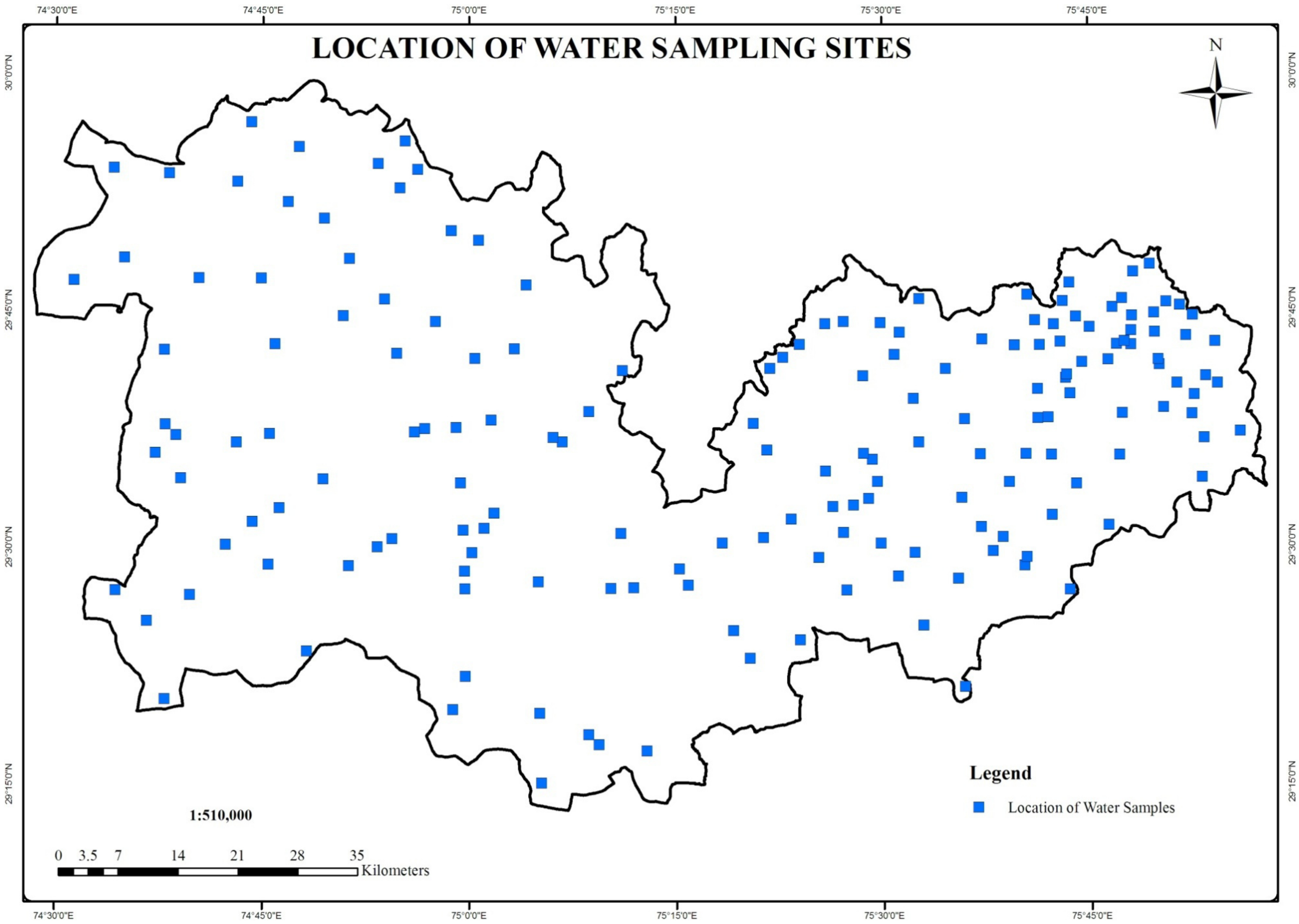

74°30'0"E
74°45'0"E
75°0'0"E
75°15'0"E
75°30'0"E
75°45'0"E
30°0'0"N
29°45'0"N
29°30'0"N
29°15'0"N
LOCATION OF WATER SAMPLING SITES
N
Legend
Location of Water Samples
1:510,000
0 3.5 7 14 21 28 35
Kilometers

Figure 4.6

Table 4.5 Chemical properties of ground water along with village location

Sr. No	Name of Village	CO3	HCO3	Cl	Ca +Mg	RSC	EC	pH	TSS	TH	SAR
1	Aboobshaher	1	8	28	13		6200	8	3968	625	20
2	Aharwan	0	10.0	4.0	6.0	4.0	850	7.4	544	300	1.44
3	Ahmadpur	2	5	4	4	4	1500	8	960	175	-
4	Akanwali	1.0	4.0	3.0	8.0	0	610	8.5	390	400	-
5	Alikan	1	10	6	5	6	1600	8	1024	270	6
6	Allalwas	0	4.0	2.0	4.0	0	260	8.5	166	200	-
7	Amani	3.0	8.0	10.0	4.0	7.0	2950	8.0	1888	200	18.03
8	Amritsar Kalan	1	7	3	6	2	800	8	512	295	1
9	Anandgarh	2	6	60	25		8200	8	5248	1250	16
10	Arnianwali	1	8	24	9	0	2600	8	1664	450	8
11	Badopal	1.6	4.0	44.0	38.0	0	6550	8.3	4192	1900	6.30
12	Bahardeen	1	7	3	8	1	900	8	576	385	-
13	Bahia	1	5	4	4	2	1000	9	640	195	4
14	Bajalpur	0	5.0	4.0	8.0	0	600	8.3	384	400	-
15	Bakarainwali	1	6	4	6	2	1100	8	704	280	-
16	Balasar	1	7	18	15		4400	8	2816	755	11
17	Baliwala	0	24.0	16.0	12.0	12.0	3150	7.8	2016	600	7.96
18	Bangon	0.6	6.0	3.0	13.0	0	1660	7.9	1062	650	1.41
19	Banwali	0	20.0	248.0	14.0	6.0	14700	8.0	9408.0	700	50.26
20	Bappan	1	12	7	10	2	1700	8	1088	510	3
21	Baragudda	1	6	36	25		5500	8	3520	1250	8
22	Barasari		12	5	10	2	1900	8	1216	520	-
23	Bawan	0	6.0	24.0	13.0	0	4360	7.7	2790	650	12.0
24	Beharwala	2	22	17	22	2	3600	8	2304	1115	4
25	Bhagsar		4	12	32		3500	8	2240	1620	-
26	Bhambhur	2	7	6	3	6	1300	8	832	145	-
27	Bhangu	1	9	26	14		4800	8	3072	720	13
28	Bharukhera	2	4	8	15		2100	8	1344	730	2
29	Bhattu	0	6.0	5.0	8.0	0	1000	7.8	640	400	1.0
30	Bhattu	2.2	4.0	5.0	8.0	0	1060	8.1	678	400	1.3
31	Bheithan kalan	1.4	15.0	11.0	6.0	10.4	5220	8.4	3340	300	26.67
32	Bhigher	1.2	10.0	10.0	10.0	1.2	2300	8.2	1472	500	5.81
33	Bhirdana	2.0	5.0	7.0	14.0	0	1480	7.8	947	700	0.30
34	Bhivan	2	22	62	30		9400	8	6016	1510	17
35	Bhoda khera	4.0	10.0	12.0	12.0	2.0	2550	8.3	1632	600	5.51
36	Bhuna	0.8	7.0	6.0	12.0	0	1400	8.0	896	600	0.81
37	Bhuna	1	4	22	11		4700	8	3008	560	15
38	Bhuratwala	2	20	16	13	9	3400	8	2176	635	8
39	Bidhai khera	1.0	2.0	9.0	4.0	0	2820	8.5	1804	200	17.11

40	Bijuwali	1	7	10	12		2500	8	1600	610	5
41	Bodia khera	0.6	7.0	4.0	8.0	0	1000	8.3	640	400	1.0
42	Bodiwali	0.6	3.0	16.0	10.0	0	2620	8.1	1676	500	7.24
43	Budanpura	1.0	6.0	2.0	7.0	0	540	7.8	345	350	-
44	Buraj Bhangu	1	5	9	10		2400	8	1536	510	6
45	Chadineal	1	9	4	13		1500	8	625	625	1
46	Chaharwala	1	7	6	12		1500	8	960	580	-
47	Chakkan	1	4	4	5	1	900	8	576	230	3
48	Chand	2	4	5	2	3	1600	8	1024	110	-
49	Chandpura	3.0	7.0	2.0	4.0	6.0	1000	8.3	640	200	4.24
50	Chattha	2	6	6	6	1	1500	8	960	315	5
51	Chautala	2	11	9	12	0	2500	8	1600	585	6
52	Chilkani Dhab	1	9	6	5	5	2000	8	1280	270	9
53	Chinder	Nil	8.0	304.0	216.0	0	18200	7.1	11648	10800	
54	Chobara	0.4	4.0	9.0	10.0	0	1530	7.7	979	500	2.37
55	Chormar	3	14	58	36		7100	8	4544	1790	8
56	Chukeria	2	8	6	6	4	1600	8	1024	290	6
57	Chuli kalan	0.2	6.0	46.0	28.0	0	6000	8.0	3840	1400	8.55
58	Chuli khurd	1.8	14.0	16.0	12.0	3.8	2680	7.8	1715	600	6.04
59	Chuli Bagrian	2.0	6.0	10.0	8.0	0	1670	8.4	1068	400	4.35
60	Dabwali	1	14	14	17		3000	8	1920	825	5
61	Dabwali	1	8	8	14		3800	8	2432	715	9
62	Dahman	2.0	8.0	12.0	10.0	0	2100	8.9	1344	500	4.91
63	Damdama	2	9	3	6	4	1200	8	768	320	3
64	Dangra	4.0	6.0	3.0	10.0	0	1280	8.7	819	500	1.25
65	Darba Rupana	1	7	23	13		3400	8	2176	670	8
66	Darewala	1	6	66	37		12000	8	7680	1835	19
67	Daryapur	0.6	9.0	21.0	26.0	0	2740	7.6	1753	1300	0.38
68	Dayar	1.0	2.0	22.0	34.0	0	5700	7.5	3648	1700	5.57
69	Desujodha		15	7	13	2	2200	8	1408	670	3
70	Desumalkana	2	10	10	9	2	2300	8	1472	450	7
71	Dhaban	1	8	12	9		3100	8	1984	440	11
72	Dhabi kalan	0.8	12.0	20.0	16.0	0	2700	7.7	1728	800	3.88
73	Dhabi khurd	0	8.0	6.0	12.0	0	1800	8.0	1152	600	2.44
74	Dhallu	2.0	22.0	8.0	10.0	14.0	3350	7.8	2144	500	10.50
75	Dhand	0.2	4.0	4.0	12.0	0	540	8.2	345	600	-
76	Dhanger	0.2	7.0	9.0	12.0	0	1460	7.3	934	600	1.06
77	Dhani Ayalaki	1.0	6.0	3.0	10.0	0	1220	8.1	780	500	0.98
78	Dhani Dhaka	0.4	4.0	4.0	7.0	0	1070	8.9	684	350	1.97
79	Dhani Jatan	1	5	21	16		5500	8	3520	775	14
80	DhaniGopal	0.4	2.0	18.0	11.0	0	3100	8.2	1984	550	8.52
81	Dhanoor	1	4	2	6		800	8	512	295	1

82	Dharampura	2	14	6	10	6	1700	8	1088	490	3
83	Dharnia	0.4	18.0	22.0	14.0	0	2980	8.0	1907	700	5.97
84	Dharseel	0	8.0	5.0	4.0	4.0	740	8.2	473	200	2.40
85	Dhing Thania	1	10	48	20		10000	8	6400	1020	-
86	Dhingsara	2.2	3.0	3.0	4.0	0.2	830	7.8	531	200	3.04
87	Dholpalia	1	5	61	60		13000	8	8320	3020	13
88	Dhudianwali	1	9	22	7	3	5000	8	3200	340	23
89	Ding	2	10	15	10	2	4600	8	2944	510	16
90	Dukara	1	5	6	20		3300	8	2112	1005	-
91	Dulat	1.6	4.0	17.0	18.0	0	2940	7.6	1881	900	3.8
92	Ellenabad	1	10	17	12		4200	8	2688	590	12
93	Faggu	1	4	34	23		6000	8	4480	1150	11
94	Farwai Kalan	1	8	3	8	2	1700	8	1088	165	-
95	Fatehabad Panchyat Bhawan	0.5	2.0	2.0	5.0	0	670	8.0	428	250	1.07
96	Fatehpure	0	11.0	14.0	16.0	0	2400	8.1	1536	800	2.82
97	Fatehpuria	1	9	11	11		2800	8	1792	530	8
98	Gadali	1	6	7	13		2200	8	1408	655	3
99	Gadli	1.0	2.0	4.0	22.0	0	2480	8.1	1587	100	0.84
100	Gadrana	1	5	22	13		3600	8	2304	655	9
101	Ganga	2	13	43	19		6600	8	4225	950	15
102	Ganga Rupana	1	6	24	34		4200	8	2688	1675	3
103	Ghaswa	0	8.0	4.0	10.0	0	1160	8.3	742	500	0.71
104	Ghoranwali	1	6	9	13		2100	8	1344	650	3
105	Gila khera	1.0	3.0	5.0	4.0	0	580	8.8	371	550	1.27
106	Gindar	1	19	10	6	13	3600	8	2304	310	13
107	Gindarkhera	1	4	2	7		800	8	512	335	-
108	Gobindgarh	2	14	67	44		11000	8	6400	2025	-
109	Goriwala	1	9	6	8	1	1600	8	1024	415	4
110	Gorkhpur	0	6.0	67.0	64.0	0	7850	7.2	5024	3200	2.56
111	Gosaiana		22	36	43		5100	8	3264	2160	-
112	Gudia Khera		7	7	8		1600	8	1024	390	-
113	Habuwana		12	77	70		11000	8	7040	3520	7
114	Hanjeera	1	4	6	7		1500	8	960	345	-
115	Hanspur	0	2.0	3.0	4.0	0	450	8.0	288	200	0.35
116	Hassu	2	7	12	9		2400	8	1536	455	7
117	Himatpura	3.0	10.0	3.0	8.0	5.0	1550	7.8	992	400	3.75
118	Hizawan kalan	0.5	4.0	3.0	6.0	0	800	8.2	512	300	1.15
119	Hizawan kalan	2.0	6.0	6.0	12.0	0	1200	7.9	768	600	-
120	Huckmanwali	4.5	6.0	18.0	4.0	6.5	4240	8.9	2713	200	27.15
121	Humaukhera	1	4	2	4	1	800	8	512	190	3
122	Indachhui	0	25.0	12.0	6.0	19.0	3160	7.7	2022	300	12.90
123	Jagjit Nagar	1	8	4	10		1500	8	960	475	3

124	Jagmalwali	2	9	5	4	6	1600	8	1024	215	8
125	Jakhal	2.0	2.0	2.0	7.0	0	360	8.1	230	350	-
126	Jalalana	2	9	10	7	3	2100	8	1344	370	7
127	Jamal		17	12	19		2900	8	1856	930	-
128	Jamalpura	0	7.0	3.0	6.0	1.0	760	8.3	486	300	0.92
129	Jandli kalan	0	6.0	12.0	16.0	0	1880	7.6	1203	1800	0.98
130	Jandli khurd	1.2	4.0	4.0	4.0	1.2	1200	7.8	768	200	5.65
131	Jandwala	1.0	4.0	20.0	42.0	0	3730	7.7	2387	2100	-
132	Jandwala	1	7	4	7	2	1400	8	896	325	4
133	Jandwala Jatan	2	8	7	6	3	1600	8	1024	295	6
134	Jhalnia	1.0	4.0	2.0	6.0	0	400	8.6	256	300	-
135	Jhiri	1	17	11	15	3	2700	8	1728	730	5
136	Jhorar Rohi	1	11	109	47		15000	8	9600	2350	21
137	Jiwan Nagar	1	9	3	6	5	1500	8	960	290	5
138	Jodhpuria	1	9	9	12		2600	8	1664	605	6
139	Jodian		23	88	69		1400	8	8960	3435	-
140	Jogiwala		7	7	5	2	1600	8	1024	265	-
141	Jogewala	1	4	3	4	1	600	8	384	215	1
142	Jutanwali	1	7	3	6	1	1000	8	640	310	2
143	Kagdana	1	16	11	17		2700	8	1728	865	-
144	Kajal heri	0.8	4.0	6.0	11.0	0	1000	8.0	640	550	-
145	Kalanwali	1	12	8	5	8	2000	8	1280	270	8
146	Kalnia	2	7	2	2	7	1200	8	768	75	-
147	Kaluwana	1	20	38	19	3	6700	8	4288	930	16
148	Kamal	2	7	3	3	6	900	8	576	170	4
149	Kamalwala	0	16.0	16.0	10.0	6.0	3000	7.6	1920	500	6.32
150	Kamana	0	4.0	4.0	4.0	0	1270	8.0	812	200	6.15
151	Kanganpur	1	8	2	6	3	800	8	512	295	-
152	Kanheri	0	24.0	30.0	8.0	16.0	4850	7.3	3104	400	20.25
153	Karainwali	1	10	9	7	4	2200	8	1408	350	8
154	Karam Sana	1	7	5	4	3	1000	8	640	215	4
155	Karandi	0	5.0	2.0	6.0	0	500	8.0	320	300	-
156	Kariwala	1	6	7	14		2200	8	1408	705	3
157	Kasikabas	1	25	28	17	9	6500	8	4160	850	16
158	Kasumbi	1	8	4	5	4	1200	8	768	265	-
159	Keharwala	1	7	7	7	1	1500	8	960	325	5
160	Kesupura	1	7	4	7	1	1700	8	1088	370	5
161	Kewal	3	12	13	9	5	2200	8	1408	465	6
162	Khabra kalan	0.2	6.0	4.0	8.0	0	1310	8.5	844	400	2.55
163	Khairi	0.2	2.0	2.0	6.0	0	460	8.7	294	300	-
164	Khaishergarh	1	9	6	8	2	1400	8	896	405	3
165	Khara kheri	0.6	6.0	32.0	34.0	0	4970	7.6	3180	1700	3.80

166	Kharati khera	0.2	18.0	6.0	18.0	0.2	2000	7.4	1280	900	0.66
167	Khari Sureran	1	8	5	7	1	1200	8	768	360	3
168	Kharian	2	27	49	13	16	7000	8	4480	650	22
169	Kheowali	1	5	4	3	3	1200	8	768	135	8
170	Khuian Malkana		13	11	10	4	2600	8	1664	475	8
171	Khuian Nepalpur	2	7	5	6	3	1000	8	640	290	2
172	Kirdhan	1.4	6.0	9.0	14.0	0	1880	8.6	1203	700	1.81
173	Kotali	1	7	3	8	1	900	8	576	140	-
174	Kotali	2	9	7	8	3	2500	8	1600	400	9
175	Kukarthana	1	11	12	11	2	3600	8	2304	535	11
176	Kumber	0	4.0	3.0	6.0	0	2890	7.7	1849	300	13.22
177	Kumharia		28	17	17	11	4500	8	2880	865	-
178	Kurngawali	3	13	37	19		4100	8	2624	945	7
179	Kutana		7	3	6	2	1000	8	640	285	-
180	Lahrian	1.0	4.0	4.0	10.0	0	800	8.1	512	500	-
181	Lali	0	5.0	3.0	6.0	0	740	8.2	473	300	0.80
182	Lambi	1	12	16	6	6	1100	8	704	320	3
183	Lehangewala	2	7	3	8	0	1200	8	576	410	-
184	Lohgarh	1	8	4	4	4	1600	8	1024	215	8
185	Ludesar	1	11	28	28		5000	8	3200	1410	-
186	Madhosinghna	2	6	5	5	2	1000	8	640	260	3
187	Makha	2	8	8	6	4	2000	8	1280	285	9
188	Makhosarani	1	5	15	22		3400	8	1095	1095	4
189	Malaheri	0	12.0	10.0	3.0	9.0	2500	8.0	1600	150	17.96
190	Malewala	2	7	6	7	2	1300	8	832	360	3
191	Malikpura	1	5	23	12		4200	8	2688	580	13
192	Mamarkhera	1	6	43	29		8000	8	5120	1470	13
193	Manawali	1.4	6.0	18.0	12.0	0	4040	7.9	2585	600	11.59
194	Mangala	2	5	3	3	4	1000	8	640	170	-
195	Mangeiana	1	28	24	24	5	4800	8	3072	1185	7
196	Manju Khera	1	7	2	7	2	800	8	512	325	-
197	Manmandori	1.0	2.0	2.0	8.0	0	1030	8.2	659	400	1.15
198	Matana	0	15.0	10.0	8.0	7.0	2080	7.5	1331	400	6.4
199	Matar	5	19	4	6	17	1500	8	960	305	5
200	Math Dadu	1	20	45	33		8500	8	5440	1530	13
201	Matuwala	1	7	20	10		4300	8	2752	475	15
202	Maujgarh	1	8	3	5	4	1000	8	640	230	4
203	Meerpur	2	6	3	6	2	1300	8	832	295	4
204	Mehanakhera	1	8	24	17		4300	8	2752	855	9
205	Mehuwala	0.2	2.0	2.0	6.0	0	870	8.2	556	300	1.55
206	Mithi Sureran	1	9	7	3	7	1500	8	960	165	1
207	Mithri	1	44	22	17	29	3700	8	2368	835	7

