LAND DEGRADATION AND INDIAN AGRICULTURE: A REGIONAL ANALYSIS

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Date: 20 July 2018

DECLARATION

I, Ratan Priya, hereby declare that the thesis entitled **"LAND DEGRADATION AND INDIAN AGRICULTURE: A REGIONAL ANALYSIS"** submitted by me for the award of the degree of Doctor of Philosophy (PhD) is my bonafide work. The thesis has not been submitted so far in part or in full, for any degree or diploma of this university or any other university.

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CERTIFICATE

It is hereby recommended that this thesis be placed before the examiners for evaluation.

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समर्पित

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Place: *RATAN PRIYA*

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ABBREVIATION

AWiFS	Advance Wide Field Sensor
FSI	Forest Survey of India
GIS	Geographical Information System
GoI	Government of India
ICAR	Indian Council of Agricultural Research
IRS	Indian Remote Sensing
IRSO	Indian Space Research Organization
IUSS	International Union of Soil Sciences
LDI	Land Degradation Index
LISS	Linear Imaging Self Scanning Sensor
MoA	Ministry of Agriculture
MoRD	Ministry of Rural Development
NAAS	National Academy of Agricultural Sciences
NATMO	National Atlas of Thematic Mapping Organization
NCT	National Capital Territory
NRSC	National Remote Sensing Center
OLS	Ordinary Least Square
SAARC	South Asia Association for Regional Cooperation
SWMCN	Soil and Water Management and Crop Nutrition Subprogramme
TDA	Total Degraded Area
TGA	Total Geographical Area
UNCCD	United Nations Convention to Combat Desertification

Preface

The soil is one of the most precious resources. Its importance increases because of its ability to provide food security to all. However, soil suffers from many types of problem e. g. losses of organic matter, physical degradation, nutrition depletion, chemical degradation, soil erosion, sedimentation and degradation of landscape function. Land degradation in rural India has multifaceted impacts. One of the major aspects is its relation to Socio-economic development. Soil salinity is one of the most important in the Indian context. Soil salinity has different dimensions in terms of the physiographical formation with the prevailing climatic condition e.g. aridity has direct relation. Human factors into the formation of soil salinity cannot be ignored in the world of rapid transformation of society in terms of the technological innovation e.g. development of drip irrigation, on one hand, can be very beneficial but on the other hand, can increase the soil salinity problem into the field.

The salinity or alkalinity has been concentrated into major three area- middle Gangetic plain, Western India and South-East India. Its' concentration in the Gangetic Plain is very high, which is affecting the agricultural productivity of the region. This can be a serious problem for the total productivity of India as the Gangetic plain is the land of food granary for India on which millions of the life is dependent. Inefficient water-use in study areas of Punjab and Uttar Pradesh has been found to be a major reason.

As the food is indispensable for the human being, the soil health is also indispensable for the food security. The different unconscious development has been contributed to the soil salinity, additional to its natural contributing factors. This is alarming for the country as well as the policymakers to focus towards the soil salinity problem in a specific manner and towards land degradation in general. This country cannot afford to be a mute spectator of this problem; otherwise, the food insecurity would mount to the head of it. Economically and ecologically, the gravity of the problem demands a strong recognition of the problem.

CHAPTER-1

INTRODUCTION

1.1 INTRODUCTION

The soil is one of the most precious resources. Its importance increases because of its ability to provide food security to all. However, soil suffers from many types of problem e. g. losses of organic matter, physical degradation, nutrition depletion, chemical degradation, soil erosion, sedimentation and degradation of landscape function (Bossio et al., 2010). Land degradation in rural India has multifaceted impacts. One of the major aspects is its relation to Socio-economic development (Pani and Carling, 2013; Pulido and Bocco, 2014; Priya, 2014; Priya and Pani, 2015; Priya and Pani; 2017). In rural areas, the poverty level varies state-wise. The increase in per capita income has a significant role in the agricultural and non-agricultural sectors. However, this is not only the factor, though is a key component to affect the livelihood in the rural areas (Nayyar, 2005). Poverty coupled with high population densities have cited as key cause for land degradation (Bossio et al., 2010; Kangalawe and Lyimo, 2010). The study by Fan et al. (2000) has inferred that improving poverty and development in the rural infrastructure enhance the productivity of the land. In turns, it might be lead to an increment in the purchasing power of the people in a country. A research by Wang (2013) in China has suggested that the reduction in poverty is possible through the better agricultural practices.

The form of agriculture practices in India mostly is of substance type and the livelihood of rural areas is depending on it. The high population pressure on land has increased the stress on the land (Kangalawe and Lyimo, 2010; Sadanandan, 2014). Yet, the agricultural sector is providing 59% employment out of total employment provided by all the sector of the economy. Due to increase in population and decreasing agricultural productivity, migration from rural areas is taking place rapidly (Sadanandan, 2014). But the process is not so easy and is not smooth (Sadanandan, 2014). The problem related to lending the farmers in a rural area is another problem. Small farmers are not capable of investing in the inputs to the field (Storm, 2006).

1.2. LAND DEGRADATION

The land is the fundamental means of production in an agrarian society for developing countries in general (Grepperud, 1997; Nkonya et al., 2008) and India in particular (Reddy, 2003; Datta and Sarkar, 2012; Bhattacharya and Guleria, 2012). Without it, no significant progress takes place, especially where agriculture is being the mainstay of the rural economy. Socio-economic privileges and dependency of the whole society in general and rural areas, in particular, revolves around it (Blaikie and Brookfield, 1987; Bojo, 1991; Tekle, 1999; Feng et al., 2005; Kingwell et al., 2008; Kosmas et al., 2013; Gerber et al., 2014; Salvati et al., 2015). The land is one of the important resources for surviving or feeding the life. Land degradation is declining of the production capability of the land for short-term and long-term (UNEP, 1992; Salvati and Zitti, 2008). Origin of the term “land degradation” has not clearly found because it is a continuous process. “Land” as a *“terrestrial bio-productive system that comprises soil, vegetation, other biota, and the ecological and hydrological processes that operate within the system”*, and its “degradation” as *“reduction or loss … of the biological ... productivity, … resulting from land uses, … or (a) combination of … processes, such as… soil erosion … deterioration of ... properties of soil … and long-term loss of natural vegetation”* (UNCCD). Land degradation is broadly refers to lowering the quality of land (ICAR & NAAS, 2010) either in the biological productivity or usefulness of a particular place due to human interference and both (Levia, 1999), hillslope (Soni & Loveson, 2003) deforestation, suffering from loss of its intrinsic qualities, decline in its capabilities (Krishan et al. 2009).

Land degradation is now an emerging danger and threat to the farming communities, by which agriculture and environment have been being infected and damaged. Stehl (1993) has stated that land degradation is the most severe environmental problem threatening agricultural productivity. Due to rapid population growth and technical backwardness in agricultural mechanism and lack of off-farm employment opportunities leads to pressure increment on the land (Huntington, 1938; Adams and Bumb, 1979). Land degradation is not limited to the reduction of the physical status but it also includes the chemical and biological status of the land (Lindskog and Tengberg, 1994). They have emphasized on the concept of net degradation that has been defined as the output extracted after subtraction of natural reproduction and restorative management from the natural degrading processes and human interference. Environmental degradation is a major factor, which is restricting the growth and development of developing countries like India. Reddy (2003) has focused on land degradation in economic term and has revealed that the environmental degradation is defined as a reduction in health cost, declining productivities of natural resources like land, water, grassland, etc. It is a very serious problem at the regional level in India and the loss of production has not been realized at the macro level. Desertification has been being occurred in some regions of India like arid and semi-arid regions. Ravi and Huxman (2009) have explained Land degradation, as the resultant to the loss of productive cropland and rangeland has increased dramatically over a period.

1.2.1 TYPES OF LAND DEGRADATION (WASTELAND CLASSES)

According to NRSA (2011), the following major categories of wastelands are identified as wasteland classes:

Gullied/ Ravine Lands: It is the result of surface runoff. This affects the unconsolidated material and results in developments of channels. However, ravines are the vast system of gullies developed along the river courses. These can be divided into two parts according to depth. First is the Medium Gullied/Ravine Land (depth ranging from 2.5 to 5 meters) and second are Deep Gullied/ Ravine Land (having depth of more than 5 meters).

Land with a scrub: These cover the areas that are dominated by shrubs and possess shallow and skeleton soil, chemically degraded with extreme slopes, severely eroded and excessive aridity. They are intermixed with the cropped areas. The colour of these areas depends on the surface moisture ranging from yellow to brown to greenish blue. Such land can be divided into two parts: (I) Dense: Having vegetation cover more than 15 percent with moderate slope in foothills and plains and surrounded by the agricultural land, (II) Open: Having sparse vegetation cover less than 15 percent having thin soil and it is also prone to degradation due to erosion.

Waterlogged /Marshy Land: Waterlogged land is that land where water stand (at/near the surface) for most of the year. Marshland is that land which is inundated by water (permanently or periodically) and covered by vegetation. Depending on duration, this can be divided into two categories: (i) Permanent Waterlogged/Marshy Land; (ii) Seasonal Waterlogged/ Marshy Land. **Land affected by salinity and alkalinity**: Access content of salt into soil has been categorised as soil salinity/alkalinity. Considering the extent of salinity in the soil, it can be divided into two subdivisions: (i) "*Land affected by salinity/ alkalinity-Strong*", in which Electrical Conductivity (EC) levels (dS/m) more than 30, pH more than 9.8 and Exchangeable Sodium Percentage (ESP) more than 40; (ii) "*Land affected by salinity/alkalinity-*

Medium" having Electrical Conductivity (EC) levels (dS/m) between 8 to 30, pH between 9.0 to 9.8 and Exchangeable Sodium Percentage (ESP) between 15 to 40.

Shifting Cultivation: Shifting Cultivation is a traditional agricultural practice, in which crops are grown on forested and vegetated hillslopes by using 'slash and burn' method. Different regions pronounced it differently, such as jhumming in Northeastern and podu cultivation in Southern states of India etc. This type of cultivation is mostly associated with mountainous or the hilly areas midst forest cover and forest cleared areas. It can be divided into two sub-division- (i) Current Jhum; (ii) Abandoned Jhum.

Table-1.1 Indicators of Land Degradation

S. No.	Category	Indicators	Substantiation
1.	Agriculture	Abandon land (Doucha and Vanek, 2006)	Land on which agriculture is not being done now (proportion to total Agricultural land).
		Arable Land (Doucha and Vanek, 2006)	Land which available for cultivation (proportion to total Agricultural land)
		No. of Cattles (Doucha and Vanek, 2006)	Cattles per farmers
		Shifting cultivation (NRSA, 2011)	Constitute "*current jhum, abandoned jhum, under-utilized/degraded notified forest land, agricultural land inside notified forest land, degraded pasture/grazing land, degraded land under plantation crop*".
2.	Economic	Mining/Industrial Wasteland (NRSA, 2011)	Industrial wasteland, mining wasteland
3.	Geographic	Sand (Desert/coastal/ravine) (NRSA, 2011)	Coastal sand, riverine sand, desertic sand (dunes less than 15 m high and interdunal areas), desertic sand-moderately high dunes and high dunes
		Barren/rocky/stony waste (NRSA, 2011)	
		Snow covered/glacial area (NRSA, 2011)	

Source: Prepared by the author by using various sourced mentioned in the citation.

Sand (desert/coastal/riverine): Located in the deserts, riverbeds or along the shores, there are formed due to the accumulation of sands in coastal or inland areas.

Mining/Industrial Wasteland: These are formed due to the large-scale mining operations which resulted in the degradation of land and mine dumps.

1.3. INDICATORS FOR MEASUREMENT OF DIFFERENT FACETS OF AGRICULTURE

The agricultural study has the vast areas to cover. As the agricultural productivity is one of the dimensions of this study, it is needed to know about the factors, which directly or indirectly impact the agriculture in general and agricultural productivity in particular.

If the agricultural indicators are categorized then it can be broadly divided into two groups, which are agricultural input related dimensions and economic related dimensions. Both the categories are having significant indicators, which substantially able to impact the agricultural output. All these have been explained in Table-1.2:

Table-1.2 Indicators related to Agriculture

S. No.	Category	Indicators	Substantiation
1.	Agricultural	Grain Yield (Yeqing et al., 2013)	Total Production out of the net sown area (kg per hectare)
		Effective irrigation (Yeqing et al., 2013)	Irrigated areas out of gross cultivable area (%)
		Technical development	Availability of different new agricultural machinery per farmers
		Abandon land (Doucha and Vanek, 2006)	Land on which agriculture is not being done now.
		Cropping Pattern (Das and Mili, 2012)	Crop diversification (pattern) refers to the raising of varieties of crops in a given area in a crop season
2.	Economic	Per capita Income from agriculture	Income per member per annum

		Gross economic output (Agriculture and non-agriculture)	Gross Value of Output (in Rs.) Agricultural Income (in Rs) i.e. Gross Value of output net of paid out cost
		Agricultural investment (Yeqing et al., 2013)	Agricultural financial expenditure/total financial expenditure (%)
		Total Financial Expenditure on agriculture out of total income (Doucha and Vanek, 2006).	Total financial expenditure as % of income
Source: Table prepared by the author by using various sourced mentioned in the citation.			

1.4. LAND DEGRADATION PROCESS AND PROSPECT

The land degradation is a threat to the world population sustainability as food security of the world depends on the land majorly (UNCCD, 2015). The impact is intensifying due to the occurrence of other phenomena simultaneously like climate change, biodiversity loss and water scarcity (Pulido and Bocco, 2014). Land degradation is a very important geomorphic process which is occurring in many parts of the world over a range of landscape but the causal determinants factors have local specificities which are yet to be fully understood. Like many another process of land degradation, the Gully initiation and evolution, are attributed by different natural and anthropogenic causes. The natural causes of ravine erosion include climate change, catastrophic storm and tectonic uplift etc. whereas the anthropogenic causes are deforestation, overgrazing, unplanned settlement, population pressure and public policy (Pani, Carling, 2013).

1.4.1 *Land Degradation and Developing Countries:*

Focusing on the land degradation in developing countries, Kishk (1990) has inferred that in developing countries, agriculture is the primary economic activity which absorbs more than half of the population, on one hand, while on the other hand, the population is increasing with a very fast pace. This is leading to huge pressure on the cultivable land and forcing people to extract more and more land under cultivation and resulting in huge deforestation and land degradation. Poverty is constraint into land management. Therefore, poor farmers have been incapable to conserve their land due to misuse and poor management. Therefore, along with the natural factors, human activities are also the major reasons for land degradation. Demographic processes and economic variables influence the land use pattern of the region (Bilsborrow & Ogendo, 1992). Rapid land degradation in developing countries has happened mainly due to soil erosion in slope and rapid changing the land use practices in the place of current land use practices. All these factors have made undesirable changes in land use and leading to forest degradation is a major concern (Coxhead et al. 1994).

Here an important question arises “who is responsible for such change?” If one makes blame on farmers then it will be wrong because a poor farmer always tries to keep the land fully productive as it is the only source of its livelihood. Then who? Perhaps it the government side who is not paying attention to the problem and not providing adequate and right policies and measures to sort out the problem. Availability of appropriate technologies is required to deal with land degradation and conservation in developing countries. The right approach, proper thinking and looking into all relevant socio-economic and cultural aspects must be a good step in mitigating the most of trouble associated with land degradation. No theories can able to explain the complex interaction between population growth and changes in land use. Understanding the causes of environmental degradation in rural areas in developing countries, factors changes in land use are useful to mark the reason for the land degradation in developing countries (Coxhead et al. 1994).

Kishk (1986) has further explained his argument by giving examples of different developing countries of the world like Egypt. The Egyptian population is growing in recent years. In spite of huge industrialization; the major need of the population is met from the agriculture only. Egypt is suffering from the problem of desertification. The risk of desertification is very high and most of the areas are subjected to the sand movement, soil stripping and salinity and spreading towards the productive areas of Egypt. This type of land degradation is causing very high destruction and irreversible losses to the highly productive cultivated land in Nile Valley and Deltas. On the other hand, the industrialization is also causing a different type of land degradation. Industrial production of bricks and other building material extracted from alluvial fertile soil, the cause of removal of topsoil.

Barker and McGregor (1988) studied the Yallahs Basin of Jamaica which is having an area of 180 km^2. But it has a high population density and suffers from land degradation and rural poverty. Yallahs Basin has a high natural propensity for high erosive activities due to having a geologically recent mountain range, which is defined as topographically by steep slopes dissected terrain with sharp ridges and deep gullies.

Putting the words on land degradation in Pakistan, Ellis et al. (1993) have stated that deforestation has occurred in Pakistan at a very fast pace. Mostly, original woodland bellowed about 2000 m has cleared. The outcome of such activity is that now the soil has been directly exposed to rainfall. If the rainfall becomes very intense, then causes to serious soil erosion. Vegetation of Murree hills (Pakistan) has totally cleared, which was associated with soil erosion and environmental problem. The layer of topsoil is becoming thinner and difficult to cultivate and reforest and this creates high runoff responses, which results in shifting and flooding in the adjacent lowland areas.

A study by Stahl (1993) has explained the condition of land degradation in East Africa. East Africa has an annual population growth of 3 % like the rest of the continent. Land degradation is threatening the very basis of East Africa farmer's societies. Although land degradation is a loss of such a precious thing, which is not returned back, there are a number of steps taken by the government to mitigate or prevent the further degradation.

Mambo and Archer (2007) tried to examine how political, economic and environmental factors influenced the current status of land degradation in Zimbabwe. The author studies the land degradation map in Agro-Ecological Zones. Accordingly, they have categorized the probability of land degradation depending on the type of agriculture. The very high probability of land degradation occurs in extensive farming and regarded as arid areas whereas, the high susceptibility to degradation in the semi-intensive farming zone under woodland vegetation. Moderate susceptibility occurred in arid areas with any vegetation including bushland and cultivation and low probability exists in semi-arid eras with any vegetation and land class type. Land degradation is an issue of the global environment. Most countries are sufferings in terms of the amount of degradation; economic impact.

1.4.2 *Land Degradation and SAARC Countries*

Regarding and concerning Land Degradation in SAARC countries, 83 million hectares or 25% of the total areas under crops and pasture are affected by water erosion in the South Asian region. Salinity and waterlogging are a major factor for land degradation in irrigated areas and in coastal areas. Salinization mainly occurs in Indus river basin, the Southern coastline of Sri Lanka. Loss of nutrient and organic matter depletion is another form of degradation. Nutrient depletion occurs in mid-altitude hills of Nepal, Northern India. Water erosion spread over the foothills of Himalayas, Riverbank erosion exists majorly in the floodplain of the Ganges, the Brahmaputra, the Yamuna, the Tista and the Meghna Rivers. Wind eroded areas are Western Rajasthan, coastal region of India and the dry region of Pakistan. Desertification is land degradation, being present in the dryland of India and Pakistan. This area mostly suffers from moisture stress, sand movement, high wind velocity, and very limited canopy cover. Agrochemical pollution has founded in Pakistan due to heavy use of Agrochemicals. By the introduction of the green revolution, undoubtedly, food insecurity problem of India has been solved. However, discriminatory agricultural practices, population pressure and other human activities have brought the problem of land degradation (Singh & Singh, 2011).

The rapid population increase in Bangladesh has increased the pressure on land resources. Approximately 220 hectares (1% of total cultivated areas) of land goes out of cultivated per day. It has serious consequences on the sustainability of land as a whole. Soil erosion has been found in the parts of high terraces of Madhupur, Barind, and Akhaura tracts, in terms of topsoil and nutrient loss. Water erosion is a serious problem in Bangladesh, because of high seasonal rainfall, low organic matter content, poor soil structure and management and rapid destruction of vegetation cover in the different slope of hills, continuously thinning the layer of topsoil. 1.7, 3.2, and 3.1 million hectare area has degraded due to water erosion, soil fertility decline, and salinization. Plantation, organic agriculture, preserving soil fertility, fertilizer management, active participation of people, mangrove plantation in coastal areas are some suggestions to reduce the degraded land (Khan, 2011).

Land degradation in Bhutan is a natural phenomenon as well as man-made. In the dynamic mountain setting of Bhutan, land degradation is a natural and inevitable process. Land degradation is dominated by water as a degrading agent through surface erosion (splash, sheet, and rill), gully formation, bank erosion, and (flash) flooding. A mass movement driven by gravity is a secondary, but often very destructive process, often interacting closely with water-induced degradation. A mass movement, flood and soil erosion occur & driving for gravity are water on steep mountain slopes with complex geology and geomorphology. In Bhutan, Land degradation results in increased sediment transport by mountain streams. Unsustainable agriculture, forest degradation, forest harvesting, forest fires, livestock rearing and grazing, land use intensification and competition, mining, and quarrying, infrastructure development, policy gap are factors, which are responsible for land degradation in Bhutan. Institutional setting for land and environmental management, as if The National Environment Commission (NEC) and The National Land Commission (NLC) are the highest decision-making body, is important to mitigate the land degradation. Sustainable land management project, SLM planning tools, National Action Program (NAP), Land Management Campaign are some programs adopted to mitigate the land degradation (Dorji, 2011).

Land degradation is a serious phenomenon in Nepal because the Nepalese economy is based on agriculture with 70% of the population engaged in it. The main cause of land degradation in Nepal is the poor economic condition, lack of knowledge, awareness, and inefficient government policies. Terrain, soil, geology, climate and land management practices are very complex, so it is difficult to measure land degradation in Nepal (Khadka & Sharma, 2011).

1.5. LITERATURE REVIEW

1.5.1 *Deforestation and Land Degradation*

It is identified that there are two serious effects of deforestation on environmental degradation and loss of biodiversity in India (Menon et al., 1998). It emphasised that deforestation in India must special concern because of the diversity of the Indian sub-continent. As deforestation has a direct correlation with soil condition, deforestation may be one of the factors affecting the productivity of land (Singh et al. 2007). Kudesia and Kiran (2009) have provided the detailed exclusive human activities lists responsible for degradation. In utilization context, land degradation means loss of biological agricultural productivity or erosion in the land’s capacity to support desirable vegetation and to maintain the yield level over the years of use. India is having 8 % of the biological diversity of the world despite having only 2.4% of the total world's land. Nevertheless, another story is that a very large part of India has degraded land as well as a continual reduction in medicinal plant species, which results in loss of biodiversity and ultimately leading towards the extinction. These problems can be solved through the cultivation of medicinal plant on degraded land, which helps to maintain our diversity, minimize pressure on crop and also sources of good income because of demand of medicinal plant in the world market and reclaim the degraded land in the country.

1.5.2 *Desertification and Land Degradation*

The United Nations Convention to Combat Desertification (UNCCD) has defined desertification as “*land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climate variation and human activities*”. According to Thomas (1993), desertification is a major environmental and social issue for several decades, studies from various disciplines also have a concern about the desertification. Degradation occurred due to many types of human activities and also affected by natural events like droughts, dryland ecological changes, harming the environment and changes in the cycle of nature. Milton et al. (1994) have inferred that denudation and desertification involve changes in soil function and erosion activity, which results in bare ground, erosion, and acidification. Indian desert is spreading annually at the rate of 12000 ha of productive land and Indian desert is characterized by huge shifting dunes, high wind Speed minimal rainfall and high solar radiation. The Sandy soil of desert is having a rapid and fast infiltration rate of rainfall water, oxidation, and high salinity. For the solution of this desertification problem of Thar region, Chauhan (2003) suggested in his paper that introduction of fast-growing exotic trees species, because Indian trees species are very few in numbers and also not growing fast in the Thar region. Stabilization of shifting sand dunes by fixing barriers or local shrub, shelterbelt plantation (consisting of rows like Acacia tortillas, Tamarix articulate, smaller trees and shrubs etc.) to decrease the wind velocity, ecological regeneration of gypsum and limestone, growth of vegetation- like trees and grasses for the protection of land that create microclimates in the Thar desert area. Creation of microclimatic condition in desert areas is a feasible solution to control desertification and ecological regeneration. The paper by Geist and Lambin (2004) identified four causes of desertification viz. agricultural activity, enlarging of infrastructure, wood extraction and increase in aridity. Desertification results in dryland degradation. This paper helps to create awareness among public and individual level which helps in the creation of national scale policies and new opportunities with advanced technology. Other ways, at the global level this paper blames that there is a lack of a set of indicator to major desertification status and lack of any global policy too.

Desertification is an important cause which changes the behavior of land. All the above-mentioned literature state the same opinion on the desertification as environmental and social issues. Thomas (1993), Geist and Lambin (2004) clearly observed that it is difficult to differentiate between human and natural causes. The detailed study is required to understand the desertification in long-term monitoring at all level such as regional and national level and there is a need to have a global concern and universal policies for mitigation of desertification. These all are necessary for practical planning, management, sustainable utilization, reduce the shortage of agricultural production.

1.5.3 *Human Intervention and Land Degradation*

Exploitation of natural resources also leads to environmental and land degradation. In this context, Rao (1995) has documented that excessive economic activities are inadequate to arrest or limit the availability of natural resources due to misallocation of resources and excessive use of resources. Soil, forest and air are natural resources, which are degraded due to biotic pressure on forests, waterlogging, salinization, deforestation, and improper management of irrigation and soil erosion. Economic growth and population growth both are responsible for land and forest degradation. This paper also inferred that poverty and environmental degradation both are closely associated with their activities. Environmental degradation is linked to the production or consumption activity of poor people. Resources degradation in India is a serious problem such as drinking water, sanitation, indoor pollution, water pollution, air pollution, resources exploitation etc. Open access to resources is another region of land degradation.

Premchander et al. (2003) have worked in a semi-arid region of Kerala, focus differently on the water depletion as causes of degradation of other natural resources. Water is a resource needed for drinking, agriculture, industry, manufacturing and livelihood as well as livestock. Water is a power for livelihood but if there is more availability of water in agricultural areas then it may convert to saline. Degradation of agricultural land in both qualitative and quantitative manner affects the health and productivity of animal and people both. Forest depletion is also declining year to year, which results in degradation of forest and land. This paper deeply concerned with the agriculture and livelihood and further informing that both small and large scale farmers invest their own resources in digging wells, borings, which helps them in irrigation. It also reveals that the groundwater depends on the porosity and permeability of ground. This infiltration of water has influenced by the depletion of rocks in hilly areas. Depletion of natural resources affect the livelihood of human beings. In a long-term solution, this paper suggested some proposal like people must understand the complex interaction between the use of resources and livelihood. Highland and lowland management are required, cutting rock and digging the bore wells strictly stopped for increasing level of groundwater. Long-term sustainability is closely linked with the management of all natural resources.

Iyengar (2003) has focused in economic perspective on the contribution of landless people on land degradation by the land use and abuse on the natural resources and focused on the emerging issues of data collection on land degradation. The scarcity of natural resources found when resources have recorded a reduction or degraded faster than they are renewed. This type of environmental and land degradation facilitate the peoples with high income at risk and health effects. Increase in degradation in the environment is mostly due to overpopulation (Premchander et al. 2003) and rural-urban migration (Shandra et al. 2003).

Sahu and Dash (2011) try to explain the impact of mining activities on land degradation. Moreover, mining activities influence water, soil quality and vegetation including forest systems and on human health. Mining activity exerted pressure on the landscape and ecosystem. The process of excavators and blasting normally does overburden removal; as a result, a large volume of waste is the outcome of this. Topographic reconstruction, replacement of topsoil and soil reconstruction are some reclamation, which is supposed to be done in mining areas to mitigate the land degradation. Rehabilitation is also a good process to restore the areas or resources affected by mining. Extraction of natural resources like mining is also affecting the land degradation. The digging of rocks by blasting has occurred in hilly areas.

Environmental scarcity causes violent conflict (Homer-Dixon, 1994). Degradation and depletion of land is also an example of natural resource scarcity (Homer-Dixon, 1994). Conversely, civil conflict severely affects the land degradation. Economic, environmental and political factors are in predicting domestic armed conflict (Hauge and Ellingsen 1998).

1.5.4 *Population Growth and Land Degradation*

Regarding population growth, sustainability, and land degradation, Daily and Ehrlich (1992) were stressing that the major impact of population is a reduction in earth's net primary productivity. The carrying capacity of the earth is not like earlier because of current technological development, the level of consumption, and socioeconomic organization. For the sustainable use of resources with this development, there is a need to establish relevant temporal and spatial scales. Mortimore (1993) critically looks at the linkage between the growth of population in dryland and process of ecological degradation in the developing world. In Malthusian point of view, population growth results in increasing demand for food and increasing cultivation areas are consequences of this. Due to spreading the cultivated land, there is happening of reduction in length of fallows. The decline in soil fertility is outcomes of maximum use of land, and this result in declining yields, soil degradation, erosion, falling output environment destruction and food scarcity. In the against of Malthusian view, Boserupian's view states that growth of population density results in increasing demand for food and cash crops, but there occur increasing labor inputs per hectare. Adoption or diffusion of yield-enhancing technologies results in improvement in soil productivity and consequences of this is an improvement in the yield per ha. Due to this, there is an increase in total production, land value and investment in conservation of vegetation and productivity. Chopra and Gulati (1997) have studied the linkage between environmental degradation (deforestation and land degradation) and movement of population from one region to another region within developing countries. The hypothesis indicates that a large part of outmigration in the arid areas is because of push factor such as environmental degradation and avoiding the action of common property resources. The micro experiment has evidenced that the outmigration process becomes slow once the property rights are well defined, either in the form of ownership or user rights (Brown, 1981).

The understanding of current theories on population changes and the environment and land degradation is also essential before making or coming to an appropriate decision. In this context, Jolly (1993 & 1994) has evaluated the four theories on population, policies, economics and land degradation. Neoclassical economist has assumed population as a neutral factor and having no significant impact on land degradation. Conversely, classical economists have identified high population growth as a major independent cause of land degradation. The similarity has been found in the Dependency theory. But the Analyst theory has taken broader and comprehensive theory which advocated that land degradation is the outcome of multiple factors including "*high population, lack of employment opportunities and misconceived agricultural policies*".

Agricultural land reported an increase in food output from an expansion of the area under cultivation as well as by using chemical, fertilizers and irrigation. Food insecurity increases due to conversion of cropland into nonfarm use, famine, loss of irrigated land,thinning of topsoil, erosion decrease in biotic diversity and degradation of soil (Ehrlich et al. 1993), “Increase in population, decline in per capita soil and water resources, increase in soil degradation and water pollution, decrease in farm income” (Lal, 2011). What should be done to reduce this insecurity? is a big matter. Public understanding of the long-term effect of cropland conservation and topsoil loss on food price has decreased the fertility rate of a human. Reduction in poverty, use of amaranths and others neglected traditional crop for increasing fertility, replacement of more productive crops in the place of less productive crops, improvement in water productivity and soil fertility, micronutrient availability, provide best opportunity for increasing income with labor-intensive agricultural technologies, restoration of soil quality, identification of alternate crops, avoid disturbance and destruction of natural resources or ecosystem, improvement in efficiency of inputs, "*adaptation of no-till farming and conservation agriculture and climate are ways to improve the soil erosion and degradation and secure the food for people*" (Lal, 2009).

1.5.6 *Poverty and Land Degradation*

Land degradation affects the human life. In spite of such concern very little attention is paid towards the problem. The study provides an idea about interlink among soil erosion, land degradation, food security and poverty with the agriculture. Land degradation is one of the factors, which influence the poverty, so it is necessary to understand the relationship between land degradation and agriculture, where it can be analyzed that how it is interlinked with the poverty and food insecurity related problem. Poverty is the social indicator of the region. It is necessary to understand social factors as well as physical factors.

1.5.7 *Literatures in context of India*

Land degradation has become a major problem in the country because of increasing pressure on land, population growth, and slow growth rate of the economy. Major factors for land degradation are soil erosion and sedimentation, acidification, soil fertility decline, accumulation of toxic substances, an increase in salinity and alkalinity, eutrophication due to overuse of fertilizers, iron toxicity, leaching of groundwater pollution and soil compaction. Loss of land productivity due to land degradation is US $ 36 /ha/yr. while the loss due to nutrient depletion is about the US $ 51 /ha/yr. Lack of knowledge and less information availability on soil erosion has found. A database should develop in these lines- fertility decline, salinity and eutrophication and recommendations for arresting land degradation have highlighted in the paper of Mapa (2011).

1.5.7.1 Growing *Pressure on Land and Unsustainable Land use*

Regarding land degradation in India, Venkateswarlu and Prasad (2011) observe that land degradation is continuously increasing due to the growing pressure on land and unsustainable land use in the country. Data shows that in India, 55.27 million hectares areas are under degraded land, land with or without scrub (18.80 M ha), contributed by gullied land (1.19 M ha), degraded pasture, sand, mining and industrial wastelands, waterlogged (0.97 M ha), shifting cultivation (1.88 M ha), saline/alkali (1.20 M ha), degraded forest and agriculture land under forest (12.66 M ha), barren /stony/snow cover. "Soil degradation increases with increased use of land" (Pohit, 2013). Reason for land degradation in India are wind erosion, water erosion, salinization, acidification, nutrient mining, waterlogging and soil physical constraints, overexploitation of groundwater ,vegetation, flood and droughts, depletion of soil organic matter, use of poor quality groundwater, excessive use of agrochemicals, Urban and industrial wastage, coastal erosion, mass erosion problem, landslide, Gullies and ravines, mine spoils and torrents (Sharda, 2011). “The productivity of acid soil is low due to low pH, the presence of toxic levels of Al, Fe, and Mn, nutrient imbalance, deficiency of Ca, Mg, S, P, B, and Mo and poor microbial activity” (Jena, 2011). Dhillon and Dhillon (2011) say that land degradation has also occurred due to selenium (se). Selenium is not only an essential element for plant growth but also its concentration in plant tissues is important for animal and human health. One thousand hectares of Se-degraded land have characterized and mapped in northwestern India.

To meet the projected biomass demand an integrated land resources management policy is needed. In this technological era, some new methodologies should be developed at the various scales using modern tools and procedures. To restore the degraded land scientific planning is necessary. Soil health card is needed to prepare by using modern soil testing tool or test kits to know the fertility status of agriculture land. Soil health card will ensure the balanced use of chemical fertilizers (Sharda, 2011). Compiling soil with a full dose of lime should replace by 0.10 to 0.20 LR dose. Broad bed and furrow (BBF) technology are suitable for the rainfall range of 700-1300 mm and for medium to deep black soils (Vertisols) with a slope up to 5%. Balance use of lime and micronutrients is recommended for vegetables, cereals, pulses and oilseeds in acid soil. Deficiency of Ca and Mg can be corrected by using dolomite or other limiting materials. Phosphorus management in such soil has done economically by using powered indigenous rock phosphate mixing with a highly active imported rock. Growing acid tolerant species and cultivars are the alternative. Conservation furrows are suitable for the rainfall range of 400-900 mm for alfisols and associated soils with a slope of 1-4%. Modified contour bunds are suitable for the rainfall range of 500-900 mm for artisols and moderate to deep black soil with a slope of 1-8 %. Contour cultivation has beneficial effects. Community-based soil water harvesting and soil conservation structure are playing a key role in soil conservation. Masonry check dam, khadin system, farm ponds, intercropping system low cast earthen check dam, gully check with loose boulder wall, afforestation and grassland management, mulching, strip cropping, agroforestry are a strategy for mitigation of land degradation.

1.5.7.2 *Regions with Specific Type of Land Degradation*

Gupta et al. (1998) observe in their study that erosion and mining are the main reason for land degradation in Palamau district of Jharkhand, Nagpur plateau. For long-term sustainability, the degraded land in the area should be rehabilitated. Very severe eroded land can be restored through the measures such as field bounding and leveling, contour cultivation, dry farming, safe disposal of excess rainwater, strip cropping and following proper crop rotation. Gullies erosion can be restored by vegetative as well as mechanical measures. The Thar Desert of Rajasthan is one among densely populated desert. The Thar Desert faces the water scarcity, due to large population concentration; there is a pressure on common property resources and the precious water resource. "The Thar Desert is affected by rapid soil degradation and vegetation loss" (Ravi & Huxman, 2009). In the Himalayan region, the main cause of land degradation is found as wetland loss and the change vegetation cover. Erosion assessment reveals that more than 48.27% of the area in the valley is under very high erosion risk. Pir Panjal region of Himalaya is more degraded than the greater Himalaya region due to the weak lithological formation. Karewa formation is mainly found to be under very sparse vegetation cover and is extensively used for soil excavation for construction and horticultural purposes. "Karewa formation found more widespread along with the Pir Panjal range is tectonically very active. It has found that the Pohru and Doodhganga watersheds of Pir Panjal range are under very high erosion" (Zaz & Romshoo, 2012).

1.5.7.3 *Concern related to Policies*

In the context of linking the land degradation with politics, a crisis of very large dimension is developing in Himalayan areas. Therefore, this is advisable for political and diplomatic reasons, to regard it as a potential super crisis. Grazing by Gaddi communities in Himachal Pradesh, India leads to land degradation in Himalaya. In a protected area the government can restrict human use of resources because this human land use leads to degradation and it is difficult to maintain the biodiversity level

(Seberwal, 1996). Indian government takes an initiative to provide land right and ownership to the tribal dwellers by enacting the Forest Right Act, 2006.

Imenson (2012) have emphasized that changes in land use by humans are the major cause of desertification of land. When the ecosystem was overexploited or exploited beyond their limit the desertification or the degradation of land occurs. Additionally to this concept that due to not preventing the forest and converting different land use type importantly unbalanced water and soil situation resulted has reported by Gerold (2010) and study in the USA by Turnbull (2014) demonstrated that frequency of natural vegetation alter due to overgrazing, warming and fire suppression has become major cause for land degradation in large extent. Supporting the issue, Crescimanno et al. (2010) have focused on Salinization as a factor of degradation happened due to excessive use of dissolved inorganic ions and molecules irrigation water. Constandache et al. (2010) have found in their study of Romania that increases in vegetation is one of the ways to mitigate the problem of degraded lands. In that study, pine plantation (one of the ways) has proved as a solution for recomposing the unproductive or low productive lands into high economic cost lands. Considering the importance of deforestation for land degradation Pimentel et al. (1986), Menon & Bawa (1998) and Lamb (2011) have discussed that likewise the world India is also facing the problem of degradation, and hence need of the hour is to pay attention to the concern.

1.5.8 *Background* of *Regionalization*

The history of regionalization can be traced in past back as early as 1921 in USSR. As after independence Indian Constitution has opted the socialism, it is quite expectable that India would have also gone towards the regionalization process before the planning. The successive Five Year Plans have stressed initially on the regional approach to the policy implications including the physio-socio-economic factors (Third Five Year Plan, 1961; 142-153). Over a period of time, the importance of economic regionalization arose at the international front, especially by the developing countries. Thus, for the period of 1960-68, a Commission on the Methods of Economic Regionalization had been formed under the International Geographical Union (Pant, 1962). In the field of regional planning, the region is a specific area, however, it cannot be said that it is the isolated area. An area is associated with numerous different problems; therefore, the regionalization process on the difference basis has started. That's why there is different types of classification e.g. physio-agro-economic region, agro-climatic region, agricultural region, animal husbandry region. A region having homogeneous features determined specifically by the purpose for which it is going to determine (ICAR, 1958). Regionalization is a broad concept in which the major aim is to divide a country into various parts (Table-1.3), each linked with the economy for the purpose of policy planning and play a role in the constructive transformation of the country (Sharma, 1973).

Although the reference related to the natural region had been found in 1911 in All India Report, first major attempt in the regionalization had been made by the Population Census in 1951 by using various demographic aspects along with agro-climatic factors (Census, 1951, paper no. 2). Further, an attempt made by the Reserve Bank of India in its Rural Credit Survey in 1951-52 in the selected 75 districts dividing into 13 regions (Sharma, 1973). Later on the basis of natural features, O. H. K. Spate (1964) has regionalized India and Pakistan. Thorner (1957) has also studied the agrarian regions of India by using 7 criteria related to socio-economic, land, labour, geographic, economic and recent developments dividing India into 16 agrarian regions.

Table-1.3 Regional Levels which used in India for Planning

1. macro-region	Group of Linguistic states such as South India
2. Meso-region	States with Intra-state regions identified on the basis of groups of districts or development blocks or *Tahsils*
3. Micro-region	A district, a *Tahsil*, a development block, or a tract comprising a group of villages
4. local Level	A village or a town

Source: Bhat, L. S. (1970). Regional Planning in India

A remarkable progress in Indian regionalization has been achieved in 1964 and the country has been divided into 7 natural regions, 3 sub-region, and 89 divisions by choosing 63 variables (Census of India, 1961). The first assemblage of different data on physical condition, climate and resource availability had been attempted by the

Planning commission to get the resource development region. Many more regionalization has been done over a period of time e.g. The Agricultural Atlas of India (1958), The National Atlas (1957), Census Atlas (1961), Economic Regionalization of India (1968)[1] (Sharma, 1973). Similarly, the climatic region and agro-climatic regions have been delineated by IMD (1971) according to the latest approach of the Thornthwaite (1948) on the basis of moisture index and thermal index and by ICAR in the project entitled National Agricultural Research (NARP, 1979)[2] respectively. Recently, Wildlife Institute of India (2000) has classified India into 10 different bio-geographic zones and 26 biotic provinces for the sustainable planning purposes. A most recent work by Peel et al. (2007) has emphasized how important is the classification in the teaching, research, planning and policy development and further tried to update the 100-year-old climatic map of the world prepared by Koppen following the methods opted by Koppen-Geiger in 1936.