208	Mochiwali	0	8.0	32.0	32.0	0	3850	7.5	2464	1600	1.62
209	Modi	1	8	5	10		1700	8	1088	480	3
210	Modiakhera	2	6	8	7	1	2200	8	1408	335	-
211	Mohamadpur Rohi	1.5	3.0	2.0	8.0	0	760	8.1	486	400	-
212	Moju Khera	2	10	5	5	6	2200	8	1408	270	10
213	Momandpur Sotar	0.6	4.0	2.0	8.0	0	640	8.1	409	400	-
214	Moujdeen	1	6	3	7	0	1000	8	640	335	2
215	Musahibwala	1	5	3	6		1000	8	640	150	-
216	Musakhera	0	7.0	2.0	6.0	1.0	840	7.7	537	300	1.38
217	Nadhari	0.4	4.0	2.0	2.0	9.4	660	8.0	422	100	4.6
218	Nagoki	2	8	23	12		3200	8	2048	605	8
219	Nahrana	1	5	2	11		1500	8	960	540	-
220	Nanakpur	2	6	3	4	4	1400	8	896	195	-
221	Nangala	4.0	8.0	10.0	16.0	0	2350	7.9	1504	800	2.65
222	Nanuana	2	35	49	16	21	12000	8	7680	815	36
223	Narail Khera	1	8	3	7	2	1000	8	640	340	-
224	Narel	2.0	8.0	4.0	8.0	2.0	780	8.4	499	400	-
225	Nathor	1	5	7	9		2000	8	1280	435	5
226	Nathusari Chopta		7	57	66		10000	8	6400	3295	
227	Neemla	1	12	23	25		6000	8	3840	1225	10
228	Nejia	2	8	21	14		5100	8	3264	675	-
229	Neju Dela Kalan	1	5	9	19		2600	8	1664	440	-
230	Nirban	1	7	40	11		2400	8	1536	555	-
231	Nirwana	2.0	6.0	6.0	4.0	4.0	810	9.2	518	200	2.89
232	Odhan	2	5	15	8		3100	8	1984	385	12
233	Odhan	1	3	3	4	1	700	8	448	180	3
234	Ottu	1	5	3	4	2	1000	8	640	190	5
235	Panihari	1	9	5	11		1600	8	1024	235	-
236	Paniwala Morika	1	6	3	6	1	800	8	512	300	1
237	Paniwala Mota	2	11	15	8	4	2400	8	1536	410	8
238	Paniwala Ruldu	1	6	4	7	0	1000	8	640	330	2
239	Panjuana	2	5	5	6	1	1100	8	704	290	3
240	Peerkhera	1	8	71	49		12000	8	7680	2460	14
241	Pili mandori	6.0	4.0	9.0	22.0	0	2920	8.0	1868	1100	2.17
242	Poharkan	2	12	5	1	13	2000	8	1280	65	23
243	Ram Nagar	2	12	61	18		7500	8	4800	915	19
244	Ramgarh	1	7	42	32		6400	8	4096	1620	8
245	Rampura	1	6	23	24		4700	8	3008	1205	7
246	Rampuria	1	20	86	47		11000	8	7040	2355	-
247	Ramsara	0	6.0	6.0	6.0	0	980	7.9	627	300	2.19
248	Randhanoa	1	10	4	10	2	1400	8	896	500	2
249	Rania	1	6	13	6	0	1000	8	640	315	2

250	Rasulpur	1	4	4	5		900	8	576	175	-
251	Ratta khera	0	8.0	4.0	18.0	0	1740	8.0	1113	900	-
252	Rattia K.T College	2.0	6.0	4.0	6.0	2.0	890	8.6	5696	300	1.67
253	Rohi Ranwali	2	19	25	8	13	3700	8	2368	410	14
254	Rori	3	13	34	18		4800	8	3072	905	10
255	Sadewala	1	7	6	7	1	1500	8	960	360	2
256	Sahuwala	2	7	10	10		2000	8	1280	505	4
257	Sahuwala-II	1	7	5	5	2	1100	8	704	255	4
258	Sainpal	1	7	6	4	4	2000	8	1280	185	12
259	Sakta Khera	1	21	82	62		13000	8	8320	3080	12
260	Salam Khera	1	7	4	5	2	1200	8	768	270	4
261	Samain	0	6.0	16.0	16.0	0	2200	7.8	1408	800	2.12
262	Saniyana	2.0	26.0	24.0	8.0	20.0	4760	8.0	3046	400	19.8
263	Sawant Khera	1	11	18	14		3600	8	2304	695	8
264	Shankar Mandori	1	7	92	27		1200	8	7680	1370	25
265	Shekhupur Daroli	1.0	2.0	19.0	112.0	0	10900	9.0	8976	5600	-
266	Shergarh	1	9	3	3	7	1200	8	768	155	7
267	Sherpura	2	10	16	12		4000	8	2560	595	12
268	Sidani	0	11.0	3.0	4.0	7.0	950	8.4	608	200	3.88
269	Sikanderpur	1	7	3	6	2	900	8	576	310	-
270	Simbalwala	2.0	6.0	3.0	18.0	0	700	7.9	448	900	-
271	Singhpura	2	7	6	7	2	1500	8	960	355	4
272	Sirsa	1	9	4	7	4	1000	8	640	345	2
273	Suchan	1	7	2	7	2	800	8	512	335	-
274	Sukhchain	4	19	49	23		4400	8	2816	1170	6
275	Sukhera Khera	1	6	8	11		2700	8	1728	560	7
276	Suli khera	0.8	8.0	14.0	14.0	0	1920	8.7	1228	700	1.96
277	Suritia	2	6	6	7	1	1200	8	768	335	3
278	Tajiakhera	1	13	5	8	6	1900	8	375	375	6
279	Takhatmal	2	17	49	26		6000	8	3840	1305	9
280	Talwara	1.0	8.0	2.0	6.0	3.0	800	8.5	512	300	1.15
281	Talwara Khurd	4	5	6	3	6	1900	8	1216	160	13
282	Tarkanwali	1	3	12	19		3000	8	1920	945	-
283	Teja Khera	1	7	8	8		1900	8	1216	420	5
284	Thiraj	2	9	28	14		3500	8	2240	715	8
285	Thobrian	2	10	6	8	3	1900	8	1216	415	5
286	Thuiyan	0	8.0	22.0	14.0	0	2180	7.6	1395	700	2.94
287	Tigri	2	24	19	9	16	2000	8	1280	820	1
288	Tilokewala	1	5	9	9		1600	8	1024	450	3
289	Titu Khera	1	6	5	4	2	1800	8	1152	220	-
290	Tohana	2.0	11.0	8.0	9.0	4.0	2000	8.1	1280	450	5.18
291	Vaidneala	1	6	2	3	3	700	8	448	120	-

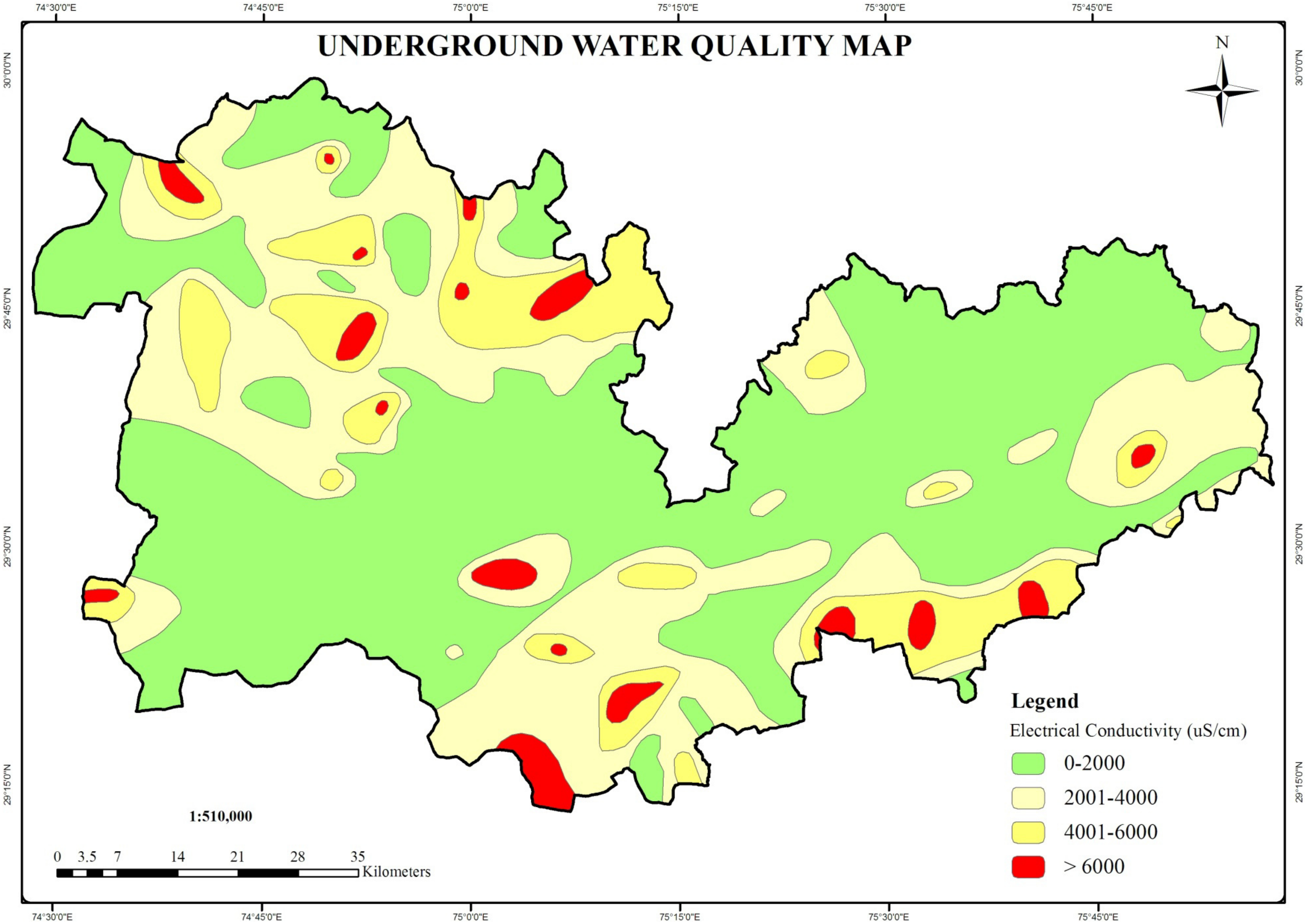


Figure 4.7 (Source: Central Goround Water Board)

All of the water samples were divided into four groups: less than 2000 uS/cm, 2000-4000 uS/cm, 4000-6000 uS/cm, and more than 6000 uS/cm. 53.95 percent (157 samples) of measured water samples had EC values below 2000 uS/cm, 25.09 percent (74 samples) of water samples had EC values between 2000-4000 uS/cm, 15.12 percent (44 samples) of water samples had EC values between 4000-6000 uS/cm, and 5.84 percent (17 samples) of water samples had EC values above 6000 uS/cm. The average value of EC of water samples collected from the sudy area is shown in Figure 4.8. As a result, the majority of irrigation wells are small to moderate in size. The considerable increase in EC values of water due to the leaching or washing out of a large portion of the solutes in the soil. Due to salt leaching from the soil, the EC values of some of the wells increased throughout the post-monsoon period. There was no link found between cropping system and groundwater EC.

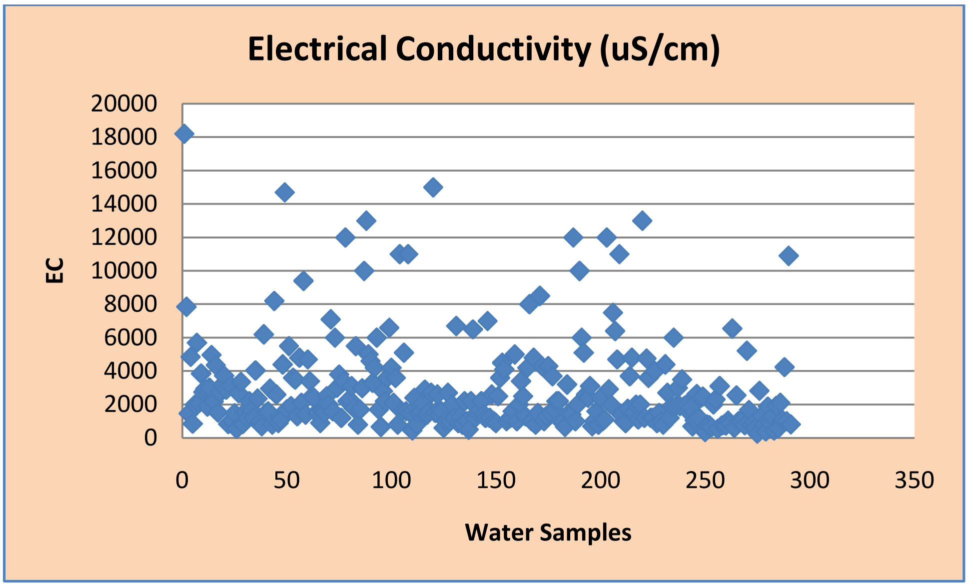


Figure 4.8

All of the water samples collected from diverse sites have different pH levels. The results ranged from 7.1 to 9.2, and none of the samples were appropriate for irrigation. The average pH value of all selected wells is shown in Figure 4.9. There was no link between pH and different cropping systems. The study's findings were backed up by chemical attributes of water samples based on pH. The pH range for irrigation water is usually between 6.5 and 8.4. All of the water samples analysed was unfit for irrigation, and cropping systems had a significant impact on pH.

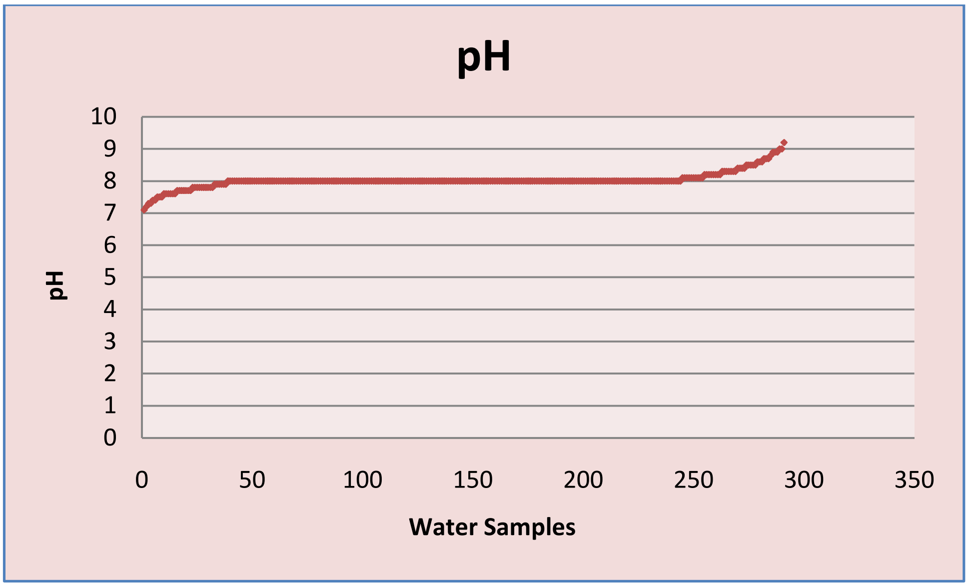


Figure 4.9

Salts can stay on the soil surface or on plant leaves after evaporation in all irrigation water, including sub-marginal, marginal, and saline water. As a result, any irrigation system in the study region has the potential to provide an increased amount of salt to the soil. Water may flow from the plant roots back into the soil if the quantity of salts in the soil water is too high. This causes the plant to become dehydrated, resulting in lower yields or possibly mortality.

Crop output declines can occur even if the effects of salinity aren't immediately obvious. Salt tolerance is determined by a crop's ability to extract water from salinized soils. Salinity has an impact on agricultural, pasture, and tree yield by interfering with nitrogen uptake, decreasing growth, and limiting plant reproduction.

4.4 Analysis of Underground Water Depth

The amount of water held in the earth is comparable to the amount of money in a bank account. If you withdraw money quicker than you deposit new money, you'll soon run out of money in your account. Pumping water out of the ground quicker than it is recharged poses comparable issues in the long run. Pumping causes the volume of groundwater in storage to decrease in several places of the study region. Continuous groundwater pumping is the primary cause of groundwater depletion. Due to overuse or exploitation, the groundwater table is steadily falling, and fresh water aquifers are converting to brackish water.

Ground water depth information has an important part to assessing the present landuse and suggesting alternate landuse for the area. The ground water depth was collected from Ground Water Cell, Haryana as shown in Figure 4.10. The map was scanned, digitized and used for integration. As per their criteria, it is categorized into six classes as shown in Table 4.6. It is obvious from the water table that about 40 percent of the study area falls under 3.01-10 M depth followed by 10.01-20 M. The depth which is considered critical and falls under waterlogged category is between 1-1.5m that covers an area of 196.15 sq. km. Maximum area having lowest water table class is found in southern region.

Table 4.6 Area under different classes of water depth

Under ground water depth (Depth in meter)	Area in sq km	Percentage to TGA
1.50-3.00	196.15	2.93
3.01-10.00	2509.79	37.50
10.01-20.00	2213.27	33.07
20.01-30.00	1211.99	18.11
30.01-40.00	371.54	5.55
>40	189.70	2.83
Total	6692.44	100.00

For many years, groundwater depletion has been a worry near hamlet Bhoda Hoshnak, Dhanger, and Ding on the Fatehabad-Sirsa district border, but rising demands on our groundwater resources have overstressed aquifers across the study area, not just in arid places (Figure 4.3). Furthermore, groundwater depletion happens at a variety of scales, from a single well to aquifer systems beneath many research areas. The extent of the effects is influenced by pumpage and natural discharge rates, aquifer physical features, and natural and human-induced recharge rates.

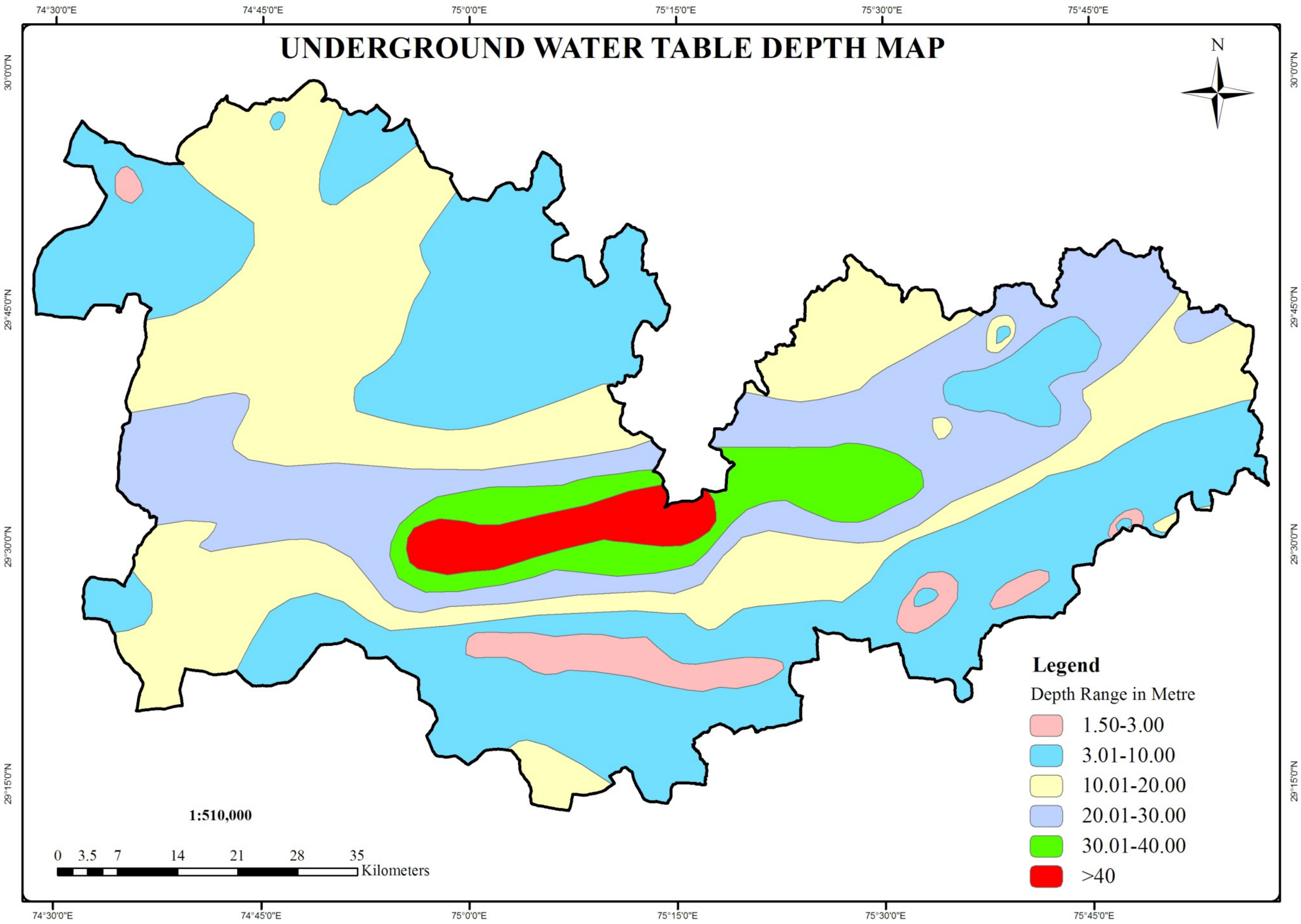


Figure 4.10 (Source: Central Goround Water Board)

4.5 Evaluation of Surface Water Resources

The study region of the Indo-Gangetic drainage basin is an alluvial plain. In both districts, there is no permanent river but the northern part of the district comes under the Ghagghar River Doab. For irrigation the study area was categories into five regions; namely Barani (low rain area where rainfed dry farming is trained), Bagar (dry sandy tract of land on the area of border of Rajasthan). Nahri (canal irrigated), Nalli (productive prairie tract) and Rangoi tract (irrigated by the Rangoi canal built for the reason of transportation flood waters of Ghagghar river to dry areas).

The study area also has a network of canals. Western Yamuna and Bhakra canals, with their distributors, minors and sub-minors, are two major canals that provide irrigation water in most of the area of north western Haryana. An area and water divide between old Drishdawati and Ghaggar are the surveyed topographical forms. The Chautang River (Drishdawati) region is wiped out and the Hansi branch of the Western Yamuna Canal is in use with its vast crammed channel course. A lot of seasonal streams overflow the neighbouring areas of the side broken up Ghaggar flood plain in the monsoon season. In almost all villages, a number of small natural ponds/tanks exist and these are essentially low-lying deviation areas and are used for bathing and drinking purposes for domestic animals. The rainwater feeds these ponds. Because of brackish underground water, the overall irrigated region in the study area is reached by canals. However, fresh under ground water and tube wells have the key foundation of irrigation in some regions of the study area. Details of surface water resources are displayed in Figure 4.11. The length of all existing canals in the study area is presented in Table 4.7.

Table 4.7 Length of canals

Canal Type	Length in Kilometers
Main Canal	402.61
Branch Canal	1366.01
Distributary Canal	677.62
Total	2446.24

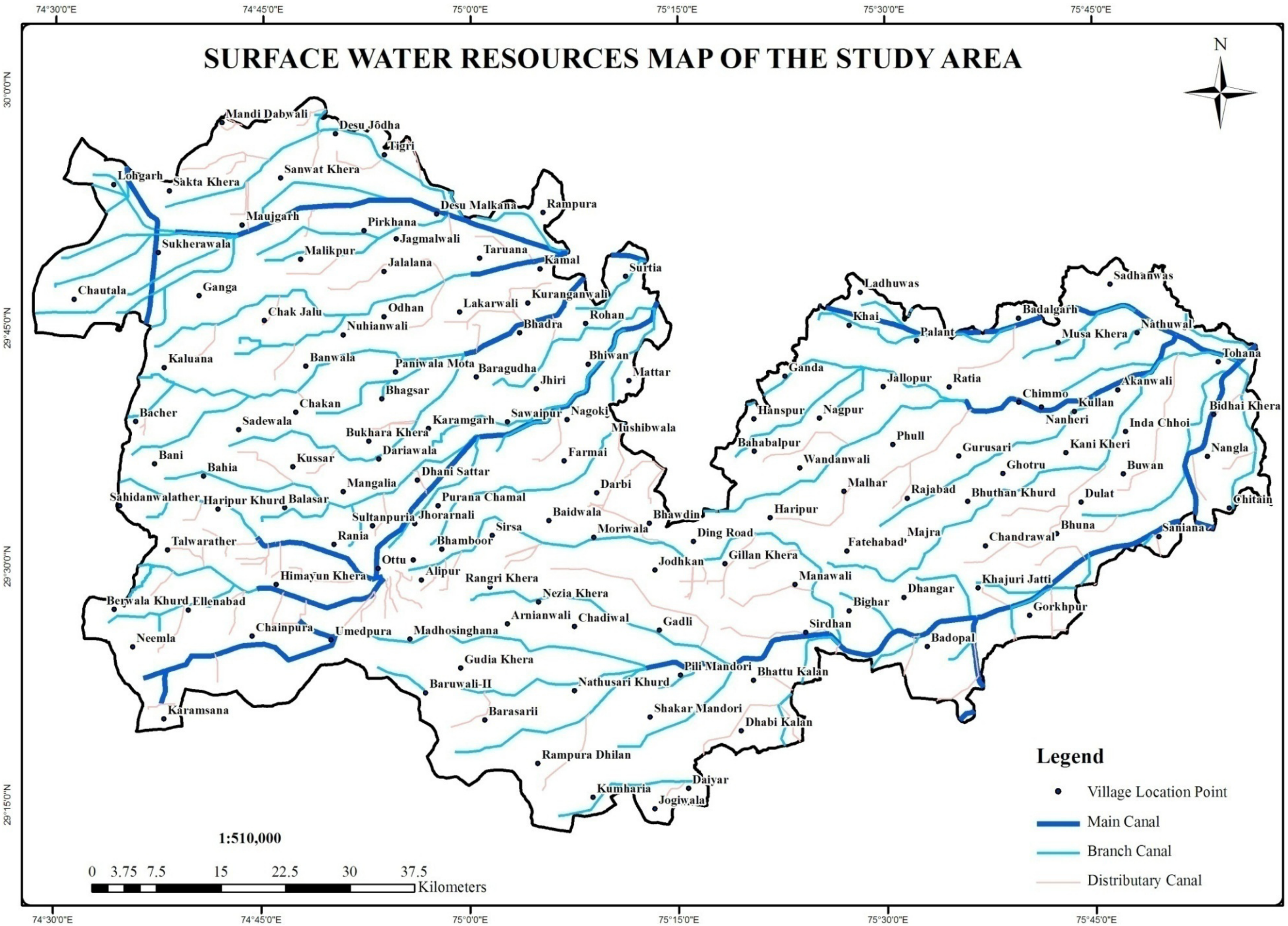


Figure 4.11 (Source: LISS III & LISS IV satellite data & SOI Toposheets)

4.6 Summary

Land or soil evaluation is a classification system that determines the soil's capability for optimal utilisation. By evaluating soil samples obtained at 0-15cm and 15-30cm depths from various physiographic units, a soil texture map of northwestern Haryana was created. The fine loamy class covers 5125.28 square kilometres, the coarse loamy class covers 108.20 square kilometres, and the sandy class covers 686.44 square kilometres of the research area. The fine loamy class is found across the research area, while the fine texture class was found in the Ghggar river belt area. The synoptic view provided by satellite pictures allows for a better understanding of geomorphology and aids in the identification and mapping of various land forms and their assembly. Traditionally, relief information is derived from satellite data and topographic maps, with field surveys used to investigate the origins of land forms and their material content. While multispectral satellite data provides morphographic and morphometric detail of various land forms, multiseason temporal data provides information on time variation features that indirectly reflect the land forms' genesis, composition, and material content.

The flood plain younger deep, which is a part of the massive Indo-Gangetic alluvium, protects around 4297.76 sq km of the study region. These flat or gently sloping plains are made up of clay, silt, and fine to coarse sand. The aeolian plain deep covers around 1067.84 sq km of the research area, accounting for 15.96 percent of the total area. Paleochannels in the studied region cover 407.77 sq km and 513.73 sq km, respectively, of small patches of sand dunes. The Central Ground Water Board collected 291 water samples from various places around the research area for the ground water quality investigation. These water samples from underground wells, tube wells, and hand pumps were gathered with GPS coordinates and evaluated in the lab for chemical parameters such as EC (dS/m), pH, Ca+,Mg (me/L), Fe, F,No3 Cl, So4, HCO3 (me/L), and Residual Sodium Carbonate (RSC).

Electrical Conductivity (E.C.) was used to group the samples into four categories: 0-2000S/m, 2001-4000S/m, 4001-6000S/m, and > 6000S/m. The largest area covered by class 0-2000 was found to be 3629.65 square kilometres, or 54.24 percent of the overall region. Other main classifications are 2000-4000, which covers 2093.18 square kilometres, or 31.28 percent of the study area, and 4001-6000 and > 6000, which cover 776.39 and 193.23 square kilometres, respectively. The ground water depth was obtained from the Ground Water Cell in Haryana, with approximately 40% of the research region falling between the 3.01-10 M depth range, followed by the 10.01-20 M range. The crucial depth, which falls under the waterlogged category, is between 1-1.5 metres, covering an area of 196.15 square kilometres. The study area was divided into five zones for irrigation: Barani, Bagar, Nahri, Nalli, and Rangoi tracts. The Western Yamuna and Bhakra canals, with with their distributors, minors, and sub-minors, provide irrigation water to the majority of the area.

CHAPTER 5
EVALUATION OF PRESENT LAND RESOURCES

5.1 Land utilization and Soil Salinty

Natural resource management, particularly land and water management, is critical for the long-term survival of all living things on the planet. Population pressure, urbanisation and industrialization have all put pressure on our natural resources, resulting in a decrease in agricultural land. Natural resources have been overexploited to meet the food, fibre, shelter, fuel, and fodder needs of an ever-increasing population, resulting in soil degradation and ecological imbalance. As a result, locating and restoring these degraded lands is vital if future demands of a growing population are to be met.

Excessive demand for land for agricultural and non-agricultural purposes has resulted in the creation of vast swaths of wasteland, including degraded land, soil salinity, water logging, desertification, soil erosion, and so on, as well as a reduction in per capita cultivable land and ecological imbalances. Natural resource management, particularly of land and water, is critical for the long-term survival of all living things on the planet. Increased population pressure, urbanisation, and industrialization have put a strain on our natural resources, resulting in less agricultural land. To meet the needs of an ever-increasing population for food, fibre, shelter, fuel, and fodder, natural resources have been overexploited, resulting in land degradation and ecological imbalance. As a result, identifying and reclaiming these degraded lands are critical in arrange to fulfil the future demands of increasing population.

With the introduction of green revolution technology in the state, there is significant increase in canal and tubewell irrigation, use of chemical fertilisers and pesticides which have increased the agricultural production manifolds but have simultaneously created many serious problems such as increase in soil salinity and sodicity, decline in fresh water table aquifer and rise in brackish water table etc. The highly intensive canal irrigation areas in the state's central and eastern regions have created salinity and sodicity. Because of over-exploitation of ground water, the water table is decreasing in the area where the rice–wheat crop rotation is plasticized. In a ten-year period, it has decreased by 6.0-7.5 metres, increasing the cost of irrigation. The constant growing of nutrient-depleted rice and wheat crops has also reduced soil fertility here.

Due to seepage of water through canals, irrigation channels, and irrigate fields in the inland drainage basin in the saucer shaped topography of north western Haryana, the brackish ground water table is continually rising, causing waterlogging and secondary soil Stalinization. The network of canals and roadways has obstructing natural drainage and exacerbating the issues. One of the most common types of soil degradation is soil salinization, which occurs when precipitation exceeds evaporation in dry and semi-arid environments. Soluble salts accumulate in the soil under certain climatic circumstances, altering soil characteristics and ultimately lowering productivity.

5.2 Cropping Pattern

Cropping pattern refers to the procedure of cultivating crops in the same region over the course of many seasons. The use of green manure in series with cereals and other crops to recharge nitrogen is a common feature of cropping pattern. Crops and their varieties should be chosen based on the soil and rainfall conditions in a specific region. To avoid droughts of various intensities, photo insensitive crops and varieties of shorter length should be selected. In the dryland area, water availability varies greatly from location to location.

India, in general and Haryana, in particular, saw a dramatic rise in agricultural production after independence. With just 1.3 percent of the nation's land area and 2.5 percent of its agricultural land, the state currently produces 5.69 percent of the nation's food crops.

5.2.1 Kharif Cropping Pattern

Rabi and Kharif are the two main cropping seasons in Haryana. Kharif season starts in May-June and continues upto September- October. Examination of remote sensing and other ancillary information told that Paddy, Sugarcane, Cotton, Bajra / Other minor crops are sown during Kharif season in the study area. Minor and non-contiguous crops are aggrigated together in the division of other crops. Paddy is evenly dominated in northern & central part of the study area where concentration of

Paddy is more. Cotton and other crops were clustered in the research area's southern and southwestern upland sandy zones. Sugarcane crops are primarily found in the study area's central region. Any Fallow land is also occupied in the study area's south eastern and western sections. Remote Sensing estimates shows that the Rice, Sugarcane, Cotton and Bajra/Guar/Jowar crops occupied 1204.03, 0.24, 3118.13 and 564.59 sq. km area, respectively as shown Table 5.1. It means thereby that major Kharif crop in the area is cotton followed by rice. It is also observed that a substantial part of the study area is fallow during Kharif season. The fallow area is found mostly in southern region of the selected region. Spatial distribution of Kharif cropping pattern is shown in Figure 5.1.

Table 5.1 Areal extent of Kharif crops

Crops	Area in sq km	Percentage to TGA
Rice	1204.03	17.99
Cotton	3118.13	46.59
Sugarcane	0.24	0.00
Bajra/Jowar/Gwar	564.59	8.44
Other crops	280.59	4.19
Fallow	921.51	13.77
Non agriculture	603.36	9.02
Total	6692.44	100.00

5.2.2 Rabi Cropping Pattern

Rabi season is the main season in Haryana in which maximum area is cultivated. Wheat is the main crop of Rabi period followed by mustard in the study area. Mustard is sown in those areas having coarse texture soils and scarcity of water. Rabi cropping pattern map of the north western Haryana was generated using satellite data of the particular season. It is clear from the Table 5.2 & Figure 5.2 that wheat crop is evenly spread all over the study area and having 4340.36 sq. km area, followed by mustard and pulses. Mustard and pulses crops are determined in south and western highlands sandy parts and occupy 967.74 & 193.84 sq. km area, respectively. Sugarcane & other crops occupy an area of 0.24 & 188.43 sq. km, respectively.

Table 5.2 Areal extent of Rabi crops

Crops	Area in sq km	Percentage to TGA
Wheat	4340.36	64.85
Sugarcane	0.24	0.00
Pulses	193.84	2.90

Mustard	967.74	14.46
Other crops	188.43	2.82
Fallow	398.21	5.95
Non agriculture	603.63	9.02
Total	6692.44	100.00

5.3 Crop Rotation

The crop rotation is growing a series of various crops in the same area in sequential seasons. The present study of cropping pattern of both seasons point out that study area have the main crop rotations are Cotton-Wheat, Rice-Wheat, Fallow-Wheat, Other Crops/Wheat, Bajra/ Jowar/ Guar-Fallow & Fallow-Cotton, Cotton –other crops and Rice- other crops. Cotton-wheat crop rotation occupies maximum area that is 2506.99 sq. km. followed by Rice -wheat which occupies 1077.77 sq. km area. Other rotations like Fallow –wheat & other crops-wheat occupy an area of 361.20 sq. km & 243.80 sq. km area, respectively. Crop rotation of the study area among its areal extent is specified in Table 5.3. Except in the south east and south eastern parts of the sample region, cotton-wheat rotation is uniformly spread. The spatial distribution of crop rotation is displayed in Figure 5.3.