1.6. STATEMENT OF THE PROBLEM

The land is one of the most important resources, which is under threat in different ways (Reddy, 2003; Khoshoo et al. 2009). Literature has inferred that land in India is suffering from different type of degradation (NRSA, 2011; Pani & Carling, 2014) due to unstable and unplanned practices (Maconachie, 2007; Morgan, 2006; Natarajan et al. 2010 and Isaac, 2010). India is having more than 60% population in rural areas which depends on its 40% cultivable land of the total geographical area (Agricultural Census). The country has witnessed different cropping pattern in different regions which is governed by variation in temperature and rainfall in general and monsoon in particular. With the cropping style, the climatic factors, and its phenomenon are also playing a role in the increasing pace of land degradation (Hong & Hongbo, 2007; Clarke & Rendell, 2007). Human activities like deforestation, overgrazing, mining and quarrying are factors affecting land degradation too (Sahu & Dash, 2011; Kumar and Pani, 2013; Turnbull, 2014; Parsons, 2014). The soil is the most important renewable resources. Loss of nutrients in soil recorded due to loss of topsoil layer (Bojo, 1991; Pani et al. 2011; Braun & Gerber, 2012). Because of given reason, the Agricultural productivity is lying down in India (National Commission on

[1] By P. Sen Gupta and Galina Sdasyuk.

[2] Under World Bank 1979, later on in 1992-93, the support was withdrawn.

Agriculture, 1976; Gupta et al. 1998; Bhattacharya & Guleria, 2012; Zaz & Ramshoo, 2012).

The biggest challenging task of 21st for the human community is going to be food security. Despite having an achievement like the Green Revolution in the form of providing food security in India, the productivity still is recording low compared to the other countries (Planning Commission of India). The approach of Agro-Climatic Regional Planning (ACRP), that is basically resource based, is applied to the agricultural and allied sectors focusing on the long-term resource efficiency through the appropriate use of technology. As this regionalization also focuses on the resource-based and area-based approach, but it lacks understanding of land degradation approach in this planning as land being a most prominent resource in the agricultural sector. Land degradation has a large impact on the agriculture economically, financially and ecologically. Thus, there is a need for an understanding of land degradation with physio-economic factors (Bojo, 1991).

Keeping the literature in the views, the study would be a comprehensive study of the prominent indicators of the land degradation in the agro-climatic regions. It has tried to combine the highly degraded areas and clubbed into the region with the specification and unique characteristics related to its features. Further, the states with agro-climatic zones have been assessed on the basis of land degradation factors. Along with it, the salient features of different types of degradation has been studied. Moreover, as salinity is one of the prominent types of land degradation, thus there was a dedicated study of linkage between land degradation and agriculture in general and salinity and agriculture in particular. Further, the study has selected the 6 villages from the high salinity affected districts of high salinity affected states of India to understand the relationship between salinity affected land with agriculture and non-salinity affected land with agriculture.

1.7. STUDY AREA

All India level analysis has been done in this study. The total geographical area is 328.2 M ha. In the term of natural location, India lies in the northern part of Indian Ocean. India lies in the north-east hemisphere between $8^{o}4'$ N and $37^{o}6'$ N latitude and $68^{o}7'$ E and $97^{o}25'$ E longitude. India has called the "land of paradoxes- a grid of high snow-capped mountains, glaciers and high-altitude forests in the north, seas washing both sides of lengthy coastline in the peninsular south and a variety of geographical formations, diversified climate and varied topographies and reliefs". The Planning Commission of India (1989) has divided India into 15 major agro-climatic regions delineated based on commonality of agro-climatic factors like soil type, rainfall, temperature and water resources etc. NRSC, 2011 has provided a detailed study area description about India. It can be detailed in the following ways:

1.7.1. GEOLOGICAL STRUCTURE

The study of geological structure helps in understanding the composition and structure of rocks, which further determine the characteristics of the soil and the availability of minerals. The geological history of India is complex as well as varies. It begins with the first formation of the earth's crust, first deposit of sedimentary rocks, first orogeny and extends up to the recent lying down of alluvial deposits. The Archaeans including the Dharwars and the associated granites and gneisses, which cover about two-thirds of peninsular India, are the earliest rock formations found in the country. These include rocks like schists, gneisses, granites, and charnockites and the basement complex around and upon which the subsequent rock systems have been laid down. The Cuddapahs, Vindhayans, Gondwana and the Deccan Traps which occupy remaining one-third of peninsular surface succeeded the Archaeans. The folding and upliftment of the Himalayas started during the Mid-Miocene period and continued in phases up to the Pleistocene period. This includes huge quality of marine sediments along with igneous and metamorphic rocks from the floor of the Tethys. The north plains (including coastal plains) came into existence during and after the Pleistocene period and largely consists of alluvial deposits.

1.7.2. GEOMORPHOLOGY

India is characterized by a great diversity in its relief and geomorphologic features. In the north lie the lofty mountains of the Himalayas with snow-capped peaks, large valley glaciers, deep Georges, longitudinal valleys, roaring waterfalls along with dense forest cover and great cultural heterogeneity (the Nagas in the east, Kumaunis in the center and the Ladakhis in the west). Towards the south, the Great Plains meets a tableland, where a complex of plateau surfaces of highly denuded rocks produces a series of scarps which in some areas, are arranged like a staircase and in others rise steeply like a wall. The peninsula tapers to the south and is girdled by the coastal plains of varying width. The two groups of islands, the Laccadive, Aminidive, Minicoy etc., and Andaman & Nicobar groups have different origins and consequently distinctive physical characteristics.

1.7.3. DRAINAGE

The Indian drainage may be broadly divided into two major systems based on their orientation to the sea. These include: (i) the Bay of Bengal Drainage and (ii) the Arabian Sea Drainage. These are separated from each other through the Delhi ridge (the Satluj-Yamuna divide), the Aravallis, the Sahyadris and Amarkantak. About 77 % of the drainage area of the country comprising the Ganga, Brahmaputra, Mahanadi, Godavari, Krishna, Pennar, Kaveri, Vaigai basins is oriented towards the Bay of Bengal. This includes major parts of the Himalayas, the Great Plains, the Peninsular Uplands and the Eastern Coastal Plains. The Arabian Sea drainage area spreading over to 23% of the country's surface flow area is confined to the northwestern Himalayas, Punjab plains, Rajasthan plains, Gujarat plains, Central Plateaus and Western Coastal Plains. It commands river basins like Indus, Narmada, Tapi, Lune, Mahi and a number of swift flowing western coast rivers descending from the Sahyadris.

1.7.4. CLIMATE

India climatically also has a huge diversity. As average annual rainfall of the whole country is 113 cm, but the diversity in rainfall is not an exception. On one hand, Thar Desert receives 100 mm and on the other hand, 11,000 mm rainfall has been recorded in Cherrapunji-Mawsynram of Meghalaya. The mean annual temperature of India recorded from 8^o to 28^o C.

1.7.5. VEGETATION

Forest occupies about 24 % of the total geographical area. Alpine forests occur in Eastern Himalayan region whereas sub-tropical and alpine forest again found in western Himalaya. In Assam region depicts Southeast Asian impact with Himalayan heterogeneity except for the Alpine vegetation. In Ganga plain, vegetation varies from semi-arid shrubs to evergreen mangroves. Thorny shrubs and trees with thick bark predominate in the Indus region including Thar due to scanty rainfall. In the Deccan region, it has vegetation related to semi-arid climatic vegetation. Vegetation type ranges from moist tropical evergreen to broadleaf mixed and monsoon deciduous type in Malabar region. The Andaman & Nicobar has been greatly influenced by the Malayan and Burmese impact with tropical evergreen forest. Laccadive is strongly dominated by different varieties of shrubs and coconut trees.

1.7.6. SOIL

The soil also varies from region to region. Alluvial soil occupies the areas from the Indus basin to the Brahmaputra basin. It also lies in the valleys of Narmada, Tapi, and some other rivers. Red soil spreads over the Peninsula from Tamilnadu in the south to Bundelkhand in north and Rajmahal in the east to Kachchh in the west surrounded by the black soil. The black soil has been developed by the weathering of the Deccan lava in a major part of Maharastra, western Madhya Pradesh, some parts of Gujarat, Andhra Pradesh, Karnataka, Rajasthan, Tamilnadu and Uttar Pradesh. Laterite soils are well developed on the summits of the Sahyadris, Eastern Ghats, Rajmahal hills, and Vindhyan. It also occurs in lower levels and in valleys. Mountainous soils are found in the valleys and hill slopes of the Himalayas at altitudes of 2100 m to 3000m. Desert soils are developed under arid and semi-arid conditions in the areas of Rajasthan, Saurashtra, Kachchh, Haryana, and south Punjab. Forest soils occur between 3000m and 3100m in the coniferous zone of the Himalayas. Saline and alkaline soils occur in the drier parts of Rajasthan, Uttar Pradesh, Bihar, Haryana, Punjab, and Maharashtra.

The study area for the micro-level study has been chosen through method, which has been discussed into section-1.10.3 of this chapter. Six villages from the three districts namely Barmer (Rajasthan), Firozpur (Punjab) and Kannauj (Uttar Pradesh) have been selected for the detailed analysis of soil salinity status (Map-1.1). The details of the micro-level study areas have been discussed in chapter-5, 6 and 7 respectively in the study area section.

1.8. OBJECTIVES

The soil degradation has been strongly associated with the three factors- water, agriculture, and winds. Moreover, there are other factors also. But all these put the greater emphasis on the role of human beings, which is of great significance (Agnew, 2002). The broad objectives of the study can be described as below:

1. (A) To categorize the land degradation types and their characteristics.

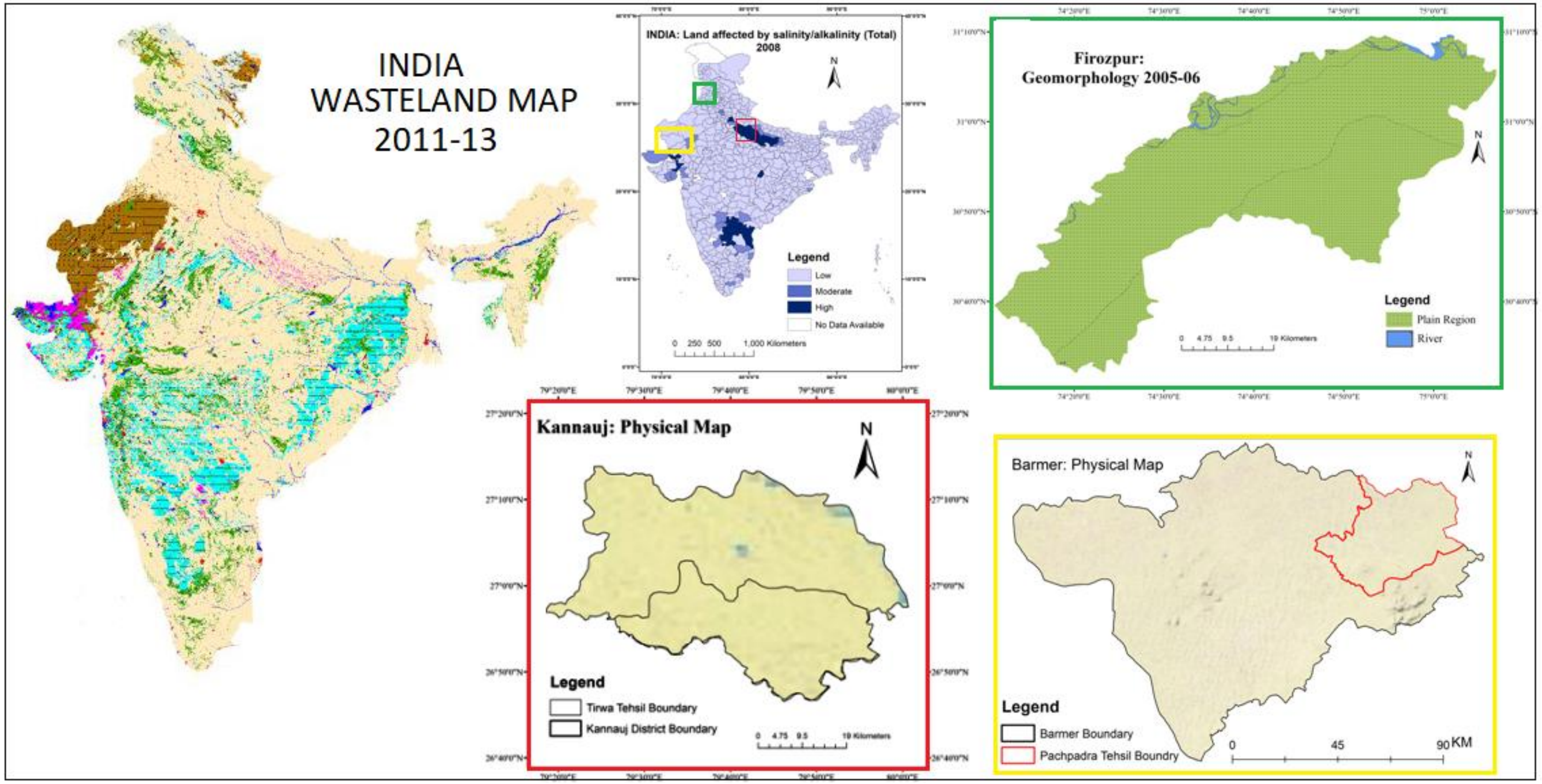
   (B) To understand the spatial distribution of land degradation in India with reference to the Agro-Climatic regions.

   (C) To understand the linkages between land degradation and agriculture, in general and between salinity and agriculture in particular.
2. To understand the salinization problem from the world to the local level.
3. To assess the salinity and agriculture status under specific agro-climatic regions at the micro level.

1.9. DATABASE

1.9.1 Secondary Data: District-wise spatial distribution of degraded and wasteland of India are made available by a collaboration of National Remote Sensing Center (NRSC) & Department of Land Resources (MoRD, GoI). These organizations have adopted the remote-sensing technology to assess the types of land degradation by using 1: 50,000 scale satellite images of Resourcesat-1 LISS-III for the year 2008-09 to the major season like Kharif, Rabi and Zaid accuracy with adequate field checks. Indeed, the accuracy of data has become higher.

Wassteland data has been used of the year 2003-05, 2008-09 and 2011-13 for the analysis. It has been taken from the various reports of the National Remote Sensing Center (NRSC) & Department of Land Resources (MoRD, GoI) (2011 and 2016).



Map-1.1 Study Area, it represents the wasteland distribution in whole India, salinity status at India level, the map in the yellow box represent the Barmer study area, map in the green box represents the Firozpur study areas and map in the red box represents the Kannauj study area.

Source: Prepared by the author through various sources like NRSC, 2011, Bhuvan Thematic Map Service, 2005-06.

Forest Survey of India (Ministry of Environment & Forest, Government of India) provides data on forestation. Forest cover data has been used of the year 2009 taken from the report of FSI 2011 and 2015. FSI has used remote sensing data of "IRS-1C/1D LISS III (Report FSI, 2001), IRS-P6-LISS III" (Report FSI, 2009), "IRS-P6-LISS III & IRS-P6 AWiFS" (Report FSI, 2011) 23.5 m resolution except IRS-P6 AWiFS (56 m resolution) on the scale of 1: 50000 for extracting the data related to forest cover. The report of 2017 of FSI has been used for the explanation of forest cover of district understanding for the case study.

The Agriculture census (1995-96, 2000-01 and 2010-11), Department of Agriculture and Corporation (MoA, GoI), has provided district and the *Tahsil* level data and other data related to agriculture is provided by Directorate of Economics and Statistics.

Census data of the year 2011 has been used to understand the demographic and agricultural characteristics of the six villages, which have been selected for the study at micro-level.

Bhuvan thematic services[3] have been used to understand the various characteristics of the case study areas. The various maps have been of different years like geomorphology map of the year 2005-06, wasteland map of the year 2008-09, soil salinity map of the year 2005-06, land use land cover map of the year 2005-06 and 2015-16 etc.

Satellite imagery of the Landsat-8 of the year 2016 of the different season[4] has been used and this has been provided by US Geological Survey[5].

1.9.2 Primary Data: The primary survey has been conducted among the farmers of the six sampled villages to get the understanding of the soil salinity perception and agricultural perspective from the farmers. The exhaustive survey has been done in the different period of time in the year 2017. The primary data collection of Barmer has been done during March 2017. For Firozpur, the survey has been conducted into November 2017 and for Kannauj, it is done in December 2017. Detail of the method

[3] The ArcGIS online tool has been used to get the various thematic maps from Bhuvan Thematic Service, NRSC, ISRO, url-http://bhuvan.nrsc.gov.in/gis/thematic/index.php.

[4] It was subject to availability of the imagery. The details of imageries about the date of scene have been chalked into the respective chapter details.

[5] USGS through the url:https://glovis.usgs.gov/app?fullscreen=1

of selecting farmers has been discussed in section-1.10.3 in this chapter and questionnaire has been listed into Appendix-II.

Focused Group Discussion (FGD) has been conducted. At least two FGD per villages has been conducted to get the more clarity of soil salinity status and agricultural knowledge. The detail has been discussed in section-1.10.3 of this chapter.

1.9.3 Field Photograph: The field photograph has been collected to get the glimpse of the study areas physiographically at micro-level.

1.10. METHODOLOGY

1.10.1. To fulfill the first objective, the following methodology has been adopted

1.10.1. (A) To categorize the land degradation types and their characteristics.

***(a)* Indicators-** The indicator related to 23 types of wasteland has been taken to fulfill this objective.

***(b)* Data Source-** The data has been taken from the Indian National Remote Sensing Center (NRSA, IRSO, 2011 and 2016) & Department of Land Resources (MoA, GoI, 2011 and 2016).

***(c)* Study Area-** District-wise analysis has been done to identify the spatial concentration of land degradation in the various region. The details of the process have been discussed in the following method section.

***(d)* Methods-** For the categorization of the 23 types of land degradation, the similar characteristics have been adopted as the base to categorize into one. Then, the simple descriptive statistics like percentage used for drawing choropleth map through the Geographical Information System (GIS). Further, the composite index has been calculated by using Principal component analysis (PCA).

"Principal component analysis (PCA) is a well-known multivariate statistical method, which has as its objective the explanation of the variance-covariance structure of a multivariate dataset through a few linear combinations of the original variables with special properties in terms of variances" (Nomikos and MacGegor, 1994; Everitt, 2010). It decomposes a matrix X *(l x J)*, where there are *J* measurement variables for *I* objects into a series of R principal components ($X = \sum_{r=1}^{r=R} t_r\, p_r$), with each characterized by a loading vector (p_r) and a score vector (t_r). "The principal components represent the selection of a new coordination system obtained by rotating the original variables and projecting them into the reduced space defined by the first few principal components, where the data are described adequately and in a simpler and more meaningful way" (Nomikos and MacGegor, 1994). "Other modeling techniques based on partial least squares and factor analysis could also be applied to obtain empirical models for such a purpose" (Dunia et al., 1996).

Principle component analysis may be useful when the following conditions have arrived-

- There are too many explanatory variables related to the number of observations.
- The explanatory variables are highly correlated.

In general, a normalized data matrix X of n population (rows) and n variables (columns) can be decomposed as follows:

$$X = \widehat{X} + E \qquad (i)$$

Where the matrices $\widehat{X}$ and E represent the modeled and unmodeled variations of X, respectively in Equation (*ii*) and (*iii*) (Dunia et al, 1996):

$$\hat{X} = TP^T = \sum_{i=1}^{t} t_i \, p_i^T \qquad (ii)$$

$$E = T_e \, P_e^T = \sum_{i=l+1}^{m} t_i \, p_i^T \qquad (iii)$$

l represents the number of principal components. The matrices *T* and *P* are the score and loading matrices, respectively. The decomposition of X is such that the composed matrix [*P* *P*e] is orthonormal and [*T* *Te*] is orthogonal. The principal component projection reduces the original set of variables to *1* principal components. Because [*P* P_e] is orthonormal, the cross-covariance between $\hat{X}$ and E is zero (Equation: *iv)* (Dunia et al, 1996):

$$\hat{X}\, E^T = 0 \qquad (iv)$$

PCA relies on an eigenvector decomposition of the covariance or correlation matrix of the process variables. For a given data matrix X with *m* rows and *n* columns the covariance matrix of X is defined as (Equation: *v*) (Wise et al., 1999):

$$cov\,(X) = \frac{X^T\,X}{m-1} \qquad (v)$$

This assumes that the columns of **X** have been 'mean centered', i.e. adjusted to have zero mean by subtracting the mean of each column. If the columns of **X** have been 'auto-scaled', i.e. adjusted to zero-mean and unit variance by dividing each column by its standard deviation, equation (*v*) gives the correlation matrix of X (Unless otherwise noted, it is assumed that data are either mean centered or auto-scaled prior to analysis). PCA decomposes the data matrix **X** as the sum of the outer product of vectors $\mathbf{t}_i$ and $\mathbf{p}_i$ plus a residual matrix **E (**Wise et al., 1999):

$$X = t_1\,p_1^T + \ t_2\,p_2^T \ldots \ldots \ldots + \ t_k\,p_k^T + \ E = TP^T + \ E \qquad (vi)$$

Here *k* must be less than or equal to the smaller dimension of **X**, i.e. *k* _ min [*m*,*n*]. The t*i* vectors are known as *scores* and contain information on how the *samples* relate to each other. The **p***i* vectors are *eigenvectors* of the covariance matrix, i.e. for each $\mathbf{p}_i$ (Wise et al., 1999):

$$cov\,(X)p_i = \ \lambda_i\,p_i \qquad (vii)$$

Where λi is the *eigenvalue* associated with the eigenvector $\mathbf{p}_i$. In PCA the $\mathbf{p}_i$ are known as *loadings* and contain information on how *variables* relate to each other. The $\mathbf{t}_i$ form an orthogonal set ($t_i^T t_j = 0\ for\ i \neq j$), while the **p***i* are orthonormal ($p_i^T p_j = 0\ for\ i \neq j, p_i^T p_j = 1\ for\ i = j$**)**. Note that for **X** and any $\mathbf{t}_i$,$\mathbf{p}_i$ pair (Wise et al., 1999):

$$Xp_i = t_i \qquad (viii)$$

1.10.1. (B) To understand the spatial distribution of land degradation in India with reference to the Agro-Climatic region.

***(a)* Indicators-** for the regionalization 23 types of wasteland (NRSA, 2012) have been considered. The indicators are listed in Table-1.4 and these indicators have been broadly classified into seven parts (Table-1.4). These characteristics of wasteland have been clubbed with the Agro-Climatic Regions to get the understanding that which type of land degradation plays a crucial role in soil quality of the specific region.

Table-1.4 Land degradation indicators categories

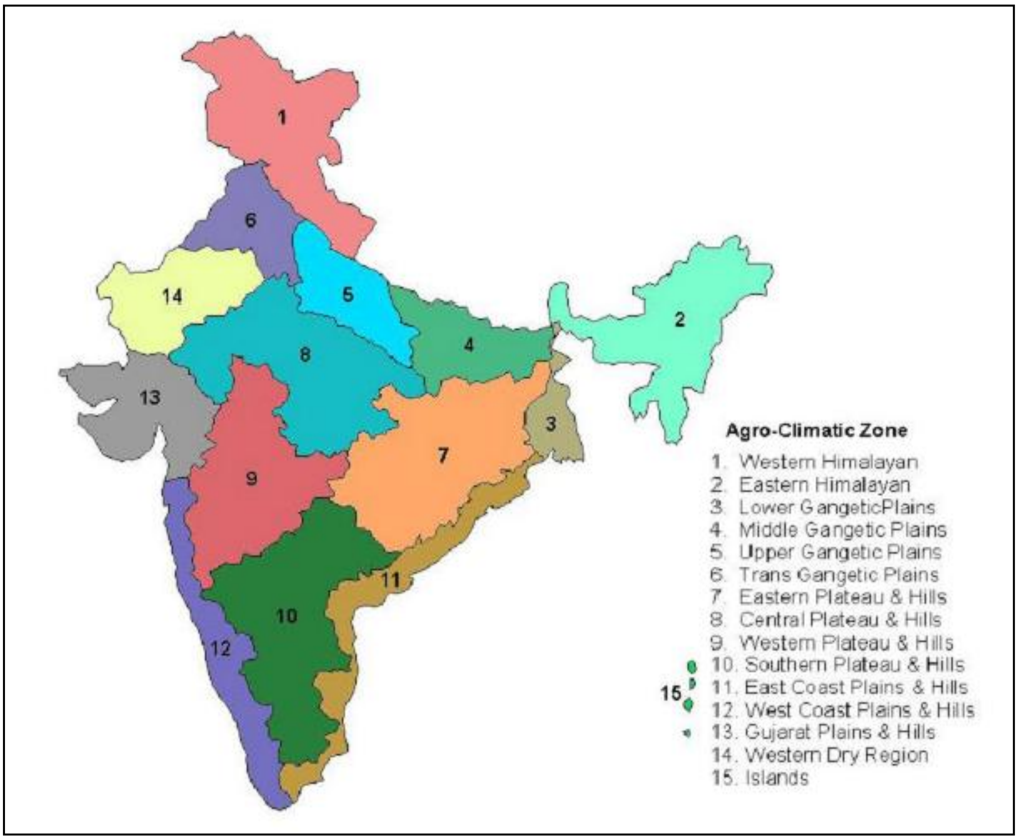
S. N.	**Wasteland Class**	**Indicators**
1.	Gullied/Ravine Land	gullied and/or ravenous land (medium), gullied and/or ravenous land (deep)
2.	Land with Scrub	land with dense scrub, land with open scrub
3.	Waterlogged/Marshyland	waterlogged and marshy land (permanent), waterlogged and marshy land (seasonal)
4.	Land affected by Salinity/alkalinity	land affected by salinity/alkalinity (medium), land affected by salinity/alkalinity (strong)
5.	Shifting Cultivation	shifting cultivation- current jhum, shifting cultivation- abandoned jhum, under-utilised/degraded forest (scrub domin), under-utilised/degraded forest (agriculture), degraded pasture/grazing land, degraded land under plantation crop.
6.	Sand (Desert/Coastal/ravines)	sands-riverine, sands-coastal, sands-desertic, sands-semi stab. (> 40m), sands-semi stab. (15- 40m)
7.	Industrial Wasteland	mining wastelands, industrial wastelands
8.	Barren/Rocky/Stony Waste	Barren/Rocky/Stony Waste
9.	Snow Covered/Glacial Area	Snow Covered/Glacial Area

Source: National Remote Sensing Agency (ISRO) and Department of Land Resources (MoRD, GoI), 2011.

(b) **Data Source-** District-wise land degraded and wastelands data are provided by Indian National Remote Sensing Center (NRSA, IRSO) & Department of Land Resources (MoRD, GOI). Forest cover data has been provided by The Forest Survey of India, GoI. The categorization of regions on the basis of Agro-climate has been taken from the Agro-Climatic Regional Planning (ACRP) Project of ICAR under Planning Commission.

(c) **Study Area-** All India classification done on the basis of Agro-Climatic regions of ACRP (Map-1.2) (Table-1.5).

(d) **Methods-** The Agro-Climatic-Degradation region has been delineated district-wise. Therefore, firstly the delineation of land degradation indicators has been done through the merging of the district according to the Agro-Climatic regions. There are 15 Agro-Climatic Regions (Table-1.5). Therefore, the delineation of land degradation has been clubbed into 15 regions. By giving the emphasis to the degradation indicators, such as wind erosion into arid and semi-arid region etc. the classification has been done (Sharma, 1973).



Map-1.2 Agro-climatic Region of India
Source: Indian Meteorological Department, Government of India.

Table-1.5 Agro-Climatic Regions of India		
S. N.	**Regions**	**Description**
1	Western Himalayan Region	Ladakh, Kashmir, Punjab, Jammu etc. brown soils & silty loam, steep slopes.
2	Eastern Himalayan Region	Arunachal Pradesh, Sikkim, and Darjeeling. Manipur etc. High rainfall and high forest cover heavy soil erosion, Floods.
3	Lower Gangetic plants Regions	West Bengal Soils mostly alluvial & are prone to floods.
4	Middle Gangetic plans Region	Bihar, Uttar Pradesh, High rainfall 39% irrigation, cropping intensity 142%
5	Upper Gangetic Plains Region	North region of U.P. (32 districts) irrigated by canal & tube wells good groundwater
6	Trans-Gangetic plains Region	Punjab Haryana Union territory of Delhi, Highest sown area irrigated high
7	Eastern Plateaus & Hills Region	Chota Nagpur, Garhjat hills, M.P, W. Bundelkhand plateau, Orissa, soils Shallow to medium sloppy, undulating Irrigation tank & tube wells.
8	Central Plateau & hills Region	Madhya Pradesh
9	Western Plateau & hills Region	Sahyadri, Maharashtra. M.P. Rainfall 904 mm, Sown area 65%, forest 11%, irrigation 12.4%
10	Southern Plateau & Hills Region	Tamil Nadu, Andhra Pradesh, Karnataka, Typically semi and zone, Dryland Farming 81% Cropping Intensity 11%
11	East coast plains & hills Region	Tamil Nadu, Andhra Pradesh, Orissa, Soils, alluvial, coastal sand, Irrigation
12	West coast plains & Hills Region	Saurashtra, Maharashtra, Goa, Karnataka, T. Nadu, Variety of cropping Pattern, rainfall & soil types.
13	Gujarat plains & Hills Region	Gujarat (19 districts) Low rainfall arid zone. Irrigation 32% well and tube wells.
14	Western Dry Region	Rajasthan (9 districts) Hot. Sandy desert rainfall erratic, high evaporation. Scanty vegetation, famine draughts.
15	The Island Region	Eastern Andaman, Nicobar, Western Lakshadweep. Typical equatorial, rainfall 3000 mm (9 months) forest zone undulating.
Source: Planning Commission of India, 1989.		

1.10.1. (C) To understand the linkages between land degradation and agriculture, in general and between salinity and agriculture in particular.

(a) **Indicators:** The indicator for the analysis of the linkage between land degradation and agriculture has been taken as the composite index of the different types of land degradation, which has been extracted through the Principal Component Analysis and agricultural productivity of crops like rice and wheat with different inputs (Table-1.2).

(b) **Data Sources:** The data related to the composite index of land degradation has been taken from the calculated indices. The agriculture-related data has been taken from the Directorate of Economics and Statistics, Department of Agriculture, Ministry of Agriculture and Farmers Welfare, Government of India. Total Output for 35 crops has been taken from the Bhalla and Singh (2012) work related to agriculture, in which the price value has been calculated for all the 35 crops.

(c) **Study Area:** Selected districts from the different degraded categories have been used to analyse the objective.

(d) **Methods:** the regression multi-linear model has been run (Equation A):

$$Y = f(X) + E \qquad (A)$$

Here, for one model, the output of 35 crops has been taken as the dependent variable to run the regression in chapter-4 section-4.2, where details of the variable and model have been discussed.

Similarly, another model has been done for the relation between wheat and rice productivity with land degradation. Where Y has been taken as total output per hectare, Rice and wheat productivity and X indicators have been taken e.g. land degradation, soil salinity/alkalinity, waterlogging, irrigation, landholding size and other agricultural related data. The details have been provided in chapter-4 section-4.3.

It is assumed that if there will be changes in the agricultural input and land degradation, it will lead to changes in agricultural productivity.

$$\mathcal{Y} = \beta_0 + \beta_1 \mathcal{X}_1 + \beta_2 \mathcal{X}_2 + \beta_3 \mathcal{X}_3 + \in \qquad (C)$$

Where Agricultural Productivity has been taken as the dependent variable and agricultural inputs and land degradation indices has been taken as an independent variable.

The details of variables and the designs of the models have been elaborated into the chapter-4.

1.10.2. To understand the general review of the salinization problem from world to the local level.

***(a)* Method:** Through various literature, data and reports, an extensive review of the salinity condition across the world as well as India have been exercised.

1.10.3. To assess the salinity and agriculture status under specific agro-climatic regions at the micro level

***(a)* Indicators:** The questionnaire has included the indicators related to the area under wastelands, the time period under the wasteland, per capita inputs in the field, income from the field, measures taken by the farmers for the remedy of wasteland, their perception regarding the ways and means to reclaim the land, cropping pattern, irrigation facility, fertilizer consumption (NKP), waterlogging condition, salinity perception, the causes of salinity etc. (Appendix-II).

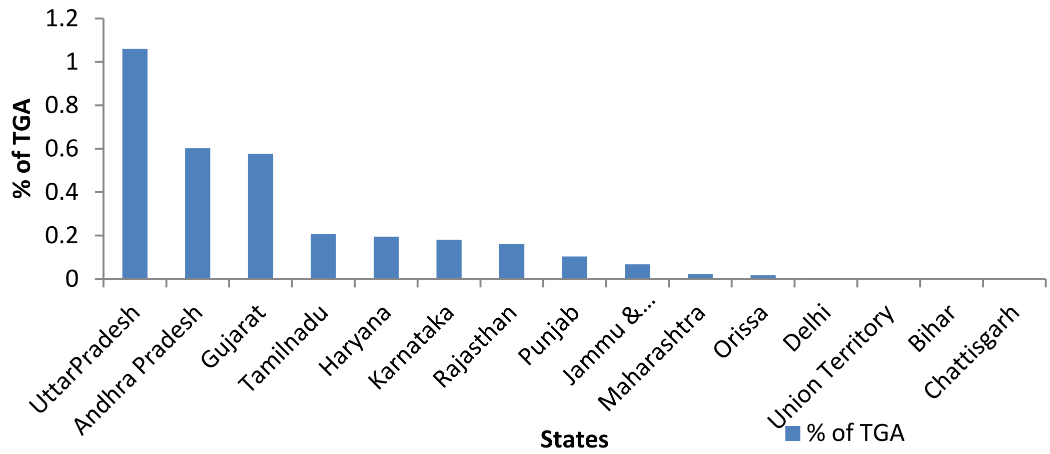
***(b)* Data Source:** Landsat-8 images have been used for the salinity and vegetation changes analysis of the selected six study areas from the three different districts as mentioned in the study area details. The village-wise and *Tahsil-wise* analysis has been done into chapter-5, 6 and 7 by taking data from the Census of India (2011) and Agricultural Census (1995-96, 2000-2001 and 2010-11). Other inferred statistics have been tabulated from the collected data through a primary survey.

***(c)* Study Area:** Six villages have been taken from the districts which are highly affected by salinity/alkalinity. These villages selected on the basis of the data provided by NRSA (DoLR, MoRD). Three districts have been selected to represent highly salinity-affected from three different agro-climatic regions. Two villages have been selected from each district, one affected by salinity/alkalinity and other not affected or low affected by salinity and alkalinity. The study area detail has been incorporated into the respective chapters to get the better understanding and perspective related to soil salinity/alkalinity of that region. Though, it has been briefly discussed in the section of the study area in this chapter.

***(d)* Methods:**

A method for Selecting Study Area (Districts): For the selection of study area at the district level, the salinity/alkalinity data of 2008-09 provided by NRSA (DoLR, MoRD) is used. First, the districts are selected from the state which is highly affected by salinity/alkalinity. After that, the ranking of districts within the states is done on the basis of salinity/alkalinity affected land proportionate to the Total Geographical Area and on that basis the highly affected districts are selected (Fig.-1.2). Uttar Pradesh stands at the top of the salinity affected area followed by Andhra Pradesh, Gujarat, Tamil Nadu, Haryana, Karnataka, Rajasthan and Punjab (Fig.-1.1) (NRSA). The three districts which are selected for this study are- Kannauj (UP), Barmer (Rajasthan), Firozpur (Punjab) (Fig.-1.2). Kannauj (125.08 sq. Km, about 6 % of the TGA) is highly soil salinity affected district in India (NRSA, DoLR, MoRD). Other two districts are highly affected by the salinity in their respective States (NRSA, DoLR, MoRD).

Fig.- 1.1 Distribution of soil salinity (percentage of TGA) in different states of India-2008-09



Source: NRSC, 2011

A method for the Selection of Villages: Satellite imageries (LANDSAT 8) of each district have been taken from the USGS web portal, and NDVI, NSDI, and SAVI has been calculated from the imageries to choose the villages for the analysis on the basis of the salinity, NDVI, NSDI, and SAVI helped to get a relatively good results in the re-classification of salt-affected soils (Shrestha, 2006; Jabbar & Xiaoling 2008; Jabbar and Zhou, 2012). After calculating the salinity index, a village located near to highly salinity concentration area and a village located far away from the salinity concentration area has been taken for a further round of analysis (Fig.-1.2).

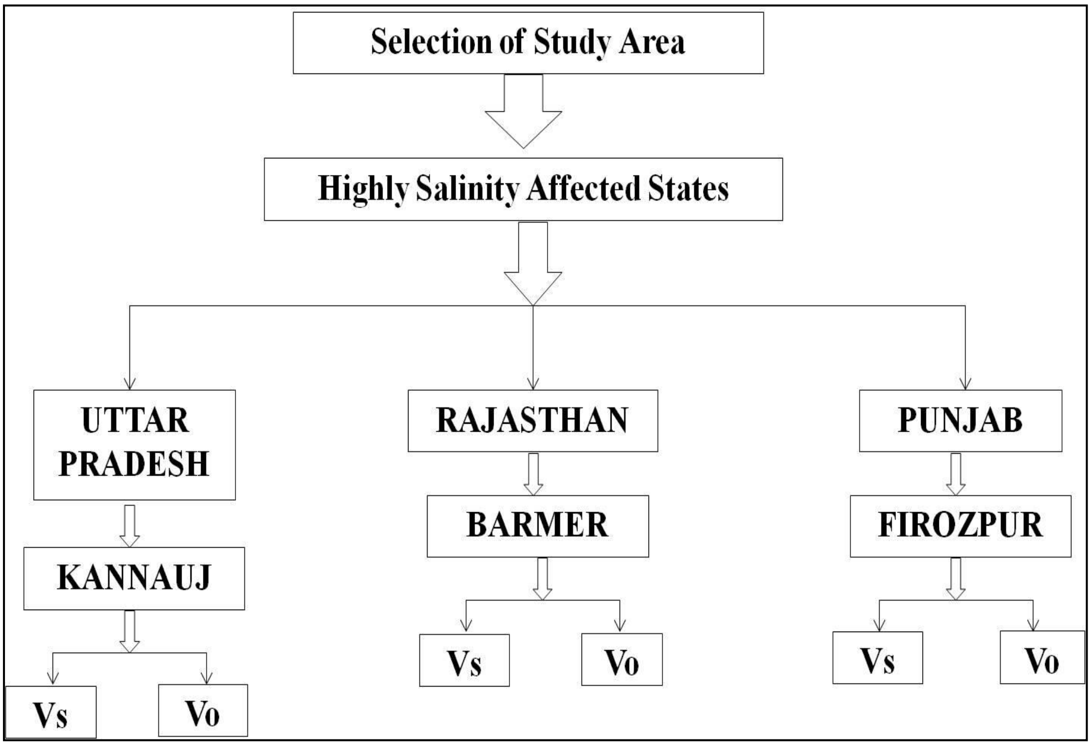


Fig.-1.2 Plan for the stages followed in the process of selection of the study areas
Source: Prepared by the author.

Sampling Method for Interview: Sampling has been done for collecting data because it is not possible to collect information about the entire group. The definition of the sample can be said to be the subset of cases selected from a population (Frankfort-Nachmias and Leon-Guerrero, 2011). Probability sampling methods have been adopted, which can be divided into three groups- (*i*) Simple Random method, (*ii*) Systematic Random method and (*iii*) Stratified Random sample.

The stratified sampling is of two types- "(*i*) Proportionate Stratified sampling and (*ii*) Disproportionate/Fixed Stratified sampling". In former, the sample selected from each subgroup is proportionate to the size of sub-group in the entire population; in later, the size of the sample is fixed or disproportionate to the size of sub-group. The later is used especially when the sub-groups are meant to compare with each other and when the size of some of the subgroups in population is relatively small (Frankfort-Nachmias and Leon-Guerrero, 2011: 201-205, Walford, 2014).