Table 5.3 Areal extent of crop rotation

Crop Rotation	Area in sq km	Percentage to TGA
Rice-Wheat	1077.77	16.10
Cotton-Wheat	2506.99	37.46
Sugarcane based	0.24	0.00
Rice-other crops	34.15	0.51
Other crops-wheat	243.80	3.64
Cotton- other crops	68.90	1.03
Bajra/Jawar/Guar-wheat	150.61	2.25
Rice- Fallow	30.01	0.45
Bajra/Jawar/Guar- Fallow	139.04	2.08
Cotton-fallow	128.16	1.92
Fallow-Wheat	361.20	5.40
Minor rotations	1348.22	20.15
Non agriculture	603.37	9.02
Total	6692.44	100.00

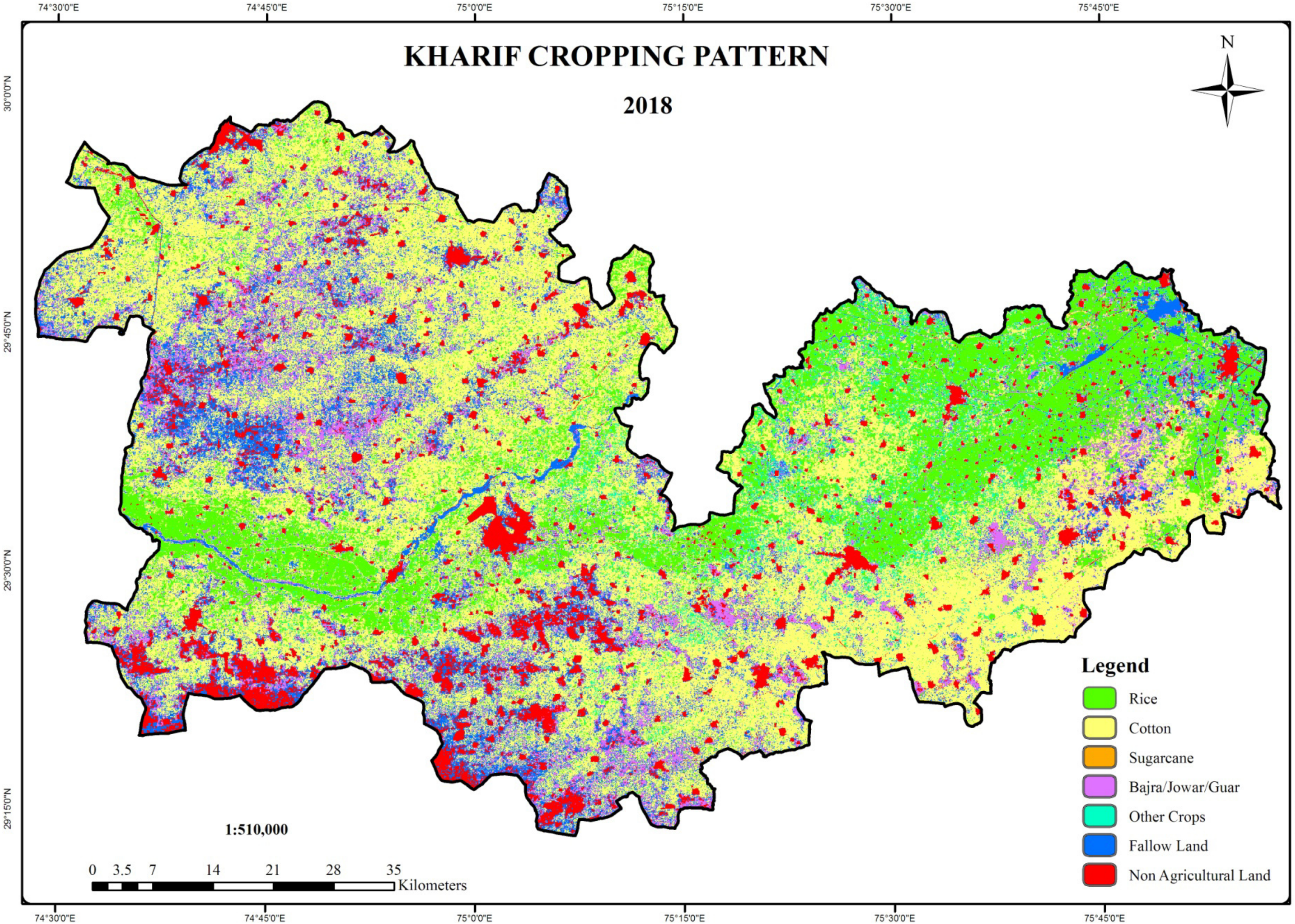


Figure 5.1(Source: LISS III & LISS IV satellite data)

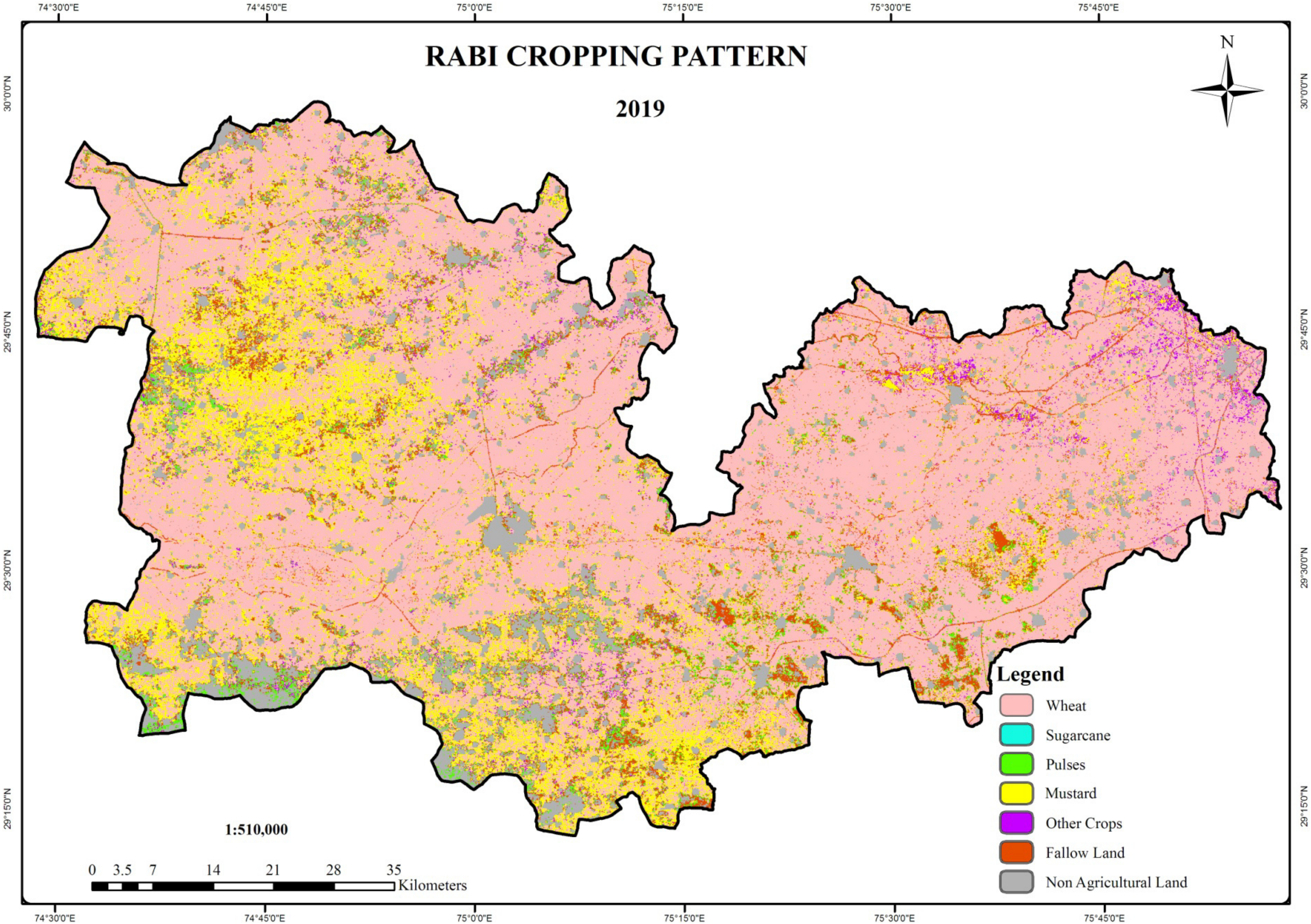


Figure 5.2 (Source: LISS III & LISS IV satellite data)

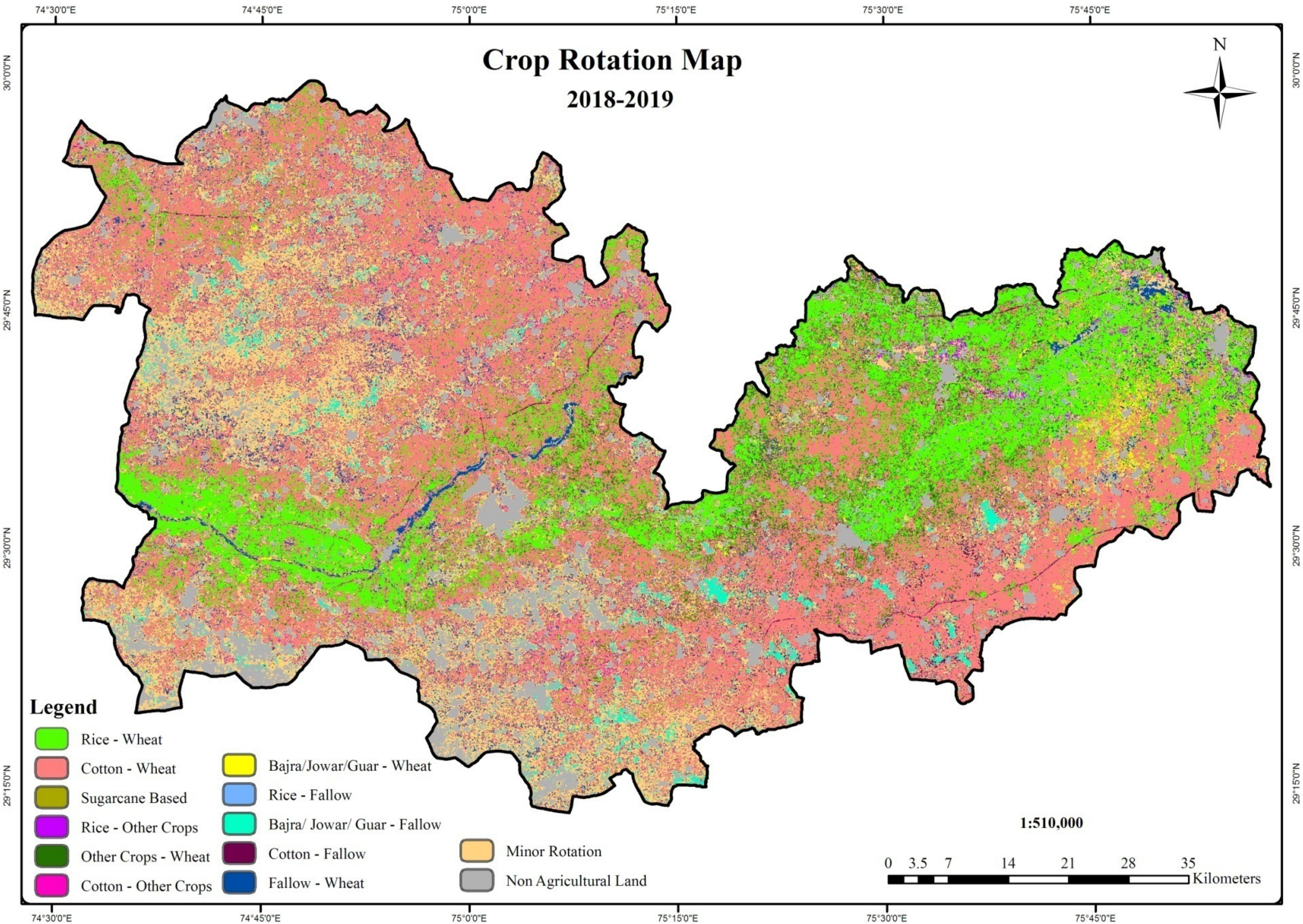


Figure 5.3 (Source: LISS III & LISS IV satellite data)

5.4 Present Land Use / Land Cover

The study area is 6692.44 square kilometers in size. On the basis of study of two seasons satellite images, the following land use and land cover groups were demarcated in the block: dual cropped field, Rabi only, Kharif only, current fallow, strip plantation, horticultural plantation, degraded pasture & grazing land, land with open scrub, sandy area, waterlogged seasonal, salt affected area, single/group building, waterbody and village settlement. Figure 5.4 represents the interpreted satellite maps for the years 2018-19. Table 5.4 shows the geographic scale of these categories during both years, as well as the change in their region. The concise explanation of different classes is as:

Built up Land: A large portion of the land is occupied by building but there is pockets of concentrated use. It is further subdivided into rural and urban areas.

Built up Rural & Urban – The research area was 120.87 square kilometers of gross built-up rural land or habitation area. The study's built-up urban area was 25.38 square kilometers.

Agricultural land: Land used mainly for the cultivation of food grains and fodder is referred to as agricultural land. This category is further classified into sub-categories such as double crop, Kharif only, Rabi only & current fallow.

Double crop- This sub-class includes a region that is cropped during the year, throughout both the Rabi and Kharif seasons. The dominant crop type in the study region is double crop. This class covers 6086.15 square kilometres or 90.94 percent of the total sample area.

Rabi only - Rabi only refers to land that is only used during the Rabi season and is left fallow during the Kharif season. This class covered 24.50 square kilometres or 0.37 percent of the sample area.

Kharif only - Plantations are cultivated trees or plants that are grown in cropland. These classes enclosed an area of 178.15 sq. km which were 2.66 percent of study area.

Current Fallow - This segment covers land that is left fallow during both Rabi and Kharif seasons for different reasons. A gross area of 118.30 square kilometres or 1.77 percent of the sample area.

Plantation: Plantations are agriculture fields with cultured trees or plants. These categories include Agricultural plantation and Horticultural plantation classes.

Agricultural *plantation*- Around the crop area, farm planting is carried out. The farm plantation occupied 2.40 square kilometers.

Horticultural plantation - Horticulture is the science and art of growing fruits, vegetables, bulbs and ornamental plants in gardens. Horticulture is a generic term that refers to the farming of fruit crops on a wide scale. The horticultural plantation spanned 2.12 square kilometers.

Wastelands: The word "wastelands" applies to corrupted fields that are actually underutilized and collapsing due to a lack of adequate soil and water management. Wastelands emerge impulsively or as a result of environmental influences, soil chemical and physical properties or management restrictions. Degraded pasture land, scrub land and sandy areas are subdivided further.

Degraded Grazing and Grass Land- These are Panchayat fields which are irregular in form and scale and are located along settlement fringes. Owing to a lack of adequate soil protection and irrigation strategies, these fields have deteriorated. This class covered 95.68 square kilometers.

Land with scrub- These lands are normally located on physically elevated ground and have sparse vegetation. Scrubs dominate the landscape which is subjected to extreme aridity. These can happen spontaneously or as a consequence of human behavior. This class covered an area of 11.46 square kilometers.

Sandy area- This class occupied a small area of 1.28 square kilometres. The rest of the sandy wastelands were leveled and cultivated.

Permanent/Seasonally waterlogged- The term "seasonally waterlogged grades" refers to regions where waterlogging occurs often during the monsoon season. These properties are mainly in plain areas where there is a lot of drainage blockage. The area is 18.69 square kilometres. The bulk of these waterlogged patches were located near Nathusari Chopta, as seen in Figure 5.4.

Salt affected area- Surplus soluble salts (saline) or high exchangeable sodium are found on salinity/alkalinity-affected lands. Salinity is caused by the flow of water and the rise of capillaries during harsh weather conditions which results in salt layers on the soil. The distinction between normal and alkali soils is defined by an exchangeable sodium percentage (ESP) of 15 or more in alkali lands. Carbonates and sodium bicarbonates are the most common salts present in alkali soils. The following two sub-classes, moderate saline / alkaline and strong saline / alkaline, may be described based on the degree of salinity and/or alkalinity. This class was included in an area of 5.69 square kilometres. Salt-affected patches can be found near the village of Nathusari, as represented in Figure 5.4.

Table 5.4 Spatial distribution of area of different land use & land cover classes

Classes of Land Use & Land Cover	Area in sq km	Percentage to TGA
Built-up rural	120.87	1.81
Built-up urban	25.38	0.38
Current Fallow	118.30	1.77
Double Crop	6086.15	90.94
Degraded Pasture and grazing land	95.68	1.43
Forest	0.06	0.00
Horticulture Plantation	2.12	0.03
Kharif only	178.15	2.66
Agricultural Plantation	2.40	0.04
Rabi only	24.50	0.37
Scrub land	11.46	0.17
Sand dunes	1.28	0.02
Salt affected Land	5.69	0.04
Waterbody	0.86	0.01
Wetland	0.85	0.01
Waterlogged /Permanent seasonal	18.69	0.05
Total	6692.44	100.00

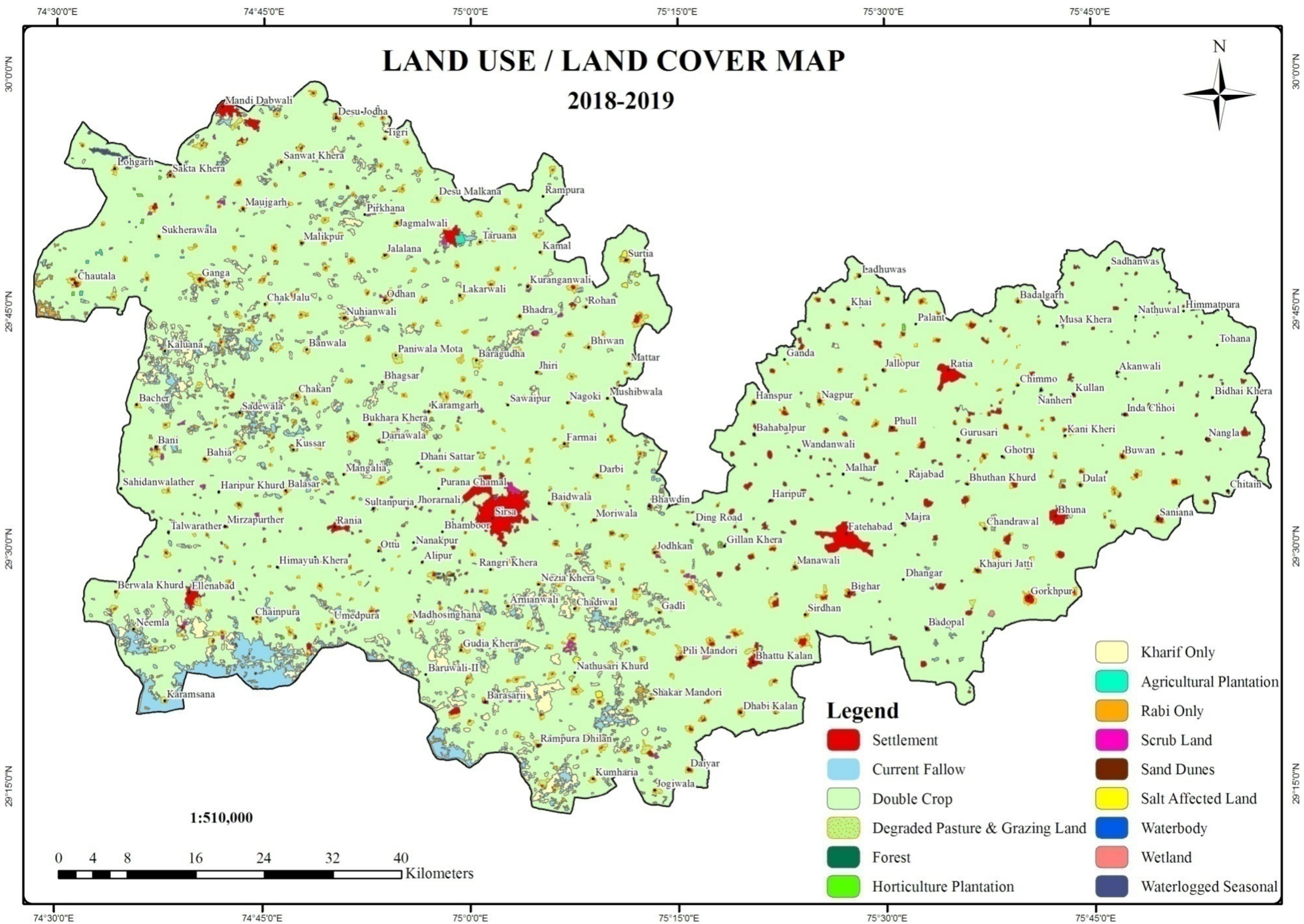


Figure 5.4 (Source: LISS III & LISS IV satellite data)

5.5 Summary

The state produces 5.69 percent of the nation's food crops while having only 1.3 percent of the nation's land area and 2.5 percent of its agricultural land. Using remote sensing estimations, it was discovered that during the Kharif season, Paddy/Rice, Sugarcane, Cotton, and Bajra/Guar/Jowar crops occupied 1204.03, 0.24, 3118.13, and 564.59 square kilometres, respectively. Cotton is the most important Kharif crop in the chosen region, followed by rice. During this time, a large portion of the research area remains fallow. According to the geographical analysis, the fallow area is predominantly found in the region's southern regions.

In the research area, wheat is the most important crop in the Rabi season, followed by mustard. Mustard is grown in locations where the soil has a coarse texture and there is a scarcity of water. Wheat crops are evenly distributed over the research region, which covers 4340.36 square kilometres. Mustard and pulses crops are found in the sandy parts of the south and west highlands, occupying 967.74 and 193.84 square kilometres, respectively.

The current investigation of cropping patterns in both seasons reveals that the primary crop rotations in the study area are Cotton-Wheat, Rice-Wheat, Fallow-Wheat, and Other Crops/Wheat. Cotton-wheat crop rotation takes up the most land at 2506.99 square kilometres, followed by rice-wheat at 1077.77 square kilometres. Other rotations, such as fallow-wheat and other crops-wheat, cover 361.20 sq km and 243.80 sq km, respectively. Cotton-wheat rotation is consistently disseminated throughout the sample region, with the exception of the south east and south eastern sections.

Based on satellite data analysis from two seasons, the following land use and land cover groups were identified in the block: double cropped field, Rabi only, Kharif only, current fallow, strip plantation, horticultural plantation, degraded pasture & grazing land, land with open scrub, sandy area, waterlogged seasonal, sat affected area, single/group building, waterbody, and village settlement.