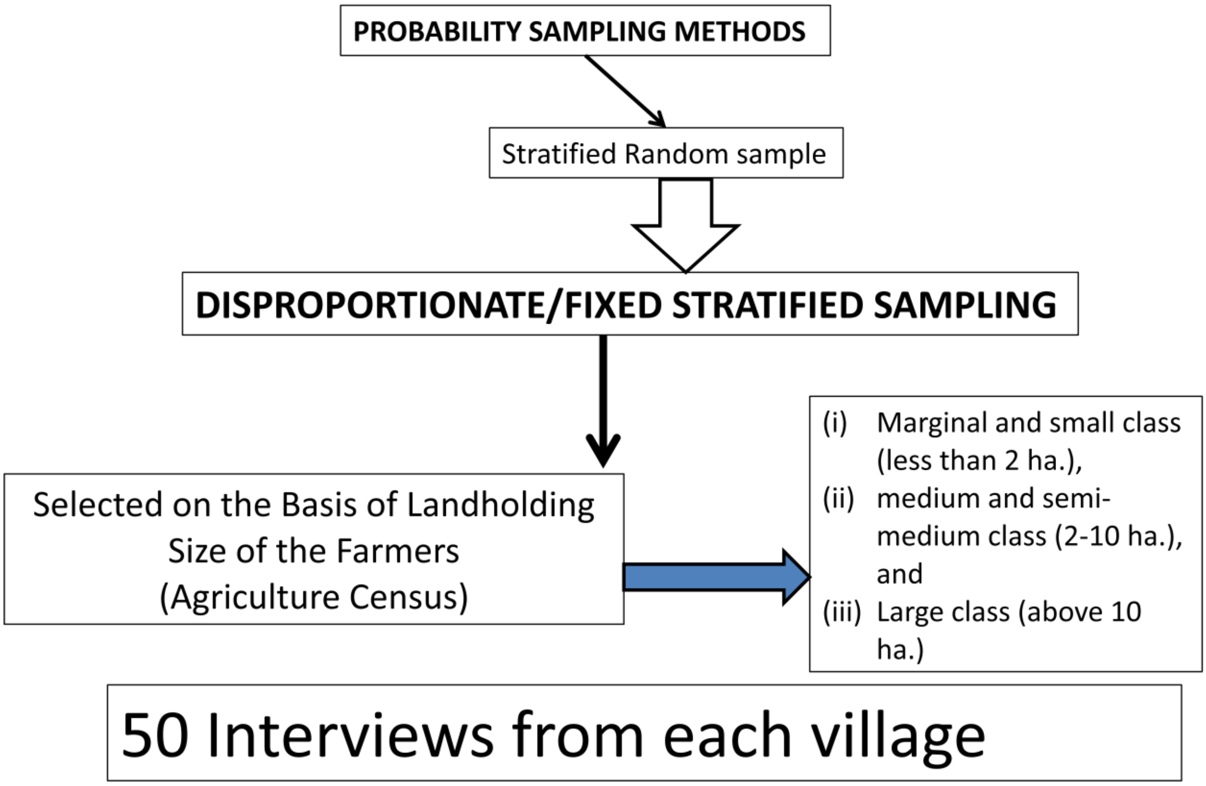


Fig.-1.3 Sampling Method for Taking Interview

Source: Prepared by the author.

The selection of the interviewer for this research has been selected on the basis of landholding size of the farmers. Firstly, in the given village, the listing of the household has been done and then, the household not involved in the agricultural occupation has been eliminated further. According to the Agriculture Census, the land holding size is broadly divided into five classes- (*i*) Marginal class (less than 1 ha.), (*ii*) Small class (1-2 ha.), (*iii*) Semi-medium class (2-4 ha.), (*iv*) Medium class (4-10 ha.) and (*v*) Large class (above 10 ha.). The land holding classes have been clubbed into three categories- Large farmers, medium farmers and small and marginal farmers. 50 interviews in every village have been taken for analysis (Fig.-1.3).

Remote Sensing Analysis for Soil Salinity Assessment: For analyzing soil salinity through satellite imagery by using LANDSAT-8, the following methodologies have been used:

Remote sensing data was obtained from Landsat Operational Land Imager (OLI-8) which was acquired in November 2016. "Typical atmospheric and radiometric corrections and spatial resolution enhancement were implemented for each band individually" (Elhag, 2016). Then, the atmospheric correction was applied in order to remove or reduce the influence of the atmosphere (Azabdaftari and Sunar, 2016).

Normalized Difference Vegetation Index (NDVI): To determine the density of green on a patch of land, researchers must observe the distinct colors (wavelengths) of visible and near-infrared sunlight reflected by the plants. "The Normalized Differential Vegetation Index (NDVI) is a standardized vegetation index which allows us to generate an image showing the relative biomass. The chlorophyll absorption in the Red band and relatively high reflectance of vegetation in Near Infrared band (NIR) are using for calculating NDVI" (ESRI).

"Leaves reflect less in the near-infrared region when they are stressed, diseased or dead. Features like Clouds, water and snow show better reflection in the visible range than the near-infrared range, while the difference is almost zero for rock and bare soil". By taking a ratio of two bands drops the values between -1 to +1. The table below shows the red and infrared bands reflectance values of features and their NDVI values. Water has an NDVI value less than 0, bare soils between 0 and 0.1, and vegetation over 0.1. Increase in the positive NDVI value means greener the vegetation (Metternicht, & Zinck, 2003; Asfaw et al., 2016).

The following formula was used to run the NDVI (Equation- i):

$$NDVI = \frac{NIR - RED}{NIR + RED} \qquad (i)$$

Here, for Landsat-8 the band-5 is Near Infrared (NIR) and band-4 is a Red band with the spatial resolution of 30.

Normalized Difference Salinity Index (NDSI): This index has been calculated in the process of making soil salinity distribution more clear. The following formula has been used (Equation- ii):

$$NDSI = \frac{SWIR\_1 - SWIR\_2}{SWIR\_1 + SWIR\_2} \qquad (ii)$$

Here, for Landsat-8, the band-6 is $SWIR\_1$ and band-7 is $SWIR\_2$ with the spatial resolution of 30.

Soil-Adjusted Vegetation Index: "Empirically derived NDVI products have been shown to be unstable, varying with soil colour, soil moisture, and saturation effects from high-density vegetation". In an attempt to improve NDVI, Huete developed a vegetation index that accounted for the differential red and near-infrared extinction through the vegetation canopy. It is formulated as in Equation-iii:

$$SAVI = \frac{(1 + L)(NIR)}{(NIR + RED + L)} \qquad (iii)$$

Where, L represents canopy background.

Primary Survey and Focused Group Discussion: The primary research process enhances the understanding study objective in a practical way (*Driscoll, 2010)*. Thus to representation from all section of the farmers, the respondent has been selected on the basis of landholding size categorised into large landholding, medium and small landholding and marginal land holding farmers. As the 50 respondents have been selected from each village to get the perspective of the two different villages, additionally, Focused Group Discussion (FGD) also has been conducted in two villages two from each.

Field Photographs used in the study: All the related field photographs have been used for analysis and inserted into different chapters under name "plate" has been collected by own from the field. Field Photographs of the Barmer study area has been taken during the fieldwork in March 2017, while photographs of the Firozpur and Kannauj have been taken during the field visit in November and December in 2017 respectively.

1.11. CHAPTERISATION

The proposed study contains eight chapters including "Introduction" and "Conclusion" chapter which respectively is the first and last chapter of the thesis. The introductory chapter has included the literature review, description of the study area, objective and methodology and database.

Chapter two has reviewed the status of salinitsation at world, national and state level. From the third chapter to the seventh chapter has covered the analysis part in which the third chapter has dealt with the description of the land degradation types and their analysis in respect of agro-climatic regions. In addition, it has dealt with the categorization of land degradation and its distributional pattern in India at the district level. Moreover, the followed chapter (chapter-4) has dealt with the relations between the land degradation and agriculture in general and linkage of salinity and agriculture, in particular. Elaborately dealing with salinity at the micro level, a detailed study of six villages from Punjab, Rajasthan and Uttar Pradesh has been done in chapter five, six and seven respectively. Finally, the last chapter has a conclusion and some suggestion based on the field experience.

CHAPTER-2

SOIL SALINITY: A MENACE TO THE SUSTAINABILITY

2.1 INTRODUCTION

In the time of the global issues of sustainability, the soil is a big concern in the world as it is going through severe change- losses of organic matter, physical degradation, nutrition depletion, chemical degradation, soil erosion, sedimentation and degradation of landscape function (Bossio et al., 2010). Additionally, when the green revolution has given a high productivity growth in the agriculture with the use of chemical fertilizer and pesticides, at the same time it too contributed to the deterioration to the health of the soil, which impacted the human health indirectly (Pimentel, 1996; Jewitt and Baker, 2007). The cardinal basis of the any agrarian society is the land in the whole world in general (Grepperud, 1997; Nkonya et al., 2008) and India in particular (Reddy, 2003; Datta and Sarkar, 2012; Bhattacharya and Guleria, 2012), where it has occupied place as the backbone of the rural economy and being the center of socio-economic dependency in rural areas. Even the minor change in its complex composition or structure has the potential to bear upon ruler social and economic structure (Blaikie and Brookfield, 1987; Bojö, 1991; Tekle, 1999; Feng et al., 2005; Kingwell et al., 2008; Kosmas et al., 2013; Gerber et al., 2014; Salvati et al., 2015). Rural areas are more vulnerable to the multifaceted impacts of land degradation (Pani et al., 2011; Pulido and Bocco, 2014). Poverty coupled with high population densities and vulnerable livelihood is both the cause and impact of the land degradation (Fan et al. 2000; Nayyar, 2005; Bossio et al., 2010; Kangalawe and Lyimo, 2010). The stress on the land is increasing due to population pressure and mismanagement of land (Kangalawe and Lyimo, 2010; Sadanandan, 2014) due to inability to invest more in the land in the rural economy (Fan et al. 2000; Nayyar, 2005; Storm, 2006). Yet, the agricultural sector is providing more than 50% employment in India with the characteristics of increasing the marginal agricultural productivity, which turned into the rural to urban migration (Sadanandan, 2014).

Emerging risk and threat for environment as well as agricultural productivity have inflicting for food insecurity (Stehl, 1993; Datta and Jong, 2002) as the pressure on land is increasing due to population growth with high inspiration with lack of "*off-farm employment opportunities*" (Huntington, 1938; Adams and Bumb, 1979). In an economic term, the land degradation is posing severe problems locally and loss at the macro level is yet to be realized (Reddy, 2003, Ravi and Huxman, 2009).

Moreover, land does not limit to the socio-economic aspect as being the total ecosystem, comprising the quality of soil, water, flora, and fauna (UNEP, 1992; Salvati and Zitti, 2008). The "land degradation", is a widely used term, acquires diverse definitions. "Land" as a *"terrestrial bio-productive system that comprises soil, vegetation, other biota, and the ecological and hydrological processes that operate within the system"*, and its "degradation" as *"reduction or loss … of the biological … productivity, … resulting from land uses, … or (a) combination of … processes, such as… soil erosion … deterioration of … properties of soil … and long-term loss of natural vegetation"* (UNCCD, 1996). Dimensions of the land degradation can be attributed to the decline in biological, chemical and physical capacity of the land (Levia, 1999; Lindskog and Tengberg, 1994) e.g. hill slope (soil erosion) (Soni & Loveson, 2003), deforestation (Bhojvaid and Timmer, 1998), suffering from loss of its intrinsic qualities, decline in its capabilities (Krishan et al. 2009), soil salinity (Lakhdar et al., 2009; Bossio et al., 2010; Yan et al., 2015) and badlands (Pani et al., 2011). Another way to express the extent of the degradation is "*Net Degradation*" (Lindskog and Tengberg, 1994), expressed in the equation- (*i*):

$$\text{Net Degradation} = (\text{natural reproduction} + \text{restorative management}) - (\text{the natural degrading processes} + \text{human interference}) \ldots\ldots (i)$$

2.2 SALINISATION: DIFFERENT DIMENSIONS

Salinization process is in which the content of salt and sodium in the soil is above the average requirement for a healthy soil (Qadir and Oster, 2004). Both the time and the space play role in the development process of the salinisation in terms of the accumulation of salts to the upper layer of the topsoil (Abrol et al., 1988; Metternicht and Zinck, 2003; Allbed et al., 2014; Gorji et al., 2015). Out of two type of salinity, "*primary salinisation is the result of natural processes e.g. physical or chemical weathering and transport from parent material, geological deposits or groundwater*". Carbonate minerals and feldspar in the basic rocks also contribute to the salt content in the soil. Moreover, specific formations including capillary effects or evapotranspiration lead to upward movement of groundwater level resultant salts accumulate an upper layer of the surface (Gorji et al., 2015; Daliakopoulos et al., 2016). Other type being the secondary salinisation, it is primarily the outcome of the processes of the human activities mainly ill-suited irrigation practices (Fan et al., 2012; Daliakopoulos et al., 2016), inefficient drainage management and unsustainable deforestation and many other non-scientific actions (Fan et al., 2012) limiting the production and land development (Daliakopoulos et al., 2016).

Soil Salinity in the agricultural field usually exists in the following regions: the arid and semi-arid region (Datta et al., 2000), the over-irrigated areas (Qadir and Oster, 2004) and the waterlogged regions (Datta et al., 2000; Datta and Jong, 2002). Irrigated lands in the arid zone are more prone to the salinization due to low and erratic rainfall, adverse evapotranspiration and prevailing soil characteristics (Datta et al., 2000; Qadir and Oster, 2004; Wicke et al., 2011; Daliakopoulos et al., 2016). With these accumulative conditions, irrigation development in the arid and semi-arid region resulted into the twin problem- waterlogging and soil salinity widespread majorly in developing countries in general (Datta et al., 2000) and in India (Ritzema et al., 2008), further becoming menace for the sustainability of irrigated agriculture in the country (Datta et al., 2000). Especially the North-western region of India has been suffering from the waterlogging and secondary salinization due to over groundwater recharge due to over irrigation. Nevertheless, in some pockets, the groundwater is pumped leading to the declining water in turn concentration of salt in upper soil layer become a common phenomenon due to the poor quality of groundwater (Datta and Jong, 2002). Associated long-term environmental impact of the irrigation is a major concern when the irrigation is playing a substantial role in the agricultural development (Datta et al., 2000).

2.3 SCOPE TO ASSESS THE SOIL SALINITY

The electrical conductivity methods are a very notable way to assess the soil salinity from aqueous electrical conductivity and from soil-paste and bulk soil electrical conductivity (Corwin et al., 1989). With the advancement of technology like Geographic Information System and the Remote Sensing coupled with the "high correlation between the soil reflection and several soil properties" has provided the facility to get the salinity indices and distinctive Spectral Vegetation Indices (SVI) as listed in Table-2.1 (Csillag et al., 1993; Cloutis, 1996). This development of non-contact measurements has added various dimensions in the study of the agricultural fields (Mulla, 2013) provided with the ground observations and integrated study (Fig.-2.1) (Mashimbye et al., 2012).

Though many indices developed over a period of time to study the salinity, no specific index appropriately assesses the salinity through the satellite imageries as its alteration depends on various natural conditions, soil type, vegetation cover and density. Yet these indices are more sensitive to soil salinity in recent studies (Table-2.1). Normalised Difference Vegetation Index (NDVI) being dependent on the reflection from various plants, it is having a limitation in the case of the area suffering from different levels of salinity. Thus to overcome this limitation, Soil Adjusted Vegetation Index (SAVI) and other models are able in distinguishing between the soil and vegetation behavior of the satellite imageries (Allbed et al., 2014). Moreover, the development of Generalised Vegetation Index (GDVI) has provided one step ahead to the soil salinity assessment with an accuracy of 86 percent (Wu et al., 2014; Dorji et al., 2015).

As the limitations of the satellite are only being sensitive to reflected solar energy, emitted thermal energy or radiation at microwaves put a limitation on the getting the variance of the reflection due to various soil constituent and varying wavelength (Csillag et al., 1993; Cloutis, 1996). The differentiation of severe saline and non-saline soils can be done with the conventional remote sensing methods (Mougenot et al., 1993; Dwivedi et al., 1999) due to severely saline soil is having the higher reflective capability (De Jong, 1994; Rao et al., 1995). Additionally, the spatial resolution has an important role in the salinity detection. It would be more accurate with the high resolution in the micro-salinity (Farifteh et al., 2006).

Table-2.1 Different methods to assess the soil salinity

Models	**Descriptions**	**Source**
Transfer function model	"To predict average values of solute concentration as a function of depth and time"	Jury (1982), El-Kadi et al. 1994
Stochastic–Convective model	"To predict solute and to estimate the leading edge of the solute migration"	Butters and Jury, 1989
Multiple linear regression model using GIS	"To study the development of salinity considering four soil salinization factors: soil permeability, depth to the groundwater, groundwater quality, and leaching fraction"	Corwin et al., 1989
Geopedologic models	"To link salinization with rather easily mapable geopedologic patterns"	Farifteh et al., 2006
Electromagnetic induction (EM) and the contact electrode	Based on Field study	McNeill, 1980b
Salinization Index	Salinity index (SI-T), Brightness Index (BI), Normalized Differential Salinity Index (NDSI), Salinity Index (SI), Salinity Index 1 (SI1), Salinity Index 2 (SI2), Salinity Index 3 (SI3), Salinity Index (S1), Salinity Index (S2), Salinity Index (S3), Salinity Index (S5), Salinity Index (S6).	Allbed et al., 2014, Huete, 1988, Tripathi et al., 2009, Khan et al., 2005, Douaoui et al., 2006, Abbas and Khan, 2007; Mulla, 2013
Canopy Response Salinity Index (CRSI).	Multi-year Landsat 7 ETM+ canopy reflectance	Scudiero et al., 2015;
Normalised Difference Vegetation Index (NDVI)	Based on Vegetation reflection	Mulla, 2013
Salinity Adjusted Vegetation Index (SDVI)	Separate soil and vegetation signals	(Gorji et al., 2015)
Generalized Vegetation Index (GDVI)	Soil salinity can be predicted with 86% accuracy with field	Wu et al., 2014a; Dorji, et al., 2015

Suitability for the salinity observation in the agricultural field can be taken best from the satellite LiDAR (1995), IKONOS (1999), EO-1 Hyperion (2000), QuickBird (2001), RapidEye (2008), GeoEye-1 (2008) and WorldView-2 (2009) (Table-2.2) (Mulla, 2013). Vegetation becoming a very significant indicator for the salinity through remotely sensed data because indirectly it governed by the salinity, thus it can be detected on bare soils or through vegetation type (Mougenot et al., 1993). However, Salt reflecting properties vary with the vegetation type and surface features (Metternicht and Zinck, 2003).

Another limitation in the irrigated land as salt concentration usually found in the upper part of the topsoil, but not on surface (Scudiero et al., 2015), rather the remote sensing technique would be more accurate in soil salinity detection when the salinity found at surface. To overcome this limitation, canopy reflectance data of various years might be more useful (Mougenot et al., 1993; Mulla, 2013; Scudiero et al., 2015). Moreover, for the visible and NIR bands are subject to the cloud, thus relatively consistent irradiance will be more suitable. Correcting imagery for atmospheric interferences might be another way to overcome the limitations (Mulla, 2013).

Electrical Conductivity (EC), which is extracted from water-saturated soil paste, of saline soil is characterized by an EC of >4 deciSiemens per meter (dS/m), an Exchangeable Sodium Percentage (ESP) of <15% and a pH (soil reaction) of 8.5 (Richards, 1954). Food and Agriculture Organization (FAO) and U.S. Salinity Laboratory has classified the soil salinity as: "1) very strongly saline, N16 dS/m; (2) strongly saline, 8–16 dS/m; (3) moderately saline, 4–8 dS/m; (4) slightly saline, 4–2 dS/m; and (5) non-saline, 0–2 dS/m" (Abrol et al., 1988; Metternicht and Zinck, 2003; Allbed et al., 2014; Scudiero et al., 2015).

Table-2.2 Different sources through which salinity can be assessed

Source	Reference	Description
IKONOS	Allbed et al., 2014	http://www.satimagingcorp.com/satellite-sensors/ikonos/
Aerial photographs and Colour infrared aerial photograph	Metternicht and Zinck, 2003	A combination of geomorphic features and Field verification
Airborne videography and digital multispectral cameras	-do-	Recording ease, immediate playback, and real-time display, enabling preliminary identification and assessment of saline problem areas.
Satellite and airborne sensors covering the thermal Infrared	Metternicht and Zinck, 2003; Scudiero et al., 2015;	Using Landsat TM
Satellite sensors covering the visible to middle infrared	Metternicht and Zinck, 2003	
Microwave Sensing	-do-	synthetic aperture radar (SAR) systems e.g. ERS 1/2, JERS-1, Radarsat
Hyperspectral Remote Sensing	-do-	Hymap airborne sensor that acquires images over the spectral range of 450–2500 nm,
Airborne Geophysics data	-do-	By an aircraft. A variety of geophysical methods is available, including seismology, gravity, magnetic, and electrical, electromagnetic, and gamma-ray spectrometry.

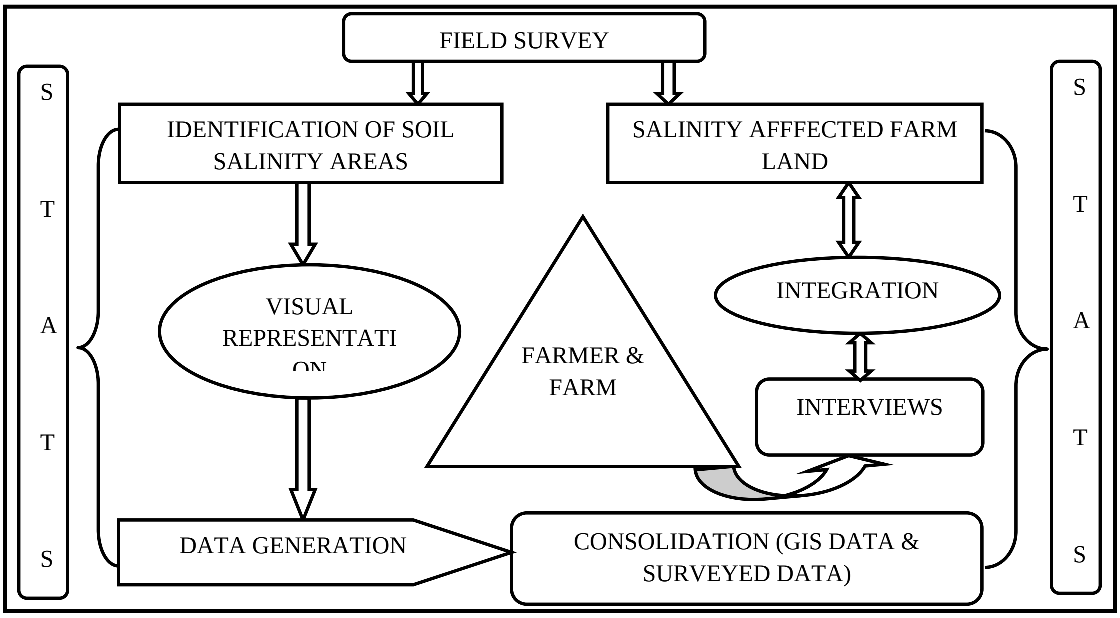
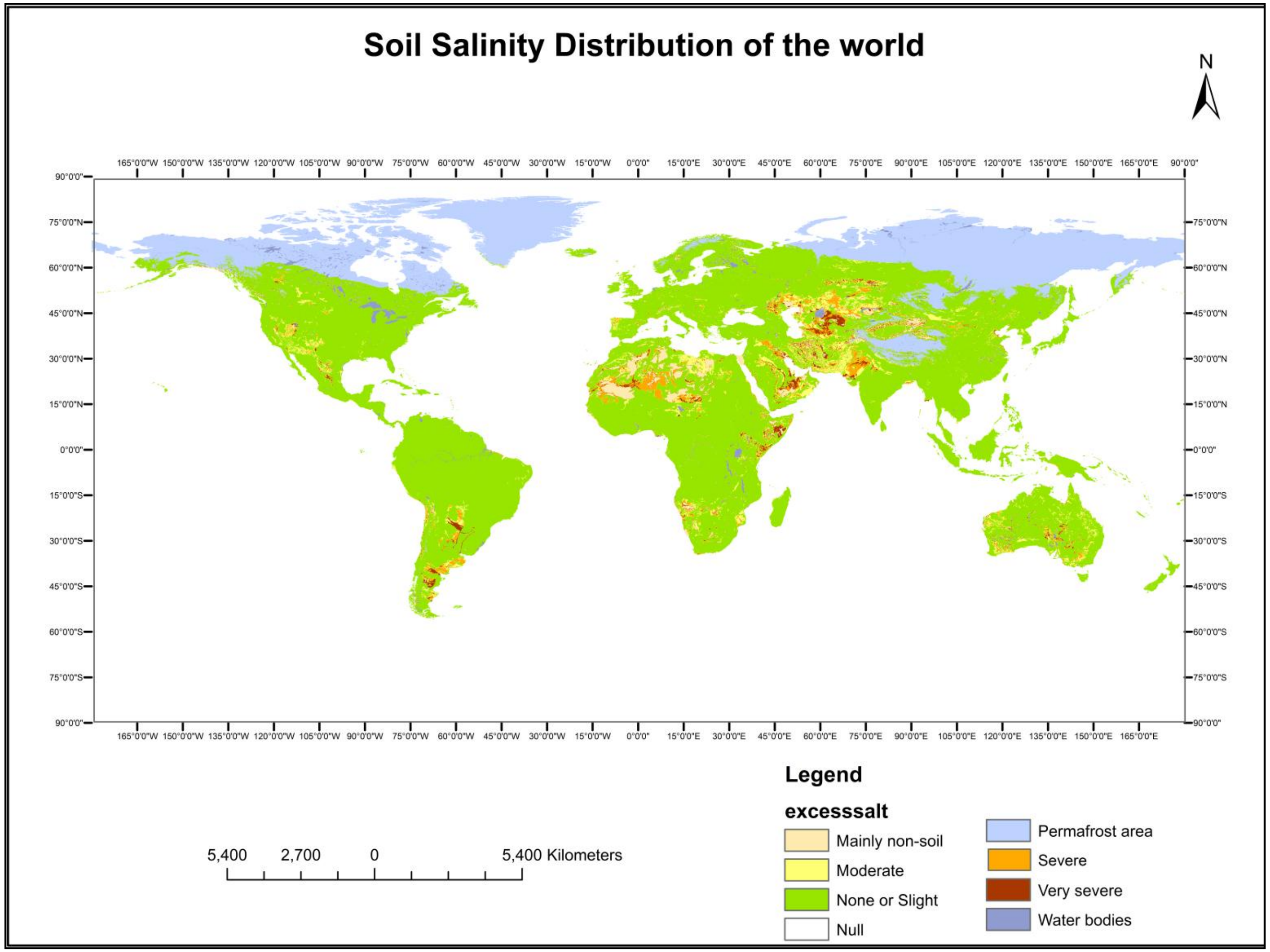


Fig.-2.1 Integrated approach to analyzing the salinity of human livelihood

Source: Designed by the author.

2.5 A GENERAL WORLDWIDE ASPECT OF SOIL SALINITY

Across the globe salinity is being vividly discussed (Lakhdar et al., 2009; Bossio et al., 2010; Yan et al., 2015) not only as an environmental issue (Metternicht and Zinck, 2003; Gorji, et al., 2015) but also as an economic (Yan et al., 2015) and social issue (Daliakopoulos et al., 2016) as its adverse consequence covers microbial functioning to the ecosystem imbalance and sustainability of the land (Xu et al., 2014; Gorji, et al., 2015; Yan et al., 2015). Almost 3% of the world's soil resources are salt-affected comprising close to one billion hectares (1128 Mha) (Metternicht and Zinck, 2002; Wicke et al., 2011) of land which is approximately seven percent of the land extent of the Earth (Gorji et al., 2015). Averagely 20% of the world’s irrigated lands are subject to soil salinity, sometimes reaching up to 30% in arid and semi-arid countries like Egypt, Iran and Argentina (Ghassemi et al., 1995).



Map-2.1 Excess soil salt distribution

Source: Food and Agriculture Organization of United nation: Harmonized World Soil Database (Fischer et al., 2008).

Global salt-affected soils are mainly saline, amounting to 60% of all salt-affected soils. Sodic soils account for 26% and saline-sodic soils for 14%. The majority of salt-affected soils is slightly affected (65%), followed by 20% moderately, 10% extremely, and 5% highly salt-affected soils (Metternicht and Zinck, 2002; Wicke et al., 2011). The magnitude and extent of soil salinity have been increasing given the effort to land reclamation in various ways throughout the world (Metternicht and Zinck, 2003).

Soil salinity is one of the most prevailing types of land degradation in arid, semi-arid and irrigated areas in poorly mismanaged drained soils (Rogers 2002; Patel et al., 2002; Gorji, et al., 2015). The accumulation of soluble salts in the root zone is able to harm the growth of most crops (Rogers 2002; Patel et al., 2002; Fouad, 2003). The degree of the peril can be figured out as up to half of the world's existing irrigation schemes has been suffering from secondary salinity and the waterlogging problem (Datta and Jong, 2002; Fouad, 2003). The severity of the salt soil exists in the arid and semi-arid land of the world comprising the North-African Regions and Central, West Asian regions, South-East South America and Some pockets of Australia mostly spreading over the deserts of the World (Map-2.1). Especially in rural Africa, this problem of soil salinity is attributed to poverty-environment linkages (Barbier, 2000; Datta at al., 2000) and unsustainable land-use is turning into the aerial reduction on farmland by 1-2% per year in arid and semi-arid areas (Gorji et al., 2015). The problem of salinity is taken in a different manner depending on the historical experiences e.g. salinisation in Europe is not taken as seriously as in Australia because of its long-term experience of salinity. But, seawater intrusion in coastal southern Europe is becoming a problem because it is leading to increase in groundwater (Daliakopoulos et al., 2016).

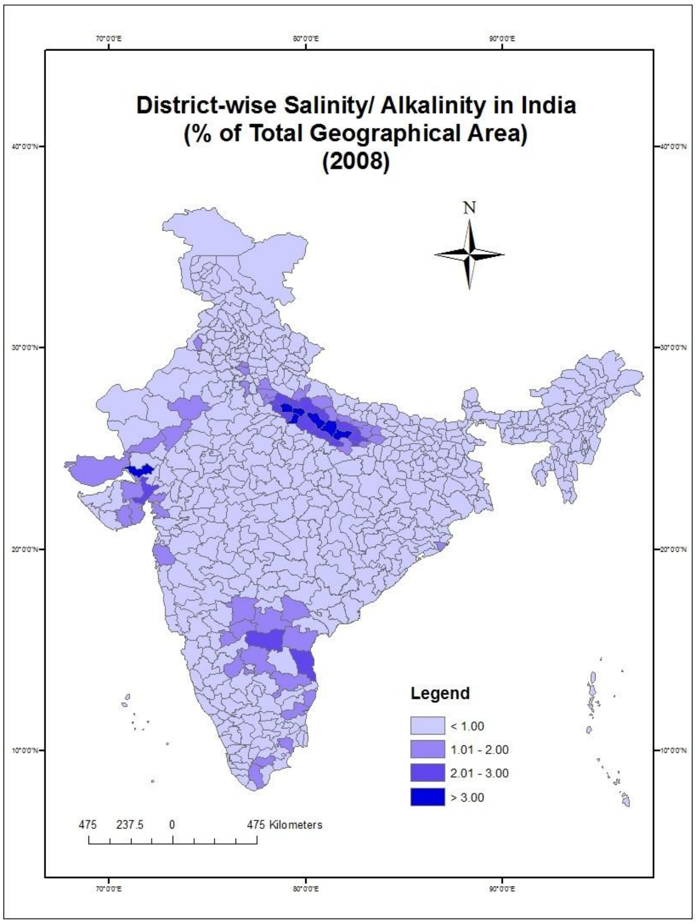
2.6 OUTLINING LAND DEGRADATION AND SOIL SALINITY IN INDIAN SCENARIO

Rapid population growth resulting in the pressure on the land in the country is creating a problem for the quality of the land and its management (Mapa, 2011; Venkateswarlu and Prasad 2011). Out of 55.27 million hectares areas under degraded land, gullied land is 1.19 M ha, land with or without scrub is18.80 M ha, waterlogged area is 0.97 M ha, soil with saline/alkali is 1.20 M ha and shifting cultivation on 1.88

M ha and degraded forest and agriculture land under forest is 12.66 M ha (NRSC, 2011). Soil degradation is proportional to the use of land (Pohit, 2013) and its causes are water erosion, wind erosion, waterlogging, salinization, acidification, soil physical constraints, flood and droughts, vegetation, nutrient mining, depletion of soil organic matter, overexploitation of groundwater, use of poor quality groundwater, Urban and industrial wastage, excessive use of agrochemicals, coastal erosion, gullies and ravines, mass erosion problem, landslide, mine spoils and torrents (Sharda, 2011). Moreover, the other aspect of land degradation is that the unprecedented growth and expansion of urbanisation in the North-Western part of India (NCT Delhi, Punjab and Haryana) is resulting into serious ecological degradation with rapid conversion of agricultural land (Paliwal et al. 1999). More important depository of biodiversity in India is in the Himalayan region, it is estimated that more than 48.27% of the area in the valley is under very high erosion risk (Zaz & Romshoo, 2012). The Thar Desert, the most densely populated the desert region of the world, is facing pressure on scarce water resources resulting into the desertification and accumulation of salt pan in the soil due to a decrease in common property under population pressure (Ravi & Huxman, 2009).

Table-2.3 Salinity causes for the various parts of India

No.	Location	Cause and impact	Source
1.	Western Himalaya, India	Climatic conditions and land use influence carbon accumulation in the soils on the Himalayan Mountain.	Singh et al., 2011
2.	Andaman and Nicobar, India	Coastal soil salinity (Low lying area) due to tsunami during 2004	Velmurugan et al., 2015
3.	North-Western India	Canal irrigation and leading to rising in groundwater level and secondary salinization	Dagar et al., 2016
4.	The Thar Desert	High Evapotranspiration and population pressure	Ravi & Huxman, 2009



Map-2.2 Distribution of salinity affected area

Source: Prepared by the author.

Table-2.4 A brief description of areas having soil salinity-2008

Type of Degradation	**Highly affected districts (More than 4% of TGA)**	**Moderately affected districts (From 2-4% of TGA)**
Salinity/ alkalinity	Kannauj, Oraiya, Rai Bareli, Unnao, Mainpuri, Pratapgarh, Kanpur, Sultanpur, Lucknow (UP), Patan (Gujarat).	Fatehpur, Etawa, Hardoi, Etah, Azamgarh, Firozabad, Jaunpur, Barabanki, Aligarh, Farrukhabad, Mau, Sant Ravidas Nagar, Kaushambi (UP), Ahmedabad, Kuchchh, Bhavnagar (Gujarat), Kurnool, Anantapur, Prakasam Mahboobnagar, Nellore (Andhra Pradesh), Panipat, Sonipat (Hariyana), Jagatsinghpur (Orissa).

Out of 8.4 million hectares of soil salinity area, waterlogged areas account for 5.5 million hectares, which is very significant causes of salinity (Ritzema et al., 2008). Moreover, the presence of acid in the soil leads to the low productivity due to high pH and toxicity level and in India, this problem spread over the about 30% of the total cultivated area (Jena, 2011). The Indo-Gangetic plains have been severely affected by the soil salinity and additionally, the salt content in the coastal soil is due to seawater intrusion. Prakasam, Kurnool, Nagpur, Anantapur, Pratapgarh, Mahboobnagar, Unnao, Nellore, and Leh are some districts, which are strongly affected by salinity (Table-2.4) (NRSC, 2005 & 2011).

2.7 SOIL SALINITY: ITS CAUSES

Comprehensive forces both the natural and human, which is dominating in the secondary salinisation process are a major factor in the soil salinity (Hong-wei et al., 2011; Imenson, 2012). The soil salinity is the result of multitude of factors inefficient canal irrigation, shortfall in the surface and subsurface drainage, inadequate and inefficient water management, poor water supply system, extraction of poor quality of groundwater; poorly balanced water distribution, faulty irrigation and farming practices (Datta et al., 2000; Datta and Jong, 2002; Ritzema et al., 2008), inappropriate cultural practices (Qureshi et al., 2008; Lakhdar et al., 2009) and population growth and its pressure on land (Wicke et al., 2011). The traditional cause of salinity lies with the high groundwater level due to its ability to reach to the root zone bring salinity to the surface; conversely, discriminately pumping out the groundwater for irrigation has become a new threat to sodication and salinization of soil (Datta and Jong, 2002). Consequently, the interruption took place in the natural equilibrium of the input and output of the groundwater leading to seepage and percolation losses (Datta et al., 2000; Ritzema et al., 2008).

Salt accumulation can also be attributed to the material and mineral composition of the patent rock stemming from the erosion and weathering (Datta and Jong, 2002). The physical process led to the degradation of the rocks through slaking, swelling and dispersion on account of surface crusting and hardsetting of soil resulting into the salt content in the soil (Qadir and Oster, 2004). Topography like low lying areas is more assailable to the soil salinity given sub-aquatic conditions (Manjunatha et al., 2004). The peripheral land areas of the basin is being more affected by the salinity due to higher the groundwater table (Datta and Jong, 2002; Hong-wei et al., 2011) and its low lying physiography (Manjunatha et al., 2004), where low human activity has been found in some of the region (Hong-wei et al., 2011). As high temperature, over evaporation and evapotranspiration is contributing to the salt-pan in the semi-arid and arid region (Minhas, 1996, Qadir and Oster, 2004; Lakhdar et al., 2009; Jin et al., 2015), soil salinity has been being intensified by the introduction of irrigation in the region (Ritzema et al., 2008).

Population pressure has pushed for farming in the drylands improved irrigation facility (Wicke et al., 2011). Improper planning for the irrigation projects and its non-sustainability and non-feasibility in the region due to reluctance to the broadening the information has added to the severity of the salinity of soil (Datta et al., 2000; Manjunatha et al., 2004; Ritzema et al., 2008; Wicke et al., 2011) e.g. introducing irrigation in arid and semi-arid region (Ritzema et al., 2008), diversion of saline and alkaline water to irrigation (Sharma and Minhas, 2005) region with rolling topography and low lying area and interceptor drainage system (Manjunatha et al., 2004) without considering the conditions of the region (Datta et al., 2000). Thus the Salinity affected regions are having a positive correlation with the effective irrigated land (Hong-wei et al., 2011). The occurrence of soil salinity can also be assigned to the old irrigation techniques which increase the pace of the waterlogging and salt accumulation (Gorji, et al., 2015). Land use policies also affect the human behavior to respond to the land management.

The size of the land, subsidizing the mechanism adopted by the farmer on saline soil and security of land tenure is having bear upon the policies of the government (Xu et al., 2016). In turn, its relevancy matters for the farmers' behavior, the cropping pattern and health of the soil (Barbier, 2000; Datta et al., 2000). Faulty policies towards the farmers and disincentives for the less-erosive farming worsens the farming system and the productivity of the land, which in turn become more harmful for the sustainability of land and development (Barbier, 2000; Datta et al., 2000; Datta and Jong, 2002). Lack of comprehensive measure e.g. use of composed solid waste for the restoration of land if not properly managed might compromise the crop productivity via toxicity and perturbation in water nutrients balance (Lakhdar et al., 2009).

2.8 SOIL SALINITY: ITS CONSEQUENCES

Soil salinity is becoming a threat to the sustainability of the land and environment and hampering the development process (Gorji, et al., 2015). As soil salinity has strong relation with the underground water conditions (Datta and Jong, 2002), the impact of soil salinity broadly determined by the aquifer and hydraulic conductivity and geological features of the soil (Daliakopoulos et al., 2016). In the arid and semi-arid regions where the salinisation is one of the processes of the desertification, it jeopardises arid ecosystems and its stability (Jin et al., 2015) resulting into slowing down microbiological activity, decreases structural stability, soil slaking, salt toxicity (Sharma and Minhas, 2005), decreasing organic and insufficient leaching, leaving salt to the upper layer instead of downward infiltration (Datta and Jong, 2002; Lakhdar et al., 2009; Yan et al., 2015). The declining microbial and enzyme activities adversely affect the soil stability (Daliakopoulos et al., 2016). The effect does not stop to this; it is becoming harmful for the plant growth (Gorji, et al., 2015) due to less water availability in the soil because of increase in the osmotic pressure (Qadir and Oster, 2004; Yan et al., 2015; Daliakopoulos et al., 2016) and changes in the respiration, residue decomposition, nitrification, and denitrification due to increased electrical conductivity (Daliakopoulos et al., 2016). Further worsening the soil and water quality (Gorji, et al., 2015), this might impact the water and air movement in soil, water holding capacity in plant and soil, root penetration, seedling emergence, runoff, erosion, tillage and sowing operation (Qadir and Oster, 2004), water intake, transfer and aeration (Datta and Jong, 2002). The structural degradation including the dispersion of the clay plays a role in the raindrop impact and drying rate of the soil (Daliakopoulos et al., 2016).

The threat to the sustainability of agricultural land with salinity is proportional to the intensity of waterlogging and salinization problem and adding insecurity to the livelihood of the farmers, particularly with small land holding size (Barbier, 2000; Qureshi et al., 2008). Sometimes, farmers forced to cultivate inferior crops due to a saline problem which reduces the return on investment (Barbier, 2000). But it is very difficult for the farmer to correlate the declining agricultural yield with the soil salinity as it is a phenomenon which is not sudden or the costs are not clear to the farmer due to unawareness (Jewitt and Baker, 2007). Eventually, it has irreparable damage to the soil and livelihood of the dependent labour in terms of decline in the production, income and employment opportunity (Singh and Singh, 1995). Increased salinity left the land deserted, in turn, people obligated to be with the limited land (Hong-wei et al., 2011). Or, this compels the farmers to expand the farming areas rather than increasing cropping intensity (Barbier, 2000) due to the limitation to the choices of crops due to salinity (Sharma and Minhas, 2005). The landless labourers are forced to migrate even in a worsening situation led to the displacement of the poor rural family (Barbier, 2000).

Economically, if the costs are calculated in terms of productivity, replacement and national cost, it would be huge for the bigger country (Bojö, 1995). Economic loss is not only with regards to the productivity but also of the loss of the profits, would have been incurred in the healthy soil (Houk et al., 2006). The demand for the inputs for the plants increases over a period of time (Wicke et al., 2011; Daliakopoulos et al., 2016). Though the cultivation on the degraded land has an endowment to add to the economy and create new employment opportunities, it has been unattractive among the people (Wicke et al., 2011).

2.9 SOLI SALINITY: REMEDIES AND MANAGEMENT

As sodic and saline-sodic soil have excess sodium, therefore the remedies lie in the use of calcium-rich mechanism (Bhojvaid and Timmer, 1998; Qadir and Oster, 2004). Both the amelioration- physical (deep ploughing, sub-soiling, sanding, and profile inversion) and chemical (use of gypsum, Calcium chloride and limestone) - should be done for the reclamation of the soil (Bhojvaid and Timmer, 1998; Lakhdar et al., 2009). More importantly, the identification of soil salinity (spatially and temporally) and timely monitoring of it is crucial of making aware of the right time to act or investment for the reclamation (Metternicht and Zinck, 2003; Abbas and Khan, 2007). Reclamation through the gypsum has become costly affaire due to increased industrial demand and declining government incentives and low quality of gypsum (Qadir and Oster, 2004; Bhojvaid and Timmer, 1998).

Degradation of forests or the removal of vegetation from the surface is the biggest reason for being more prone to the salt-pan due to high evaporation (Constandache et al., 2010; Imenson, 2012), thus the mismanagement of the vegetations should be the avoided (Pimentel et al., 1986; Menon & Bawa, 1998 and Lamb, Bhojvaid and Timmer, 1998). This step will provide for the conservation of unbalanced water and soil situation (Gerold, 2010). Agroforestry can be one of the means for the promoting aforestation (Bhojvaid and Timmer, 1998; Sharma and Minhas, 2005) which will enrich the rhizosphere helping the restoration of the soil fertility (Bhojvaid and Timmer, 1998). Conversely, Vegetation loss and bareness of the soil to the atmosphere can also be attributed to overgrazing, warming and fire, which should be avoided utmost (Turnbull, 2014). Rainfall in the monsoon region led to the infiltration into the soil decreasing salinity in the upper layer provided with the not wasting water through high surface runoff (Minhas, 1996, Qadir and Oster, 2004).

The management practices related to soil should be integrated with many dimension e.g. quality, rationale and optimistic use of water, fertilisers (Bhojvaid and Timmer, 1998; Lakhdar et al., 2009). Desalinisation through the collection of rainwater with strong contour bunds in the field can function in the arid and semi-arid region (Bhojvaid and Timmer, 1998; Qadir and Oster, 2004; Ritzema et al., 2008). Saline water itself can be good for the irrigation in the saline soil, which can maintain the salinity as well as the productivity, but it required robust and adequate drainage system (Sharma et al., 1991) and understanding of soil moisture (Liu et al., 2012). But if it is in the monsoonal region, then proper management is required for the available water during the same period (Sharma et al., 1991). This method is more suitable to the areas with limitation in quality of water. Moreover, this mechanism will be helpful in expanding irrigation cover as well as reducing drainage disposal and the affiliated environmental problem (Sharma et al., 1991; Qadir and Oster, 2004; Ritzema et al., 2008). Dryland salinity management requires a rich understanding of the groundwater system and its water balance component because this region is prone to waterlogging due to intense rainfall short span of time and not able to discharge adequately (George et al., 1991). An overabundance of inorganic ions in irrigation water too leads to the increase in salt content in the soil, which can be overcome through the pine plantation at the coastal region into high economic cost lands (Crescimanno et al., 2010).

Irrigated land with salinity must be facilitated by the adequate water supply so both requirements of irrigation and leaching should be balanced, which would filter out the soil content in the soil and irrigation of soil should be more frequent in this case to reduce cumulative water deficit. It should be done with caution because mismanagement can result in the aeration problem (Minhas, 1996, Qadir and Oster, 2004). Another way is the micro irrigation for the salinity control, which controls the water at 25 mm, at the same time it can result into the salt accumulation (Minhas, 1996, Qadir and Oster, 2004).

Subsurface drainage management is capable to tackle twin problem of waterlogging and the soil salinity (Ritzema et al., 2008). Through technological innovation for the surface and subsurface drainage management (Datta et al., 2000; Manjunatha et al., 2004; Houk et al., 2006; Ritzema et al., 2008) coupled with irrigation, though costlier for poor farmers, has proven to be most feasible for the sustained soil salinity reclamation (Datta et al., 2000; Houk et al., 2006; Ritzema et al., 2008) as it provides the room for the leaching and irrigation, disposal of the low-quality drainage effluent, storage of drainage effluent at the same time not threatening the financial feasibility of the investments (Datta et al., 2000). As it is a collective task, therefore the planner must take the surface and subsurface into consideration for the drainage planning with the consideration of the farmer's conditions in the region (Datta et al., 2000; Ritzema et al., 2008; Shao et al., 2012).

Cultural practices can also be helpful (Sharma and Minhas, 2005; Lakhdar et al., 2009; Bhojvaid and Timmer, 1998) e.g. irrigating with the mixed canal and groundwater or alternatively irrigating with canal and groundwater, even distribution of irrigation water (Datta and Jong, 2002), mixing up of saline/alkali water with fresh water for irrigation to control salinity at threshold (Sharma and Minhas, 2005), crop rotation, traditional and local irrigation methods, efficient water use methods, shallow water management (managing the drainage system depending on the availability of the water table), crop management (in different stages of the field) and chemical management including fertilizer and pesticides (Minhas, 1996, Qadir and Oster, 2004). Salinity tolerant agro-forestry system and bio-saline agriculture should be developed as a cultural practice to deal with the salinity reclamation (Sharma and Minhas, 2005).

The two approaches are required to tackle with the saline environment with the integration- (1) modify the environment according to the need of plants and (2) modifying plant species according to the saline environment (Sharma and Minhas, 2005). The development of crops compatible with the saline, sodic and waterlogged soil and the incentive to encourage the same to the different stakeholders from scientist to the farmers will replenish the sustainable land and aid in maintaining soil permeability (Qadir and Oster, 2004). Salt-tolerant species can be conducive for the remediation of soil salinity and (Yuvaniyama, 2001, Bell, 2002; Sharma and Minhas, 2005; Lakhdar et al., 2009) e.g. Damodar rice and Kharchia wheat (Minhas, 1996, Qadir and Oster, 2004), termialia arjuna, prosopis juliflora (Bhojvaid and Timmer, 1998), parkinsonia aculeata, druce (Qadir and Oster, 2004). Due to scientific progression bioremediation method is able to accommodate calcite within the root zone catering the need of calcium (Qadir and Oster, 2004; Bhojvaid and Timmer, 1998) and some bioremediation crops are kallar grass, sesbania, bermuda grass, sordan, (Qadir and Oster, 2004). Microorganisms are adequately able to enrich soil, crops, land use (Yan et al., 2015) and rhizosphere (Bhojvaid and Timmer, 1998). Some salt tolerating farming practices have also provided encouraging results e.g. cultivation of lowland paddy leaching the salts from the soil profile (Manjunatha et al., 2004; Houk et al., 2006).

Importantly, for the rural economy particularly small farmers should be provided with such facilities, policies and programmes through which they can overcome the poverty to be focused towards the farming (Barbier, 2000). The small farmers with the fragmented land problem are very much reluctant to the restoration (Xu et al., 2016). Mainly these farmers leased in the land from the other landholders in those condition farmers do hesitate to take measure for the reclamation due to stability and integrity in land tenure even though if subsidy for the same is provided (Xu et al., 2016). Thus in this regards, the policy is required which secure the tenure and increase the confidence of the farmers for the land and the investment done (Xu et al., 2016). In salinity environment, policies promoting different remedial practices for the salinity should be committed from the administrative sphere integrated with the efficient use of the land and water resources for the higher yield in a sustainable manner (Sharma and Minhas, 2005). The policymakers should try to integrate the community based planning for their experiences and practices for the same (Bhojvaid and Timmer, 1998; Sharma and Minhas, 2005).

Electro-reclamation (treatment with electric current) is instrumental to the soil reclamation (Lakhdar et al., 2009; Bhojvaid and Timmer, 1998). Use of solid waste can also be advantageous for the soil recovery with taking care of solid waste management as its mismanagement can lead to the discharge of organic and inorganic pollutants (Lakhdar et al., 2009). If it is used appropriately, then it is highly qualified to be the best method because of its double advantages- (1) as added organic matter led to the more porosity and aeration in the soil improving leaching of salt content and (2) composed material provide organic fertilizer in place of inorganic one which is becoming harmful to the soil health (Lakhdar et al., 2009). Moreover, the new technological development with the modern tools should be promoted for the optimum utilization of land resources including wastelands (Datta and Jong, 2002; Qadir and Oster, 2004; Sharda, 2011).

2.10 CONCLUSION

As food is indispensable for the human being, the soil health is indispensable for the food security. The different unconscious developments have contributed to the soil salinity, addition to its naturally contributing factors. The planning for salinity reclamation required an integrated approach with the needful higher yield with sustainability. The ever-increasing expectation for the land and water resources should only be fulfilled when each stakeholder keeping the knowledge of own responsibility contribute to the management with comprehensive manner. Though many researchers have been done important analysis in the different varying field related to soil salinity, there is missing focus towards the farmers' actions after the deserted land, its different uses afterward and further its feasibility for the sustainable land environment. The chapter can be concluded on the note of-

1. Soil salinity has different dimensions in terms of the physiographical formation with the prevailing climatic condition e.g. aridity has direct relation. Human factors into the formation of soil salinity cannot be ignored in the world of rapid transformation of society in terms of the technological innovation e.g. development of drip irrigation, on one hand, can be very beneficial but on the other hand, can increase the soil salinity problem into the field.

2. There are various models have been developed to found the level of soil salinity/alkalinity through remote sensing with high accuracy. However, a field-based study on soil salinity/alkalinity has remained the best ways of evaluation.

3. In all over the world, the soil salinity has remained the significant problem. The middle-east countries have been the most sufferer of the same, where the natural cause has been a dominating factor among all.

4. In India, the evidence of both natural-induced and human-induced soil salinity/alkalinity are found. Natural-induced soil salinity/alkalinity has recorded into

the Thar Desert, where evaporation exceeds the transpiration. Human-induced soil salinity/alkalinity can be evident into Punjab region and Western Uttar Pradesh.

5. Soil salinity/alkalinity has emerged as a threat to the sustainability of the agricultural land as well as the food security especially in India case where the population is the second largest in the world. It involves greater economic costs than thoughts.

6. Thus, comprehensive remedies and management is need of the hour. All stakeholders should be involved in the management by combining the advanced technological method of remedies with the traditional one.

CHAPTER-3

LAND DEGRADATION AND ITS STATUS IN INDIA

3.1 INTRODUCTION

Productive land and soil are critical natural capital assets that it is essential for agricultural productivity, conserving biodiversity and the provision of ecosystem services, such as carbon sequestration, water purification, storage, biofuels, climate protection and regulation, and natural heritage (UNCCD, 2013). The declining land quality is termed as land degradation (Shroder et al., 2016). Land degradation is often the result of land mismanagement, including deforestation, overgrazing, monoculture, salinization, misuse of fertiliser and chemicals, poor farming practices, and soil erosion (Schauer, 2014). There are several types of land degradation due to the various causes. It has direct implications on the ecosystem and the agricultural productivity (Xu et al., 2016). This phenomenon is affecting (directly or indirectly) billions of people around the world and may lead to the overexploitation of soil resources, loss of ecosystem productivity, shifts in vegetation composition, and loss of rural livelihoods (Shroder et al., 2016).

Land degradation is both natural and human-induced process. It existed before the human race populated the earth and will continue to exist. However, humans have a two-sided effect on it: mitigate or accelerate (Zdruli et al., 2010). However, before mitigation or acceleration understanding of land degradation, it is more necessary for all especially in developing countries (Gupta and Sharma, 2010). Therefore, Indicator-based approaches are often used to monitor land degradation and desertification from the global to the very local scale. Indicators are becoming increasingly important for communicating information to policymakers and the general public, as well as for assessing the environmental performance and the progress made by actions applied to mitigate land degradation and desertification (Kairis et al., 2013).

Therefore, this study will first try to understand the spatial distribution of land degradation types. Then the indexing of land degradation will be done, and its spatial extent will be seen according to agro-climatic regions.

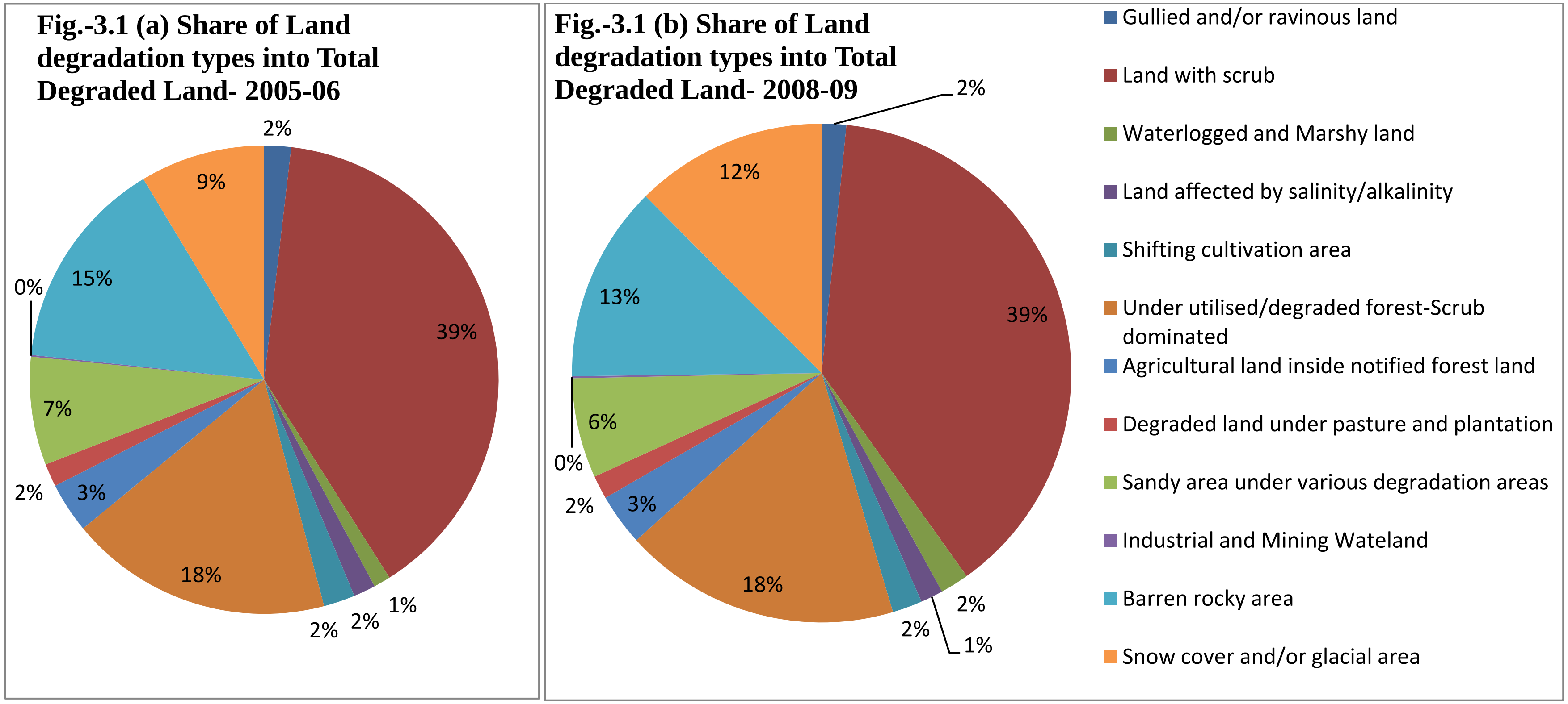
3.2 EXTENT OF LAND DEGRADATION

Total land degradation areas in India has been recorded over the areas of 4,67,021 Sq. Km. in 2008-09 (NRSC, 2011), while recorded area increased to 4,72,262 sq.km from 2005-06. It is 14.75 percent of total geographical areas under different types of the land degradation in the year 2008-09. The categorisation of land degradation types has been done differently in the different year by the National Remote Sensing Agency, Government of India. Therefore, this study has tried to explain different years land degradation types separately. The Year 2008-09 has recorded decline in the degraded land by 5240.78 Sq. Km. from the year 2005-06 (NRSC, 2011). Similarly, the area under desertification in India has been increased by 1.16 million hectares from 2003-05 to 2011-13 (NRSC, 2016). In 2005-06 and 2008-09, the share of "Land with scrub" category of land degradation to Total Degraded Area (TDA) is 39.17 percent and 38.54 percent respectively, which is highest among all categories (Fig.:3.1 (a) and (b). This is followed by underutilised/degraded forest-Scrub dominated (17.92 percent), barren rocky area (12.74 percent), Snow cover and/or glacial area (12.46 percent), Sandy area under various degradation areas (6.48 percent), Agricultural land inside notified forest land (3.36 percent), shifting cultivation (1.93 percent), waterlogged and Marshy land (1.86 percent), gullied and/or ravinous land (1.59 percent), degraded land under pasture and plantation (1.52 percent), land affected by salinity/alkalinity (1.46 percent) and industrial and mining wasteland (0.14 percent) (Fig.-3.1 (b).

Similarly, NRSC (2016) has given different types of degradation explanation. Water erosion (~37 percent) accounts for the highest degradation into TDA in 2011-13, and it had recorded a decrease from 2003-05 when it was ~38 percent of TDA. Vegetation Degradation (~30 percent of TDA) and wind erosion (~19 percent of TDA) has not been changed over the period of 2003-05 to 2011-13. Similar is the case with the Salinity (~4 percent of TDA), waterlogging (~1 percent of TDA), mass movement (~1 percent of TDA), Barren/rocky (~2 percent of TDA) and settlement (~2 percent of TDA). On another hand, frost shattering has witnessed an increase of ~1 percent of TDA from the year 2003-05 to 2011-13 (Fig.-3.3 (a) and (b).

Fig.-3.1 (a) Share of Land degradation types into Total Degraded Land- 2005-06

Fig.-3.1 (b) Share of Land degradation types into Total Degraded Land- 2008-09



Source: *NRSC Wasteland Atlas, 2011.*

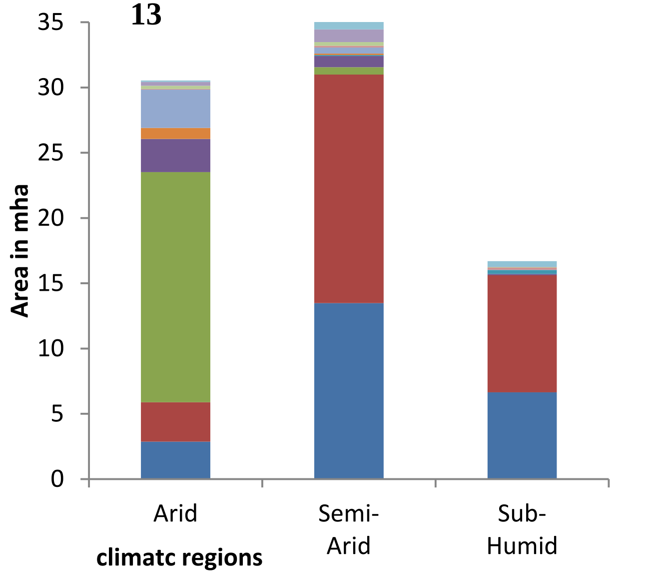


Fig.-3.2 (a) Land degradation Types into various Climatic Region- 2011-13

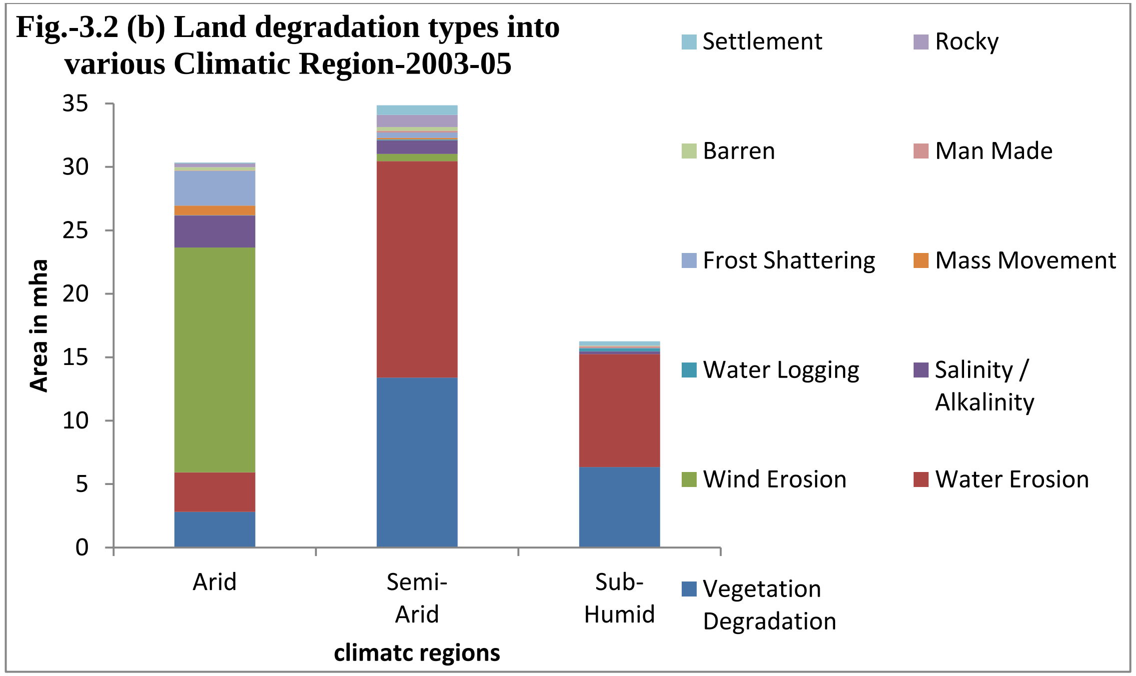
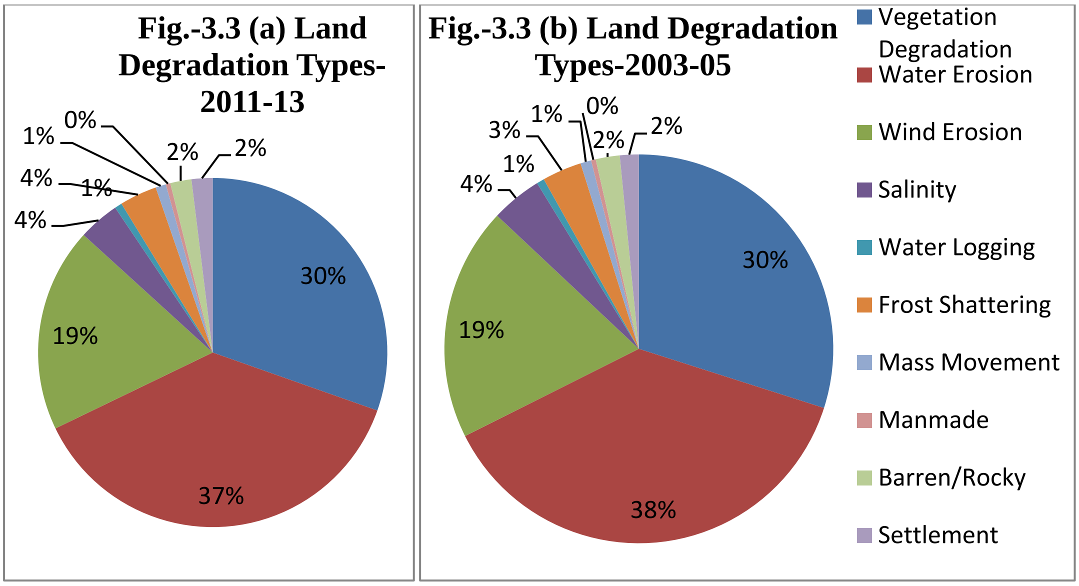
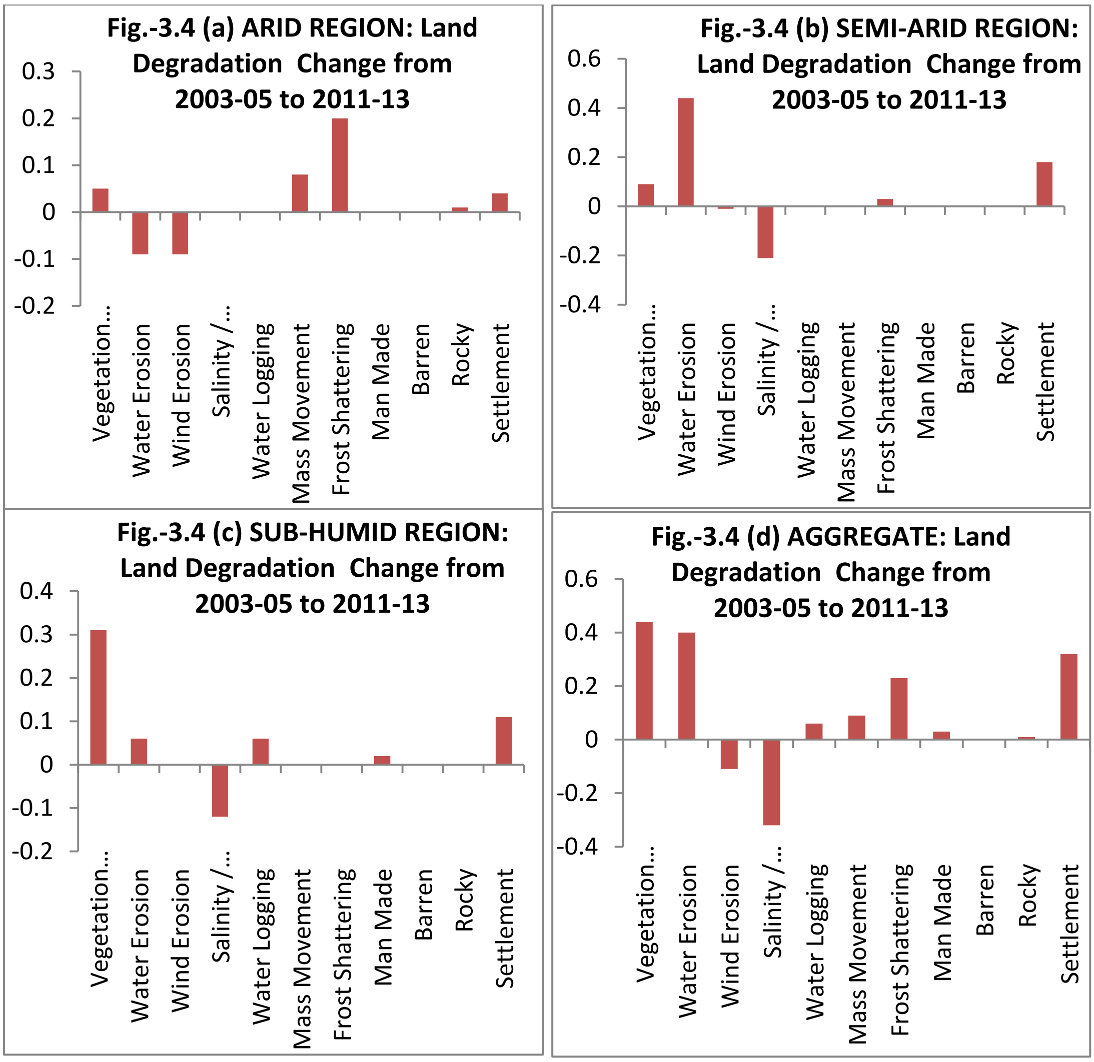


Fig.-3.2 (b) Land degradation types into various Climatic Region-2003-05

Source: *NRSC Wasteland Atlas, 2016.*



Source: *NRSC Wasteland Atlas, 2016*



Source: Prepared by the author by using data from the Wasteland Atlas of India, NRSC, 2016.

The climatic region-wise analysis reveals that the Semi-arid region has the highest share of degradation into TDA amounting 34.85 percent and 35.4 percent in the year 2003-05 and 2011-13 respectively (Table-3.1). This is followed by arid region and sub-humid region (Table-3.1). The arid region has experienced wind erosion heavily accounting 17.63 million hectares (mha) area in 2011-13. In the same region, the degradation types like water erosion (3.03 mha), frost shattering (2.94 mha), vegetation degradation (2.86 mha) and salinity and alkalinity (2.52 mha) are very much prominent among others (in the year 2011-13) (Table-3.1 and Fig.-3.2 (a).

However, the semi-arid region has gone through water erosion significantly reporting 17.51 mha (2011-13) area has suffered from it. This is followed by the vegetation degradation (13.48 mha), rocky areas (0.97 mha), settlement (0.93 mha), salinity/alkalinity (0.86 mha) and wind erosion (0.56 mha) etc. (Table-3.1 and Fig.-3.2 (a).

Table-3.1 Area under the different process of land degradation

	Area under Desertification (mha)							
	2011-13				**2003-05**			
Process of Degradation	**Arid**	**Semi-Arid**	**Sub-Humid**	**Total**	**Arid**	**Semi-Arid**	**Sub-Humid**	**Total**
Vegetation Degradation	2.86	13.48	6.65	22.99	2.81	13.39	6.34	22.55
Water Erosion	3.03	17.51	8.97	29.51	3.12	17.07	8.91	29.11
Wind Erosion	17.63	0.56	0	18.19	17.72	0.57	0	18.3
Salinity / Alkalinity	2.52	0.86	0.09	3.48	2.52	1.07	0.21	3.8
Water Logging	0.02	0.08	0.31	0.42	0.02	0.08	0.25	0.36
Mass Movement	0.84	0.11	0	0.96	0.76	0.11	0	0.87
Frost Shattering	2.94	0.46	0.01	3.41	2.74	0.43	0.01	3.18
Man Made	0.04	0.14	0.16	0.35	0.04	0.14	0.14	0.32
Barren	0.25	0.28	0.05	0.58	0.25	0.28	0.05	0.58
Rocky	0.3	0.97	0.02	1.29	0.29	0.97	0.02	1.28
Settlement	0.11	0.93	0.44	1.47	0.07	0.75	0.33	1.15
Grand Total	**30.54**	**35.4**	**16.7**	**82.64**	**30.35**	**34.85**	**16.28**	**81.48**

Source: *NRSC Wasteland Atlas, 2016*

Fig.-3.4 (a) illustrates that the arid region has recorded increase into vegetation degradation (increased by 0.05 mha), mass movement (increased by 0.08 mha), frost shattering (increased by 0.20 mha), rocky area (increased by 0.01 mha), and settlement (increased by 0.04 mha). However, water erosion (decreased by 0.09 mha) and wind erosion (decreased by 0.09 mha) has witnessed a decrease in an arid region. In addition, the degradation types such as salinity/alkalinity, water logging, man-made degradation and barren land have recorded no change/negligible change (Fig.-3.4 (a). Overall, the arid region has registered a growth in total land degradation by 0.19 mha. Interestingly, semi-arid region (increase by 0.55 mha land degradation area) is witnessing more increase in overall land degradation compared to arid (increased by 0.19 mha) and sub-humid region (increased by 0.42 mha) from the year 2003-05 to 2011-13 (Table-3.1).

The semi-arid region has seen increase into vegetation degradation (increased by 0.09 mha), water erosion (increased by 0.44 mha), frost shattering (increased by 0.03 mha) and settlement (increased by 0.18 mha). Water erosion (decreased by 0.01 mha) and salinity/alkalinity (decreased by 0.21 mha) has witnessed a a decline into the semi-arid region. Indeed, the water logging, mass movement, man-made degradation, barren land and rocky land have not indicated any change from the year 2003-05 (fig-4 (b). Fig.-3.4 (c) reveals about changes in land degradation areas into the sub-humid region. It is brought out that vegetation degradation, water erosion, waterlogging, man-made degradation and settlement have recorded an increase by 0.31 mha, 0.06 mha, 0.06 mha, 0.02 mha, 0.11 mha respectively. Conversely, only salinity/alkalinity has witnessed a decrease of 0.12 mha (Table-3.1).

Overall in these regions, there is a change of 1.16 mha in land degradation from 2003-05 to 2011-13. The total increase in different types of land degradation into these areas is vegetation degradation by 0.44 mha, water erosion by 0.40 mha, water logging by 0.06 mha, mass movement by 0.09 mha, frost shattering by 0.23 mha, man-made degradation by 0.03 mha, rocky land by 0.01 mha and settlement by 0.32 mha. Wind erosion (by 0.11 mha) and salinity/alkalinity (by 0.32 mha) areas have declined totally. There is recorded no change in the barren land into total climatic regions (Table-3.1 and Fig.-3.4 (d).

Table-3.2 Status of land degradation in states from 2005-06 to 2008-09

State Name	Total Wasteland (hectare)					Percentage of TGA		
	2005-06	2008-09	Change	Total Reduction	Total Increase	2005-06	2008-09	% Change over 2005-06
Andhra Pradesh	38788.22	37296.62	-1491.6	1682.1	190.46	14.1	13.56	-0.54
Arunachal Pradesh	5743.83	14895.24	9151.41	108.48	9259.89	6.86	17.79	10.93
Assam	8778.02	8453.86	-324.15	862.56	538.04	11.19	10.78	-0.41
Bihar	6841.09	9601.01	2759.92	1895.09	4654.41	7.26	10.2	2.93
Chhattisgarh	11817.82	11482.18	-335.64	379.06	43.15	8.74	8.49	-0.25
Delhi	83.34	90.21	6.87	3.62	10.27	5.62	6.08	0.46
Goa	496.27	489.08	-7.18	11.48	3.99	13.41	13.21	-0.19
Gujarat	21350.38	20108.06	-1242.32	2858.99	1616.67	10.89	10.26	-0.63
Haryana	2347.05	2145.98	-201.07	232.2	31.92	5.31	4.85	-0.45
Himachal Pradesh	22470.05	22347.88	-122.17	197.25	75.57	40.36	40.14	-0.22
Jammu & Kashmir	73754.38	75435.77	1681.39	1191.48	2872.78	72.75	74.4	1.66
Jharkhand	11670.14	11017.38	-652.76	1183.5	531.16	14.64	13.82	-0.82
Karnataka	14438.12	13030.62	-1407.5	1477.98	70.82	7.53	6.79	-0.73
Kerala	2458.69	2445.62	-13.07	247.55	234.44	6.33	6.29	-0.03
Madhya Pradesh	40042.98	40113.27	70.29	258.95	329.25	12.99	13.01	0.02
Maharashtra	38262.81	37830.82	-431.99	469.93	38.22	12.44	12.3	-0.14
Manipur	7027.47	5648.53	-1378.94	2391.1	1012.14	31.48	25.3	-6.18
Meghalaya	3865.76	4127.43	261.67	93.86	355.13	17.24	18.4	1.17
Mizoram	6021.14	4958.64	-1062.5	2669.27	1606.71	28.56	23.52	-5.04
Nagaland	4815.18	5266.72	451.55	721.37	1172.6	29.04	31.77	2.72
Orissa	16648.27	16425.76	-222.51	271.75	48.69	10.69	10.55	-0.14
Punjab	1019.5	936.83	-82.67	112.7	30.56	2.02	1.86	-0.16
Rajasthan	93689.47	84929.1	-8760.37	10264.6	1503.37	27.38	24.82	-2.56
Sikkim	3280.88	3273.15	-7.73	11.83	4.29	46.24	46.13	-0.11
Tamilnadu	9125.56	8721.79	-403.77	426.78	22.74	7.02	6.71	-0.31
Tripura	1315.17	964.64	-350.53	486.15	135.07	12.54	9.2	-3.34
Uttarakhand	12790.06	12859.53	69.47	440.35	509.86	23.91	24.04	0.13
Uttar Pradesh	10988.59	9881.24	-1107.35	1269.71	163.08	4.56	4.1	-0.46
West Bengal	1994.41	1929.2	-65.21	92.98	28.46	2.25	2.17	-0.07
Union Territory	337.3	315	-22.3	27.33	4.68	3.55	3.32	-0.23
Total	472261.9	467021.2	-5240.78	32340	27098.43	14.91	14.75	-0.17

Source: NRSC Wasteland Atlas, 2011.

Table-3.2 has explained the status of land degradation into the various states of India. The average land degradation in whole India is 14.75 percent of total geographical areas (TGA). Ten states have recorded more than the average of India (proportionate to TGA). These states are Jammu and Kashmir (74.4 percent of TGA), Sikkim (46.13 percent of TGA), Himachal Pradesh (40.14 percent of TGA), Nagaland (31.77 percent of TGA), Manipur (25.30 percent of TGA), Rajasthan (24.82 percent of TGA), Uttarakhand (24.04 percent of TGA), Mizoram (23.52 percent of TGA), Meghalaya (18.40 percent of TGA) and Arunachal Pradesh (17.79 percent of TGA). Besides, other states have recorded less than the average of India; notably, they have still significant areas under land degradations.

The changes from 2005-06 to 2008-09 are very noticeable. Eight states have registered an increase in areas under a different type of land degradation. These states are Arunachal Pradesh (increase of 9151.41 km^2 -10.93 percent of TGA), Bihar (2759.92 km^2 -2.93 percent of TGA), Jammu and Kashmir (1681.39 km^2 -1.66 percent of TGA), Nagaland (451.55 km^2 -2.72 percent of TGA), Meghalaya (261.67 km^2 -1.17 percent of TGA), Madhya Pradesh (70.29 km^2 -0.02 percent of TGA), Uttarakhand (69.47 km^2 -0.13 percent of TGA) and Delhi (6.87 km^2-0.46 percent of TGA) (Table-3.2). Overall India has witnessed a decline in the areas of degradation by 5240.78 km^2, which accounts for 0.17 percent of TGA. This is indicative of that the majority of states have recorded the decline, in which the major states are Rajasthan (decline by 8760.37 km^2 - 2.56 percent of TGA), Andhra Pradesh (1491.6 km^2 -0.54 percent of TGA), Karnataka (1407.5 km^2 -0.73 percent of TGA), Manipur (1378.94 km^2 -6.18 percent of TGA), Gujarat (1242.32 km^2 -0.63 percent of TGA), Uttar Pradesh (1107.35 km^2 -0.46 percent of TGA) etc. (Table-3.2).

As many as 260 districts are affected by the gully/ravines (medium) in India covering 6145.96 km^2 areas in 2008-09. The districts like Morena (498.25 km^2) and Bhind (422.57 km^2) of Madhya Pradesh are having highest areas under gully/ravines, which are reportedly about 10 percent and 9.5 percent of TGA of district respectively. Districts like Morena (9.98 percent of TGA), Bhind (9.48 percent of TGA), Bilaspur (5.46 percent of TGA), Rajouri (3.97 percent of TGA), Jalaun (3.37 percent of TGA), Perambalur (3.37 percent of TGA) and Una (3.04 percent of TGA) are affected by intense gully/ravine (medium) (Map-3.1 (A). The districts such as Rajouri (2.25 percent of TGA), Bundi (3.44 percent of TGA), Firozabad (3.01 percent of TGA), Kathua (2.6 percent of TGA), Dhaulpur (1.02 percent of TGA), Etawah (2.21 percent of TGA), Agra (1.46 percent of TGA), Auriya and Leh (both ~1 percent of TGA) are highly affected by gully/ravines (deep). Total 51 districts are affected by the gully/ravines (deep) accounting 1266.06 km^2 (Map-3.1 (B). Overall, 273 districts are being affected by both types of gully/ravines. Morena, Bhind, Rajouri, Bilaspur, Bindi, Firozabad, Kathua, Jalaun and Dhaulpur are highly affected by Very high gully/ravines type of land degradation (Map-3.1 (C). Interestingly, only one very highly gully/ravines affected district has witnessed both the medium and deep ravines, which is Rajouri district of Jammu and Kashmir (Map-3.1).

Mismanagement of surface run-off, especially deforestation, overgrazing and unsuitable farming practices are attributed as causes of gully erosion by the various studies. The pace of developing gully usually intensifies due to the concentration of rainfall during the monsoon. Specifically, the relative significance of climatic factors in ravine formation in India has been a source of controversy. However, most of the studies favor multiple combinations of socio-economic and biophysical factors rather than any single set of factors responsible for ravine formation (Sharma, 1980; Pani, Mishra, and Mohapatra 2011; Pani and Carling, 2013, Priya, 2014; Priya Pani, 2015).