CHAPTER – 6
DEVELOPMENT OF MANAGEMENT PLAN FOR WATERLOGGED AND SALT AFFECTED AREA

6.1 Land and Water Resources Development Plan

IRS LISS III and Sentinel satellite images were utilized to produce the thematic maps of land use & land cover and waterlogged and salt affected area. IRS (LISS-III) and Sentinel satellite data of specific season was also used for reference purpose. Other collateral images was also collected and analyzed for development of action plan. Agro climatic data was combined with various thematic maps like soil, slope, land use/ land cover, geomorphology, water quality and underground water depth and a appropriate grouping of practices was suggested for the area. A series of practice packages has been recommended for overall sustainable development in the area for long term. On the basis of these developmental packages, various attributes have been grouped in two parts viz.

6.1.1 Environmental Factor

6.1.1.1 Landforms /Geomorphology

In environmental protection, geomorphological applications have grown over time. Precisely, the geomorphology discipline has constant to put in technological knowledge and resources to permit its practical scientists to address environmental issues better. The superior accessibility of extrapolative gear, mostly derived from GIS-based topography modelling to determine substitute supervision scenarios, has been noteworthy in this regard, thus increasing the visibility and accountability of geomorphology-centered solutions. Socially, the importance of geomorphology in environmental problem solving has been gradually recognised by environmental managers and the public, most important to better information of geomorphologists interacting among community policy (Kneupfer and Petersen, 2002).

6.1.1.2 Ground Water Depth and Quality

One of the main problems restricting the global dependance on groundwater in aquifers is the depletion of groundwater quality due to salinization processes. Because the salinization of low aquifers is narrowly related to the salinization of the root region, it is important to consider the two together. Initially, this chapter discusses the physical and chemical processes that cause root-zone and low aquifer salinization, outlining the complexities of these process and how irrigation and drainage practices can affect them, thus demonstrating the connectivity between salinization of soil and groundwater. There is discussion of the mechanisms foremost to aquifer salinization in internal and coastal regions. There is no more division between the criticalities and possible consequences of poorly controlled water supplies than when the equilibrium among surface water and underground water varaiabilty is disrupted and too much concentrations of salt are accumulated on the exterior and in the low sub-surface.

6.1.1.3 Types of Soil

Electrical saturation soil extract conductivity more than 4 dS/m at 25 °C are classified as saline soils (Richards 1954). Despite the fact that the Soil Science Society of America's vocabulary committee dropped the saline-non-saline soil boundary in the saturation extract to 2 dS/m, this value is frequently used worldwide. The most popular soluble salts are sodium chlorides and sulphates, as well as calcium and magnesium chlorides and sulphates. Nitrates can rarely be found in appreciable amounts. The most prominent ions are sodium and chloride, especially in extremely salty soils, whereas calcium and magnesium are frequently present in sufficient proportions to meet crop nutritional needs. Some saline soils have a high content of gypsum (CaSO4. 2H2O) in their profile. Insoluble carbonates are still missing. The pH of saturated soil paste is frequently less than 8.2 and almost always close to neutrality (Abrol et al., 1980).

6.1.1.4 Rainfall Characteristics

Waterlogging occurs when the soil is so saturated that there isn't enough oxygen in the open space for plant roots to breathe properly. Other gases that are detrimental to root growth, such as carbon dioxide and ethylene, accumulate in the root zone and have an impact on plants. Plants differ in their oxygen requirements. There is no uniform quantity of soil oxygen that can recognise waterlogged conditions for all plants. Furthermore, the demand for oxygen from a plant in its origin zone may differ with its phase of expansion. The improvement of drainage from the busy enclosure will decrease the length of digester conditions for the crop roots.

6.1.2 Human Induced Factor

Many crop plants are susceptible to salinity, which is aggravated by elevated soil salt concentrations and the impacted area of soil is widening by the day. A wide variety of adaptations and mitigation techniques are needed to deal with such impacts. In order to overcome salinity tension, successful resource management and crop/livestock development will help to develop better breeds.

6.1.2.1 Land use/Land cover

A variety of biophysical and cultural variables drive land-use and land-cover change, which operate on several spatiotemporal scales and in complex webs of site and time-specific connections. Local climate and temperature, terrain, bedrock and soil type, surface water, and groundwater are all essential biophysical variables at the level of the individual geographical area. The study of land use /land cover (LULC) changes is significant for the planning activities of land supervision, climate and policy formulation. Ecosystems are facing changing consequences of local, regional and global human socio-economic activities.

6.1.2.2 Irrigation Practice System

Human activities can enlarge the soil salinity by applying salts to irrigation water. Salt buildup can be reduced with good irrigation control, which involves having adequate runoff water to filter extra salts from the soil. In salt accumulations, disorderly drainage patterns which provide leaching may also result. Salinity can grow in drylands where the water table is two or three metres below the soil surface. Capillary activity raises the salts from the sediment to the surface of the soil. Sodic soils have unique issues due to their thin composition, which restricts or prevents water penetration and runoff. They continue to collect those essentials in the root zone, such as boron and molybdenum, at amounts that can be detrimental to plants.

6.1.2.3 Cropping Pattern & Crop Rotation

Soil quality refers to the soil's ability to work within habitat borders in order to retain or increase yield and livestock quality, preserve or improve ecological protection, and improve global individual fitness. Anthropogenic actions like favoured cropping methods and active land use control could modify soil health in agro-ecosystems, which can have a negative influence on soil functions. In previous agricultural soil health tests, non-biological characteristics like soil nutrients and structures were paired with soil eco-functions. Biological characteristics, such as soil bacteria, have recently been identified as critical components for soil health. Under different cropping activities, systemic reviews of soil quality and its possible importance to human society are also limited.

6.1.2.4. Socio-Economic Status

The use of salt water and the reuse of irrigation runoff water are both dependent on long-term policies that ensure the socio-economic and environmental sustainability of agricultural systems. Soil is a nonrenewable property that can't be replaced in a human lifetime. For 10,000 years, soil salinity has been a cause of degradation in farming communities, second only to soil erosion as a source of land loss. Just 2.4 percent of the global land area supports 18% of the global persons and 15% of the global livestocks (Bhattacharyya et al., 2015). After freedom, India has complete enormous strides in cultivation. From 50 million tonnes in 1950 to 275 million tonnes in 2017, nation's foodgrain creation enlarged by about 5.5 times, contributing it not only independent but also a net food grain exporter. According to Tiwari, the country produced 285.17 million tonnes of total foodgrains in 2018-19, including 116.48 million tonnes of rice and 103.60 million tonnes of wheat, respectively (2020).

6.2 Problems of Waterlogging and Soil Salinity

Agriculture is the primary source of income in the study region. Irrigation from canal supplies is extensively relied upon in the study area's northwestern corner. Owing to leakage losses in the transportation and sharing system, as well as leakage from irrigated lands, the water table is steadily increasing. Since the groundwater in the study area is brackish, its use is limited, leading to waterlogging and salinity. Aeration is disturbed when the watertable reaches the root zone, resulting in a substantial reduction in farm productivity and the area being referred to as waterlogged. Areas with a watertable depth of 0-1.5 m were declared fully flooded in October. Salinity raises the osmotic ability of soil solution, making it more complex for plant roots to absorb wetness and nutrients. Table 1.3 displays a preliminary description based on crop growth and the observations of the US Salinity Laboratory.

6.2.1 Causes of Waterlogging and Soil Salinity

The study area is in arid and semi-arid countries, where irrigation is largely supplemented by surface water, groundwater or a combination of the two. Surface water was conveyed over long distances from (Bhakra/Tajewala) and distributed to farmers' fields using an unlined irrigation scheme in the early stages of its implementation. As a result of continued seepage and percolation through the irrigation system's primary, secondary and tertiary levels, the groundwater body was recharged. Even after the irrigation system's lining hasn't improved much, seepage losses have continued. Land levelling issues, insufficient water application techniques, and irrational drainage activities all contribute to rising water tables.

Groundwater extraction for irrigation is reduced in the study region due to low groundwater conditions. As a result, the recharge to the freshwater body has outpaced the disposal, resulting in a hydrological surplus and an increase in the water level in these regions. The rise of watertable has subsequent effects :-

i)The salt level of the groundwater rises as it approaches the watertable, which is comparatively deeper.
ii) Salts are transferred from deeper soil layers to the exterior or outside layers by rising groundwater due to capillary action.
iii) The growing water table restricts usual runoff and prevents salt leaching.

The rest of the research area is affected by the rising watertable. In certain cases, the water table has reached the ground level, creating significant floods. As the area lies in desertic and semi- desertic areas with high evaporation demands, salt deposition in waterlogged areas is growing. The salt content in canal water is 0.3-0.4 dS/m. The salt load in the soil profile is aggravated by the application of this water to the field without sufficient leaching. The salt deposition in the root zone gradually allows the soil to become salt affected.. Crop yields in such areas are slightly decreased in the first years but have a substantial impact in subsequent years, making them entirely unproductive. Villages like Nathusari Chopta, Makhu Sheorani, Ludesar, Lohgarh, Mattar, Surtia, Badopal, Gorakhpur, Khabra Kalan, Deshu Khurd, Fhaggu and Rajpura have salinity issues. The major causes of soil salinity growth are :-

i. Salt deposition on the soil exterior as a result of a high water table.

ii. Irrigation/conveyance and device framework seepage.

iii. The region has poor drainage (surface/subsurface).

iv. Irrigation water of low quality.

v. Climates that are arid or semi-arid.

vi. Topographic disorder.

vii. Geohydrological circumstances.

All of these factors decide main position in the production of salinity, either separately or in conjunction with other factors. But, in large sections of the sample region, irrigation activities, topographic depression and geohydrology are largely to blame for waterlogging and increased soil salinity. Secondary salinization has been around since the dawn of irrigated irrigation.

6.2.2 Consequences of The Problem of Waterlogging and Soil Salinity

In reference to ourcountry, there are several statistics on the amount of waterlogged and saline/sodic soils. The coverage of the region is expected to be between 5.5 and 13 million hectares. The issue is of major proportions, posing a threat to the agricultural economy's prosperity and the effects of saline and waterlogged soils can be seen on field, state and national levels.

6.2.2.1 Farm Level Effects

The following are the negative results at the farm level:

(i) Endangering the long-term viability of land capital

(ii) Agricultural construction decreases due to (a) crop abandonment, (b) resource productivity declines and (c) resource utilization reductions.

According to farmers in chosen irrigation schemes, irrigation-induced salinity and waterlogging cause major yield reductions in essential crops (Table 6.1). Crop growth is hampered by high salt and water tension, resulting in a dramatic reduction in cropped areas. The in general consequence of soil salinity on production reduction ranged from about 40% for sugarcane in areas of the Western Yamuna canal and the Bhakra system to about 50% for paddy in the Sharda Sahayak irrigation scheme in waterlogged areas of the Sharda Sahayak irrigation project, wheat yields fell from less than 14 percent in parts of the Western Yamuna Canal and the Bhakra system to about 60 percent for all crops. The sowing of Rabi crops was delayed in areas with high watertable in parts of Haryana but as time passed, the watertable declined and the crop was supplied with alters by capillary growth.

Table 6.1 Yield of important crops in different type of soils (Kg/ha)

Crop	Normal Soils	Salt affected soils	Waterlogged soils
Sharda Sahayak Irrigation Project			
Paddy (HYV)	2773	1349	1630
Paddy (Local)	1958	1067	1450
Wheat	2596	1139	580
Western Yamuna canal and Bhakra			
Paddy	5979	4047	4837
Wheat	3281	2418	2838
Cotton	1022	592	412
Sugarcane	38730	22849	16333
Indira Gandhi Canal Project			
Wheat	1920	170	1150
Groundnuts	11890	1320	1150

The benefits of irrigation will be negated by the emergence of soil salinity problems and a rise in the watertable, since it is not cost-effectively practicable to farm on problematic soils with no remedial action.

6.2.2.2 Regional Level Effects

The geographic effects are as follows:

(i) Labor dislocation from manufacturing.

(ii) Widening wage gaps.

(iii) Have an impact on the secondary and tertiary sectors' long-term competitiveness.

Labor work is reduced due to lesser production in fairly degraded regions and the finising of crop processing actions in severaly affected regions. Paddy, cotton and sugarcane, for example, have heavy labour requirements and their productivity is critical to many agro-based industries. Any fall in crop production has an effect on the industries' long-term competitiveness and job opportunities in the secondary sector.

6.2.2.3 National Level Effect

The effects of soil salinity and waterlogging can be observed at the national level in the form of –

(i) decrease in crop output.

(ii) GDP (Gross Domestic Product) Impact

(iii) Reduce the demand for essential crops to be exported.

(iv) An increase in the import bill.

Many essential crops, such as maize, sugarcane, cotton, wheat and groundnut, would be adversely affected by land depletion. Recent economic initiatives aimed at liberalising the global economy by expanding a range of benefits may have an effect on land and water resource sustainability. Several advantages exist in the form of-

(i) export incentives for tradable goods.

(ii) In the domestic market, remunerative minimum support rates.

(iii) Input incentives would allow non-traditional areas to intensify essential crops like corn, sugarcane and cotton.

The World Bank and the International Commission on Irrigation and Drainage (ICID) have established checklists and recommendations to help with the ecological evaluation of drainage and irrigation systems and ensure their long-term viability. There are a number of important water quality problems that have recently surfaced or have been overlooked in the preparation of modern irrigation and drainage schemes that need careful consideration.

Water quality is a big stumbling block to irrigation and wastewater schemes' long-term achievabilty. Any of the challenges, such as irrigation water safety and the environmental consequences of waste water irrigation, are not recent. There hasn't been a comprehensive study to determine the impact of waterlogging and soil salinity on crop yields and production under various conditions.

However, a preliminary analysis of Haryana's agroeconomic capital undertaken under a UNDP project showed that waterlogging reduced the net production value per ha in economic terms substantially (Waterlogging reduced the value of the land from Rs. 15,000 to Rs. 3000) under similar agro-climatic conditions. (Waterlogging and Soil Salinity, Master Plan, High Level Committee).

6.2.3 Strategies for Combating Menace of Waterlogging and Salinity

Waterlogging and salinity issues have occurred in many areas of northwestern Haryana underlain with stagnant groundwater as a result of canal drainage and short and durable remidial measures for environmentally sound agricultural productivity must be taken. The reventive steps would go a long way toward avoiding land erosion in regions where the water table is still deep. The above are suggested prevention and curative steps.

6.2.3.1 Short Term Preventive Measures

1. Promoting effective on farm level water conservation techniques, such as current irrigation techniques (sprinkler, drip, furrow and so on) by providing daily instruction on how to best use available water supplies.

2 A 25% reduction in canal water supply in the study area from15th July to 15th September and December to February, allowing farmers to irrigate resistant crops like barley, cotton, mustard, safflower and semi-tolerant crops like bajra, oats, sorghum, maize and guar with freshwater groundwater instead of or in addition to canal water. The water saved in the canal system must be changed to water-scarce areas and the raise canal irrigation system.

3. Effective lining of residual canals and waterways, as well as their routine upkeep, to prevent seepage losses.
4. Building balancing/storage reservoirs in critical places in canal command areas to store surplus canal and flood water for later use.

6.2.3.2 Short Term Curative Measures

1. Install an adequate surface or sub-surface irrigation scheme in those regions the water table has less than 1.5 metres of the ground surface and where waterlogging and soil salinity are a significant hazard. Wherever feasible, a built-in reuse mechanism should be used.
2. Switching from the existing "warabandi" to "warimetric" plan, which allows farmers to use saline groundwater, to expand the use of inland groundwater in combination with river water in distressed areas. Farmers should be confident to build fresh tubewells for watering crops and growing agro-horticulture, agroforestry plantations, and grasses for which appropriate incentives and electric connections should be made available as soon as possible.

6.2.3.3 Long Term Measures

To develop an artificial drainage canal or Rann of Kutch, with a height of around 100 metres that passes through several states is needed for a long-term and stable solution for drainage effluent disposal. It must be enforced on a regional scale, involving other northwest Indian states that are suffering waterlogging and salinity issues.

6.3 Development of Management Plan for Waterlogged Areas

6.3.1 Database and Methodology

The study's key aim is to establish an action plan for the region that is ideally tailored to the landscape and the creative capacity of home resources, ensuring that production levels are preserved without erosion over time. The suggested activities of the action plan were created with the finances, climatic and terrain parameters in mind. To create the land resource action plan map, the subsequent steps were concerned: -

- Person thematic maps are examined.
- Combinations of maps are studied.
- Creation of action plan decision-making rules

- Creating a dumb action plan
- Expert review of the action plan
- Incorporation of suggestions from experts.
- Finalization of action plan.

6.3.1.1 Study of Individual Thematic Maps

The use of specific thematic maps allowed for a spatial assessment of relative changes in resource potentials and landscape conditions across a wide variety of terrain conditions. This analysis provides a brief overview of the research area's unique characteristics, such as water quality, wastelands, soil erosion and slope restriction.

6.3.1.2 Study of Theme Maps in Combinations

The study of combined thematic maps is an extension of the previous study, in which the natural and rational interaction of different parameters of one theme with those of the other is investigated. This connection analysis assists in a more detailed understanding of cause and effect, not just in terms of challenges and limits, but also in terms of the research area's potentials.

6.3.1.3 Development of Decision Rules for Action Plan

In the preparation of decision rules, a number of spot measurements covering the whole region were planned, including various land types, soils, ground water content, rainfall conditions, climatic zones, current land use and so on. On a scale of 1:10,000, each location was labelled. Each site's current land use, irrigation infrastructure and cropping pattern, as well as the land personality/parameters mapped in the individual theme maps, were all documented. Future concerns such as groundwater exploitation, the likelihood of implementing more effective irrigation schemes and water storage and other site changes by soil and water conservation approaches were also held in mind when considering alternative suggestions for land use activities. The abundance of better crop types, trees, shrubs and grasses, as well as the benefits of agriculture's interdependency, live stock and other methods such as advanced farming systems, were all taken into account. Decision rules were developed based on these findings.

6.3.1.4 Development of Draft Action Plan Map

Based on the conclusion policy, a brief discussion was held about the optimal usefulness of the current landuse pattern, particularly in terms of sustainable invention and ecosystem quality. Later, different developmental practices such as forestry, horticulture, agroforestry, agrohorticulture, sites for exterior water processing structures, underground water superiority extraction and strengthen and so on were considered and the suitability of these activities was assessed based on the findings of experimental research. On a scale of 1:10,000, a detailed action plan map with recommended activities was created. As a result, a tentative integration scheme was developed, taking into account the basic research findings of CCS HAU and ICAR. The most up-to-date technologies in the fields of research development and management were also considered. Furthermore, at HAU, useful discussions were held with scientists from various disciplines and a series of packages/measures recommended for the area's eco-development were adopted. These packages were displayed as a 1:10,000 scale action plan map (Figure 6.3).

6.3.1.5 Finalization of Action Plan

The arranged draught action plan, which depicted site-specific action plan items on a 1:10,000 scale, was discussed with concerned specialists for their valuable input. Those ideas were evaluated critically with the concept of sustainability in mind, then incorporated and finalised.

6.3.2 Cropping Practices for Shallow Water Table and Flood Affected Areas

It is not possible to produce even a solitary crop throughout the entire year in areas where floods occur for the majority of the growing season. Flooding occurs in standing crops from time to time, causing crops to fail and farmers to lose a lot of money. There haven’t been any comprehensive or sufficient scientific studies to recommend acceptable crop and watering methods for such demanding circumstances. Crop selection in flood-prone areas is influenced by the depth and length of water stagnation in the fields, the time it takes for flood waters to recede, and the availability of land in working conditions for planting suitable crops, as well as crop air stress and salt resistance, irrigation water quality and quantity, and other agro-climate requirements. Suggestion map of cropping pattern for Kharif & Rabi season (Only for waterlogged and salt affected area) are shown in Figure-6.1 & Figure-6.2. With these factors in mind, the following cropping pattern is suggested, which corresponds to the timetable for the receding of flooded water and the state's agro-climatic conditions.

Kharif season crops

- Dhaincha (green manure/seed)
- Dhaincha and Jowar
- Jowar and Patsan
- Jowar and Paddy
- Paddy
- Sugarcane

(A) Seeding of crops matching with the time of receding of flooded water post rainy seasons.