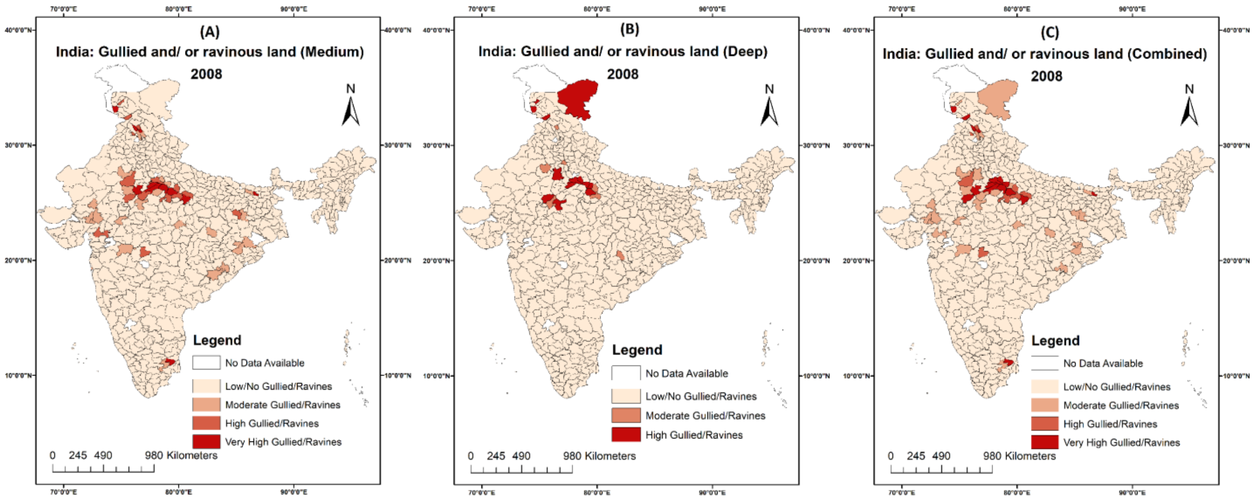
More than 524 districts are being affected by the dense scrub covering the area of 86979.91 km^2 in 2008-09 (Map-3.2 (A). Land with open scrub problem exists into almost every districts (covering 93033.00 km^2) except 17 districts like Baghpat, Chennai, Auraiya, island territories, Dakshin Dinajpur, Nadia, North 24 Parganas, Hugli, Kolkata, Haora, South 24 Parganas, Thiruvarur, Mansa, Mumbai, Nalbari, Maharajganj (Map-3.2 (B). Similarly, overall land affected with scrubs is spread across India except for 16 same districts excepting Baghpat (Map-3.2 (B). The whole area under the scrub was 180012.91 km^2 in 2008-09. Districts like Korba, Senapati, Rajamasand, Churachandpur, Hamirpur, Jaisalmer, Mon, Tawang and North Cacher Hills etc. are very highly affected by scrubs (Total) (Map-3.2 (C).

According to the proportionate to TGA, the high waterlogged/marshy land (permanent) districts are Puri, Purba Champaran, and Katihar. Area-wise scenario is the same with the area of 133.37 km^2, 77.33 km^2 and 58.68 km^2 respectively. 198 districts are being affected by waterlogging/marshy land, which has covered 1757.07 in km^2 2008-09 (NRSC, 2011). On the other hand, areas under waterlogged and marshy land (seasonal) are 6946.31 km^2 spreading across 211 districts (NRSC, 2011). Overall, the district of Munger (24 percent to TGA) is highly affected by waterlogging and marshy land and districts like Madhepura, Nawada, Saharsa, Buxar, Bhagalpur, Hopalganj, Khagaria and Nalanda are moderately affected by the waterlogging and marshy land problem each accounting more than 10 percent to TGA (Map-3.3 (C).

India is estimated to have about 58.2 million hectares of wetlands, many of which are distributed around the Indo-Gangetic plains. Generally regarded as ‘‘a water-surplus area’’ Waterlogging, closely associated with salinization and/alkalinization, continues to be a threat to sustained irrigated agriculture (Pandey et al., 2010).

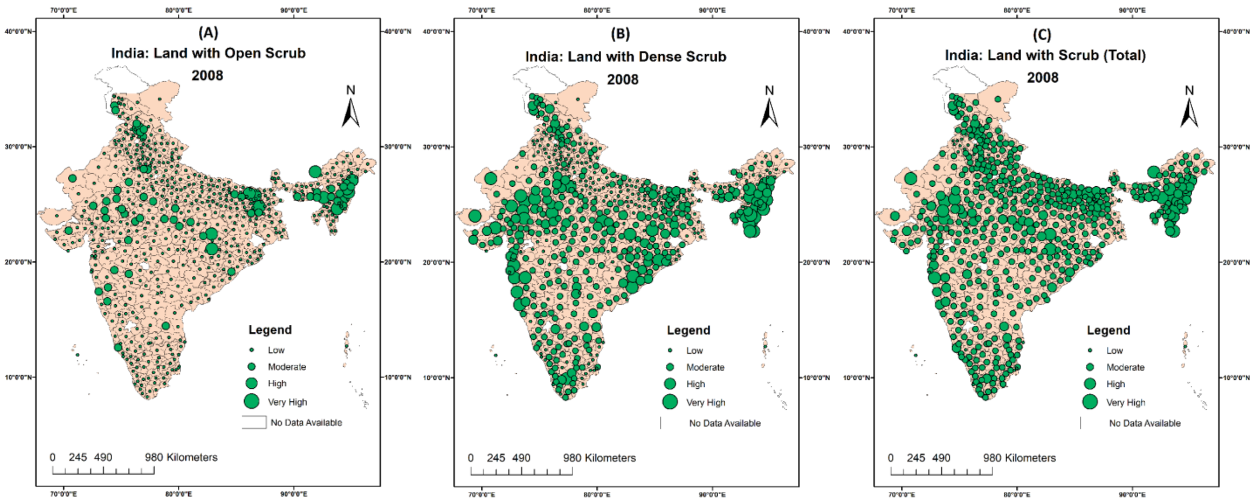
The soil salinity/alkalinity problem is also being one of the prominent land degradation types in India. 168 districts are being affected by salinity/alkalinity (moderate/medium) spreading over 5414.53 km^2 area, accounting for 0.17 percent of TGA (NRSC, 2011). Major districts like Kannauj, Raebareli, Auraiya, Mainpuri, Kanpur rural, Unnao, Kanpur Urban etc. are affected by the salinity/alkalinity (moderate/medium) (Map-3.4 (A). Similarly, 104 districts are affected by salinity/alkalinity-string covering the areas of 1391.09 km^2. Major districts are so many, which is highly affected by salinity/alkalinity (strong) and some are Pratapgarh, Unnao, Sultanpur, Lucknow, Kannauj, Kurnool, Sonipat etc. (Map-3.4 (B).

The soil salinity is the result of multitude of factors inefficient canal irrigation, shortfall in the surface and subsurface drainage, inadequate and inefficient water management, poor water supply system, extraction of poor quality of groundwater; poorly balanced water distribution, faulty irrigation and farming practices (Datta et al., 2000; Datta and Jong, 2002; Ritzema et al., 2008), inappropriate cultural practices (Qureshi et al., 2008; Lakhdar et al., 2009) and population growth and its pressure on land (Wicke et al., 2011). The traditional cause of salinity lies with the high groundwater level due to its ability to reach to the root zone, bring salinity to the surface; conversely, discriminately pumping out the groundwater for irrigation has become a new threat to sodication and salinization of soil (Datta and Jong, 2002). Consequently, the interruption took place in the natural equilibrium of the input and output of the groundwater leading to seepage and percolation losses (Datta et al., 2000; Ritzema et al., 2008).



Map-3.1 (A) Spatial pattern of gully and ravines land (medium) in India (B), Spatial pattern of gully and ravines land (deep) in India, and (C) Spatial pattern of gully and ravines land (combined) in India

Source: Prepared by the author by using data provided by NRSC through Wasteland Atlas, 2011.

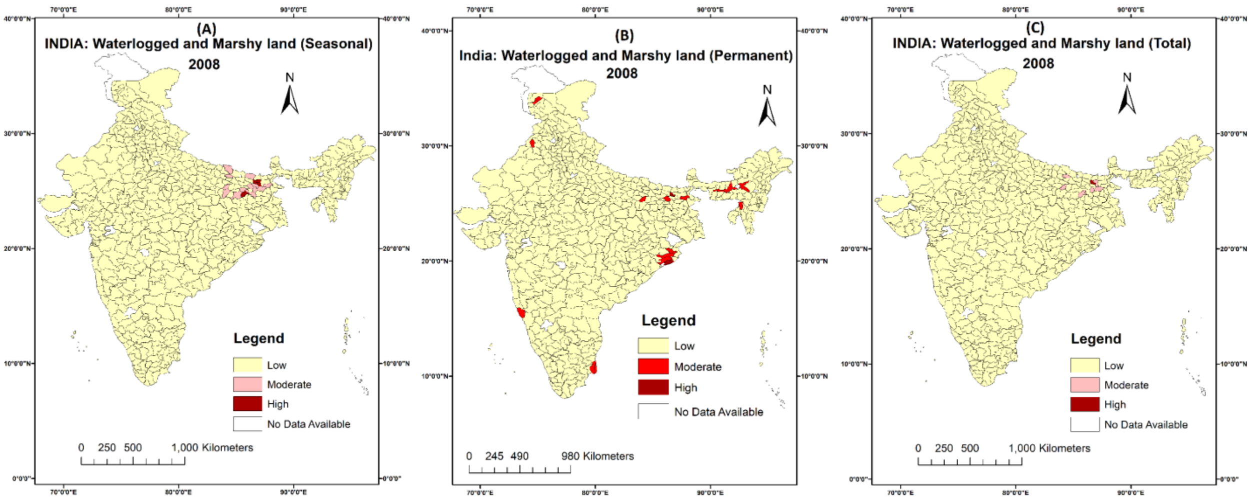


Map-3.2 (A) Spatial pattern of land with an open scrub in India (B), Spatial pattern of land with a dense scrub in India, and (C) Spatial pattern of land with scrub (total) in India

Source: Prepared by the author by using data provided by NRSC through Wasteland Atlas, 2011.

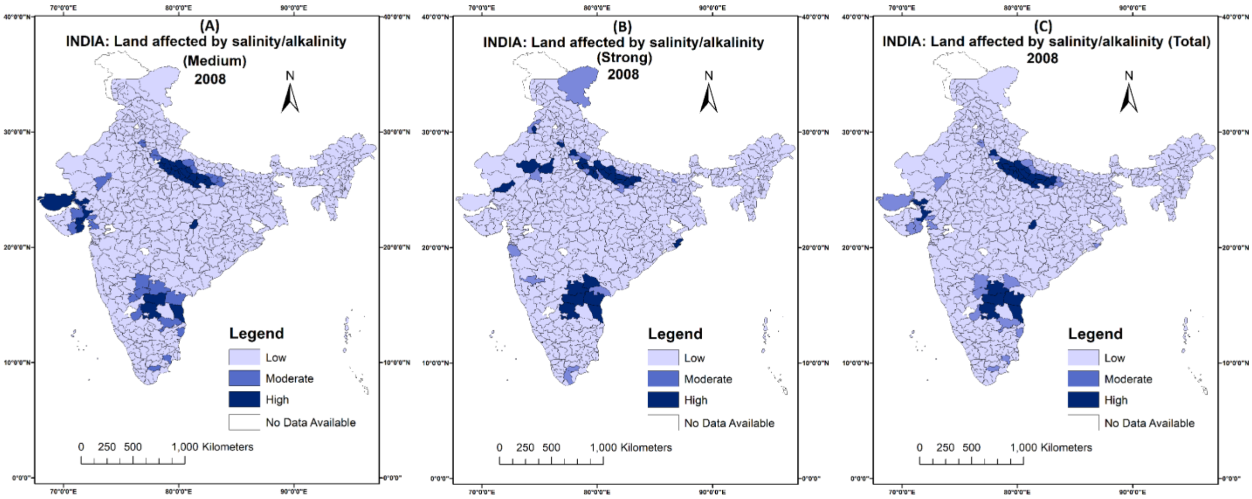
As an whole the highly salinity/alkalinity affected districts are Kannauj, Raebareli, Unnao, Auraiya, Mainpuri, Pratapgarh, Kanpur-rural and urban, Sultanpur, Lucknow, Etah, Etawah, Fatehpur, Hardoi, Patan, Firozabad, Jaunpur, Rajnandgaon, Farrukhabad, Nellore, Kaushambi, Ahmadabad, Sant Ravidasnagar, Kurnool, Anantpur and Prakasham etc. (Map-3.4 (C).

Shifting cultivation has affected the quality of the soil, therefore impacting the productivity in negative ways (Lindskog and Tengberg, 1994; Reddy, et al., 2002; Yao, et al., 2013). India's significant portion of the areas is under the two different categories of shifting cultivation. The total of 79 districts is under the category of shifting cultivation-current jhum spreading over 4814.68 km^2 (Map-3.5 (A) (NRSC, 2011).



Map-3.3 (A) Spatial Pattern of waterlogged and marshy land (seasonal) in India (B), Spatial pattern of waterlogged and marshy land (permanent) in India, and (C) Spatial pattern of waterlogged and marshy land (total) in India

Source: Prepared by the author by using data provided by NRSC through Wasteland Atlas, 2011.



Map-3.4 (A) Spatial Pattern of land affected by salinity/alkalinity (medium) in India (B), Spatial Pattern of Land Affected by Salinity/Alkalinity (Strong) in India, and (C) Spatial pattern of land affected by salinity/alkalinity (total) in India

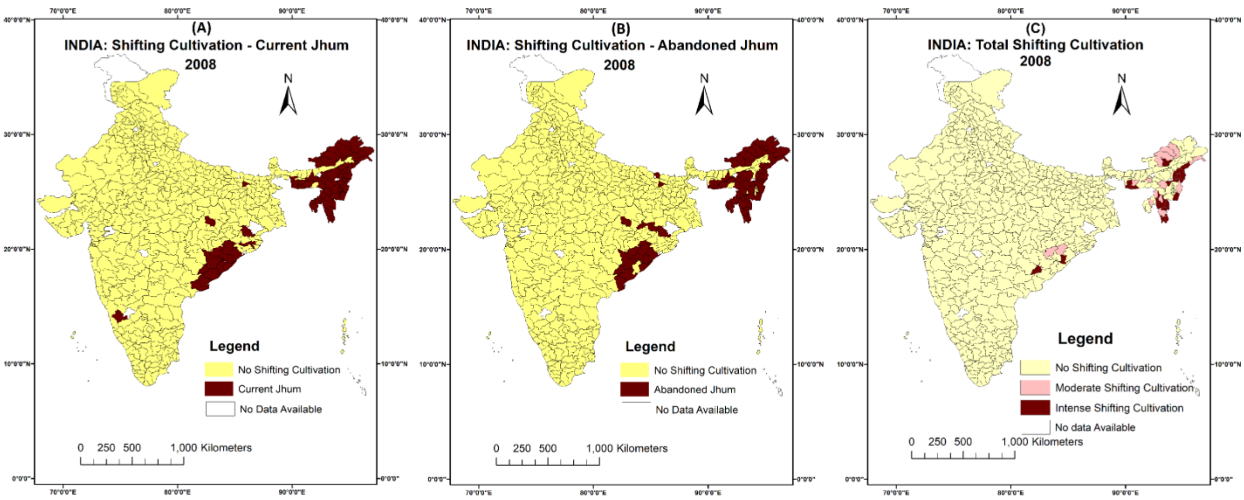
Source: Prepared by the author by using data provided by NRSC through Wasteland Atlas, 2011.

In addition, 70 districts are under the abandoned jhum extending over 4210.46 km^2 (Map-3.5 (B) (NRSC, 2011). In India, total 9025.14 km^2 areas are under shifting cultivation. The intensity of the shifting cultivation is high in the Northeastern region and some districts of Odisha (Map-3.5 (C). Highly intense shifting cultivation areas are found in the districts like Tirap (27.40 percent of TGA), Mon (22.13 percent of TGA), Tuensang (21.26 percent of TGA), Mokokchung (18.84 percent of TGA), Champai (15.68 percent of TGA), Serchhip (12.81 percent of TGA), Zunheboto (12.53 percent of TGA), Gajapati (10.68 percent of TGA) etc. (Map-3.5 (C).

The under-utilised forest is the major cause of concerns for the sustainable and optimum use of resources globally. India too is facing this problem through different intensity in different areas (Balooni and Singh, 2003). Under-utilised/degraded forests under agriculture are found prominent in more than 300 districts spreading over 15680.26 km^2 in 2008-09 (NRSC, 2011). Under it, districts like Korba, Sitamarhi, Kabeerdham, Golaghat, Kokrajhar etc. are highly degraded (Map-3.6 (A)). Besides, there is another category of degraded forest. This is degraded forest under scrub domination, which is found across more than 450 districts of India accounting 83699.71 km^2 under the same degradation types (NRSC, 2011).

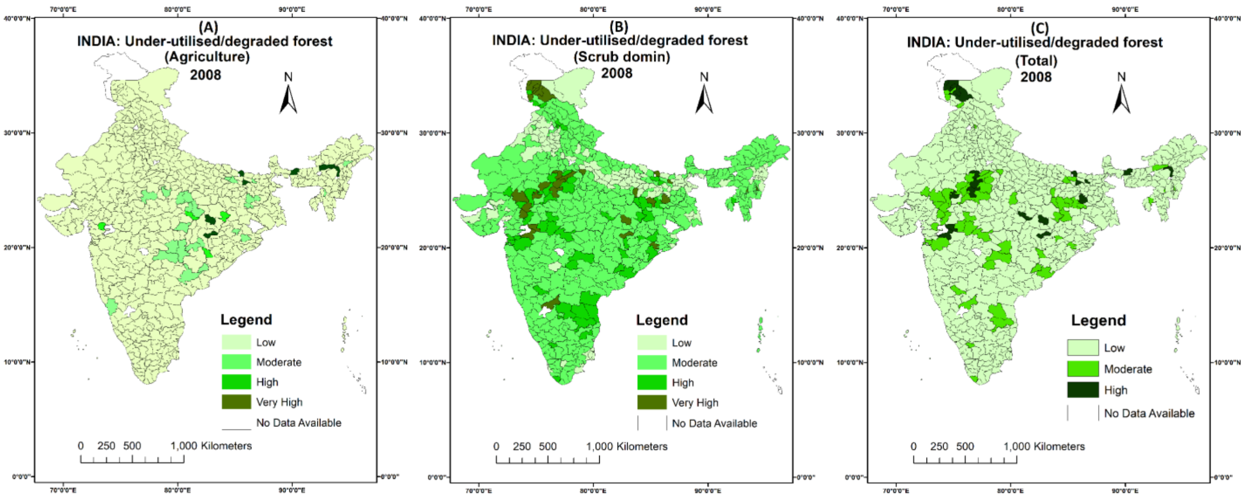
Korba, Srinagar, Sitamarhi, Kabeerdham, Karauli, Sheopur, Neemuch, Barwani etc. are some districts which are accounting more than 15 percent of TGA under Under-utilised/degraded forest (Scrub domin) (Map-3.6 (B). Indeed, after combining both the category of the under-utilised/degraded forest, Korba district has recorded as high as 72.71 percent area to TGA under it. It is followed by Sitamarhi (59 percent to TGA), Kabeerdham (40.55 percent to TGA), Srinagar (25.19 percent to TGA), Karauli (20 percent to TGA), Sheopur & Kalan (19.67 percent to TGA) etc., which are under high degraded forests (Map-3.6 (C).

Degraded pasture/grazing land has dominated in the region of Arid and Semi-arid as well as some parts of hilly areas. 6832.17 km^2 areas are under it spreading over 135 districts. Very Highly degraded pasture/grazing land in India found in the districts like Erode, Idukki, Sonipat, Jhajjar, Rohtak, Bageshwar, Jind, Jodhpur etc. (Map-3.7 (A). Degraded land under plantation crops is not so prominent in the country. It accounts for only 278.53 km^2 and prominent district under it are Kupwara (1.58 percent to TGA) and Mahendragarh (1.35 percent to TGA) (Map-3.7 (B). Moreover, total high degraded land under pasture and plantation are found in the districts like Erode, Karimnagar, MahendraGarh, Idukki, Jhajjar, Sonipat, Rohtak etc. (Map-3.7 (C).



Map-3.5 (A) Spatial pattern of shifting cultivation-current jhum in India (B), Spatial pattern of shifting cultivation-abandoned jhum in India, and (C) Spatial pattern of total shifting cultivation in India

Source: Prepared by the author by using data provided by NRSC through Wasteland Atlas, 2011.



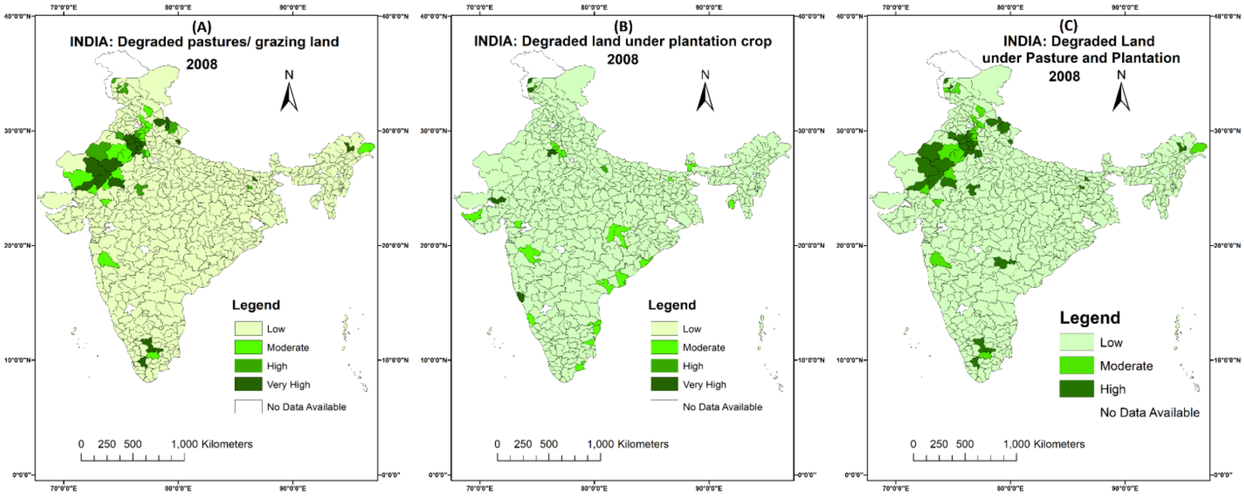
Map-3.6 (A) Spatial pattern of under-utilised/degraded forest (agriculture) in India (B) Spatial pattern of under-utilised/degraded forest (scrub domination) in India, and (C) Spatial pattern of total under-utilised/degraded forest in India

Source: Prepared by the author by using data provided by NRSC through Wasteland Atlas, 2011.

Catchment erosion has been found in the riverine zone of the river (Molina-Navarro et al., 2014). The Sand-Riverine is one of the important types of land degradation (NRSC, 2011). This has been dominated into the areas of river basins covering 2111.96 km^2. The Indus, The Ganga and The Brahmaputra basin are the major regions of this category of degradation. Districts like Vaishali, Leh, Una, Korba and Dhemaji etc. are highly affected by this type of degradation problem (Map-3.8 (A): Marked by Blue colour). Sands-Coastal has more dominated into the east coast compared to the western coast of Indian coastal region. Island territories are also affected by the coastal sands. The districts which are highly affected under the sands-coastal are Lakshadweep, Ramanathpuram, Puducherry, Nellore, Kancheepuram, Thoothukkudi, Kanniyakumari, Srikakulam, East Godavari and Mumbai Suburban etc. (Map-3.8 (A): Marked by Violet colour in the map). The third type is the Sand-Desertic, which is mostly dominated in the Thar Desert and Punjab Region. Districts like Jodhpur, Bikaner, Bhatinda, Mansa, Jalor, Muktsar, Ganganagar, Jaisalmer, Firozpur and Hanumangarh etc. are highly affected under the Sand-Desertic land Degradation (Map-3.8 (A): Marked by light green colour).

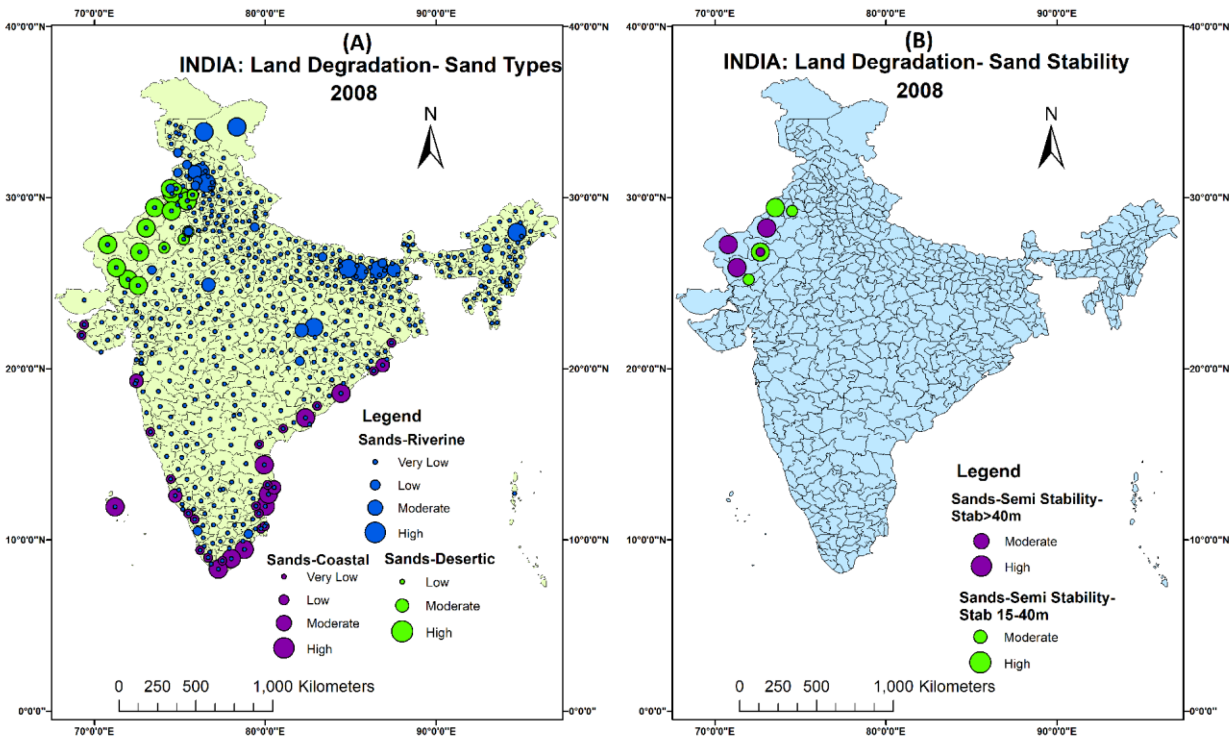
Shifting of sand is the major cause of desertification across the world and so is for India. Thus, sand stability has been a major indicator to assess the same. Sands-Semi Stable-Stab>40m has recorded only in five districts of Rajasthan- Jaisalmer, Barmer, Bikaner, Jodhpur and Jalor (Map-3.8 (B): Marked by Violet colour). Moreover, Sands-Semi Stable-Stab 15-40m is found highly concentrated in five districts-Bikaner, Jaisalmer, Ganganagar, Jodhpur and Barmer. Other 15 districts majorly from North-western India are having a moderate concentration of it (Map-3.8 (B): Marked by light green colour).

Mining is emerging as a factor of degradation of land (Harden and Mathew, 2000). The same problem has been encountered in different mining areas of Eastern India region (Chhotanagpur etc.), parts of Northern India, some districts of southern India and sparsely in western India. Highly affected districts of this category are Faridabad, Cuddalore, North Goa, Rajsamand, Kannur etc. (Map-3.9 (A). Industrial wastelands have been experienced in 61 districts covering areas of only 58 km^2. Highly affected districts are Chennai, Badgam, Bhagalpur, Sonbhadra, Kendujhar and Thoothukkudi (Map-3.9 (A).



Map-3.7 (A) Spatial pattern of degraded pasture/grazing land in India (B), Spatial pattern of degraded land under plantation crop in India, and (C) Spatial pattern of degraded land under pasture and plantation in India

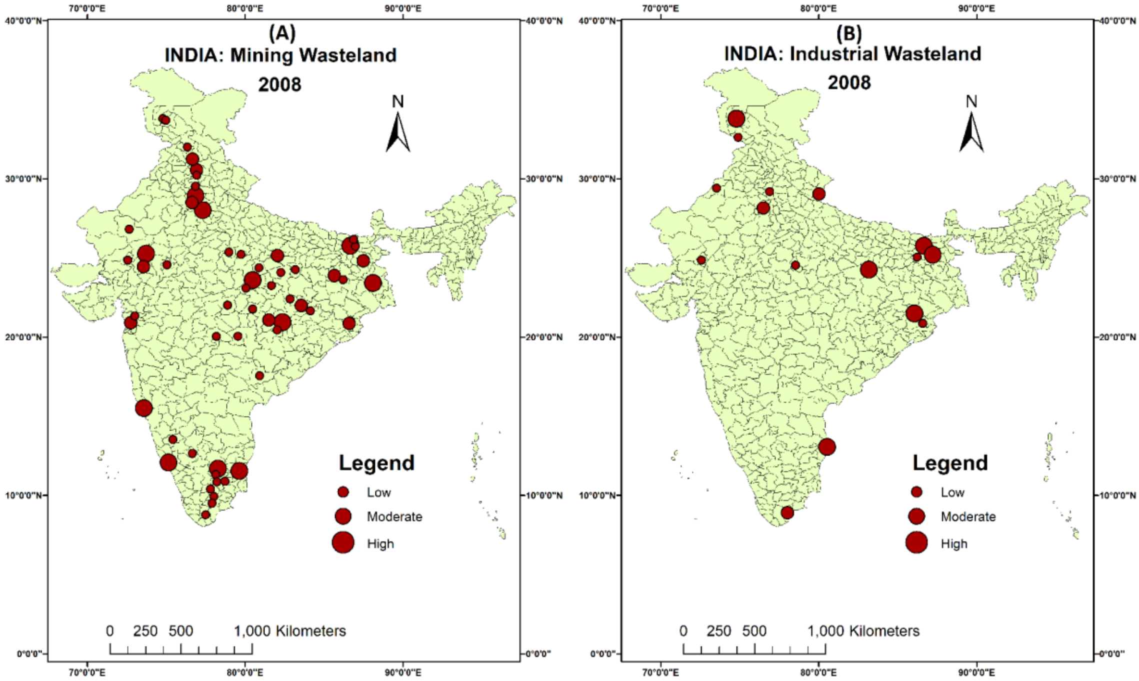
Source: Prepared by the author by using data provided by NRSC through Wasteland Atlas, 2011.



Map-3.8 (A) Spatial pattern of sands- ravines, coastal and desertic in India, and (B) Spatial pattern of sand stability in India

Source: Prepared by the author by using data provided by NRSC through Wasteland Atlas, 2011.

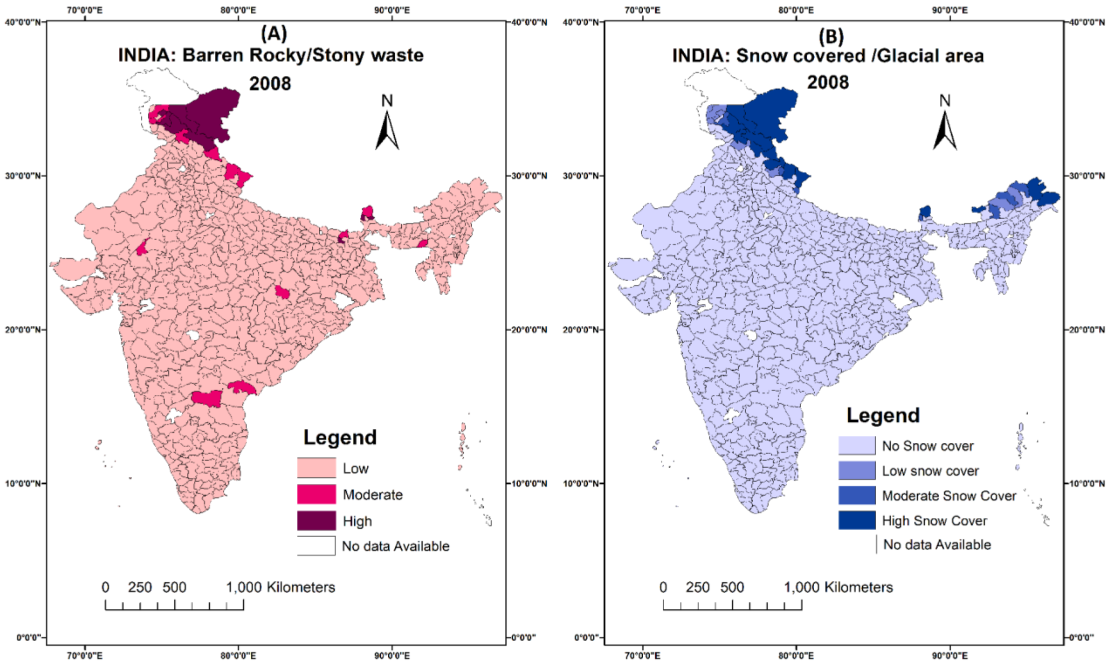
NRSC (2011) has categorised barren/stony land and/or snow cover/glacial area under wasteland, which has extended to 59482.29 km^2 and 58183.44 areas respectively. Both types of wasteland have dominated the western Himalayan region and snow cover extend to the eastern Himalayan region too (Map-3.10 (A) and (B).



Map-3.9 (A) Spatial pattern of mining wasteland in India, and (B) Spatial pattern of industrial wasteland in India

Source: Prepared by the author by using data provided by NRSC through Wasteland Atlas, 2011.

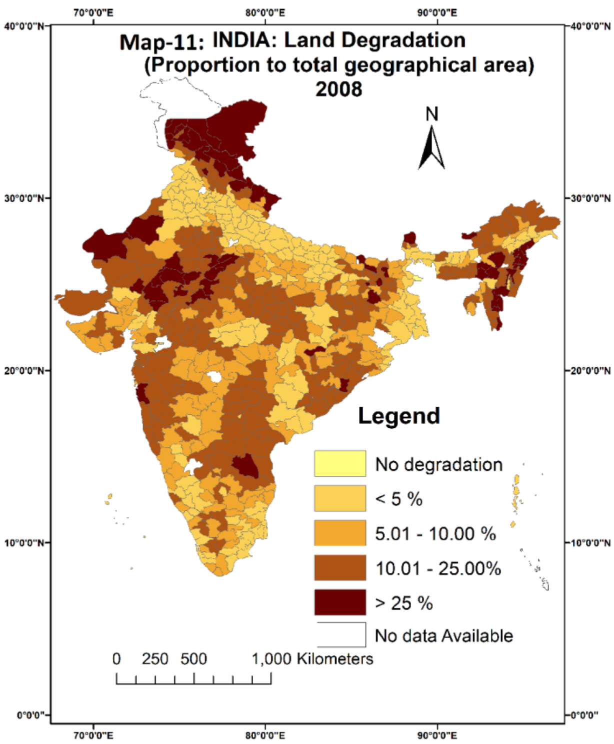
If the total degraded land is analysed, the ~ 60 districts of the country are such that more than 25 percent of areas to TGA are under different types of land degradation. ~190 districts are such where 10.01 to 25 percent areas to TGA are being affected by land degradation. Moreover, ~ 140 districts are those whose 5.01 to 10 percent areas to TGA areas are being affected by land degradation. ~182 districts are having degradation under < 5 percent to TGA. Some of the major and highly degraded districts are Kargil, Leh, Lahul & Spiti, North Sikkim, Kabeerdham, Jaisalmer, Sitamarhi, Kinnaur, Rajsamand, Udaipur, North Cacher Hills, Neemuch, Bikaner, Morena etc. Moderately affected districts are Deoghar, Kohima, Pune, Pulwama, Jodhpur, Vishakhapatnam, Saharsa, Chittoor, Umaria, Kota, Banka, Ratnagiri, Anantpur, Kutch, Barmer, Nellore, Nashik, Vaishali etc. The geomorphological distribution of the land degradation is very uniquely set up. The highly degraded areas are concentrated in Eastern Himalayan Region, Purvanchal hill complex, Thar Desert, North-Central Plateau, near Nallamala hills and some parts of Chhotanagpur plateau. Notably, the moderate land degradation areas are concentrated into the surrounding districts of the highly degraded districts with some exceptions (Map-3.11).

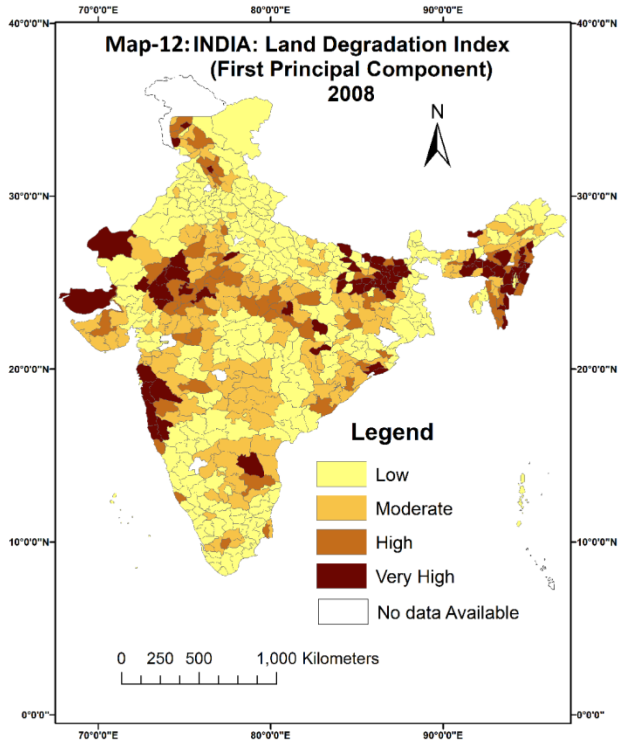


Map-3.10 (A) Spatial pattern of barren rocky/stony waste in India, and (B) Spatial pattern of snow covered/glacial area in India

Source: Prepared by the author by using data provided by NRSC through Wasteland Atlas, 2011.

Principal Component Analysis (PCA) has been performed and through use of the coefficient of Principle component one, the index has been calculated and plotted into Map-3.12. 23 types of land degradation provided by NRSC (2011) has been clubbed into 12 indicators namely gully/ravines (donated by 1 in tables), land with scrub (2), waterlogged areas (3), soil salinity/alkalinity (4), shifting cultivation (5), under-utilised/degraded forest (6), degraded land under pasture and plantation (7), land degradation in sandy areas (8), sand stability (9), industrial and mining wasteland (10), barren land (11), snow cover (12). None of these indicators are highly correlated which is one of the basic requirements to run the PCA in is given data (Table-3.3).





Map-3.11 Total degraded land in India (proportionate to total geographical areas): 2008-09, and Map-3.12 Land Degradation Index made by using Principal Component- one

Source: Prepared by the author by using data of NRSC, 2011 and principal component-1 is calculated by using software IBM SPSS Statistics-20

Further, the variance matrix has revealed that the component-one is able to explain 79.21 percent variance of the raw data (Table-3.4). By using the coefficient score (Table-3.4), the mapping is plotted to analyse the spatial pattern of land degradation. 71 districts are very highly degraded spreading majorly into Western India, Central India, Eastern and North-Eastern India. 61 districts are highly degraded and 150 districts are moderately degraded (Map-3.12).

Table-3.3 Correlation matrix of selected variables for Principal Component Analysis

	1	2	3	4	5	6	7	8	9	10	11	12
1	1	0.24	0.25	0.023	-0.051	0.267	0.016	0.074	-0.021	0.113	0.02	-0.03
2		1	0.8	-0.085	0.144	0.599	0.124	0.169	0.059	0.418	0.059	-0.031
3			1	-0.012	-0.013	0.553	0.15	0.183	-0.006	0.495	0.059	-0.012
4				1	-0.056	-0.083	-0.033	-0.026	-0.023	-0.023	-0.03	-0.051
5					1	-0.052	-0.051	-0.046	-0.017	-0.017	-0.03	-0.015
6						1	0.068	0.142	-0.039	0.26	0.08	-0.018
7							1	0.139	0.09	0.09	0.02	0.08
8								1	0.358	0.08	0.236	0.044
9									1	-0.007	0.012	-0.016
10										1	0.026	-0.016
11											1	0.407
12												1

Note: Gully/ravines (donated by 1 in tables), land with scrub (2), waterlogged areas (3), soil salinity/alkalinity (4), shifting cultivation (5), under-utilised/degraded forest (6), degraded land under pasture and plantation (7), land degradation in sandy areas (8), sand stability (9), industrial and mining wasteland (10), barren land (11), snow cover (12)

Source: Calculated by the author.

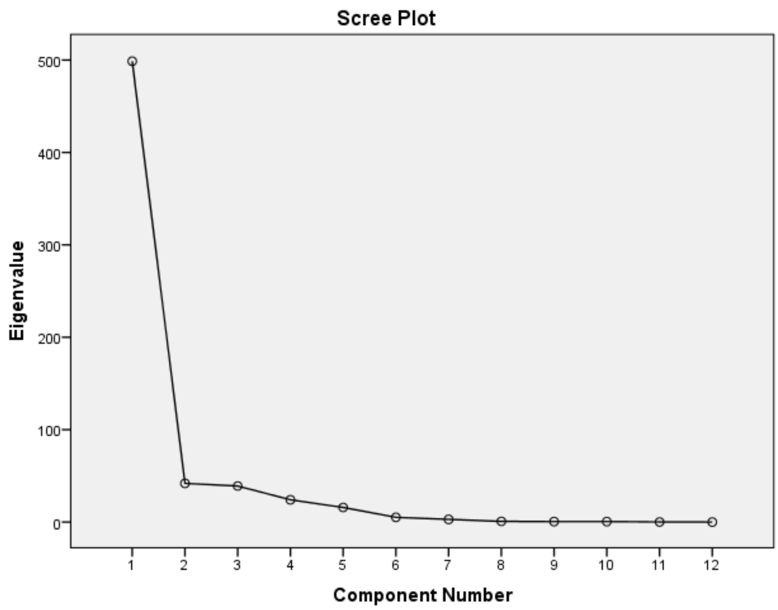


Fig.-3.5 Plot of eigenvalue explaining variance

Source: Prepared by the author.

Table-3.4 Eigenvalue, explained variance and coefficient matrix

	Initial Eigenvalue		Component Score Coefficient Matrixa
Component	**% of Variance**	**Cumulative %**	**Component- one**
1	79.21649	79.21649	0.000458
2	6.654995	85.87148	0.190203
3	6.195778	92.06726	0.806663
4	3.830446	95.89771	-3.1E-05
5	2.514517	98.41222	0.000158
6	0.817499	99.22972	0.056701
7	0.458703	99.68843	0.000167
8	0.126007	99.81443	6.76E-05
9	0.085629	99.90006	2.71E-05
10	0.077295	99.97736	6.84E-06
11	0.021819	99.99918	0.003061
12	0.000825	100	-0.00116

Source: Calculated by the author.

3.3 LAND DEGRADATION IN AGRO-CLIMATIC REGION

The land degradation has very much correlation with the climatic factor of the region. At the same time, it also associates itself with the agricultural conditions of the given region. Therefore, there is a crucial relationship between the land degradation types and the prevailing agro-climatic regions. India has been divided into the 15 agro-climatic regions (Planning Commission, Government of India, 1989) and each is characterized by a particular type of land degradation. Western Himalayan region has been witnessing the major degradation in terms of barren land and degradation of snow cover. Another prominent degradation is land with scrub, under-utilised/degraded forest and gully/ravines. Eastern hill region has some similar characteristics of degradation in terms of prominence of snow cover degradation, land with scrub and under-utilised/degraded forest. In addition, the shifting cultivation is highly practiced in the region. Even it has highest percentage areas under shifting cultivation among all agro-climatic regions (Table-3.5).

However, Lower Gangetic Plain region is the lowest degraded region among all agro-climatic regions, and it has degradation types like land with scrub, under-utilised/degraded forest and mining and industrial wastelands. Notwithstanding, the Middle Gangetic Plain region is highly affected by waterlogging/marshy land problem among all category of land degradation as well as among all agro-climatic regions. It is also affected by the problem of scrub, salinity/alkalinity and under-utilised/degraded forest. Primarily, Upper Gangetic Plain region has been highly affected by the salinity and alkalinity among all agro-climatic regions and also among all categories of land degradation (Table-3.5).

Interestingly, the Trans-Gangetic Plain region is having the problem of sand shifting into the region. In addition, it is the waterlogging problem, which another problem of land degradation (Table-3.5). This is associated with the problem of soil salinity in the region (Dagar et al., 2016). Eastern Plateau Region has witnessed the highest under-utilised/degraded forest problem and one of highest mining and industrial wastelands among all the agro-climatic regions. Likewise, Central Plateau Region is primarily dominated by gully/ravines and land with scrub compared to other regions. Western Plateau Region is most significantly affected by land with scrubs, under-utilised/degraded forest and Gully/ravines. A similar type of land degradation is also found in the Southern Plateau Region. In addition, the barren/rocky areas are also witnessed (Table-3.5).

Table-3.5 Land degradation status into agro-climatic regions in India, 2008-09

Agro-climatic Region	1	2	3	4	5	6	7	8	9	10	11	12	Total Degraded land (Square Km)	% of TGA
West Himalaya	**0.42**	3.85	0.04	0.03	0.00	3.60	0.41	0.82	0.00	0.01	21.82	22.38	110293.77	53.37
Eastern Himalaya	0.00	**7.41**	0.33	0.00	**2.75**	2.12	0.08	0.02	0.00	0.00	0.28	4.34	47651.56	17.33
Lower Gangetic Plain	0.02	1.14	0.03	0.00	0.00	0.53	0.00	0.03	0.00	0.04	0.03	0.00	1267.19	1.82
Middle Gangetic Plain	0.09	3.91	**6.44**	0.17	0.00	3.13	0.05	0.09	0.00	0.02	0.25	0.00	24130.75	14.15
Upper Gangetic Plain	0.46	0.91	0.42	**1.63**	0.00	0.67	0.00	0.02	0.00	0.01	0.07	0.00	5820.31	4.19
Trans Gangetic Plain	0.07	0.99	0.17	0.09	0.00	0.18	0.77	0.61	0.96	0.03	0.08	0.00	4399.98	3.94
Eastern Plateau	0.18	5.59	0.04	0.06	0.23	6.25	0.01	0.07	0.00	0.04	0.53	0.00	49430.96	12.97
Central Plateau	**0.80**	**8.99**	0.00	0.05	0.00	5.22	0.31	0.04	0.00	0.04	0.65	0.00	60328.05	16.11
Western Plateau	0.21	**7.70**	0.00	0.00	0.00	4.21	0.06	0.00	0.00	0.01	0.47	0.00	42001.47	12.67
Southern Plateau	0.10	4.90	0.00	**0.38**	0.00	4.09	0.37	0.01	0.00	0.02	0.96	0.00	41363.32	10.72
East Coast Plain And Hill	0.12	4.11	0.28	**0.38**	0.28	3.40	0.07	0.26	0.00	0.03	0.45	0.00	20044.89	9.38
West Coast	0.01	**8.26**	0.13	0.07	0.00	2.65	0.15	0.08	0.00	0.03	0.56	0.00	18023.88	11.95
Gujarat Plain And Hill	0.17	**8.34**	0.01	**0.57**	0.00	1.05	0.03	0.03	0.00	0.01	0.04	0.00	20170.00	10.26
Western Dry Region	0.20	**9.55**	0.04	0.22	0.00	0.62	1.29	1.75	12.79	0.02	1.39	0.00	48968.17	27.87
Island Region	0.00	0.00	0.00	0.00	0.00	2.84	0.00	0.04	0.00	0.00	0.00	0.00	239.02	2.89

Source: Calculated by author.

Coastal regions like Gujarat Pain and Hills Region, East Coast Region and Western Plateau region are having land with scrub very dominantly, Additionally, these are having striking features like salinity/alkalinity and under-utilised/degraded forestland. Western Dry Region has the highest land with scrub, degraded land under Pasture and Plantation, land with sandy problems and sands stability problem among all the climatic regions. This is the region which is having second highest degradation area proportionate to the TGA. On the other hand, Island regions are majorly affected by the degraded forests (Table-3.5).

3.4 CONCLUSION

Indian land is suffering from all the major land degradation. Among all the degradation of the forest has been the most critical concern. Scrubland has been spread all over India except some area, which is having a direct relationship with the vegetation cover. The declining vegetation accelerates the other processes of land degradation due to loosening of upper soil. The second most important type of degradation has been gully/ravines which concentrated into the river valleys especially into central Indian highland into the Chambal river valley. Most of the marshylands/waterlogged have traced into the Tarai belt of Gangetic Plain. Moreover, soil salinity/alkalinity has been concentrated into three area- middle Gangetic plain, Western India and South-East India. Shifting cultivation has been prominent into the tribal-dominated areas especially Odisha and Northeastern states. Moreover, the pastureland of western India has been declining. The same region is also having the problem of aridity and related land degradation problem e.g. sand movement. Industrial wasteland and mining wasteland has been drastically increasing and concentrated in those areas which are having mineral mines and industrial zone. The Major conclusion can be listed as-

1. Overall, land degradation has recorded an increase of 1.16 percent of TGA. Among all categories of land Degradation, degradation of vegetation cover has recorded highest decline by 0.44 percent of TGA, while soil salinity/alkalinity has recorded most decline by 0.32 percent of TGA.

2. Each type of land degradation have their different concentration zone e.g. Gullies/Ravines are more prominent in Yamuna-Chambal valley and other Indian

river valley areas, Sand movement is in the Thar Desert, Salinity/alkalinity in Western India, Punjab, Western Uttar Pradesh and South-East India and so on.

3. Land Degradation Index shows overall the land degradation is not a uniform phenomenon in India. The clusters of land degradation have been clearly visible from the map plot. Four-zone of land degradation is identified- North-Western India, South-Western India, Northern-East India and North-Eastern India.

4. Different region of India is having different types of land degradation problem at a prominent level. It is somehow related to the agro-climatic condition prevailing over the regions. Degradation of snow cover, stony degradation and Gully are more prominent in Western Himalaya, while shifting cultivation is more prominent in the Eastern Himalaya. In case of soil salinity and alkalinity, it is prominent into Upper Gangetic Plain, Southern Plateau, East Coast Plain and Hills and Gujarat Plain and Hills. More or less these regions are either come under the arid and semi-arid region or having oceanic influence.

CHAPTER-4

LAND DEGRADATION AND INDIAN AGRICULTURE

4.1 INTRODUCTION

Agricultural practices contribute to the economy of the country. Increase in agricultural productivity kicks the growth in three ways- providing capital for economic growth, providing employment, and increasing the purchasing power of the rural people (Christensen and Yee, 1964; Braun and Gerber, 2012). In India, rice and wheat is major food grain (Easter et al. 1977), therefore in the study, it is focused. The agricultural production receives much more attention by the social scientists with economic concern. Introduction to new varieties, along with the increased availability of fertilizers and irrigation, highly raise the production potential. One study by Dobbes and foster (1972) have summarized that these inputs- high yielding seeds, fertilizers, tube wells etc. has mainly attached to large former but the former with small holdings are not getting high benefits. While India stands in the same condition that the production is not improving fast, it is slow still. The study analyzes that only irrigation and fertilizer does not affect significantly. If it happens, then all areas do not vary where irrigation and fertilizer facilities are very improved (Easter et al., 1977). It means the natural productivity of land influence to some extent to the agricultural output. Everyone believes that the green revolution comes to minimize the world's population problem. There is need to think that whether green revolution is a fact or myth, consequences of an agricultural discover in population control are threatening. To fulfill the food requirement of the world's population, it demands the high use of chemicals, which is a type of pollutants directly, affects the human and especially children's health (Paddock, 1970).

A paper by Ranade (1986) has stated that it was technology, which brings changes in rice production, which also helped in tapping the comparative advantage of the state like Punjab and Haryana. The local shift effects took place only after technological changes (Adams and Bumb, 1979). Consequently, the contribution of the pure yield effect was more in pre than post-green revolution. This study also has concluded that there is no green revolution taking place in rice production in Punjab and Haryana. The new varieties of grains are highly responsive to fertilizers (Posgate, 1974; Ranade, 1986). Chakravarti (1973) has worked on green revolution and stated that by the use of high yielding varieties the overall production has increased and that too relatively high for wheat.

4.2 LAND DEGRADATION AND AGRICULTURE: ALL CROPS

This section of study has taken the total crop output per hectare in terms of price (Rupees) as a dependent variable to understand the linkage between the Agriculture and land degradation. The data has been taken from the Bhalla & Singh (2012) calculation of value output of total 35 crops. For this analysis, 263 districts from all over India have been selected. To get the different sense of relation with agricultural productivity, four types of multi-linear regression model has been run keeping the Value Output of 35 crops as dependent variable for all model- (1) keeping all input variable to agriculture as independent variable without land degradation, (2) selecting all input variable to agriculture with different types of land degradation as independent variable, (3) choosing all the input variable to agriculture with Land Degradation Index as independent variable and (4) running regression with taking all the input variable to agriculture with soil salinity/alkalinity as independent variable.

The analysis has established the correlation between the land degradation and agricultural output as many research talks about the same. Conversely, its explanation and justification are found to be difficult due to the changing nature of agriculture last few decades in the wake of the green revolution. Though increased inputs into agriculture have increased the cost, it has yielded comparatively more drastically. Additionally, increased input added to the declining fertility too. But more inputs availability has led to the hiding of the same. Therefore, the increased agricultural inputs have undermined the real impact of land degradation on the field (Pimentel, 1996; Jewitt and Baker, 2007; Paddock, 2014).

Correlation between agricultural value output and variable related to inputs to agriculture is 0.529. This is without the land degradation as an independent variable. The R square for the same is 0.28 with the F-value of 19.95 which reflect that the model is significantly high at the level of <0.001. Whereas, with the aforesaid variable with different types of land degradation as independent variables, the R-value has significantly increased to 0.601, which refers that there is 60 percent correlation among the variables. The R square for the same is 0.322 with the F-value as 9.29 significant at the level of < 0.001. The increased R-square value (by 15%) indicated that the model fits well and land degradation explains higher variability for the agricultural output (Table-4.1).

Table-4.1 Determinants of yield per hectare@

Model-1 Without Land Degradation *		Model-2 With Different types of Land Degradation *		Model-3 With Land Degradation Index*		Model-4 With Salinity*	
Determinants	B-value	Determinants	B-value	Determinants	B-value	Determinants	B-value
(Constant)	6.64**	(Constant)	8.68**	(Constant)	7.44**	(Constant)	6.63**
No of agricultural workers per ha	-0.98**	No of agricultural workers per ha	-0.88***	No of agricultural workers per ha	-1.02**	No of agricultural workers per ha	-0.97**
N+P+K per ha	10.29**	N+P+K per ha	8.46**	N+P+K per ha	9.97**	N+P+K per ha	10.18**
No of tractors per ha	-65.79**	No of tractors per ha	-62.26**	No of tractors per ha	-66.20**	No of tractors per ha	-65.76**
No of Tube wells per ha	15.28**	No of Tube wells per ha	14.93**	No of Tube wells per ha	15.08**	No of Tube wells per ha	15.25**
Irrigation (area percentage of GCA)	0.04**	irrigation (area percentage of GCA)	0.03^{++}	Irrigation (area percentage of GCA)	0.04***	Irrigation (area percentage of GCA)	0.04**
		Gullied and/ ravine land (%)	-0.22	Land Degradation Index	-0.004***	Salinity/alkalinity (%)	-0.20**
		Land with Scrub (%)	-0.18***				
		Waterlogged & Marshy land (%)	-0.29				
		Soil Salinity/alkalinity (%)	-0.34				
		Shifting Cultivation (%)	-0.53				
		Under-utilised/degraded forest (%)	-0.15				
		Degraded land under Pasture and Plantation (%)	-0.67				
		Wind Erosion (%)	0.19				
		Sand Stability (%)	-0.15				
		Mining and Industrial Wasteland (%)	4.68				

@ Dependent Variable: Value Output of 35 Crops

1. Adjusted r-square for the model-1 is 0.266.
2. Adjusted r-square for the model-2 is 0.322.
3. Adjusted r-square for the model-3 is 0.288.
4. Adjusted r-square for the model-4 is 0.264.

* F-value is significant at the level of < 0.001

** T-test is significant at the level of <0.001.

*** T-test is significant at the level of <0.005.

+ T-test is significant at the level of <0.010.

Source: Calculated by author.

In Model-2, it has revealed that different types of land degradation have an impact on agricultural output to a significant level. It is inferred that with all the inputs to agricultural land, the impact of land degradation is not very easy to avoid (Table-4.1).

Another model (Model-3) also has been run with taking the land degradation index as an independent variable with other variables related to agricultural inputs instead of taking various types of land degradation as done in Model-2. This model has been run because land degradation index is another refined variable compared to simply taking the different types of land degradation. It has provided a holistic outcome by composing all the land degradation types into one. The R-value for this model has been recorded as 0.551 and R square as 0.304, which is much lower than the model being run by taking different types of land degradation. It has represented another polished level result by cutting down the variable size. The F-value is 18.63 with the significant level of <0.001. Furthermore, one more regression model has been performed by taking soil salinity/alkalinity (percentage of TGA) as an independent variable by keeping variables related to agricultural input with it. R-value of this model is 0.530 which is one of lowest among the four models with the R-square of 0.28 and the F-value of 16.63 with the significance level to < 0.001. The difference between the R-value for model-1 and model-4 is very negligible. This least difference of R-value is indicative of that agricultural inputs have dominated impact which undermines the impact of soil salinity/alkalinity into the field (Table-4.1).

The coefficient for the different variables in all the four models has been calculated to get the share of the impact of the different variables on the agricultural value output among all the selected variables as independent variables. If the model-1 has been analyzed, beta-coefficient for the no. of an agricultural worker per hectare has a negative impact with the value of -0.982, of which t-test is significant at the level of <0.001. This means an increase in agricultural workers, agriculture output decreases. It can be implied that the labour into the technological development era has remained a non-significant factor of agricultural production. Similarly, the availability of no. of tractors per hectare has also the negative impact with the beta-coefficient value of -65.789, which is highest among all the selected variables, with t-test significant at <0.001 level. Conversely, irrigation (area percentage of GCA) has a least positive impact with beta-coefficient of 0.041 having t-test significant at the level of <0.001.

Among positive beta-coefficient, availability of tube wells per hectare has recorded highest to 15.279 with t-test significant at the level of <0.001. It is followed by the fertiliser (N+K+P per hectare) with beta-value of 10.288 with t-test significant at the level of 0.001. Thus, it can be inferred that fertliser and irrigation have still remained a crucial factor for the agricultural production (Table-4.1).

The second model, where different types of land degradation have been taken as an independent variable with agricultural input data, the beta coefficient was recorded highest for no. of tractors per hectare almost similar to the earliest model and it is negative. Highest positive beta-coefficient was for the no. of tube wells per hectare (14.926), followed by fertilizer (8.463) and mining and industrial wasteland (4.683). Among all the indicators of land degradation mining and industrial waste has more shares in the beta-coefficient, reflecting high impact but positively. However, other indicators of land degradation had negative but negligible beta-coefficient except for wind erosion and mining and industrial wasteland. The t-test for the wind erosion is not significant, while it is relatively significant for mining and industrial wasteland. Among other types of land degradation, degraded land under pasture and plantation has negatively impacted the agricultural yield with a beta coefficient of 0.669 followed by shifting cultivation (beta-coefficient -0.525) and soil salinity/alkalinity (beta-coefficient -0.335). If it is compared among all the selected independent variable, the indicators related to agricultural inputs are having significantly more influential share into total agricultural output compared to other indicators related to land degradation. This analysis again has proved that the secondary interferences to agriculture have successfully undermined the actual existing health level of soil resultants through land degradation problem (Table-4.1).

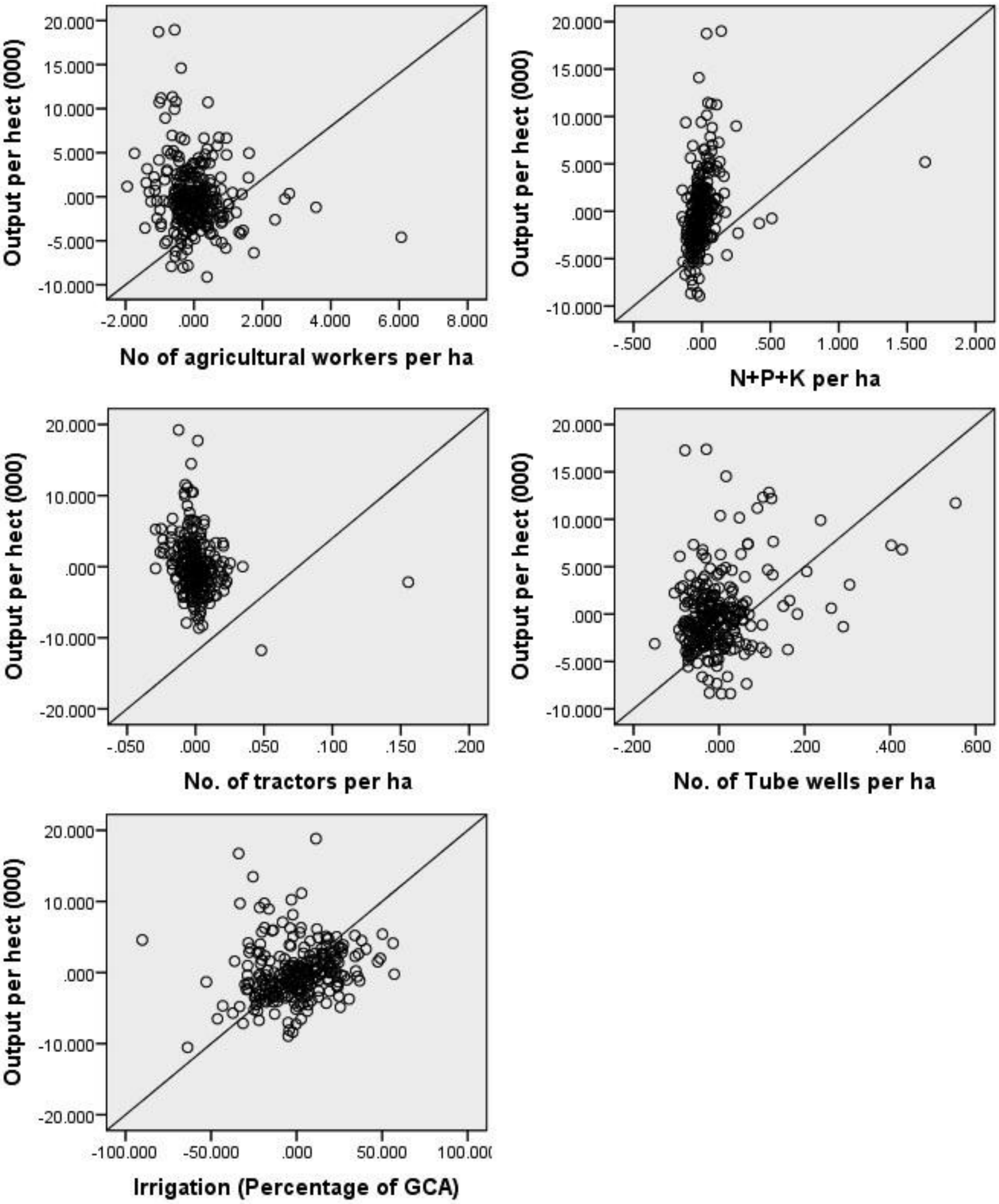


Fig.- 4.1 Partial regression Plot of Output of All crops per hectare with various agricultural input variables

Source: Prepared by author.

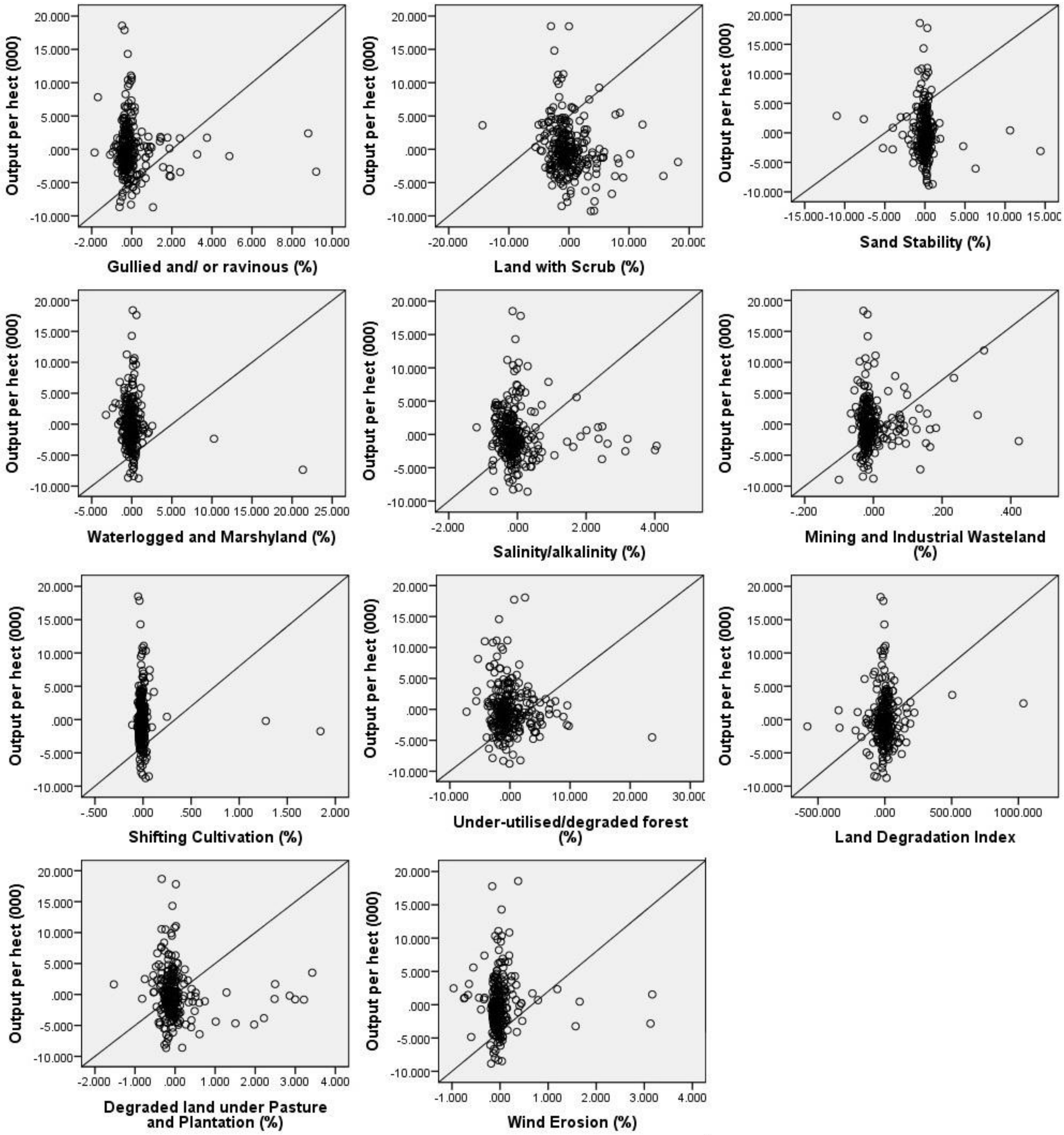


Fig.- 4.2 Partial regression Plot of Output of All crops per hectare with various Land Degradation variables

Source: Prepared by author.

The regression model-3 has tried to calculate the relationship by taking the composite index of land degradation, which is calculated through the principal component analysis (PCA). It is found that beta-coefficient for the LDI (-0.004) is too less but negatively correlated. T-test for the same is significant at the <0.003 level. While the regression model-4 has inferred that the salinity/alkalinity has comparatively more impact over agriculture with beta-coefficient of -0.201. However, the t-test for it is not so significant (Table-4.1).

4.3 LAND DEGRADATION AND AGRICULTURE: WHEAT AND RICE

Ten districts from each category of very high, moderate and low degraded districts have been selected for assessing the relationship between the land degradation and agriculture. Similarly, ten districts are being taken from each category of high, moderate, low and no salinity/alkalinity affected districts.

4.3.1. WHEAT

This section has tried to analyse whether there is a relationship between the land degradation and agriculture. For regression analysis, wheat productivity (yield) has been taken as the dependent variable with two separate groups of different independent variables. Group-1 of independent variables include Land Degradation Index, Irrigation (Areas in hectares), Land Holding Size (in hectares), Fertilisers-Nitrogen (N), Phosphorous (K), and Potash (P). Group-2 of Independent variables is Soil salinity/Alkalinity, Waterlogging Irrigation, Land Holding Size, Fertilisers-Nitrogen (N), Phosphorous (K), and Potash (P) (Table-4.1). The correlation of wheat productivity with both the group of independent variables has not been so strong amounting R is 0.258 and 0.271 respectively (Table-4.2). Wheat productivity is negatively correlated with the most of variables excluding phosphorous, though each variable has not recorded strong correlation (Fig.-4.3).

R square value is very low to 0.067 and 0.073 respectively for Group-1 and Group-2 indicators. The F value has been recorded as 0.511 and 0.474 for Group- one and Group-2 respectively (Table-4.3). Table-4.3 explains the share of different variables into wheat productivity through unstandardized coefficients. It has revealed that irrigation and land holding size is major impactful factors contributing to the wheat productivity in both groups. However, in both the case the role of different fertilisers has been recorded very negligible. Interestingly, given both land degradation and soil salinity factors, the soil salinity is having a more striking impact on wheat productivity compared to the land degradation as a whole (Table-4.3). Additionally, it can be inferred from the given analysis that the overall impact of land degradation and soil salinity has been undermined due to various input factors to the agriculture.

Therefore, the overall outcome of correlation does not reflect a significant relationship. It is important to note that land degradation index and soil salinity has a negative and significant impact on wheat productivity. Similarly, the irrigation, land holding size and nitrogen (N) has established a negative coefficient on wheat productivity (Table-4.2 and Fig.- 4.3). Therefore, it can be derived that the over-irrigation, large land holdings and over-implementation of nitrogen can lead to lower productivity.

Table-4.2 Wheat in Sampled Districts: Model Summary

Group	R	R Square	Adjusted R Square	Std. Error of the Estimate	F
1.	0.258[a]	0.067	-0.064	40.776	0.511[+]
2.	0.271[*]	0.073	-0.081	41.112	0.474[+]

[a] Predictors: (Constant), Land Degradation Index, Irrigation, Land Holding Size, Fertiliser- N, K, and P.
[*] Predictors: (Constant), Soil salinity/Alkalinity, Waterlogging Irrigation, Land Holding Size, Fertiliser- N, K, and P.
[b] Dependent Variable: Wheat (yields tonnes per hectare).
[+] Not Significant.

Source: Calculated by author.

Table-4.3 Wheat in Sampled Districts: Coefficients

Group		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1.	(Constant)	18.27	13.27		1.377	0.175
	Land Degradation	-0.36	1.203	-0.045	-0.295	0.769
	Irrigation	-3.4	5.77	-0.092	-0.584	0.562
	Land Holding Size	-3.87	3.765	-0.156	-1.027	0.310
	N (Nitrogen)	-0.001	0.0012	-0.697	-1.182	0.243
	P (Phosphorus)	0.0038	0.0029	0.549	1.291	0.204
	K(Potassium)	0.0013	0.0013	0.544	1.109	0.273
2.	(Constant)	19.72	14.214		1.388	0.172
	Soil Salinity	-0.850	4.341	-0.037	-0.196	0.846
	Waterlogged Area	0.064	0.105	0.111	0.615	0.542
	Irrigation	-4.6	6.17	-0.125	-0.741	0.463
	Land Holding Size	-5.583	4.70	-0.226	-1.186	0.242
	N (Nitrogen)	-0.001	0.0013	-0.621	-0.979	0.333
	P (Phosphorus)	0.0038	0.003	0.560	1.285	0.206
	K(Potassium)	0.0013	0.0012	0.507	0.996	0.325

Source: Calculated by author.

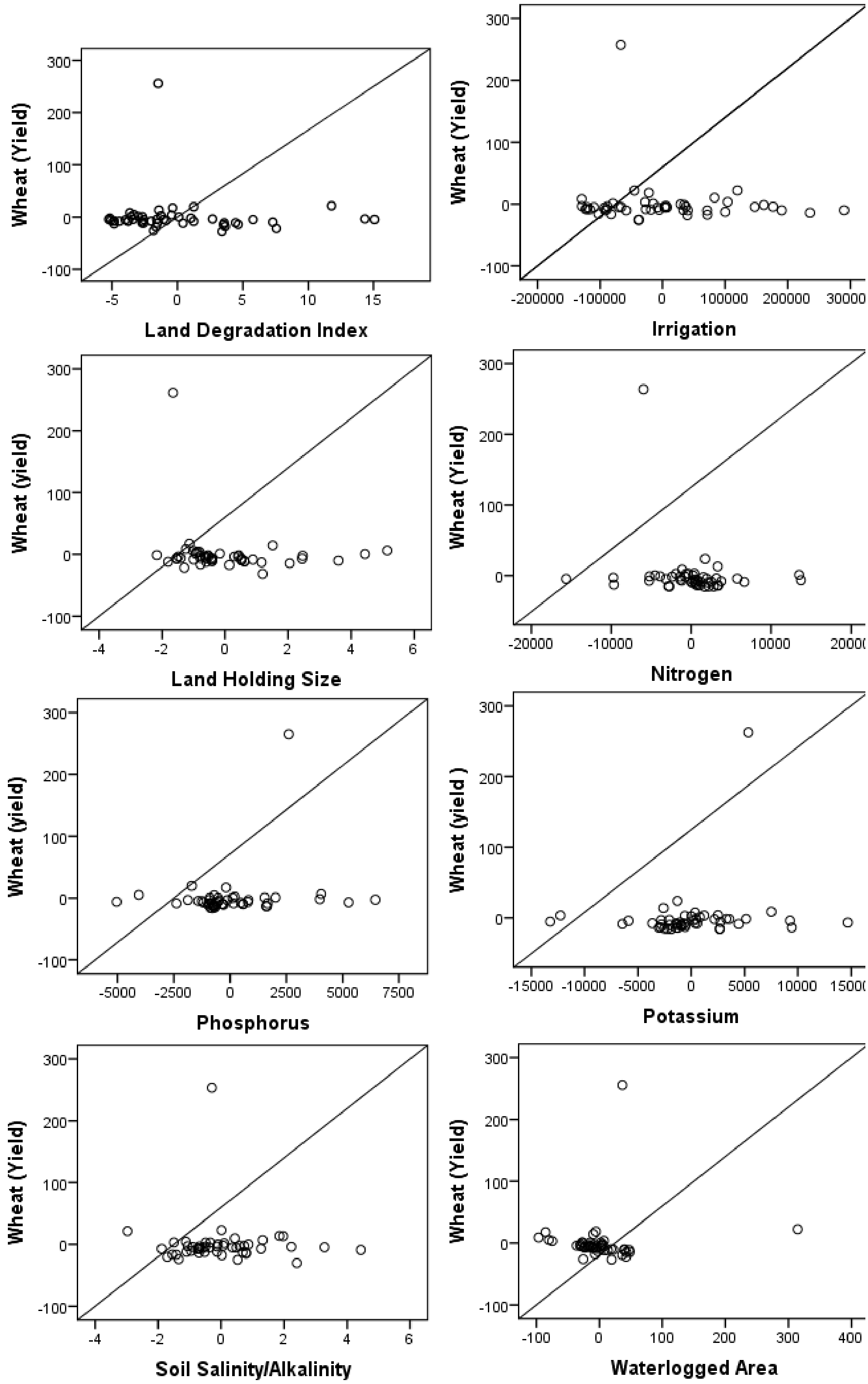


Fig.- 4.3 Partial regression Plot of Wheat (Yield) with various independent variables

Source: Prepared by author.

4.3.2 RICE

Rice productivity (yield) has been taken as the dependent variable for the multi-linear regression model where two groups of independent variables have used been up to carry out the model. Group-1 and Group-2 independent variables have been taken as same which has aforesaid been mentioned under section-3.3.1 of this chapter. The R is 0.402 and 0.405 for the Group-1 and Group-2 variables respectively with R square of 0.161 and 0.164 in the order given (Table-4.4). If it is compared with the wheat productivity, then it is found that the correlation with rice productivity has registered comparatively higher and stronger correlation (Table-4.4 and Table-4.2). Thus, it can be inferred that the impact of different independent variables like irrigation, fertiliser, land holding size, land degradation and soil salinity/alkalinity has more impact on rice productivity compared to the wheat productivity. But, it is important to note that the rice cropping system in India is of puddle transplanted system (Bhatt et al., 2016) which is water intensive. Irrigation method has not been much opted due to natural rainfall availability during the monsoonal season. Therefore, the coefficient of irrigation is low (Table-4.6). On the contrary in case of wheat productivity irrigation has a significant role (Table-4.3) though overall it has a low correlation (Fig.- 4.3). Moreover, this has been so due to wheat cultivation involves more than mentioned inputs to get the wheat productivity e.g. ploughing (results in the exposure of the hidden organic matter), mechanisation (use of technology) etc.

Table-4.4 Rice: Model Summary

Group	R	R Square	Adjusted R Square	Std. Error of the Estimate	F
1.	0.402[a]	0.161	0.044	1.342	1.379[+]
2.	0.405[*]	0.164	0.025	1.335	1.178[+]

[a] Predictors: (Constant), Land Degradation Index, Irrigation, Land Holding Size, Fertiliser- N, K, and P.

[*] Predictors: (Constant), Soil salinity/Alkalinity, Waterlogging Irrigation, Land Holding Size, Fertiliser- N, K, and P.

[b] Dependent Variable: Rice (yields tonnes per hectare).

[+] Not significant.

Source: Calculated by author.

Due to more dependency on natural means of inputs (in case of rice), the impact of various secondary inputs like fertiliser, irrigation etc. have provided more impetus to rice productivity. Therefore, the structural deterioration of the soil does not clearly reflect compared to other indicators into the output of productivity e.g. coefficient of land degradation among all variables are least (Table-4.6). On the other hand, productivity is also influenced by other inputs, for instance, the availability of irrigation, use of conventional inputs, credits and extension services and encourages the adaptation of mechanical and chemical technologies (Adams and Bumb, 1979).

Table-4.6 Rice: Coefficients

Group		Unstandardized Coefficients		Standardized Coefficients	T-test	Sig.
		B	Std. Error	Beta		
1.	(Constant)	1.577	0.550		2.867	0.006
	Land Degradation	0.055	0.043	0.191	1.288	0.205
	Irrigation	1.51	2.09	0.112	0.720	0.475
	Land Holding Size	0.358	0.169	0.342	2.104	0.041
	N (Nitrogen)	9.05	3.31	0.102	0.273	0.786
	P (Phosphorus)	-2.9	6.05	-0.096	-0.481	0.633
	K(Potassium)	7.11	2.81	0.081	0.253	0.801
2.	(Constant)	1.745	0.562		3.103	0.003
	Soil Salinity	0.007	0.121	0.008	0.055	0.956
	Waterlogged Area	0.04	0.036	0.199	1.299	0.201
	Irrigation	1.06	2.13	0.079	0.498	0.620
	Land Holding Size	0.343	0.177	0.328	1.940	0.059
	N (Nitrogen)	9.31	3.38	0.105	0.275	0.784
	P (Phosphorus)	-2.3	6.32	-0.075	-0.359	0.721
	K(Potassium)	5.18	2.86	0.059	0.181	0.857

Source: Calculated by author

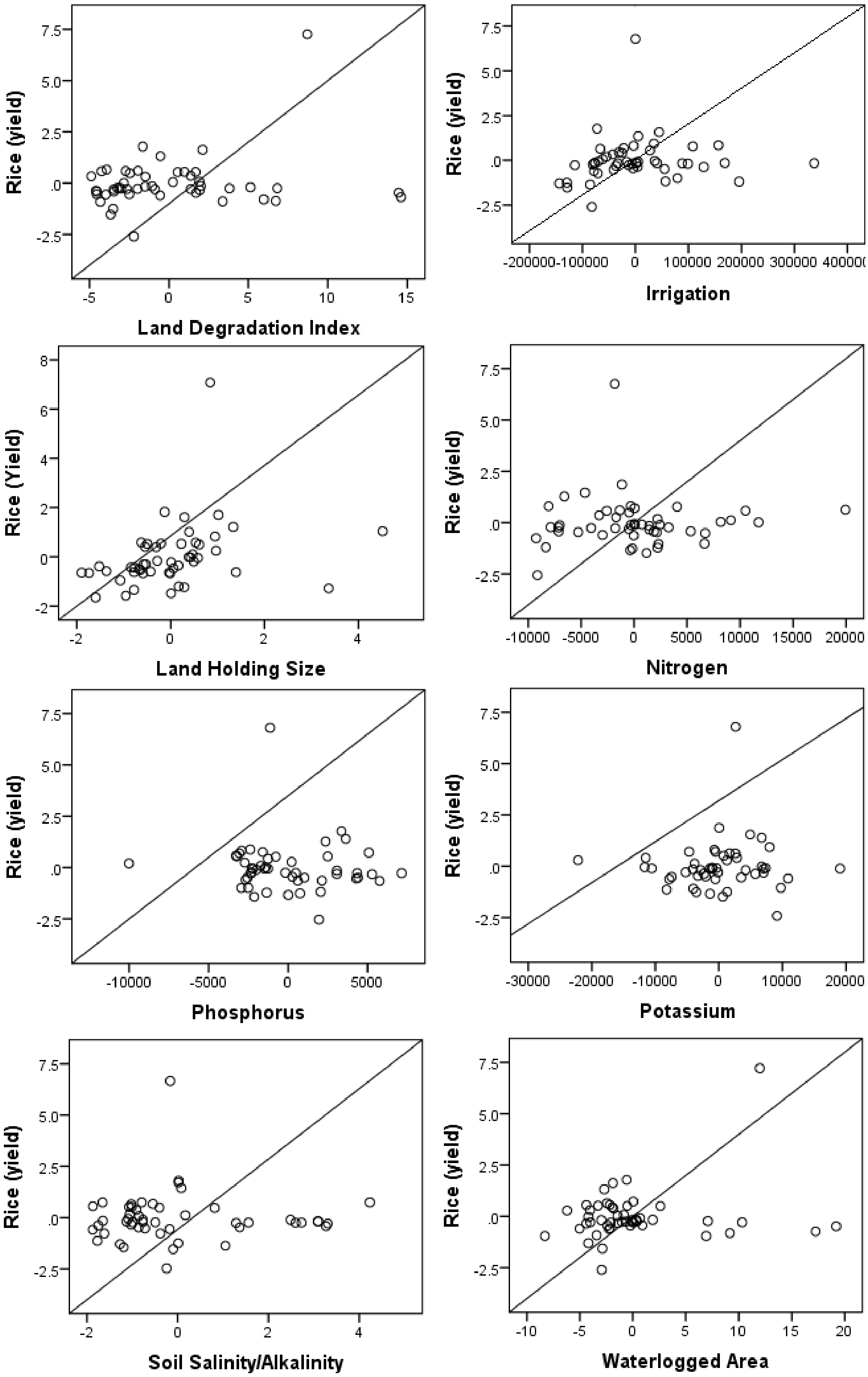


Fig.- 4.4 Partial regression Plot of Rice (Yield) with various independent variables

Source: Prepared by author.