First week of September to end of September

- Maize and cowpea (upto last week of September for fodder)
- Toria (Upto 2nd fortnight of September)
- Japanese rape/Chinese cabbage (for fodder)
- Gobia sarson (first cut for fodder and thereafter for grains)

End of September to mid – October

- Berseem and rapeseed
- Mustard and rapeseed
- Multicut oats (OS 6 and OS 7)
- Autumn sugarcane (COH 99, COH 92 and CO 7717)

Mid – October to Mid – November

- Autumn sugarcane (COH 99, COH 92, CO 7717)
- Raya (Varuna, RH 30)
- Barley (BH 331)
- Berseem (Muskavi)
- Oats (OS 6, OS 7)

Mid November to Mid December

- Wheat: KRL 1-4 & WH 157 (for moderate saline conditions)

- UP 2338, PBW 343, WH 147, WH 542, & WH 533 (for normal sowing)
- UP 2338, WH 291, Sonak, HD 2285 (late sowing conditions)
- Barley (BH 331: Normal sowing)
- Oats (OS 6, OS 7: late sowing)

Second fortnight of December

- Methi/metha (grain/fodder)
- Oats (grain/fodder)
- Barley (BH 338)

First fortnight of January

- Berseem (One cut for fodder / seed production)
- Oats (single cut fodder)
- Barley (BH 338 for fodder / grain)

Mid January to end of January

- Sunflower (Jwalamukhi)
- Sugarcane (COH 99, COH 92, COS 7717)
- Maize / cowpea (fodder)

March – April

- Cucurbits (water melon, mask melon, tar kakari)
- MP chari
- Sugarcane (COH 99, COH 92, COS 7717)
- Jowar and Dhaincha (Intercropping: Jowar for fodder and dhaincha for grain and fibre)

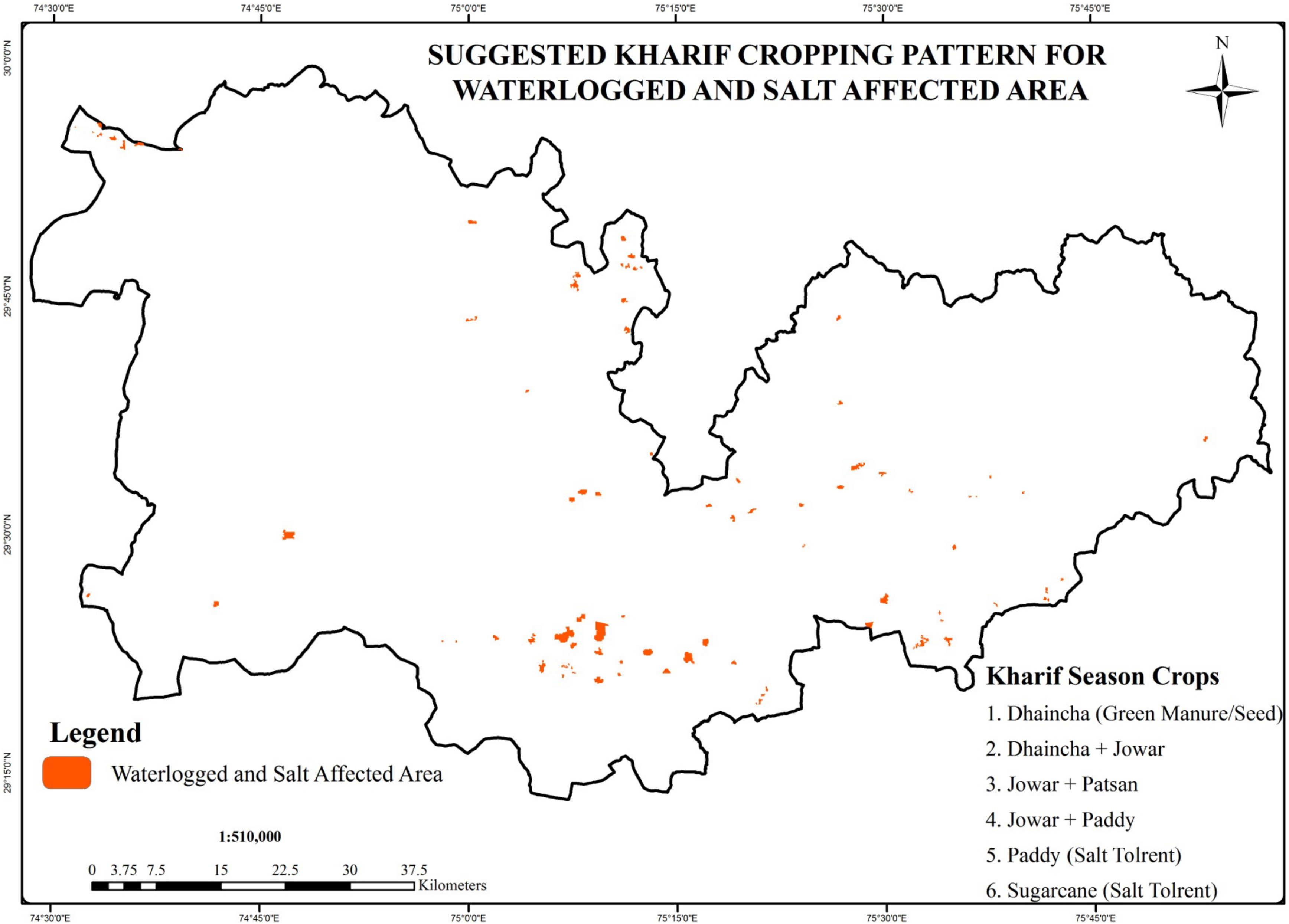
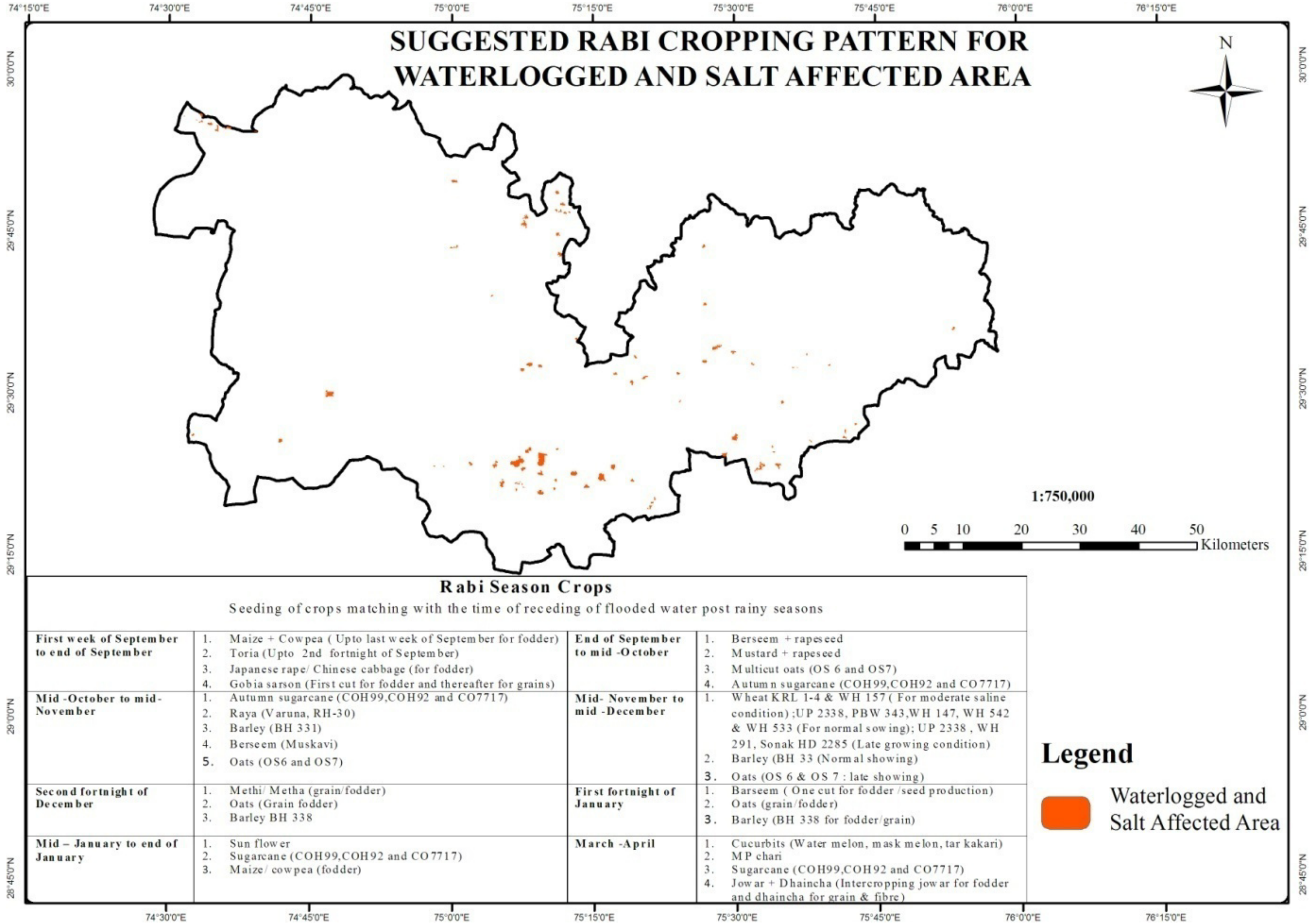


Figure-6.1 Suggested land use / cropping system for Kharif season



Rabi Season Crops

Seeding of crops matching with the time of receding of flooded water post rainy seasons

First week of September to end of September	1. Maize + Cowpea (Upto last week of September for fodder) 2. Toria (Upto 2nd fortnight of September) 3. Japanese rape/ Chinese cabbage (for fodder) 4. Gobia sarson (First cut for fodder and thereafter for grains)	**End of September to mid -October**	1. Berseem + rapeseed 2. Mustard + rapeseed 3. Multicut oats (OS 6 and OS7) 4. Autumn sugarcane (COH99,COH92 and CO7717)
Mid -October to mid-November	1. Autumn sugarcane (COH99,COH92 and CO7717) 2. Raya (Varuna, RH-30) 3. Barley (BH 331) 4. Berseem (Muskavi) 5. Oats (OS6 and OS7)	**Mid- November to mid -December**	1. Wheat KRL 1-4 & WH 157 (For moderate saline condition) ;UP 2338, PBW 343,WH 147, WH 542 & WH 533 (For normal sowing); UP 2338 , WH 291, Sonak HD 2285 (Late growing condition) 2. Barley (BH 33 (Normal showing) 3. Oats (OS 6 & OS 7 : late showing)
Second fortnight of December	1. Methi/ Metha (grain/fodder) 2. Oats (Grain fodder) 3. Barley BH 338	**First fortnight of January**	1. Barseem (One cut for fodder /seed production) 2. Oats (grain/fodder) 3. Barley (BH 338 for fodder/grain)
Mid – January to end of January	1. Sun flower 2. Sugarcane (COH99,COH92 and CO7717) 3. Maize/ cowpea (fodder)	**March -April**	1. Cucurbits (Water melon, mask melon, tar kakari) 2. MP chari 3. Sugarcane (COH99,COH92 and CO7717) 4. Jowar + Dhaincha (Intercropping jowar for fodder and dhaincha for grain & fibre)

Figure- 6.2 Suggested land use / cropping system for Rabi season

6.3.2.1 Irrigation Requirement

Depending on the deepness and length of waterlogging, the types of soil, the superiority of irrigation water, the type of crop and differences in water table depth, as well as other agro-climatic conditions in the region, these crops can need less frequent irrigation. Under shallow water table (150 cm) conditions, the water table can play a significant role in water use in wheat (30.5 cm) and barley (27 cm) (Table-6.2). As a result, depending on the depth of the water table in the region, the occurrence of irrigation in different crops must be minimized. In areas with a high water level, some vegetable crops can be tried during the after monsoon season. To avoid overwatering in these fields, a pressure irrigation system (sprinkler/drip irrigation) should be used. The delivery of canal water in critical shallow water table regions should be controlled to allow for the simultaneous use of brackish and fresh water.

Table 6.2 Irrigation requirement of field crops under shallow water table conditions

Crops	Watertable Depth (cm)	Irrigation Schedule	Number of Irrigation	Irrigation Requirement (cm)
Wheat	100-110 120-200 220-250	CRI ID/CPE 0.4 ID/CPE 0.6	1 2-3 4	6 12-18 24
Mustard	200	No irrigation		
Barseem	110-170	ID/CPE 0.8	8	45
Winter Maize	100-225	ID/CPE 0.4	4	24
Sunflower	100-225	ID/CPE 0.5	5	30

6.3.2.2 Impact Points

For better control of flooded fields, the following activities are recommended:

(A) Reduced irrigation depth and regularity in field crops, based on flooding depth and length, soil types, irrigation water quality, crop type and water table depth fluctuation.

(B) In salt-affected fields, pre-sowing irrigation with canal water to ensure improved crop establishment.

(C) Where groundwater is unsuitable for cultivation, use a combination of canal and brackish water drainage.

(D) The use of additives such as gypsum in sodic soils and organic matter in salt soils has an effect on salty habitats.

(E) (E) For better establishment, dhaincha, jowar, and straight seeded rice should be sown by the end of June.

(F) During the Kharif seasons, Dhaincha is grown for green manure/seed under temporary flooding conditions.

(G) During the Kharif season, in flood-affected areas, grow a rice + Jowar mixture for risk cover and crop protection in flooded or low-rainfall conditions.

(H) Acceptance of a series of suggested practises for various crops, as well as timely distribution of seed and additional inputs to farmers in the study area for demonstration purposes.

6.3.3 Recommendation for Waterlogged Area through Proper Drainage Systems

Waterlogged lands in the area could be reclaimed by selecting a proper drainage method or combination of drainage methods. The possibilities for the disposal of drainage water should also be chalked out. Area under different suggested recommendations is discussed in Table 6.3. In the study area, following methods depending upon the existing conditions are suggested:

- Horizontal drainage system
- Vertical drainage system
- Bio-drainage system.
- Sub Surface vertical Drainage (Network of Tubwell)
- Link drain (Subsurface field drainage system)
- Ditch drain (Subsurface field drainage system)

6.3.3.1 Horizontal Drainage System

The horizontal drainage System is one which receives excess water directly from field end conveys it to the main drainage system through a net work of field laterals, sub-collectors/collectors and main drain. The field laterals are the field drains or decant drains meant primarily to check the fluctuation of ground water table at the required depth. The water from the laterals flows into sub-collectors/collectors from where it is conveyed to main drainage system and finally carried to the out let of the area. The horizontal drainage system is suggested in the areas where following problems are being faced:

- Stagnation of rain water during monsoon
- Saline ground water
- Secondary salinization.

The sub-surface horizontal drainage system is adopted in several locations around the villages Nathusari Khurd, Darba Kalan, Sakkar Mandori, Pili Mandori, Ludesar and Makhu Sheorani in the north western Haryana for reclaiming waterlogged and salinity problems (Figure 6.3). The societies of farmers should be formed for the action and proper maintenance of the system.

Table 6.3 Area under different Suggested Recommendation

Recommendation Type	Area in Square Kilometers	Percentage to total Waterlogged area
Bio Drainage	2.49	12.27
Horizontal Drainage Area	10.29	50.69
Sub Surface vertical Drainage / Network of Tubewell	6.42	31.63
Vertical Drainage Area	1.1	5.42
Total	20.3	100.00

6.3.3.2 Vertical Drainage System

The areas in the state facing the problem of rise in the water table are generally underlain by poor underground water quality. With the excessive recharge from fresh canal water, water seepage, losses in the field, losses in water courses, minors and distributaries etc., a relatively less saline water layer has developed over the main ground water body. In inspection of the non availability of the disposal out-let, the efforts should be concentrated to pump out ground water of relatively good quality so as to reuse it locally or at the downstream end. Thus these waters in the upper layers have to be removed either by shallow wells of large diameter or shallow tube wells.

As a result, shallow tube wells are commonly seen alongside drainage channels where a ground water collection has formed and a fresh water layer floats over soil water due to density differences. These shallow tube wells are recommended in the study area near village Humayun Khera where waterlogging areas exist due to canal seepage. HSMITC has carried out several pilot studies on vertical drainage schemes that have authinticate to be very successful in reducing the water table. If the canal water is lowered in comparison to the with-drawl, the mechanism will efficiently control the increase in the water level. In order to reuse the pumped water effectively and to reduce the number of pumping units, seven to eight wells should be connected by an underground collector and pumped from central well. It is also suggested that during monsoon, the provision of storage should be made for effective operation of the system.

6.3.3.3 Bio-drainage System

Bio-drainage is plantation of tree species, which have been found effective to control water table. Some of the studies regarding bio drainage were conducted at HAU, Hisar and found that *Eucalyptus tereticomis* is most effective species in reducing the water table depth due to its huge quantity of evapotranspiration. In another study conducted at Victoria (Australia) it was reported a fall of 3 to 5 m in water table in an area under 3 years old plantation. The plantations were established in 3.4 ha. with species of *Eucalyptus botryoides, Eucalyptus grandis, Eucalyptus salina* and *Eucalyptus globulus* (Salinity and water logging in Haryana, a high-level committee report).

Therefore, the above studies reveal that bio-drainage holds good promotion for tackling the problem of waterlogging and soil salinity in irrigated region. This biodrainage system has been suggested in some isolated waterlogged areas near the villages Moriwala, Majra, Chandrawal, Bhuthan Khurd and Gorkhpur of the study area as shown in Figure-6.3.

6.3.3.4 Sub Surface vertical Drainage (Network of Tubewell)

Pumping groundwater into tubewells in areas near drainage channels groundwater mass conditions can be used to artificially remove groundwater. Tubewell drainage is an optimal way to lower deeper water tables and reduce the chance of waterlogging in irrigated areas. The machine must be operated by a pump that is powered by an electric or diesel prime mover. Geo-hydrological conditions, aquifer, well layout and design, system installation and maintenance and farmer involvement are all essential factors in a tubewell drainage project's performance.

Since the salinity of groundwater increases with depth, it's important to plan the structure and run the tubewells so that fresh water from the upper brackish groundwater is skimmed off and the more saline groundwater remains below the well floor. The emergence of salty groundwater should be avoided, taking into account the depth of the interface between fresh or brackish water on one side and saline water on the other, the relative density difference between the two waters and the permeability and anisotropy of the aquifer on both sides. Anisotropy or the ratio of horizontal to vertical permeability in stratified soils, is a helpful factor in preventing salt water from entering the environment, resulting in a higher healthy yield.

Near the villages Badopal, Mattar, Malhar, Surtia and Lohgarh of the study area, it has been suggested to pump out ground water through tubewells and use it for irrigation purpose as the soils of this area are sandy and water quality is also marginal. The area recommended for this activity is shown in Figure-6.3.

6.4 Preventive Remedial Measures

6.4.1 Canal Water Allowance

The study of water table growth indicates that during the monsoon season, the water table grows by more than 50%. (July to September). Since canal water and rainfall are usually obtained in excess of irrigation water requirements in the canal command region, this is the case. To prevent water table increase during the monsoon season, the supply and demand mismatch must be corrected.

The study of crop use, efficient rainfall, net irrigation demand, canal water and groundwater supply, as well as canal water and groundwater availability, shows a shortfall in irrigation water demand in areas with waterlogging issues. In contrast, the shortfall in the research region where the water table is dropping is even larger, extending from the study area to the study area. Since water supply in increasing areas is similar to demand, the combined use/exploitation of groundwater is much less than the watertable optimum, lowering the watertable. In areas with declining watertables, on the other hand, the high irrigation water deficiency has harmed agricultural production, as the watertable has fallen by more than 5 to 10 metres in the last 20 years. The rice-wheat crop rotation's long-term viability will be questioned unless steps were taken to improve groundwater recharge.

Under the above water availability – demand scenario, it is highly recommended that canal water supply be reduced by around 25% in the study region from mid-July to September and December to February to enable farmers to improve marginal quality groundwater usage for which electric connections should be prioritised. The canal water therefore saved can be preoccupied to locations where there is a concern with falling water levels.