4.4 CONCLUSION

Although many research shows that land degradation has a direct implication on agricultural productivity, but this analysis has revealed that to prove on the ground is a complex task. This happens so because of the complexity of the nature of agriculture due to various technological innovations in the field of agricultural inputs. These technological up-gradations in the passage of time and its use in agriculture have assisted into neutralising the impact of land degradation and the soil salinity/alkalinity. Man-made factors are exercising high influence for productivity compared to the natural declining fertility of the land resources. The major findings are-

1. The relation between the agriculture and land degradation changes with the changing variables into the regression models as section 4.2 has demonstrated with running four regression models with the varying indicators. By adding salinity model/ variable agriculture output varies.

2. Agricultural inputs into the field have been playing a crucial role in increasing and sustaining the productivity. As beta coefficients of all model show a higher value for the agricultural inputs indicators with a high significance level of the t-test, it can be deduced that penetration and increased use of various agricultural inputs like fertilizer per hectare, the irrigated area per hectare and no. tube wells per hectare have a direct and positive impact.

3. In the wake of technological advancements in agriculture, the importance of human labour has been reduced. This has been reflected by the negative beta-coefficient for the no. of an agricultural worker per hectare which decreases agriculture productivity. It reflects that the significance of manual labour is decreasing in the coming of technology.

4. Though the relation between land degradation and agricultural output per hectare has not been witnessed so strong, its relation has not been totally ignored by the correlation coefficient. It is observed that though it has minimal relation but has the negative relation with the total output per hectare. Compared to Land Degradation Index, the Soil salinity/alkalinity (% of TGA) has comparatively greater negative relation with the agricultural output.

5. The impact of land degradation and soil salinity/alkalinity is not uniform throughout the selected districts. It has been subject to the various other factors of the agricultural structure. Though the implication of land degradation and soil salinity/alkalinity with other inputs have been clearly seen on wheat and rice productivity; however within the limited variables (selected one) the land degradation and salinity/alkalinity are significantly impacting the wheat productivity to the greater extent.

CHAPTER-5

SOIL SALINITY STATUS: STUDY OF RAJASTHAN

5.1. INTRODUCTION

Soil salinization is one of the most common land degradation processes, especially in arid and semi-arid regions, where precipitation exceeds evaporation. Under such climatic conditions, soluble salts are accumulated in the soil, influencing soil properties with an ultimate decline in productivity (Asfaw et al., 2016). The similar climatic condition also influences Rajasthan to be the driest state of India, in which out of 15 basins only 2 basins (Chambal and Mahi) are perennial. The state has extreme geographic and climatic conditions. Rajasthan is the largest state in the country having an area of 3.42 lakh sq km, which holds 10.4% of country's area and 5.5% of nation's population, whereas bearing only 1% of country's water resources. Due to the unavailability of surface water in the state, groundwater plays an important role for all uses particularly as a drinking water source. About 91% of drinking water comes from the groundwater source (Singh *et al.*, 2011; Saxena *et al.*, 2014; Munoth et al., 2015). This precious source is facing the problem of salinity, fluoride and nitrate contamination in most of the districts of the state (Munoth et al., 2015). Groundwater is also the primary source for irrigation in the state of Rajasthan (Khanna *et al.*, 2008; Munoth et al., 2015). Therefore, the availability of groundwater has been depleted by the excessive and improper use, overexploitation and unwise uses of groundwater and the quality of groundwater also makes inferior and scarce (Srinivas *et al.*, 2015; Munoth et al., 2015). Intensive studies on drinking water availability of Rajasthan have reported that out of 237 blocks in Rajasthan that only 49 are safe in terms of groundwater exploitation while 101 are critical and semi-critical and 86 are overexploited (Mohapatra *et al.*, 2009; Chouhan and Flora, 2010; Perumal *et al.*, 2013; Munoth et al., 2015).

This chapter has tried to explore the extent and pattern of land degradation in the Rajasthan state in general. Further, the spatial distribution of the soil salinity has been assessed to get the trend and pattern of soil salinity in the state. The investigation shows that the Barmer District is the highest soil salinity affected district of Rajasthan in terms of the proportion of the soil salinity affected land to the Total Geographical Area (TGA). Applied remote sensing techniques[1] *viz.* Normalized Difference Vegetation Index (NDVI), Normalized Difference Salinity Index (NDSI), and the Soil

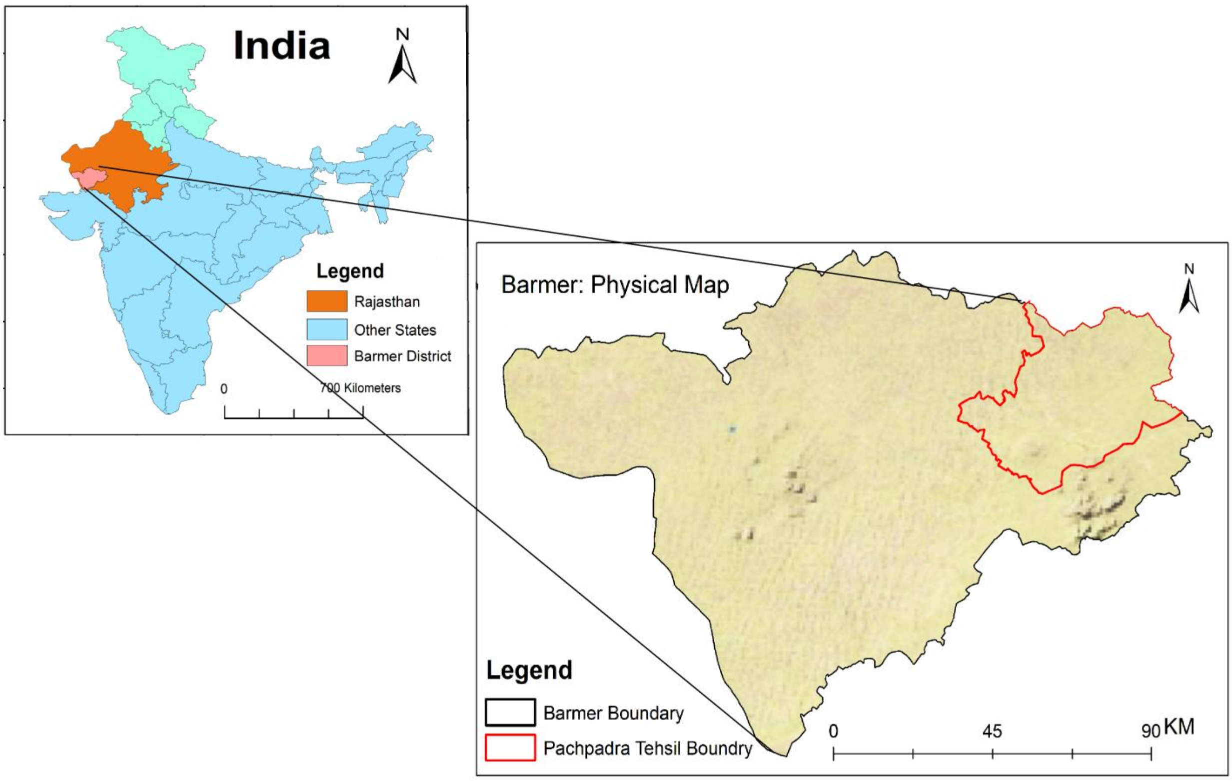
[1] Detailed methodology has been discussed in Chapter-1, Section-1.10 methodology part.

Adjusted Vegetation Index (SAVI) have been applied for detail analysis of the salinity problem across the Barmer District. An in-depth analysis shows that the Pachpadra Tehsil of the Barmer District is significantly affected by salinity in compare to others tehsils. Therefore, Doodhwa (25°55'21.87"N; 71°59'9.20"E) and Bagundi (25°55'9.81"N; 72° 3'5.11"E), two sample villages have been selected from the Pachpadra Tehsil to understand the role of soil salinity on the agricultural productivity through conducting the interview of farmers of these two villages (Map-5.2).

5.2. STUDY AREA

The district Barmer, in the Rajasthan state of India, is divided into 4 sub-divisions – Barmer, Gudhamalani, Balotra and Sheo, and 8 tehsils. Barmer is located at 25.75° N 71.38° E. It has an average elevation of 227 meters (744 feet) (Map-5.1). The total area of Barmer District is 28387 km². The whole district lies between 24°58′ N - 26°32′ N and 70°5′ E– 72°52′ E. Barmer District is about 1,136 m (3,727 ft) above sea level and 22 km in length. The longest river in the district is the Luni River. It is 480 km in length and drains into the Gulf of Kutch passing through Jalore. The variation in temperature in different seasons is quite high. In summers the temperature soars to 46 °C to 48 °C. In winters it drops to 5 °C. Primarily, Barmer District is a desert where average rainfall in a year is about 277 mm. Apart from a small offshoot of the Aravalli hills in the east, the area is a vast sand covered track with a substratum of gneiss, hornblende and quartz, which here and there rises up through the sand, in some instances to a height of about 243 to 304 meters. In the extreme north and west, the sandy plain is broken by sand hills called *tibbas* which sometimes rise to a height of 91 to 122 meters. This area is dreary and inhospitable and forms part of Thar Desert. The highest peak in the district is the Chhappan-ka-Pahar in Siwana District, which is about 973 meters above the sea-level.

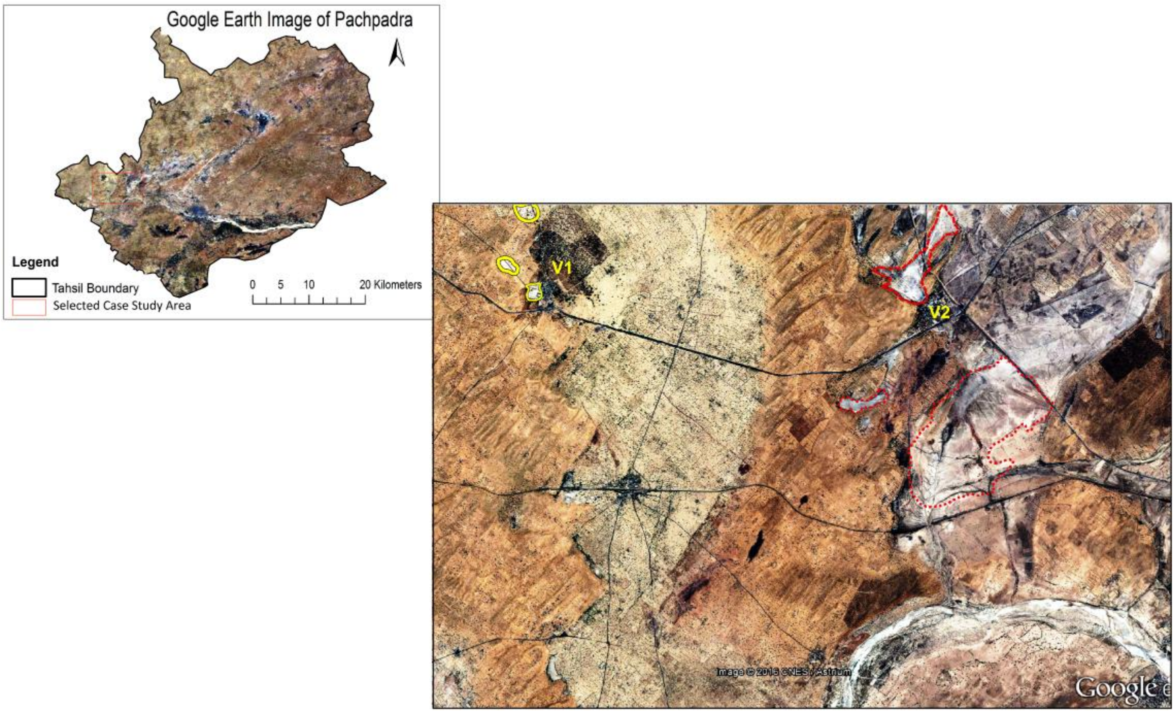
There are numerous small ponds called ‘pars’ which are used for bed cultivation of wheat during the years of heavy rains. Most of the ponds are dry by early summer, whereas the ponds of Rewana in Pachpadra and Sheo District usually retain some water throughout the year. The characteristic features of the climate of the district are its dryness, extremes of temperature and the fitful and erratic nature of the rainfall. The soils of the district are the broadly desertic type. Qualitatively the soils are very poor and devoid of humus content. These soils are very deep and sandy, associated with dunes; interdunes and sandy plain covering about 31 percent of the area. Dunes are the spectacular feature of the district and these occur scattered all over the area. In some parts of Barmer, red desert soils are also found. Soil texture varies from sandy loam to sandy clay loam, becoming slightly heavier with depth. Calcium carbonate is at varying depths and is frequently cemented. Solanchak (saline soils) are also found in the district (District Human Development Report, 2008). The district has reported only 1.14% area under forest cover in 2010-11 (Forest Survey of India, 2011). The district is having only 9.19% area under Net Irrigation to net sown area, while gross Irrigated area reached 12.85% of its Gross Sown Area (District Profile, Barmer).



Map.-5.1 Study area map of Barmer and Pachpadra Tehsil
Source: Map designed and generated by the author.

Within the Barmer District, Pachpadra Tahsil has been selected for the detailed study of salinity. Pachpadra District is spread over 3458.27 km^2, located at 25°36'42.55"N to 26°19'18.74"N latitude and 72°43'37.41"E to 71°52'8.38"E (Google Earth). Its demographic characteristics comprise 422784 populations covering in 284 villages. The Luni River flows in this region and the Balotra city is located on the river bank. The sand also contains salt, which has been loosened by rain over the ages to collect in the Pachpadra depression. Salt with sodium chloride is extracted from Pachpadra Lake (District Human Development Report, 2008).

Further through the spatial distribution of salinity index, two villages have been selected for the primary survey on the basis of soil salinity affected area and the soil salinity less affected area (Map-5.2). The names of these two villages are Bagundi and Doodhwa respectively. These villages consist of 148 and 220 households with the characteristics of involving in the farming and livestock occupation majorly. The location of Doodhwa is 25°55'21.87"N and 71°59'9.20"E and that of Bagundi is 25°55'9.81"N and 72° 3'5.11"E.



Map-5.2 Study area location of the villages selected from the Pachpadra Tehsil of the Barmer District: V1- Doodhwa Village, which is less saline affected (saline area marked by yellow colour) and V2- Bagundi Village, which relatively high salinity affected village (saline area marked by red colour)

Source: Google Earth image has been used to generate map dated December 2016, Prepared by the author.

5.3. RESULT AND DISCUSSION

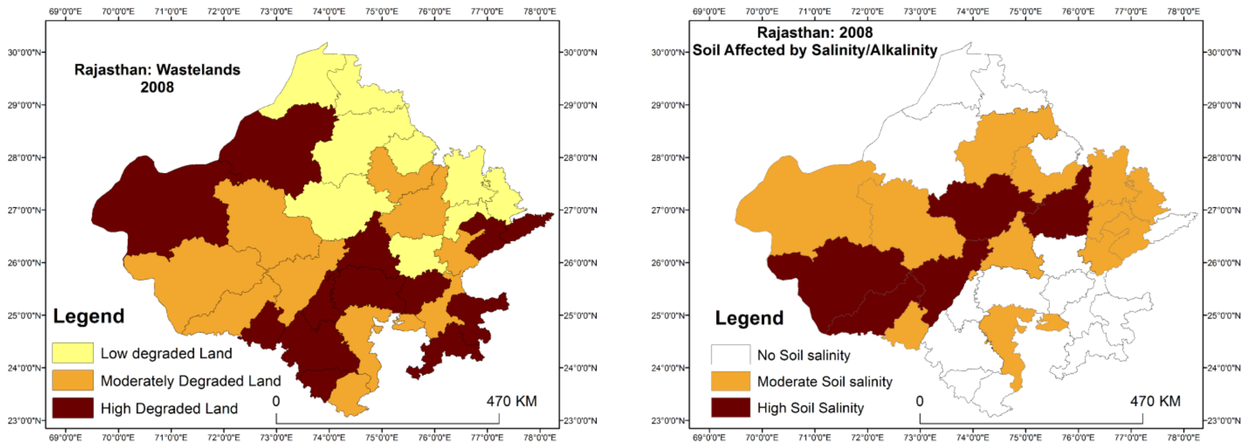
Wasteland problem is very severe across the Rajasthan State. Approximately, 25 percent of its total geographical area is affected by the different type of the land degradation problem; out of which share of the scrubland to the total degraded land is very high, followed by sandy soil (Table-5.1). Spatial distribution of the wasteland has suggested that Districts named Jaisalmer, Rajmasand, Udaipur, Dungarpur, Sirohi, Bikaner, Bhilwara, Dhaulpur, Karauli, Baran, Jhalawar, Bundi and Ajmer are highly affected by the land degradation (more than 25 percent of their total geographical area (TGA) (Map-5.3). However, the geographical properties of the salinity distribution vary very differently from those of the total degraded area (TDA). The general concentration of the degraded land is primarily in the western and eastern part of Rajasthan, whereas the soil salinity/alkalinity concentration has been recorded in the middle and western part of the Rajasthan mainly (Map-5.3). Additionally, in respect to proportion to TGA, very minor area is affected by soil salinity in Rajasthan, which covers almost 550 km^2 areas (Table-5.1) (NRSC, 2011). Out of this, the share of the Barmer District is almost 20 percent of the total salinity area in Rajasthan extending to 108.78 km^2 areas (NRSC, 2011), however, the share in total TGA is very low (0.38 percent) (Table-5.1). Out of the TDA in Rajasthan, the land with scrub is dominating in the state followed by the area under sand (Table-5.1 and Fig.-5.1). Conversely, in Barmer District, the land with sand dominates followed by the land with scrub (Table-5.1 and Fig.-5.1).

Table-5.1 Share of the different types of land degradation- 2008 (in percentage)

Wasteland	Barmer (Share in TDA)	Rajasthan (Share in TDA)	Barmer (Share in TGA)	Rajasthan (Share in TGA)
Gully/Ravines	0.40	1.80	0.07	0.45
Land with Scrub	26.68	42.91	4.72	10.65
Waterlogged/Marshyland	0.43	0.14	0.08	0.035
Land affected by Salinity/alkalinity	2.17	0.65	0.38	0.16
Land: underutilized	5.37	17.15	0.95	4.25
Area under sand	57.03	31.84	10.08	7.90
Industrial Wasteland	0.06	0.15	0.01	0.04
Barren Rocky/Stony Waste	7.87	5.37	1.39	1.33
Total	100	100	17.68	24.82

Source: Wasteland Atlas of India, NRSC, 2011

As the Rajasthan is dominated by the desert especially in the western part, the location of the Barmer District in the western Rajasthan explicates its physical characteristics of sand dunes dominated land with Some of the remains of the Aravali range in the eastern part (Fig.-5.1) (Chauhan, 2003). The NDVI reveals that the region is experienced with lack of healthy vegetation except for the limited floodplain of Luni River and hilly area of Aravali Range (Map-5.4 [B]).



Map-5.3 Spatial distribution of land degradation and soil salinity/alkalinity in Rajasthan

Source: The map has been generated by the author by using the data taken from the National Remote Sensing Center, ISRO, in the year 2008.

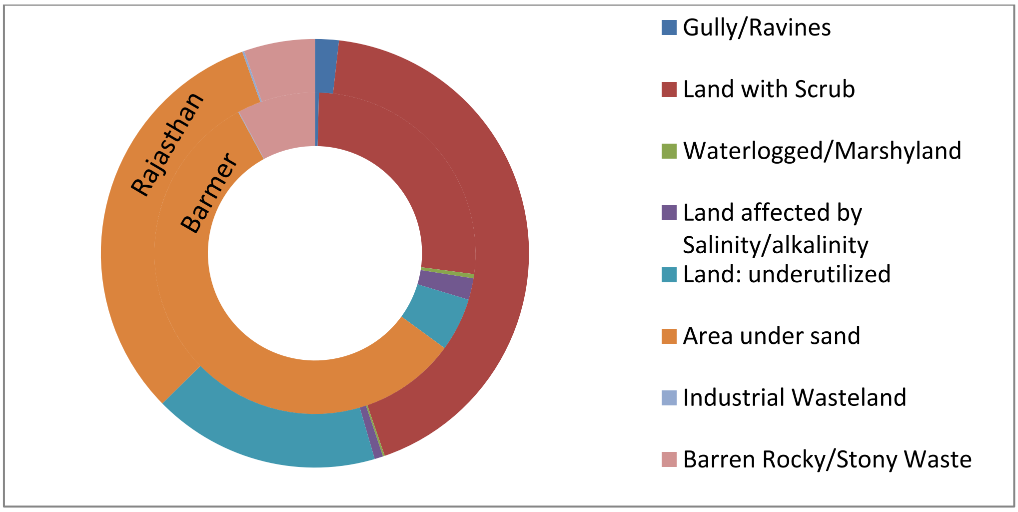
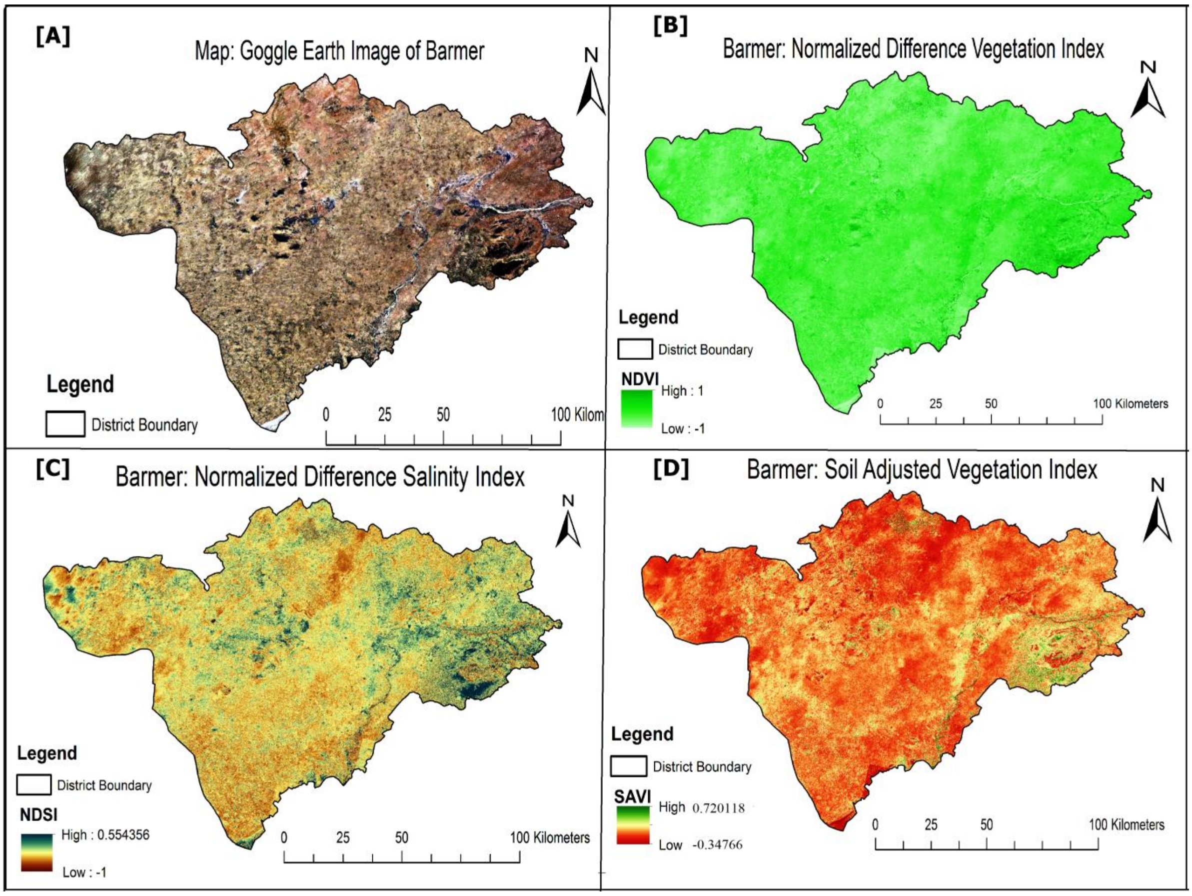


Fig.-5.1 Representation of the resemblances of the land degradation types in Rajasthan and Barmer

Source: Prepared by the author by using data provided by the author using NRSC data-2008

Interestingly, the vegetation distribution is very sparred even through the SAVI image (detailed methodology has been discussed in chapter-1, section-1.10 methodology part), which is done through one step more ratification from the NDVI (detailed methodology has been discussed in chapter-1, section-1.10 methodology part) by the inclusion of the methods of removing the soil reflection impact (Map-5.4 [D]). Nevertheless, NDSI (detailed methodology has been discussed in chapter-1, section-1.10 methodology part), which image explains the salinity distribution based on the reflection of the canopy and revealed that the soil salinity of Barmer District is mainly concentrated in the Pachpadra Tehsil (Map-5.4 [C]). Soil Salinity has been also recorded in the north-eastern part of the Barmer District (Map-5.4 [B]).

The Pachpadra Tehsil is being famous for its salt lake in the Pachpadra Village [called Pachpadra Lake (Plate-5.1 (A) and (B)], which is an area of severely affected by soil salinity in the Barmer. The dense forest is almost negligible in the Pachpadra. The biomass of the tehsil includes mainly the cropland, shrubs, herbs and grasses etc. (Map-5.5 [A]). Majority of the biomass includes the shrubs called *Babool* (Scientific name: *Acacia nilotica*) and Khejri (Scientific name: *Prosopis cineraria*) and perennial and nutritive grasses like cenchrus ciliaris, cenchrus setigerus, dichanthium annulatumand lasiurus sindicus etc (Plate-5.2).



Map-5.4 [A] Google Earth image of the Barmer District dated December 2016, [B] Map representing the NDVI in the Barmer District-2016, [C] Map representing the NDSI in the Barmer District-2016 and [D] Map representing SAVI for the Barmer District-2016.

Source: The map prepared by the author by using a various band of Landsat-8 imageries provided by the USGS through the url:https://glovis.usgs.gov/app?fullscreen=1, the images acquisition dates were of 23rd March 2016, 31st January 2016 and 14 March 2016 to cover the whole area of Barmer.

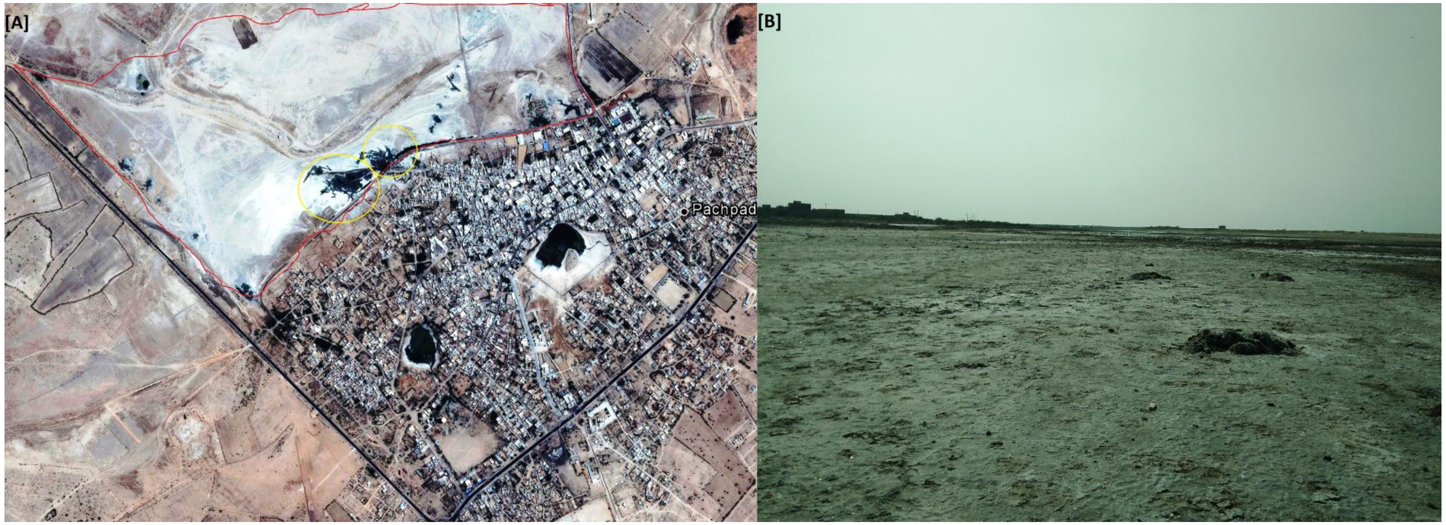


Plate-5.1 (A) Google Earth image of Pachpadra Lake (taken on 20 May 2016): red colour demarcating the area of the Pachpadra Lake and yellow colour shows the dumping of waste into the lake (B) Field Photo of Pachapadra Lake: Image is taken from inside the Lake

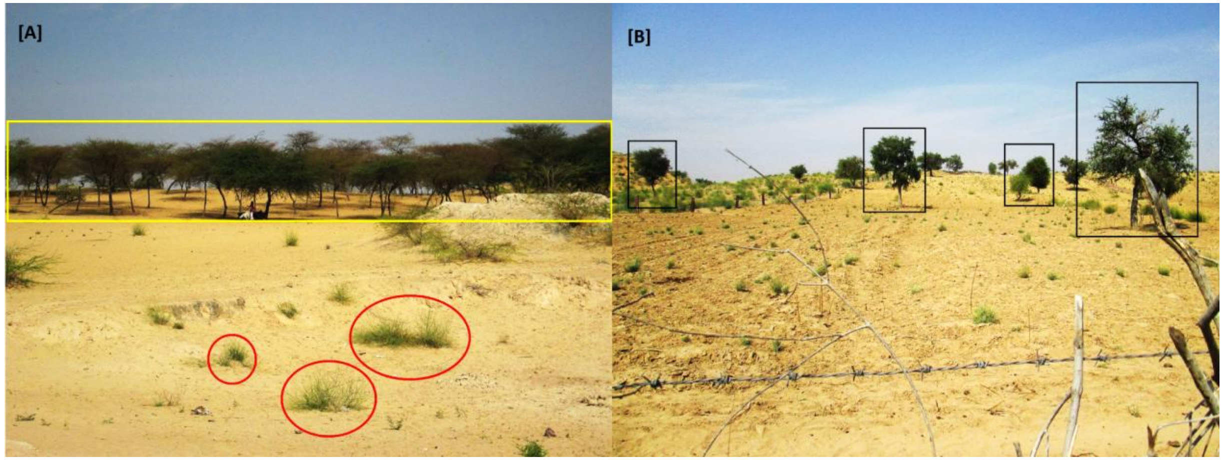


Plate-5.2 [A] Babool tree demarcated by yellow colour and other shrub demarcated by red colour is "sewan grass" (Lasiurus sindicus) for the desert livestock and [B] Khejri tree is an important species of the desert (Photo taken at Doodhwa Village)
Source: Photograph taken during the field work by the author on March 2017

A glimpse of ground realinity through media:

(A) "We want water not 'power,' says Barmer village"

Times of India, Jan 9, 2017.

……….in Barmer district protested against the administration's plan to construct a power substation at a spot frequented by migratory birds.
Villagers said that the land also served as a rich catchment area for water due to which there was no water scarcity in the area…..
…….. In revenue records, this land is listed as 'gauchar' or grazing land, marked for cattle to graze. This area serves as a catchment area for several large lakes in the vicinity, including the largest in the Jodhpur division, Gangawas. Several migratory birds nest in the trees in this area. The Sarus crane and a large number of migratory and resident birds,……
Environmentalist Harsh Vardhan said, "On the one hand, chief minister Vasundhara Raje speaks of water harvesting, on the other, the state machinery attempts to destroy natural sites that recharge rainwater."
Concerned citizens have now taken the matter to the National Green Tribunal (NGT). …..

(B) "NGT dismayed by tehsildar's inspection of Korna site"

Times of India, Jan 9, 2017.

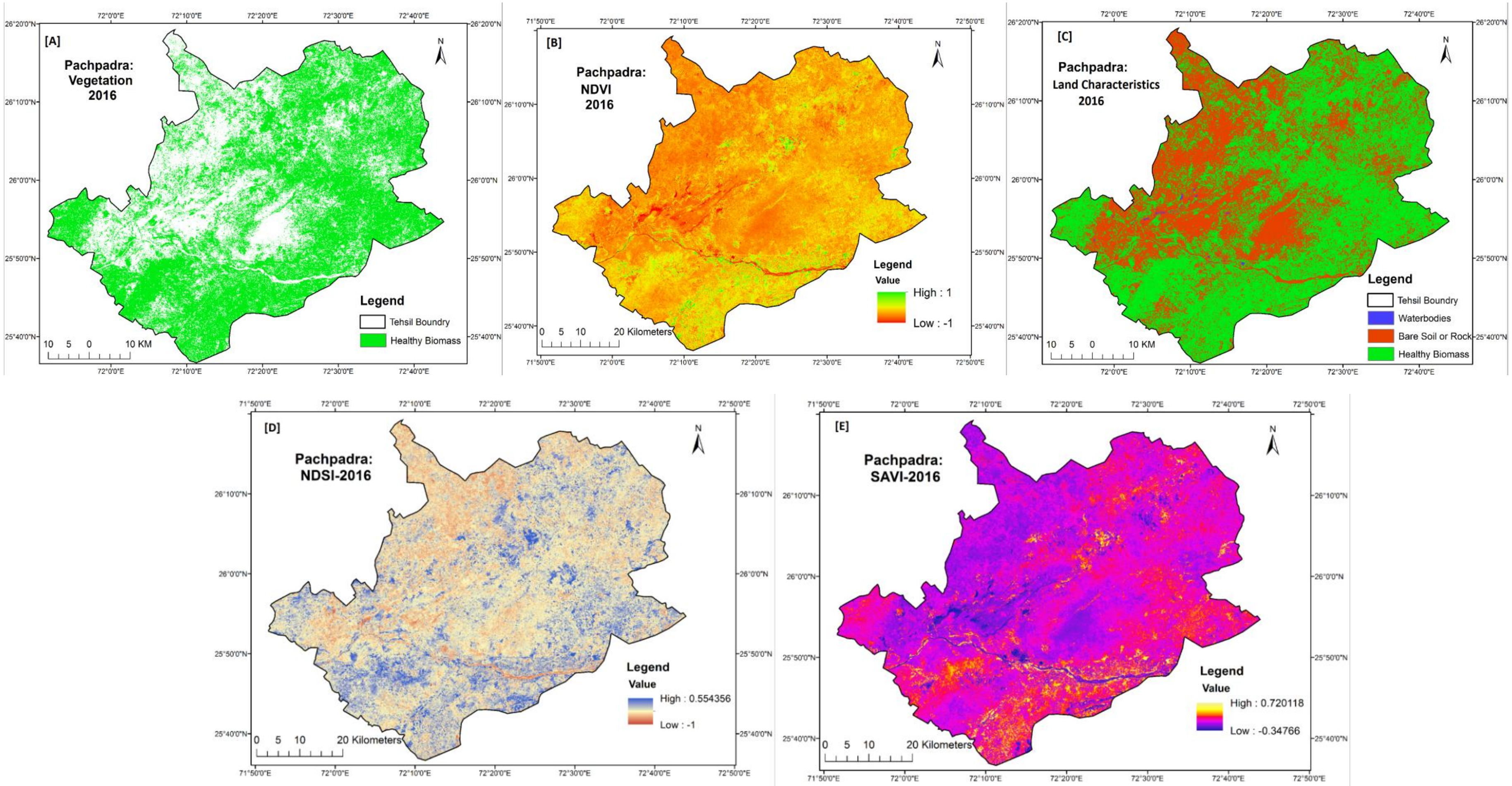
National Green Tribunal, Bhopal, expressed displeasure over the quality of the inspection report submitted by authorities on the matter of the proposed location of a power substation in Pachpadra tehsil of Barmer.
………………
However, we are not satisfied with the kind of investigation that has been made. We direct the learned counsel to submit the topo-sheet of Survey of India for the entire region would include the existing site and the alternate site which has been found at 38 km distance so that we are in a better position to appreciate the submission."

National news paper reporting:

The dying Khejri trees of Rajasthan

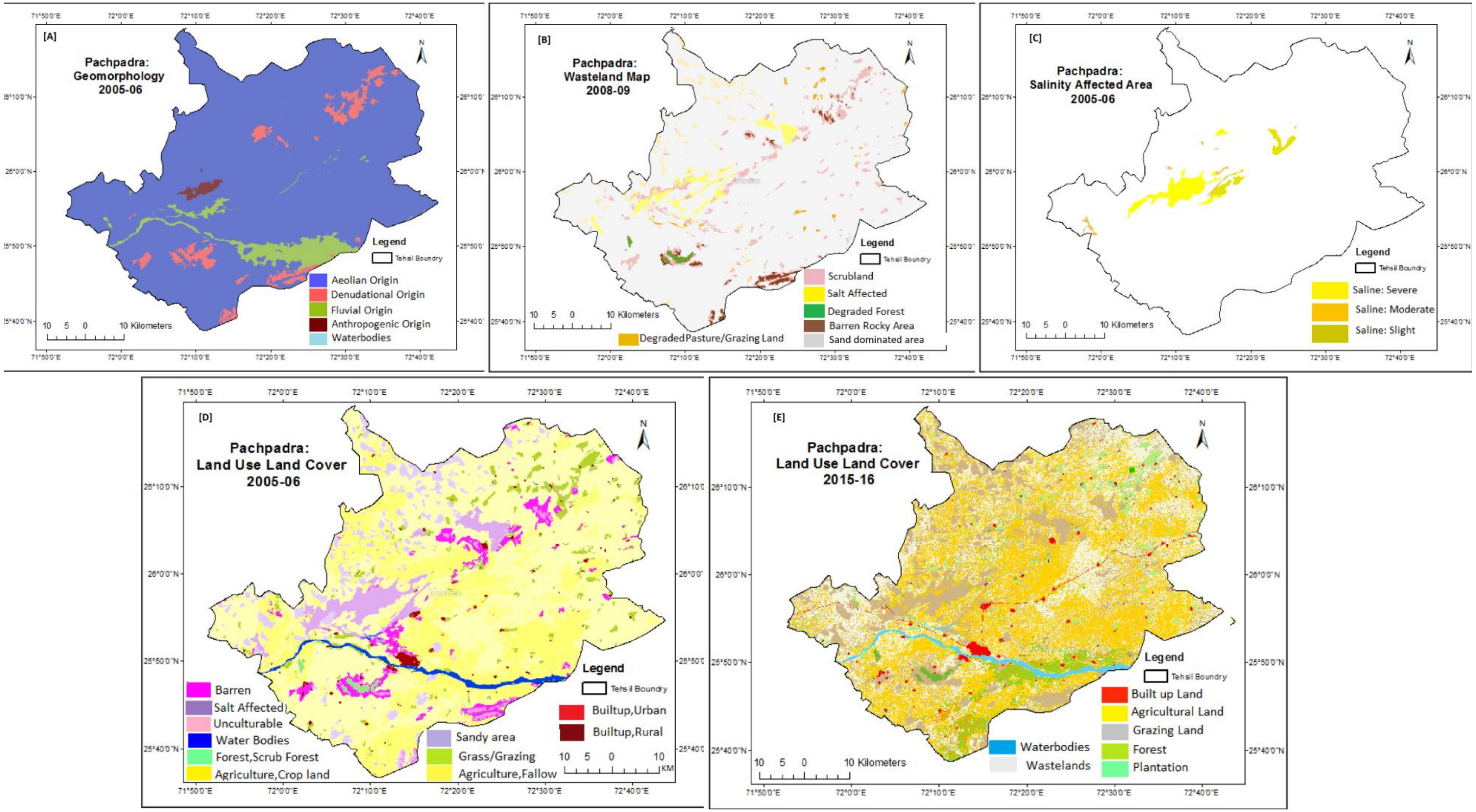
The Hindu November 06, 2014

Rajasthan's State tree — Khejri — is dying a slow death, scientists and environmentalists have warned.
Khejri (Prosopis cineraria) covers about two-thirds of the total geographical area of the State and is of immense significance culturally and economically. The tree supports rural economy like no other wild vegetation does.
……….. The dead leaves of the tree are natural fertilizers. Other parts are fed to the cattle as it increases the milk yield.
…….
The Desert Tree, as it is also known as, was the lifeline of the people in Western Rajasthan in the earlier times…….