Balancing Reservoirs: Along the canal and depressions, balancing water storage reservoirs (like Ottu) can be provided to redirect excess canal water supplied, especially during the monsoon season, which can then be used for irrigation during drought periods or for providing pre-sowing irrigation to oil seed/pulse crops. The surplus rain runoff water may be drained by gravity/pumping from the farmers' fields to some degree. The crop will be saved from waterlogging and irrigation commands as a result of this.

6.4.2 Maintenance of Canals and Watercourses (Lining and Repair)

A canal system has been built to provide irrigation facilities to the entire study district. These canal systems have also been interconnected so that supplies can be supplemented if required. Under the canal modernization programme, the canal networks were also lined. However, due to insufficient periodic repair and maintenance arrangements, seepage through the canals near the villages Pili Mandori, Rajpura, Makhu Sheorani, Badopal and Gorakhpur continues. Lands adjacent to canals are being waterlogged as a result of seepage, necessitating lining repairs, including joint filling of current lining. A total of 1000 km of lined irrigation channels need to be repaired immediately, at a cost of around Rs. 23 crore. In addition, 5400 lined water sources with a entire length of 22000 kilometer need to be repaired at a cost of around Rs. 20 crore. (Waterlogging and soil Salinity, Master Plan, High Level Committee, CCS HAU, Hisar).

6.4.3 Land Development and Farm Irrigation System

Haryana has a water shortage. The estimated irrigation water requirement for a cropping pattern projected in the year 2000 at 50% overall irrigation efficiency is 4.3 million hectares, compared to the total potential availability of about 1.85 million hectares through surface and groundwater resources. Weak land leveling/grading and incorrect irrigation system selection result in significant field application losses, ranging from 27 to 41 percent. The following are the three most important considerations to remember when ensuring a productive farm irrigation system:

a. When to irrigate i.e. timing.
b. During each irrigation, how much water can be added ?
c. Irrigation strategy.

Water management experts at the CCS HAU have developed detailed knowledge, recommendations and criteria for various crops, soil types, climates, water availability, water quality and watertable depth requirements, which are included in the kit of practices also available at the CCS HAU, Hisar. These suggestions should be pursued as closely as possible. As a result, it's vital to make the optimum use of scarce and expensive resources by reducing irrigation water losses and enforcing recommended farm water management practices. This would not only help increase irrigation command, but it would also significantly reduce water table rise/waterlogging and soil salinity issues.

Bad quality land leveling work is the major reason of low irrigation productivity in canal command regions. Effective on-farm water conservation necessitates a through understanding of the soil-water-climate-plant relationship, as well as its association with other inputs such as nutrients, crops and agronomic practices. It involves land planning for receiving and storing water in the soil root region, as well as built devices such as field channels/dits, pipelines and sub-plots for water application according to the irrigation system chosen.

While technology for efficient on-farm water management is available, adoption by farmers, with the exception of sprinkler irrigation, is quite restricted. Adjusting the water supply to satisfy crop demand has its limits. However, due to a lack of suitable mechanisms and infrastructure for knowledge transfer, technology on irrigation scheduling and field water application approaches could not be transferred to the full extent necessary. Since there is a scarcity of qualified staff and cadre, efficient on-farm water storage is not owned by irrigation or agriculture departments. It is recommended that these agencies create the infrastructure and skilled staff.

6.5 Management of Salt Affected Areas

Water soluble salts are present in all soils in some manner. Even non-saline soils in desertic and semi-desertic areas have a significantly greater concentration and range of salts than non-saline soils. Considering the special management requirements and extensive occurrence, USDA divided the salt affected soils into three classes (Richards et al, 1954). These are alkali soils, saline soils and saline-alkali soils. List of salt tolerant crops with their varieties for both Kharif and Rabi season is discussed in Table 6.4 and Table 6.5 correspondingly.

Table 6.4 Salt tolerant crops with their varieties for Kharif season

Crop Type	Name of crop	Varieties
Salt tolerant crops	Bajra	Pennisetum, Glaucumm
	Cotton	Goskykium, Barbadense, Goskykium Hiroupum
	Guar	Cyamopsis, Tetragonoloba
	Black Currant	Gusadar, Coronate
Salt Semi tolerant crops	Maize	Barnali, Khoi Vutta, Mohor, BARI
	Jowar	R.S. 630, R.S. 501, S-832, Pokran, E-Hegari, Jowar Pali
	Tobbaco	Hicks F.C., Hicks D.R. 1, K.Y.58, Virginia Gold
	Pomegranate	Punica, Granatum
Salt Sensitive crops	Pulses	Phaseolus, Vulgari
	Peanuts	Kadiri -2, Gaug-1, Kuber
	Paddy/Rice	CSR-10, CSR-13, CSR-23, CSR-27, CSR -30, CSR-36
	Mango	18Mie IF, Mie IF 1A-A,

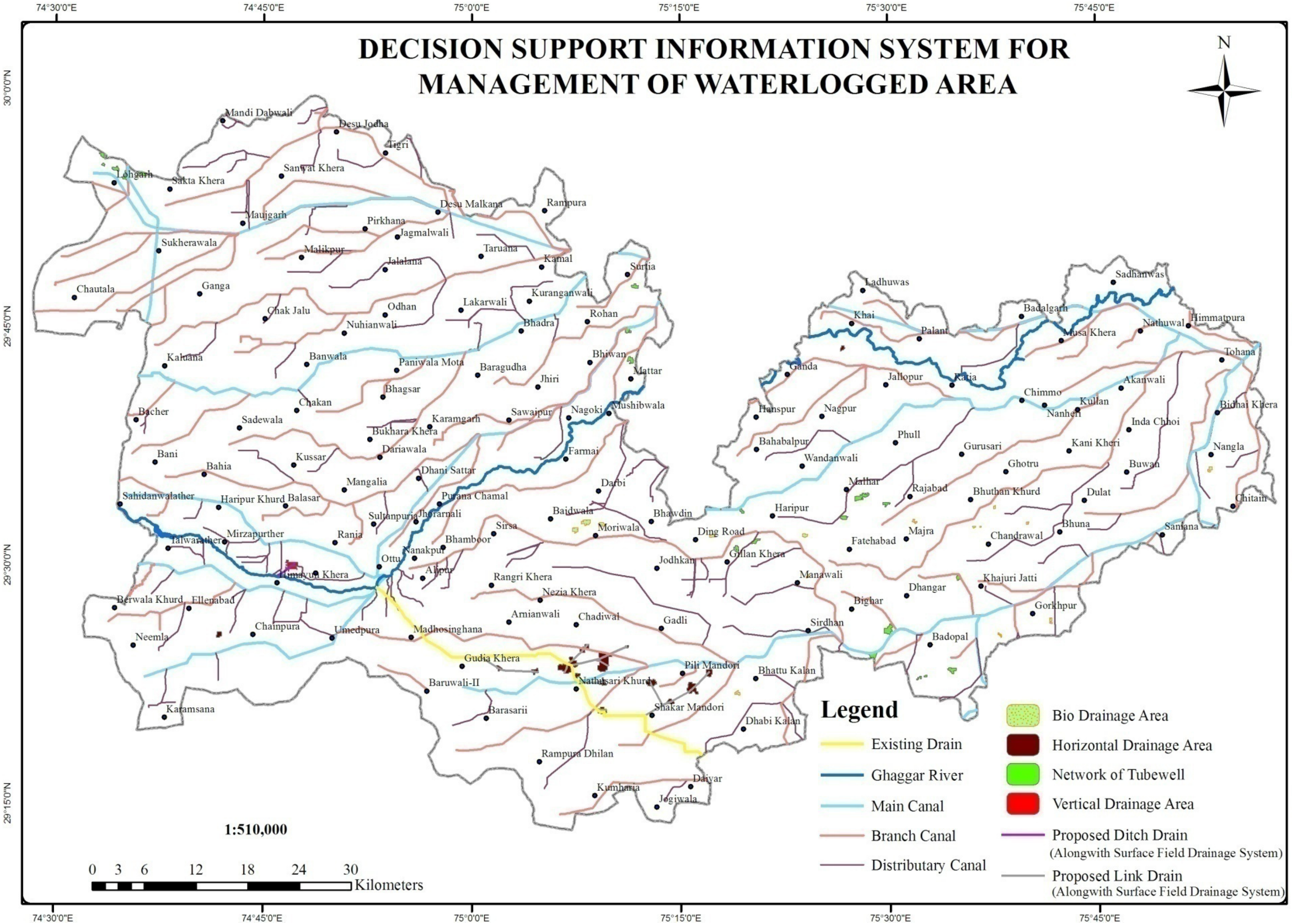


Figure 6.3 Decision Support Information System for management of waterlogged area

Table 6.5 Salt tolerant crops with their varieties for Rabi season

Crop Type	Name of crop	Varieties
Salt tolerant crops	Wheat	Sehar-06, LU-26, NARC-09, BARC-09, Pirsbak-09
	Mustard	CS-52, CS-54, CS-56
	Barley	CM-72, Numar, Gairdner, ZUG-403
	Palak	Khardar, Virofaly Duch
	Safflower	Safflower-31, Safflower-32, Safflower-35, Safflower-38
	Jujube	Bianhesuan, Qiyuexian, Zhanhuadongzao
Salt Semi tolerant crops	Barseem	Helaly, Serw-1
	Peas	B-6, 110121, 10431
	Cabbage	Stomhead, Golden Acre, Green Bell
	Broccoli	Naxos, Gea, Triton
	Guava	Krioula, Paluma, Ogawa
Salt Sensitive crops	Gram	Karnal Channa 1
	Papaya	Ranchi Dwarf, Honey Dew, Farm Selection, Local
	Citrus/ Lemon Plant	Cleopatra, Mandarin, Macro Phylla

6.5.1 Reclamation of Alkali Soils

Soils with an surplus of salts competent of alkaline hydrolysis like sodium bicarbonate and/or sufficiently exchangeable sodium to stymie the growth of most crop plants fall into this group. The exchangeable sodium percentage (ESP) should be greater than 15, the pH of saturated soil paste should be greater than 8.5, the electrical conductivity of saturation extract (ECe) should be less than 4 dS/m (Bhargava et. al., 1976).

For the recovery of alkali soils many inorganic amendments are used, but among all, gypsum is most cost effective and easily available. The physio-chemical characteristics of soils, nature and degree of deterioration and the kind of crops to be grown are important in deciding the dose of gypsum application. Gypsum application proved most effective when mixed in surface 10 cm soil and maximum reactivity of gypsum has been found when it is ground to pass through 30 netwrok filter. Repeated gypsum application may be needed in alkali soils with sodic groundwater and high residual sodium carbonate (RSC). Gypsum should be added @ 25 kg/acre/irrigation (6 cm deep) to neutralize 1 meL^{-1} of RSC (Package & Practices of Rabi & Kharif crops).

6.5.2 Reclamation of Saline Soils

These soils have sufficiently neutral salts (calcium, magnesium and sodium chlorides and sulphates) to prevent most crop plants from growing. Saline soils are those that have a pH of less than 8.5, an ECe of more than 4dS/m and an ESP of less than 15.

The saline soils need salt leaching to make the root zone free of excess salts and maintain the reclaimed soil at such optimum level of solute concentration that crops do not suffer in future. Soil porosity is the major factor which influences leaching of saline-soils and it depends on texture, structure and clay mineralogy of the soils. In Haryana, as per CCS HAU recommendations, these saline soils can be reclaimed by allowing the water to stand in the field upto 30 cm and growing the salt tolerant and semi-tolerant crops. A proper drainage system is the ultimate answer to these soils (Package & Practices of Rabi & Kharif crops).

These soils have high amount of water soluble salts, mainly chlorides and sulphates of calcium, magnesium and sodium. pH of these soils is seldom less than 8.7 and crop growth suffers due to excess of salts. Before starting the reclamation, soil samples from such fields need be tested and expert advice obtained. However, excessive water soluble salts can be got rid off by following steps:

- Removal of salts by scrapping the surface layer and dumping these into a wasteland. Later on flood the field to leach down remaining salts.
- Level the field as carefully as possible and divide the field into small plots.
- Add sufficient organic wastes such as FYM, compost or waste straw in these plots.
- Plough these plots and mix organic wastes into the layer very well.
- Leach the field with 30 cm of water in two consecutive installments.

- After the soil is at friable stage, sow recommended salt tolerant crops and add 25% extra fertilizers over the recommended doses.
- Keep water table low (below 1.5 m) by pumping out sub-soil water. If the quality of this water is reasonably good, this water may be used for leaching and irrigating the crops.
- Do not allow the field to dry hard.

6.5.3 Reclamation of Saline-Sodic Soils

Soils containing significant concentrations of acidic salts (Calcium, Magnesium and Sodium chlorides and sulphates), as well as small amounts of salts capable of alkaline hydrolysis and/or adequate exchangable sodium, obstruct with the development of most crop flora. pH is normally less than 8.5, ECe is greater than 4 dS/m and ESP is greater than 15.

Sodic soils require drainage to lower the saline or sodic water table which often occurs at shallow depths coupled with leaching of salts with superior quality irrigation water and application of gypsum to neutralise developing alkalinity and rising pH. Crops tolerant to both salinity and alkalinity should be preferred in these areas. (Bhagava, 1989).

These soils have high amount of exchangeable sodium connected with bicarbonate. pH of these soils always exceeds 8.7 except in degraded alkali soils. Growth of crop in these soils suffers due to poor physical conditions coupled with nutritional gypsum disorders. Such soils can be reclaimed by adding gypsum, a cheaper source of calcium. The quantity of gypsum to be applied can be known only after its testing in soil testing laboratory. This would be calculated by factors such as exchangeable sodium percentage (ESP), cation exchange capacity (CEC) and the variety of crops to be grown. The gypsum requirement can be calculated using the following formula:

$$\text{Gypsum requirement} = \frac{(ESP-15)*CEC*1.72}{100}$$

For example if the ESP of the area is around 40%, CEC of the soil is 17, gypsum requirement to bring down the ESP to 15 would be 7.3t/ha.

Nearly 12-15t/ha gypsum is needed for soils in a high state of declaration. The application of gypsum is required in the first year of reclamation and need not to be repeated in the subsequent years.

For reclaiming such soils, following steps may be followed:

- Get the soils sample tested from the nearest soil testing laboratory to know the exact requirement of gypsum.
- Bund the field. Bunds should be 30m high.
- Give two irrigations of 15 cm deep water to remove excess of sodium carbonate/ bicarbonate from surface layer.
- When field is in "water" broadcast the recommended dose of gypsum (powdered) and give shallow ploughing of 10cm.
- Grow the green manuring crop of "Dhaincha" during April and May. Green manure this crop in the end of June and transplant rice nursery of 40-45 days old by keeping 15 cm distance among rows and 15 cm among plants. At least 3 seeding may be planted in one hole. Add 25% extra dose of nitrogen and 50 kg zinc sulphate per hectare.
- The field should not be allowed to go dry. Keep on giving light but frequent irrigations.
- After two years of paddy-wheat/barley rotation, go in for paddy -barseem rotation.
- Keep on getting the soil samples tested to know the extent of reclamation and problems, if any.
- Never keep the field fallow and add sufficient amount of FYM/ compost.
- Keep water table below 2.5 and as far as possible mulching should be done in hot summer days.

6.6 Summary

Using IRS LISS-III and Sentinel satellite data, various thematic maps of land use and land cover, as well as waterlogged and salt-affected areas, were generated. To recommend a grouping of activities for the area, agroclimatic data was merged using numerous thematic maps, including soil, slope, land use/land cover, geomorphology, water quality, and subsurface water level. Various attributes are classified into environmental and human components based on development packages. A variety of on-site surveys encompassing the entire area were planned during the design of the decision-making rules, including varied land types, soils, groundwater content, rainfall conditions, climate zones, and existing land use circumstances.

Future challenges such as groundwater extraction, the prospect of adopting more effective irrigation systems and water storage, and other site alterations through soil and water conservation approaches were all examined while assessing alternative recommendations for land use activities. Better crop types, more trees, shrubs, and herbs, as well as the advantages of agricultural interdependence, livestock, and other ways (such as sophisticated farming systems), are all considered. Decision-making criteria were developed based on these findings. This chapter discusses farming techniques for flood-prone and shallow-water locations.

Crop seeding is timed to coincide with the receding of inundated water during wet seasons. During the post-monsoon season, several vegetable crops can be tried in places with a high water level. A pressure irrigation system should be employed in these fields to minimise overwatering.

Waterlogged lands in the area could be reclaimed by selecting a proper drainage method.In the study area, following methods depending upon the existing conditions are suggested such as horizontal, vertical, bio-drainage, sub-surface drainage system. The list of salt-tolerant crops and their variations suited for the Kharif and Rabi seasons was also discussed.Many inorganic additions are used to rehabilitate alkali soils, but gypsum is the most cost-effective and widely available. Gypsum application was shown to be most effective when mixed in 10 cm of surface soil, and gypsum reactivity was found to be greatest.

The appropriate suggested recommendation for management of waterlogged and salt affected area is based on agricultural engineering techniques of CCS HAU, Hisar, CSSRI and ICAR. The use of traditional methods to monitor the rise of the water table appears to be insufficient. Surface drainage, subsurface vertical drainage, subsurface horizontal drainage, conjunctive water usage system, bio-drainage, water supply tube wells, and sewerage development are among the different solutions suggested for minimising waterlogging. In addition to the lining of canals and water channels, farm water management could be very beneficial. In waterlogged and salt-affected areas, technology needs to be improved and upgraded immediately.

CHAPTER-7

SUMMARY AND CONCLUSIONS

7.1 Summary

Land and water resources are critically important natural resources and whose exploitation beyond their regenerative ability has led to degradation of environmental, enlarging the life sustaining mechanisms elsewhere their remidial boundaries. The quickly growing of population puts serious demand on natural resources and production systems. Thus increasing emphasis is being laid on scientific supervision of natural resources to safeguard their optimum uses, keeping the view of environmental, conservation and socio-economic needs in mind.

Problem of waterlogging and soil salinity were leading user of soil and water resources is dangerous to sustainable development. Modern agricultural practices and technologies settled and extended over three decades have donated unprecedented growth in food production of the nation. But now it is rising concern that these mainstream expertise which have profits as well as charges, might also not be sustainable. Therefore, there is definite need of supervision of soil and water resources of the region to ensure development of rural as well as urban areas in harmony by providing much needed food, livelihood and environmental security in a judicious and sustainable basis.

The present study aimed on provision of management of waterlogged and saline area in north western Haryana. In June 1996, the water level in dam-irrigated areas rose to within 3 metres of the ground surface, resulting in land loss due to waterlogging and secondary salinization. It is also predicted that the city will be in a critical state in the future. If no remedial steps are taken, the depth of the water table would rise fourfold. The study recommends the optimal usage of land & water resources through soil and water conservation measures, selection of efficient crops with alternate farming system which are appropriate to local agro-climatic conditions and socio-economic needs as well as fit into national objectives of sustainable development of natural resources.

In the sample region, the waterlogged patches are often located in local depressions or near canals. Water pools in the depressions during the rainy season, causing floods. The seasonal waterlogged region of the research area is 12.20 sq km, or 0.18 percent of the whole geographical area, whereas the permanently waterlogged area is 8.10 sq km, or 0.12% of the total geographical area. The total area affected by salt is 6.31 square kilometres, with sodic soil covering 1.48 square kilometres. Saline soil covers 1.34 square kilometres, whereas saline-sodic soil spans 3.49 square kilometres.

Present research work has demonstrated strategies for the site specific land use plan, cropping system and proper drainage network to counter the problem of waterlogging and soil salinity in selected region and suggest a Decision Support Information System (DSIS) to manage the water logged and soil salinty in the region. The study is based on that combination of remote sensing and GIS with high resolution satellite data and agricultural engineering techniques that play main role in assessment and management of water logged and salt affected area. Remote sensing provide time to time, accurate, cost effective and unbiased information on various natural resources which are prerequisite for optimal utilization and effective management for water logged and salt affected area.

IRS (LISS-III, IV) and Sentinel satellite images were used as primary data source with Survey of India, 1:50000 scale topographical sheets as secondary data source for mapping of waterlogged and salt affected mapping. Ancillary data taken from district administration & Census 2018, literature related to remote sensing & GIS with other related fields and exhaustive field observations through visual analysis of remote sensing data, various theme maps were prepared and further based on field ground truth observations of the area, these maps were finalized. These maps are digitize and demarcated in the GIS atmosphere and after due correction and attributes attachment, final digital maps waterlogged and salt affected area and other different thematic maps were also prepared. The Decision Support System for salt affected and waterlogged area has been prepared using integration techniques various thematic maps in GIS environment.

The completions of the Bhakra Irrigation scheme in the early 1960s, the state implemented canal irrigation on a wide scale, resulting in an increase in the ground water table in the study region. The areas where water levels are rising are still underlain by brackish groundwater. Huge swaths of land have been waterlogged and salinized due to critical water level depths (>1.5 m). This has resulted in a reduction of crop yields as well as the destruction of buildings and highways, as well as the emergence of environmental health hazards.

The overall underground water prospects of the study area vary from poor to excellent. The units of alluvial origin have very good to excellent underground water scenarios but on the other hand, ground water prospects in aeolian plain and sand dunal areas are moderate and poor respectively. The ground water quality found in area is good to saline. These include fresh water (54.24 %), sub marginal (31.28%) marginal (11.60%) and saline (2.89%). It was observed that adjacent to water body like canal, ponds and river, the sub surface water quality is good.

The underground water table depth in the study area is 1.5 to >40 M below ground level (BGL) in various parts. 70.57 percent of total area falls under the depth zone of 1.5 to >20 meters below ground level during pre monsoon. Highest depth of water table observed in Bhawdin, Moriwala and Ding villages. Surface water resources of the area are available in form of ephemeral river Ghaggar, Bhakhra Canal Network and village ponds. Ghaggar River is main seasonal stream flowing along northern boundary of the study area. In normal condition water flow is very less in this river but during monsoon it becomes very active and many time adjoining areas are flooded by water over flowing the embankments.

The map of land use and land cover was created by visual analysis of October 2018 and March 2019 satellite images. The land use of the study area has been narrowly divided into constructed land, agriculture, wastelands and bodies of water. The landuse statistics reveals that major land use in this area is agriculture, which covers 6407sq. km including double harvest, only Rabi, only Kharif and existing fallow-class. While double cropped area under agriculture land use constitute 90.94 percent of total area. The study indicated a moderate intensity of cropping of 191.92 percent. The wasteland categories viz. degraded pastures, scrublands and sands comprises of only 1.72 percent of total area. Built-up land use categories occupy 2.19 percent of total area and rest (0.01) is covered by water bodies.

The alluvial plain adjacent to Ghaggar river of the study area is plasticized by cropping pattern of rice-wheat and northern alluvial plain have high intensity of rice wheat and cotton wheat crops. The central plains have suitable conditions of heavy soil and availability of ground and surface water resources. But soils of the southern plain is loamy sand and less suitable for rice cultivation.

It is concluded that area under input intensive crops of green revolution has increased at the cost of traditional crops and desi cotton, gram, pulses and millets cropped area have declined significantly.

Due to these input intensive agriculture, the area is suffering from decreasing water table, excessive use of fertilizers and pesticides primary to serious ecological difficulties. The study has exposed that there is serious need for diversification of cropping pattern. Waterlogging and soil salinity are troubles in the area; there is an immediate need to consider all pertinent aspects of the troubles; viable and realistic solutions were devised based on the area's current agro hydrological conditions, as indicated in this report.

Geomorphologically, the study area were divided into mainly aeolian plain, dune complex, stabilized sand dunes, flood plain deep and alluvial plain. As per the soil texture the study area is established mainly consist of fine, loamy and sandy. The soils of the salt affected patches of study area have been evaluated on the basis of collected soil samples from the study area. The suitability and sustainability of waterlogged and salt affected soils for main agriculture crops and agricultural plantation of land evaluation and soil sustainability status of different crops along with their varieties are also discussed.

The chief objective of present study is to generate Decision Support Information System (DSIS) for the study area that is optimally appropriate to the topography, climate and creative probable of home resources then the production level will be maintained without decay over time. Current technology of agricultural engineering, resource capacity, terrain and environment criteria have been taken into account in the resource plan recommendations.

The Decision Support Information System (DSIS) and proper drainage network have been prepared for waterlogged and salt affected area by integrating different thematic maps such as landuse / land cover, geomorphology, lithology, soil texture, ground water quality, underground water table depth, rainfall and surface water irrigation facilities. These thematic maps were evaluated individually and jointly for preparation of management plan. For recommending land and water resource action plan various decision rules have been formulated related to the causes of waterlogging and soil salinity in north-western Haryana. Consequences of the Problem of waterlogging and soil salinity were also discussed in action plan. These consequences were discussed from farm to national level. For management of waterlogged and salt affected area different strategies for fighting threat of waterlogging and salinity was suggested. The suggested strategies are Short term preventive and curative measures as well as Long term measures. Different cropping practices with their varieties for shallow water table and flood affected areas were suggested for Rabi and Kharif season.

Horizontal drainage system, Vertical drainage system, Bio-drainage system, Sub Surface vertical Drainage (Network of Tubwell), Link drain (Subsurface field drainage system) and Ditch drain (Subsurface field drainage system) were the major recommendation those are suggested for the management of waterlogged and salt affected area. Decision Support Information System for management of waterlogged and salt affected area plan map was prepared along with reclamation of alkali, saline and saline-sodic soils.

The appropriate suggested recommendation for management of waterlogged and salt affected area is based on agricultural engineering techniques of CCS HAU, Hisar, CSSRI and ICAR. The use of standard approaches to track the growth of the water table seems to be ineffective. Land drainage, subsurface vertical drainage, subsurface horizontal drainage, conjunctive water use scheme, bio-drainage, water supply tubewells and sewerage growth are among the different steps proposed for controlling waterlogging. In addition to the lining of canals and water courses, farm water control may be very useful. In waterlogged and salt-affected areas, infrastructure has to be improved and upgraded immediately.

7.2 Conclusions

Based on research work carried out in this thesis, following conclusions have been derived:

- The study establishes the role and usefulness of remotely sensed and GIS for monitoring and mapping of waterlogged and salt affected area and for formulating integrated Decision Support Information System plan on land and water resources growth for its judicious management. Space borne data & GIS has also proved their worthiness in creating timely and reliable, nominal and unbiased information on natural resources.
- Remote sensing and GIS modern technologies of natural resources inventories and management are prerequisite for implementing sustainable development plan and continuous assessment of natural resources at local, regional and national level.
- • The research area is plagued by waterlogged soils and soil salinity, as well as overexploitation of land and water resources, degradation, and management issues. Waterlogged and salt-affected areas are prevalent in the canal and river's vicinity. Low soil fertility, light texture, low carbonic & organic matter, soil erosion, and poor quality subsurface water are also difficulties in these waterlogged and salt-affected areas.
- It is concluded that the crop production in the waterlogged and salt affected area is negligible. The study shows that there is urgent need to implement suggested land & water resources development for sustainable agriculture development of waterlogged and salt affected area.
- In the Ghaggar tract, attempts have been made to lift and reinforce the Ghaggar embankments as required, as well as provide drainage drains to increase the ability of the Ghaggar river and prevent overflow. An artificial lake known as Ottu has been built in the district of Sirsa to provide water storage during peak discharge in the Ghaggar and to prevent flooding in the state. In this tract, a network of surface drains consisting of link, tributary and

main drains has been built to transport storm water from this area to an outfall in Ghaggar.

- The research region is in the desertic and semi-desertic areas, where agriculture is mostly increased by surface water, groundwater, or a combination of both. In the early stages of its implementation, surface water was transported over long distances (Bhakra) and spread to farmers' fields by an unlined irrigation scheme. As a result, the groundwater body was recharged by continued seepage and percolation through the main, secondary and tertiary stages of the irrigation system. The irrigation system's lining hasn't changed significantly since then and there are already seepage losses. Weak land levelling, ineffective water application techniques and irrational drainage policies all add to the issue of rising water tables.
- Irrigation in a different rergions causes a chain reaction of social, ecological, hydrological and environmental changes. Our failure to predict the effects of canal irrigation, particularly in desertic and semi-desertic regions, as well as our failure to take adequate steps to mitigate the changes wrought by irrigation, has inevitably resulted in a slew of problems. Heavy irrigation in semi-desertic and desertic regions causes soil salinity and waterlogging.
- Land use decisions are also decisions of water use. Non-scientific irrigation techniques in the area have led to over utilization of underground and surface water resources. Due to this, at present area is in problem of waterlogging and soil salinity. These parameters of waterlogging and soil salinity in concern with soils, sub-surface water prospects and quality, availability of surface water, present land use, futuristic consideration etc. are taken into account for formulation of waterlogged and salt affected area management plan.
- Under this sustainable plan for waterlogged and salt affected area the practices suitable for the area are crop diversification with less water consuming crops, dry land crops with their management and location improvements using soil and water conservation methods. In addition to these, study area have urgent need to implement this farm level management plan and package practices such as sprinkler irrigation, drip irrigation, mixing of saline with fresh water,

lining of irrigation channels and regular training of farmers and field functionaries for efficient water management.

- The area has suffered complete loss of natural resources such as soil and water; this miserable situation forces us to make inspiring call to take serious remedial measures to avoid foreboding of an ecological disaster. To restore the agricultural productivity from waterlogged and salt affected area with Govt. support should be launched without delay.
- There is frightfull necessity for launching of people supported Land and Water Care Movement and driven by grass root level local bodies with proper legal, technical and financial resources.
- In the protection and management of natural resources, voluntary organizations and NGOs have a significant role to play. It is also necessary that government department should have workable and effective linkages and collaborations with NGO for successful management of natural resources.
- Gram Panchayats should be main community based organization for all activities related to land and water resources managing and development.
- After implementation of management plan, the area will have tremendous potential for crop production. It is universally accepted that the future resources of food requirements of an expanding population can be fulfilled by concentrating all resources on improving the stage of maintenance of lands already under cultivation and ploughing the potentially arable soils that are currently uncultivated.
- The potential benefits of management of waterlogged and salt affected region development plan in the form of improved output of agricultural products. The Decision Support Information System plans will also help to generate employment opportunity and improve economic and nutrition standard of the farmers. In order to save the land from erosion, boost soil fertility, increase the area under irrigation and reduce the effects of drought, this resource development plan would improve all environmental conditions in the area.

7.3 Workshop and Awareness Campaign with Farmers

During field visit at the time of soil sampling and ground truth of land cover/ land use, I have discussed with the farmers of villages Surtia, Kalanwali, Ludesar, Nathusari Chopta, Badopal, Deshu Khurd, Phaggu , Khabra Kalan and Makhu Sheorani regarding the problems of waterlogged and soil salinity. Afterthat suggestion received from the Hon'ble Panel Members during PhD Pre Submission Seminar village level workshop were organized at farmer level at Nathusari Chopta, Ludesar, Phaggu, Makhu Sheorani, Kalanwali, Badopal, Khabra Kalan and Surtia. It is not possible to conduct these Workshops at large scale due to Covid pandemic and lockdown situation in Haryana. These Workshops organized with those farmers who are facing the problems of waterlogged and soil salinity in above listed villages.

I have prepared a pamplet in Hindi medium for the farmers and distribute it among the farmers during awareness compaign programme. This pamphlets inclused causes responsible for the problems of waterlogging and soil salinity in the study area, its impacts, solutions related to judicious management of land and water resources, soil and water testing facilities, varities of crops seed for rabi & kharif with salt tolrent and role of geoinformatics in managing of waterlogging and soil salinity.

After the Covid or lockdown period, I will try to fix a meeting with the Deputy Commissioner of Fatehabad and Sirsa districts regarding the management of problems of waterlogging and soil salinity and I also provide a copy of my Final PhD Thesis to the Administration for the help of policy / deceison makers.

7.3.1 Suggestions /View of Farmers

Farmers claim that residents in the high saline area have lower annual income and expenditures than those in the low saline area. People in low-saline areas use their property for a variety of reasons, including rice cultivation, white fish production, shrimp culture, and so on, but farmers in high-saline areas have no such options.

Farmers' reactions to salinity are unfavourable. According to the results of the survey, they did not have a unified strategy for dealing with the salinity issue. Farmers' reactions to soil salinity don't follow any discernible pattern. They grow crops on their lands, which have a low salt level. On these agricultural grounds, they aim to diversify their output. They also stress the importance of increased government involvement in resolving the salinity issue. Installing a good drainage system, for example, is crucial for successful and long-term restoration. Farmers will clearly be unable to establish such a large drainage system without the assistance of the government or non-governmental organisations. The farmers also underline the need of keeping ground water at a level where re-salinization may be kept to a bare minimum for long-term reclamation.

Shrinivash, the farmer of Ludesar told that the production is very low. They are facing the problem of waterlogged soil salinity. Only wheat and mustard are the crops of this field. During kharif season, they have no production.

Nathusari's farmer Manoj Kumar shared his view on his problem of poor economic condition. He had tested his soil in the laboratory and found saline-sodic soil. Wheat is the only crop that is seeded in rabi season while during kharif, he has no production from his ranch. He is also worried about the high rate of diesel (diesel is used in pump set).

Bahadur, the rancher of Badopal worried on waterlogged and soil salinity problem. He is getting only 6-7 quintals/acre wheat. The land is fallow during kharif season. The ranchers are facing the problems of waterlogged and soil salinity from last 20 years.

Another farmer Balwan from Deshu Khurd told that the production is very less in his farm. In rabi season, they are getting the production of wheat while in the kharif season, the crop of cotton is almost negligeable. The wheat production is 10-12 quintals/acre.

Mahender Singh from Phaggu told that the level of water is very upish. During monsoon season, the water comes on the surface oftenly. They are not getting the money which they had spent on the farm. Wheat is the only crop that is sown in rabi season. They are facing the problem of waterlogging since 15 years.

Suraj Bhan, the farmer of Nathusari Chopta discussed his problem of waterlogged and salinity. They are not getting 25% production that should be happened. From last 11-12 years, the salinity and waterlogged are too much in his area.

Another farmer Mangal, belongs to Khabra Kalan shared his view about salinity of the soil. He had checked his soil in laboratory but the report of the testing indicates saline-sodic in his field. They are getting only wheat (rabi season).

Devender , the farmer of Ludesar is worried about the less production of his farms. He told that we can see white layers in the fields. The productivity of wheat is very less and they are getting only 12 quintals/arce.

Makhu Sheorani's farmer, Vishnu discussed his poor economic condition. They have not enough money to maintain their daily requirements. Their expenditure is not fulfilled by their fields. Only 4 quintals/acre is their production of wheat. They are suffering from the problem of sail salinity and waterlogged.

In brief, we can say that the farmers of the affected areas are facing the problems of both waterlogged and soil salinity. Their crop production are very low. It is almost zero. They are suffering from poverty. They have no money even to celebrate their children marriage. The requirements of daily life are also not fulfilling. The government is ignoring the problems of the farmers. The problems are so sorrowful that the farmers can't sale their land. There are no purchasers of the land. The government has not taken any action regarding the problems of waterlogged and soil salinity.

7.3.2 Author Suggestion / Request to the Administration

It is my personally request to Government and Administration to focus on the problems of waterlogged and salt effected area. The farmers are in very poor economic condition and they have not enough sources to survive their life. Mismanagement of water and land resources has put the rural economy and agriculture in North-Western Haryana in risk. Excessive irrigation and incorrect cropping techniques have rendered a major portion of the land unusable for agriculture. Due to water logging and salinity, a huge portion of valuable productive land is becoming barren. Only by understanding the reasons and developing a practical, cost-effective plan on a sustainable and environmentally sound foundation can such areas be reclaimed. The pH level in the research region is also between 8.00 and 9.00, according to laboratory test results.

In North-Western Haryana, there is a pressing need to address rising water logging and salinity levels. Traditional water drainage systems are not only expensive, but they also degrade the environment and cause nutrient leaching. Horizontal drainage system, Vertical drainage system, Bio-drainage system, and sub-surface vertical drainage system are some of the approaches for reducing water logging and salinity.

My research work is based on latest and innovative technology of remote sensing and geographical information system with tools of agricultural engineering that provides sustainable basis solutions for above mentioned problem.

Annexure-I (Field Photo of Waterlogged and Salt Affected Area)

Soil Sample Collection at Deshu Khurd

Waterlogged area at Surtia

Soil Sample Collection at Nathusari Chopta

Waterlogged area near Pili Mandori

Soil Sample Collection at Lohgarh

Soil Sample Analysis (CCS HAU, Hisar)

Annexure-II (Workshop and Awareness Campaign with Farmers)

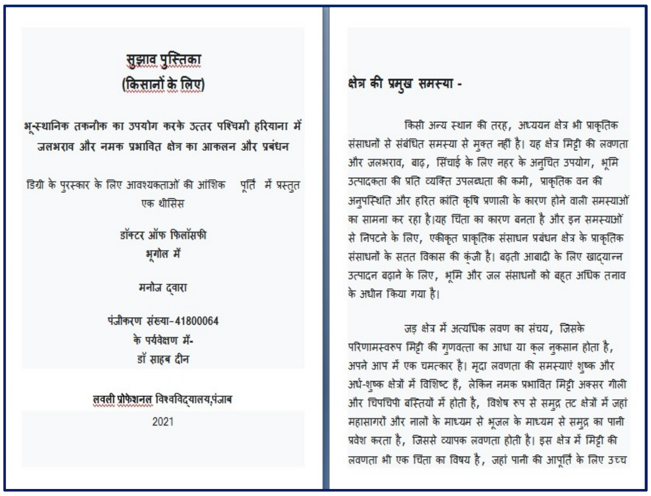
Farmers of village Makhu Sheorani

Farmer Mahender, Phaggu

Farmer Manoj, Nathuari Kalan

Farmer Balwan, Deshu Khurd

Farmers of village Kalanwali



सुझाव पुस्तिका
(किसानों के लिए)

भू-स्थानिक तकनीक का उपयोग करके उत्तर पश्चिमी हरियाना में जलभराव और नमक प्रभावित क्षेत्र का आकलन और प्रबंधन

डिग्री के पुरस्कार के लिए आवश्यकताओं की आंशिक पूर्ति में प्रस्तुत एक थीसिस

डॉक्टर ऑफ फिलॉसफी
भूगोल में

मनोज द्वारा

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के पर्यवेक्षण में-
डॉ साहब दीन

लवली प्रोफेशनल विश्वविद्यालय,पंजाब
2021

क्षेत्र की प्रमुख समस्या -

किसी अन्य स्थान की तरह, अध्ययन क्षेत्र भी प्राकृतिक संसाधनों से संबंधित समस्या से मुक्त नहीं है। यह क्षेत्र मिट्टी की लवणता और जलभराव, बाढ़, सिंचाई के लिए नहर के अनुचित उपयोग, भूमि उत्पादकता की प्रति व्यक्ति उपलब्धता की कमी, प्राकृतिक वन की अनुपस्थिति और हरित क्रांति कृषि प्रणाली के कारण होने वाली समस्याओं का सामना कर रहा है।यह चिंता का कारण बनता है और इन समस्याओं से निपटने के लिए, एकीकृत प्राकृतिक संसाधन प्रबंधन क्षेत्र के प्राकृतिक संसाधनों के सतत विकास की कुंजी है। बढ़ती आबादी के लिए खाद्यान्न उत्पादन बढ़ाने के लिए, भूमि और जल संसाधनों को बहुत अधिक तनाव के अधीन किया गया है।

जड़ क्षेत्र में अत्यधिक लवण का संचय, जिसके परिणामस्वरूप मिट्टी की गुणवत्ता का आधा या कुल नुकसान होता है, अपने आप में एक चमत्कार है। मृदा लवणता की समस्याएं शुष्क और अर्ध-शुष्क क्षेत्रों में विशिष्ट हैं, लेकिन नमक प्रभावित मिट्टी अक्सर गीली और चिपचिपी बस्तियों में होती है, विशेष रूप से समुद्र तट क्षेत्रों में जहां महासागरों और नालों के माध्यम से भूजल के माध्यम से समुद्र का पानी प्रवेश करता है, जिससे व्यापक लवणता होती है। इस क्षेत्र में मिट्टी की लवणता भी एक चिंता का विषय है, जहां पानी की आपूर्ति के लिए उच्च

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