Map-5.5 [A] Vegetation expansion in the Pachpadra Tehsil of Barmer, including the cropland, [B] Pachpadra Tehsil: NDVI, [C] Pachpadra Tehsil: Land characteristics in terms of availability of biomass, [D] Pachpadra Tehsil: NDSI and [E] Pachpadra Tehsil: SAVI

Source: The map prepared by the author by using a various band of Landsat-8 imageries provided by the USGS through the url:https://glovis.usgs.gov/app?fullscreen=1, the image acquisition date was of 23rd March 2016.



Map-5.6 [A] Geomorphology of the Pachpadra Tehsil with it origin characteristics, [B] Wasteland distribution in the Pachpadra Tehsil, [C] Concentration of the Soil Salinity in the Pachpadra Tehsil, [D] Land used characteristics in the Pachpadra Tehsil-2005-06 and [E] Land used characteristics in the Pachpadra Tehsil-2015-16.

Source: Maps are reproduced by the author by using the ArcGIS online tool to get the various thematic maps from Bhuvan Thematic Service, NRSC, ISRO, URL-http://bhuvan.nrsc.gov.in/gis/thematic/index.php.

The region is dominated by the sandy undulating aggraded older alluvial plain. Consequently, the land supports those trees or plant only which can sustain the same type of soil given the climatic conditions (Chauhan, 2003). It is apparent through the NDVI map that only the regions nearer to the Luni River have some healthier biomass (Map-5.5 [B]). The classification has been done through the NDVI value to categorised the Pachpadra Tehsil into three zones named: Water bodies, bare soil and the healthy biomass (Map-5.5 [C]). It is observable that the soil in the western part of Pachpadra Tehsil is more exposed to atmosphere termed as bare soil. The field observation has also proved that these regions are majorly dominated by sand dunes (Plate-5.3). The NDSI and SAVI maps also reveal the similar result across the study area (Map-5.5 [D] and [E]). The value of NDSI map varies from – 1 to + 0.55 and for the SAVI map it varies from -0.35 to +0.72 (the theoretical value varies from -1 to +1), where a significant part of land with lower values in both maps indicates the presence of high salinity and vice versa (Map-5.5 [D] and [E]). To verify through field observations, two points have been selected each from soil salinity affected and non-salinity affected area from the Landsat-8 imageries based salinity index calculation and visited the sites to validate the ground realities (Plate-5.4 (a) and (b). Through the visual representation of the map, it is manifested that physiography of the area is directly correlated to the vegetation type in the region e.g. the region with the fluvial origin have been endowed with the vegetation cover to some extent and conversely Aeolian origin land is either having shrubs or being devoid of the vegetation (Map-5.5 and Map-5.6 [A].

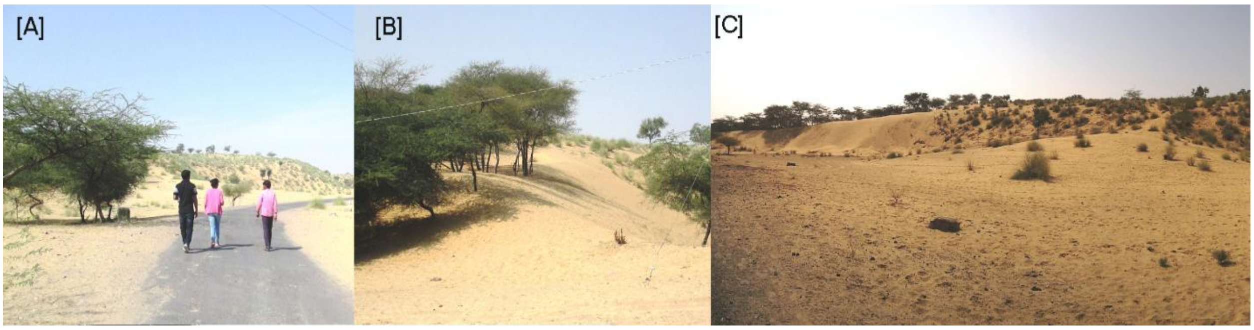


Plate-5.3 Extensive sand dunes exist in the Pachpadra Tehsil (Photograph was taken at the Doodhwa Village

Source: Photograph taken during the field work by the author on March 2017

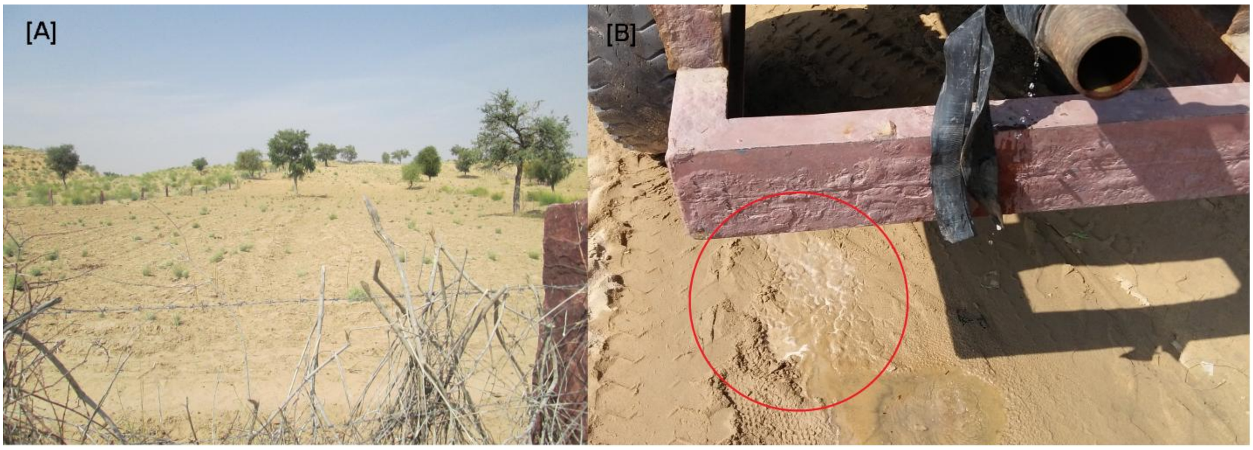


Plate-5.4 (a): [A] Field at the Doodhwa Village, which is described as the less saline area by the people and in the image analysis too. Locals have considered their soil as "*Mitha Mitti*" meaning "*Sweat Soil*". [B] While, when some water poured into the field the slight salt content can be visible.

Source: Photograph taken during the field work by the author on March 2017.

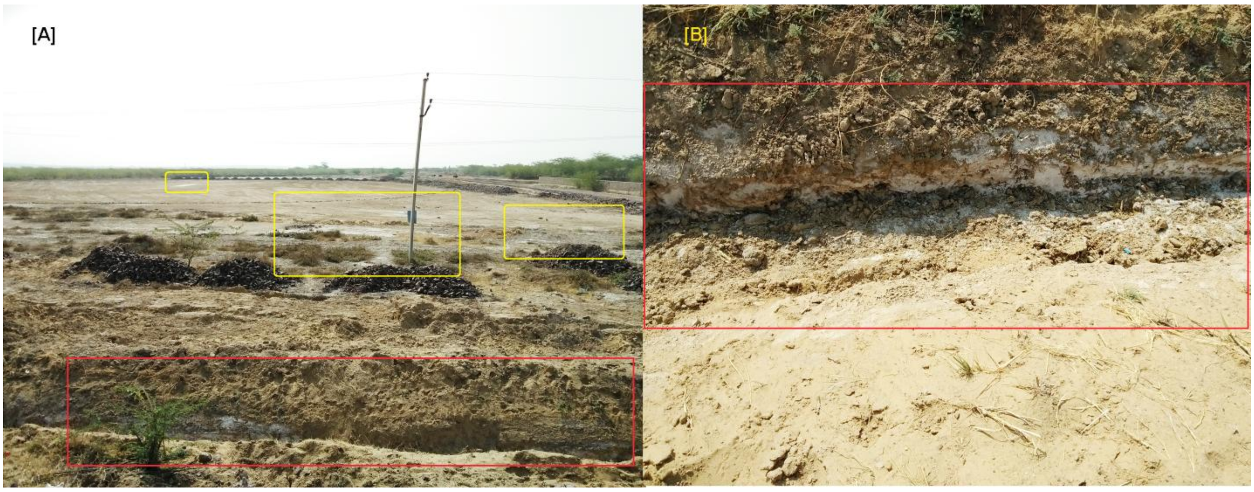


Plate-5.4 (b): [A] Field at the Bagundi Village, which is in the areas, described as one of the highest salinity affected area by the people and same found in the satellite image analysis too. Locals have considered their soil as "*Khara Mitti*" meaning "*Saline Soil*". Some of the patches of the soil salinity were witnessed in the field marked in yellow colour. [B] The area in red colour in picture [A] was dug by the people working in the field. It has given the opportunity to see the salt content into the upper layer of the soil, zoomed and marked in red colour in picture [B].

Source: Photograph taken during the field work by the author on March 2017

The Pachpadra region is affected by the different type of wasteland problems e.g. scrubland, salt-affected land, degraded forest, barren or rocky area and sandy soil (Map-5.6 [B]. Degradation of the forest is happening over the remains of the Aravalis, which have a denudational origin (Map-5.6 [A]. The area with the anthropogenic origin is affected by the severe soil salinity (Map-5.6 [C]), which is either not cultivated or left fallow (Map-5.6 [D]). However, some of the lands are mined for the salt production in the region (Plate-5.5). Built up area has been increased over a period of time, especially along the roads (Map-5.6 [C] and [D]). The forest cover has also shown improvement in terms of more area under the forest over the period of 2005 to 2010 (Map-5.6 [C] and [D]), however, degradation of the forest cover has also happened in some areas (Map-5.6 [B]). The Forest Survey Report has also been demonstrated that during the period of 2005 to 2011, there has been a very minimal decline in the forest cover in the Barmer Districts. In a 2005 report, it recorded 172 km^2 areas under total forest, while the 2011 report has recorded 169 km^2 areas under total forest (Forest Survey of India Report, 2005 and 2011). However, the FSI Report 2015 has reported a significant increase in forest cover, which is reaching 190 km^2 in the Barmer District. Similarly, FSI Report (2017) has also recorded a drastic increase by 86 km^2 from 2015. It is attributed to high increase into open forest.

The agricultural characteristics of the region can be seen in terms of the availability of irrigation facility and land use pattern. Overall, the Rajasthan state, Barmer and Pachpadra have been recorded increased in the total Gross Cropped Area (GCA) by 33 percent, 38 percent, and 9 percent respectively from 1995-1996 to 2010-11. At the same time, there has been recorded increase of area under the agriculture and unirrigated land at state, district and tehsil level. However, land under irrigation has been seen as a relatively different pattern. Both the Rajasthan and Barmer have recorded increased in the irrigated land as high as approximately 35 percent and 218 percent respectively. Conversely, the Pachpadra Tehsil has witnessed a decline in the irrigation land by approximately 80 percent from 1995-96 to 2010-11 (Fig.-5.2 [A]). The land use pattern is also one of the indicators to understand the agricultural status of the area. Net Sown Area (NSA) has registered growth at all the administrative level (the State, Barmer District and Pachpadra Tehsil) approximately by 12 percent, 20 percent and 11 percent and area under current fallow has been shown drastic decline in the same period in the administrative level (The State, Barmer District and

Pachpadra Tehsil) approximately by 45 percent, 39 percent and 16 percent, respectively. Though, in Pachpadra Tehsil the changes in the current fallow land are not so drastic compared to the state; another uncultivated land excluding fallow land, fallow land other than current fallows and total uncultivated land has come down drastically compared to the Rajasthan by the percentage of 53, 44 and 95 respectively (Table-5.2).

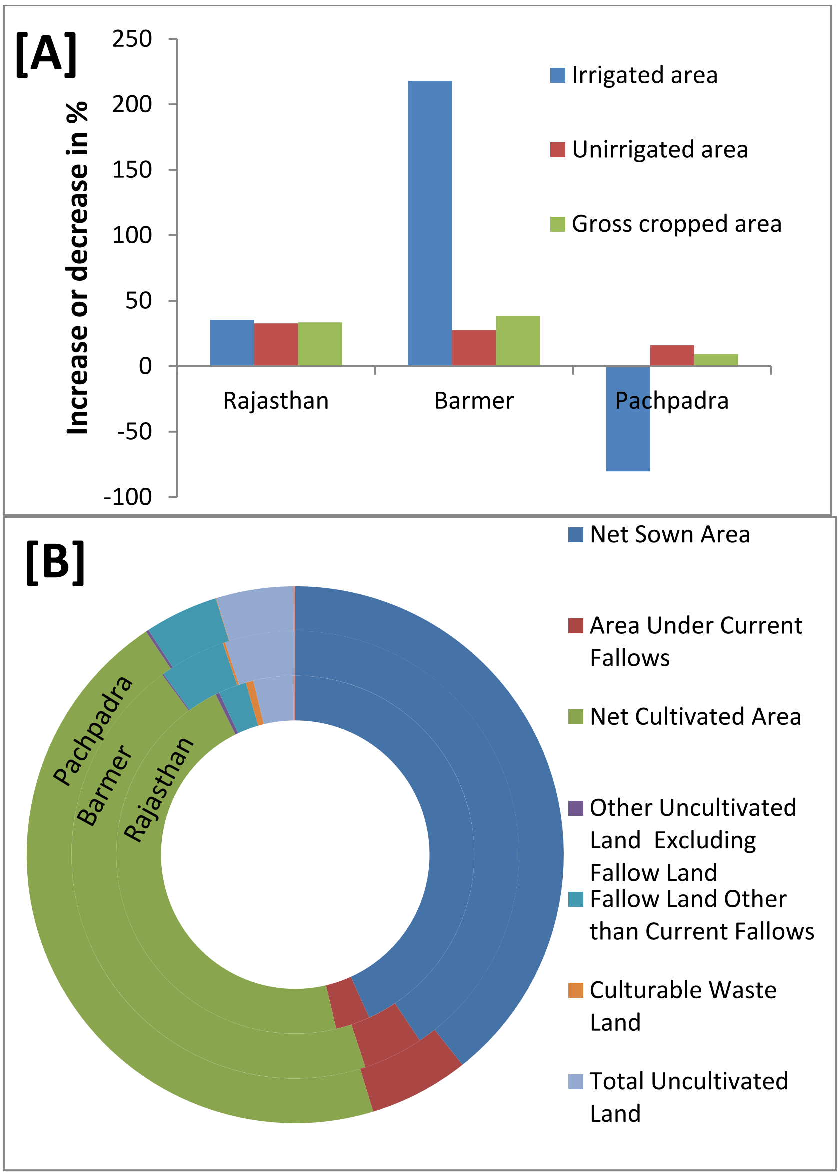


Fig.-5.2 [A] Change in cropping pattern from 1995-96 to 2010-11 and [B] Land-use pattern in the year 2010-11

Source: The graph is designed by the author by using the data provided by the Agriculture Census of India on various agricultural inputs and the land use pattern.

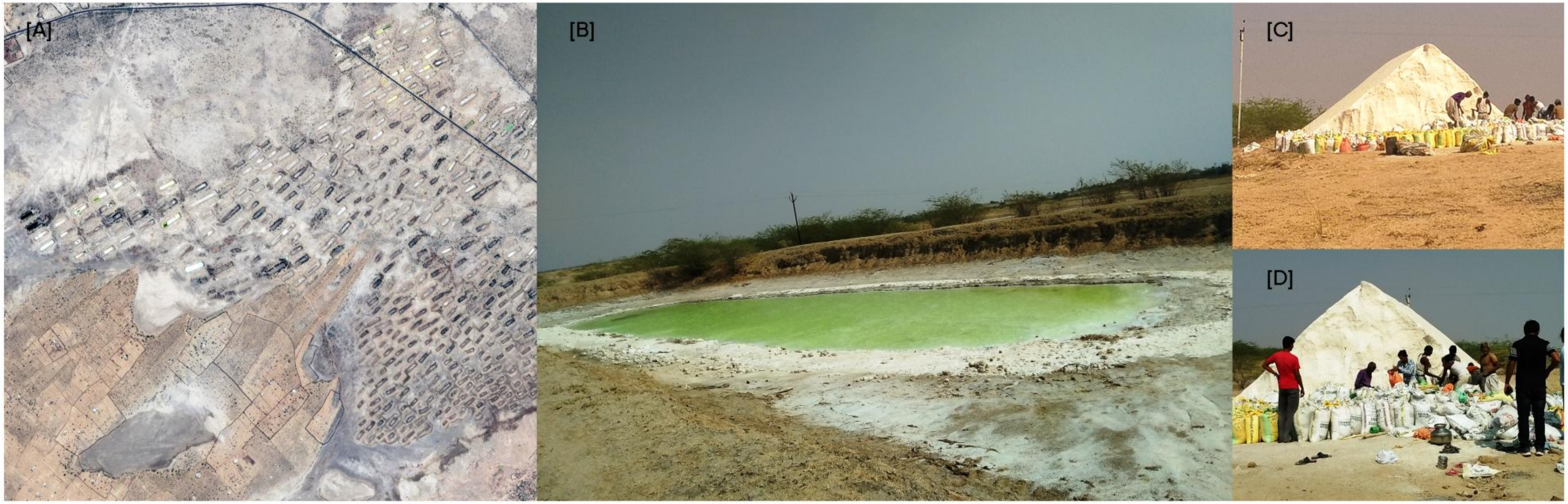


Plate-5.5 [A] Google Earth image of the Soil Salt mining Area, [B] A site of the soil salt mining, [C] Salt accumulation (salt is taken out from the mining land and deposited) and [D] Packing of the salt for the supply by the labours.

Source: Photograph taken during the field work by the author on March 2017

Table-5. 2 Land-use changes from 1995-1996 to 2010-11 (in percentage)			
Land Use	**Rajasthan**	**Barmer**	**Pachpadra**
Net Sown Area	12.00	20.86	11.45
Area Under Current Fallows	-45.24	-38.92	-16.55
Net Cultivated Area	4.66	10.45	6.70
Other Uncultivated Land Excluding Fallow Land	-47.47	-87.08	-53.56
Fallow Land Other than Current Fallows	-11.72	-25.19	-44.66
Culturable Waste Land	-69.29	-94.19	-95.99
Total Uncultivated Land	-38.09	-49.87	-49.04
Land Not Available for Cultivation	-40.65	-38.47	250

Source: Calculated by the author by using data provided by the Agriculture Census. of India

Table-5.3 Irrigation characteristics at different administrative level

	Irrigated areas by source 2010-11 (in hectares)			Changes in Irrigated area under different sources from 1995-96 to 2010-11 (in percentage)		
Source	**Rajasthan**	**Barmer**	**Pachpadra**	**Rajasthan**	**Barmer**	**Pachpadra**
Canals	1625874	0	0	4.35	0	0
Tanks	50299	104	0	-52.83	104	0
Wells	2147371	143084	240	-20.86	98.26	-97.91
Tubewells	2827081	49913	1227	338.52	810.82	17428.57
Other Sources	93862	80	0	24.98	900	0

Source: Calculated by the author by using data provided by the Agriculture Census of India.

Under the category of the land not available for the cultivation, the changes over the period of 1995-96 to 2010-11 have been of importance for the Pachpadra. As on one hand, the Rajasthan and Barmer have recorded decline by 40 percent and 38 percent in 2010-11, while on the other hand, the Pachpadra has witnessed a drastic increase in a land not available to cultivation (by 250 percent) (Table-5.2). It is noted that on one hand, the irrigated areas have declined in Barmer (Fig.-5.2 [A]), on the other hand, fallow land and culturable wasteland too has shown a decline (Table-5.2). It might indicate that the irrigation and the fallow land in the Barmer would not have a great relationship. It might be a soil quality more dominating factor towards the same. Among all the agricultural type of land use, the most of the land is used under the Net Sown Area and Net Cultivated land in all the administrative level followed by all types of fallow lands (current and other than current) (Fig.-5.2 B). Major sources of the irrigation in Rajasthan are wells and Tube wells, but due to the expansion of irrigation infrastructure through Indira Gandhi Canal, the canal has also emerged as one of the major sources of the irrigation (Table-5.3 and Fig.-5.3). But the Barmer has not the canal irrigation till 2012 (extension of Indira Gandhi Canal in western Barmer), in turn; Pachapadra too does not get canal irrigation. The main source of the irrigation in Barmer is wells, while in Pachpadra it is tube wells. Tube wells in Pachpadra have shown a drastic increase from 1995-96, while the irrigation through wells has declined (Table-5.3). This might be attributed to the increase into groundwater level in Barmer in the recent years through groundwater recharge (One India, 21st April 2016; Times of India, 23rd March 2018).

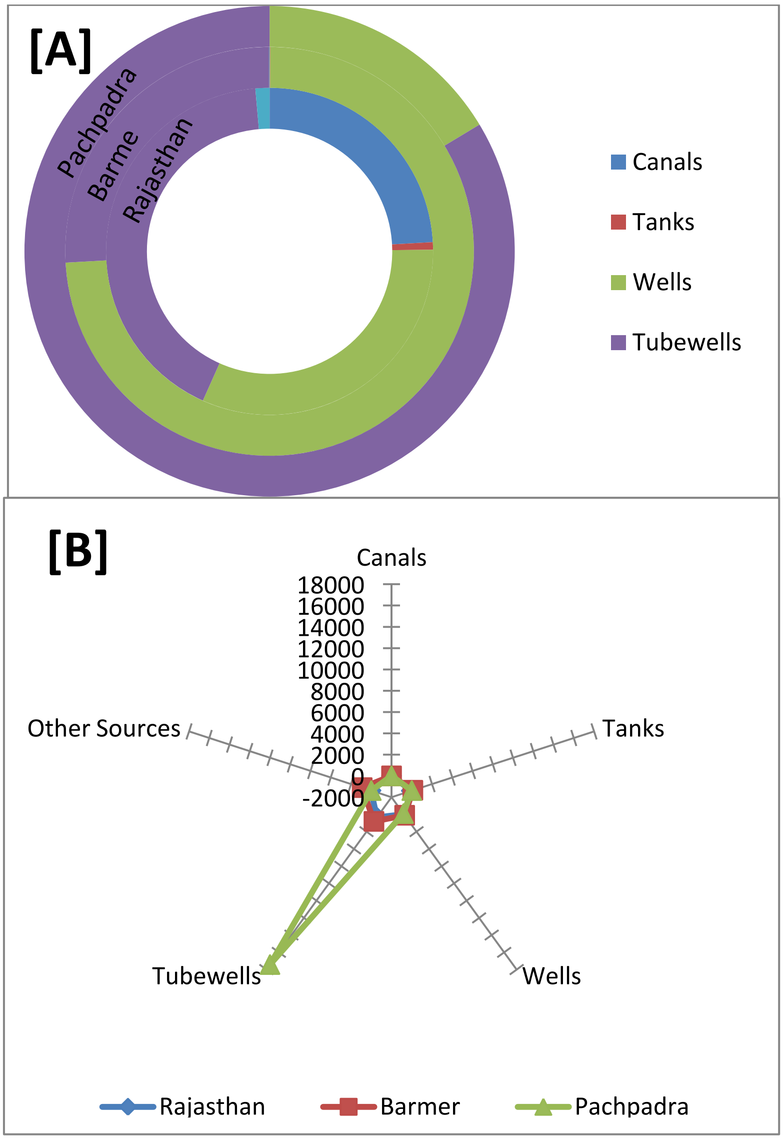


Fig.-5.3 [A] Irrigation by different sources in year 2010-11and [B] Changes in irrigated areas under various sources from 1995-96 to 2010-11

Source: Graph has been constructed by the author by using data taken from the Agriculture Census of India

The above analysis has been provided a foundational glimpse for the case study at the micro-level. The two villages- Doodhwa and Bagundi- have been further studied in section-5.3.1 and 5.3.2 extensively to know about the different dimensions of soil salinity at the ground level among the farmers.

5.3.1 CASE STUDY-1

The Doodhwa is relatively low soil salinity area compared to the adjoining village Bagundi. The village is having 148 households with the very low population density according to the 2011 census. Sex ratio is 987 and the child sex ratio is 943 (Census, 2011). Female literacy (22 percent) has been recorded very low compared to the male literacy (52 percent). The village is characterized by the low female participation to the total workforce (9 percent), low female participation to the main workforce (9 percent) and low female participation to the main cultivator (3 percent). Female participation in total main agriculture, female participation in the marginal workforce, female participation in marginal cultivator and female participation in marginal agriculture have not been witnessed in the village. More than 66 percent of the female population comes under the non-working population (Fig.-5.4). Participation of the women in the main workforce is more than the marginal workforce. About 28 percent of the total population is in the workforce and all involve in the main workforce. Interestingly, the village population has not involved in the marginal workforce. Out of the total workforce, the population is involved in the other type of the main workforce (Fig.-5.5).

Findings of Primary Survey: 50 household surveys have been conducted in the village Doodhwa, out of which 15 interviews taken from the large farmers, 29 from the small and medium farmers and 6 from the marginal farmers. Education among large farmers is comparatively high to the marginal and small and medium farmers (Fig.-5.6 (A). The physiographic condition has been investigated through the interview as well as from Focused Group Discussion (FGD). Due to the dominance of deserted land, the people are rarely seeing the inundated land in the village. However, there is some evidence of surface runoff during the monsoon season in the years when the village receives an adequate amount of rainfall. The village has been usually received about four months of rainfall concentrated into the monsoonal season only (FGD-1 in Doodhwa Village). All the respondents have agreed that the soil quality is bad because the soil is totally sandy in nature. At the same time, the access to irrigation is not found a uniform in the region, while some of the large farmers (20 percent), small and medium farmers (4 percent) could access the irrigation facilities through tube well (Table-5.4). The vegetation is sparse in the area (Plate-5.2 and 3) and it is especially dominated by the *Babool*, which is used as fuel, the barrier to spread the sand dunes. However, the people are believed that the *Babool* is proving to be poisonous for the soil (FGD-1 in Doodhwa Village).

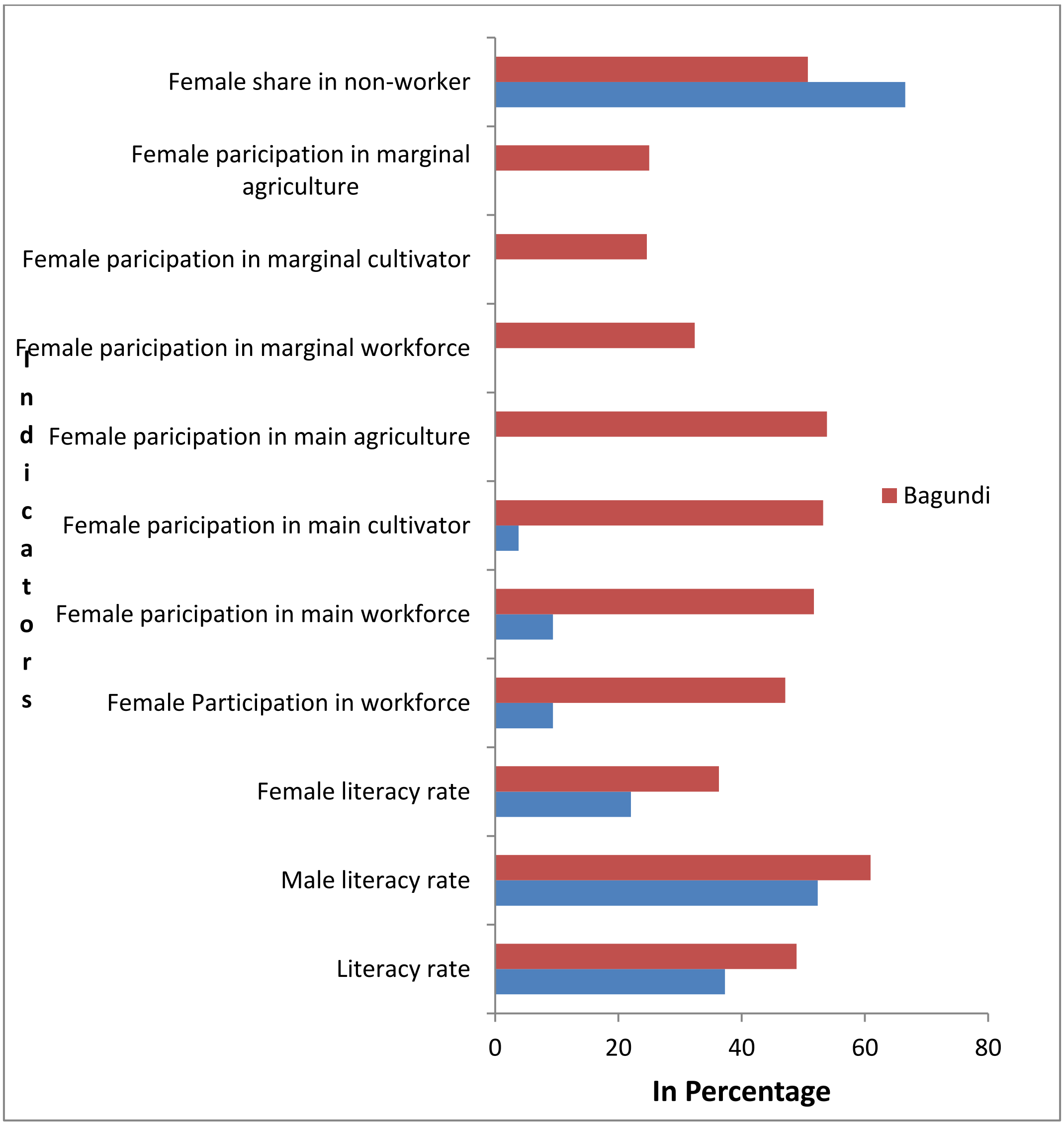


Fig.-5.4 Agro-demographic characteristics of the village Doodhwa and Bagundi especially focusing on the female participation

Source: Prepared by the author by using data provided by the Census of India, 2011.

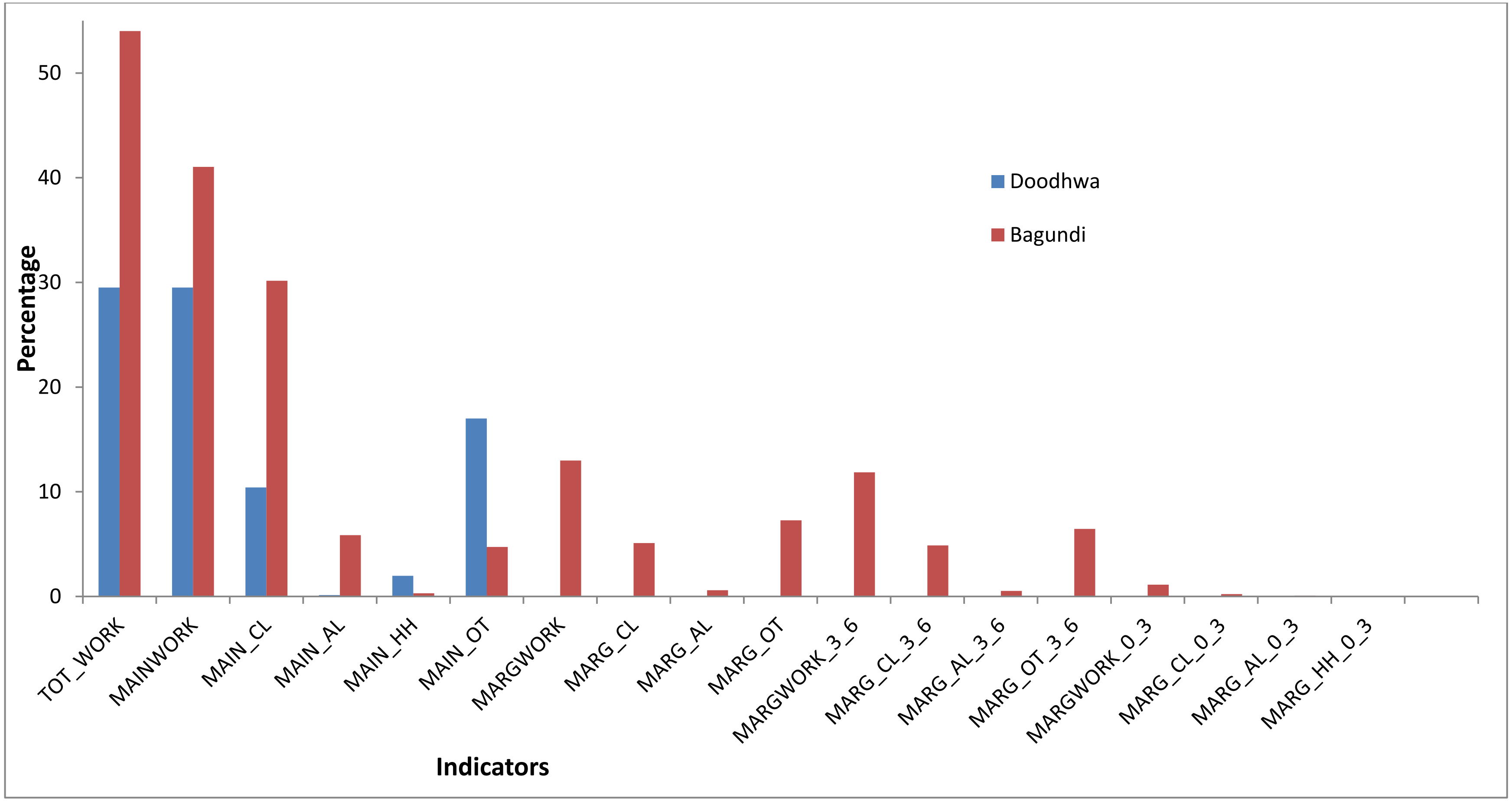


Fig.-5.5 Agro-demographic characteristics of the village Doodhwa and Bagundi

Source: Prepared by the author by using data provided by the Census of India, 2011.

Plate-5.6 Different types of cattle rearing practices in the selected villages for the study

Plate-5.7 [A] Household surveying at Doodhwa [B] Household Surveying at Bagundi
Source: Photograph taken by the author during the field visit in March 2017.

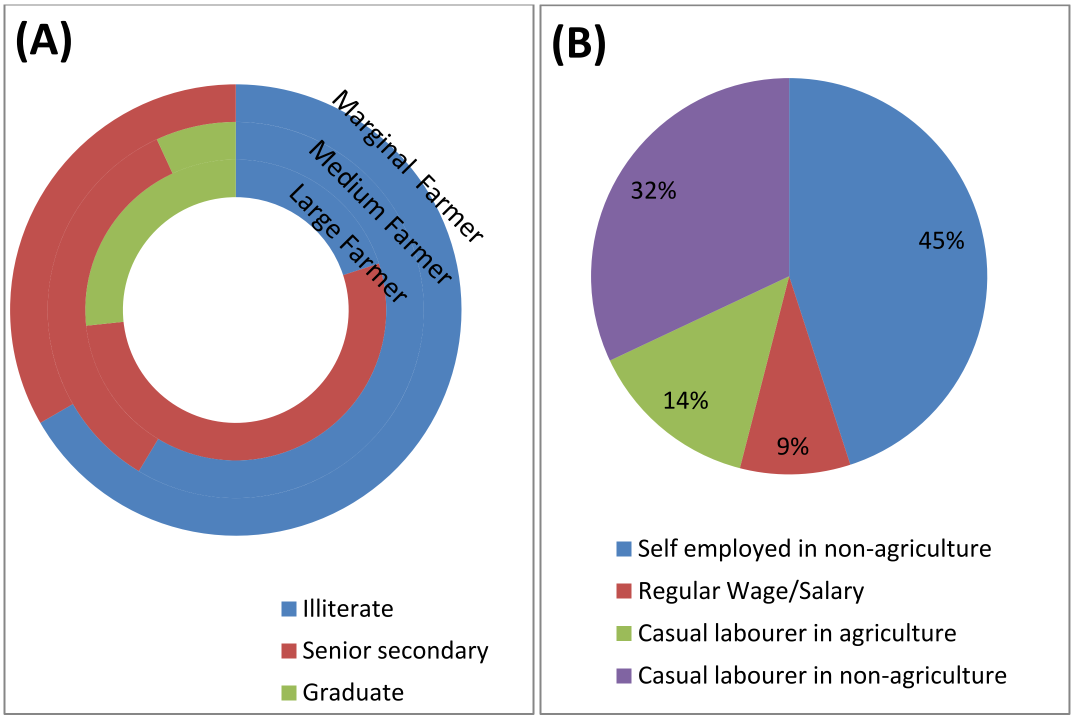


Fig.-5.6 (A) Education level among the sampled farmers and (B) Occupation of the sampled farmers other than the farming in their own land in the Doodhwa Village

Source: The graph prepared by the author by using the data collected from a primary survey in March 2017.

The interviewed farmers are totally dependent on the agriculture for the livelihood, but almost 45 percent of the farmers are self-employed in the non-agricultural, 9 percent have been receiving the regular wage or the salary, 14 percent are the casual labourer in agriculture and 32 percent are a casual labourer in non-agriculture (Fig.-5.6 (B). All the respondent are having the livestock for their livelihood as the region is coming under semi-arid region and the production out of the land is mostly used for the consumption purposes. Very diverse type of livestock has been found during the fieldwork comprising sheep, goats, buffalos, cows and camel (Plate-5.6). The terms of the land leasing is found of two type: one being on the condition of the half of the crops without getting the any input cost by the owner of the land and other being based on the condition of the two third of the total output of the crop with getting total agricultural input from the landowner (only 12 percent of respondent involving into the contract farming especially marginal and small farmers). As the land is not so productive, small and marginal farmers prefer to cultivate only on the limited land so that they can meet the need for food. It is not that they have no land. However, even with the large landholding, farmers leave their land abandoned (FGD-2 in Doodhwa Village (Plate-5.7 [A]).

Though all the respondents have been involving in the cultivation of their land, they do not do farming in all the land which they hold it. The average land holding size in the villages is very high, though some people with very little land (1 *Bigha*[2]) or no land. The farmers with a large amount of land do not prefer farming on the entire land (Table-5.4). However, marginal farmers are forced to farming on the same land every year due to the limitation of the land resources. The rotation of the farming land as a good practice has been witnessed in the village (FGD-2, in Doodhwa Village). Due to huge availability of the land to the large farmers, they are able to do the crop rotation to get their land reproductive periodically and fertility can be maintained over a period of time (FGD-2, in Doodhwa Village). Moreover, the large farmer has been able to get some profit on the investment to the land compared to the small and marginal farmers. Almost 93 percent of the sampled large farmers are able to manage profit out of the farming (Table-5.4). Additionally, the large farmers compared to the other type of farmers able to sell their product in market e.g. almost all large farmer either manage to sell <25 percent or 25-50 percent of their agricultural production. While the majority of small and medium farmers manage to sell <25 percent of farm products and marginal farmers have not able to sell it (Table-5.4). The marginal farmers have been even not meeting their yearly need through the farming; they need to work additionally for their livelihood (FGD-2 in Doodhwa Village).

Most of the respondents (79 percent) have been involved in the mixed farming because they are working in agriculture as well as in livestock (Table-5.5). Some of the respondents have also been having forestry in their land (21 percent) additionally with the mixed farming (Table-5.5). Respondents (98 percent) found difficulty in using their land because of sandy soil and it's relatively unproductiveness with the difficult climatic condition with the non-availability of the irrigation facilities (Table-5.5 and FGD-1 in Doodhwa Village).

[2]It is the local term for the measurement of the land in the rural India.

Table-5.4 General agricultural profile of the sampled respondents of the Doodhwa Village of the Pachpadra Tehsil (based on the answer of respondents)

		Education status of the farmers			Landholding and farming land		Irrigation
	Sample interviews (No.)	Illiterate (No.)	Senior secondary (No.)	Graduate (No.)	Average land holding size (Hectares)	Average land used in farming (%)	Access of irrigation sources (%)
Large Farmers	15	3	8	4	35	35	20
Medium farmers	29	17	10	2	5	70	4
Marginal farmers	6	4	2	0	1	100	0
	Return on investment (% of the respondents)			Sell of the share of the total output (% of the respondents)			
	Total Agricultural Input cost only	Total more than Agricultural Input	Total less than Agricultural Output	0-25 %	25-50 %	50-75 %	75-100%
Large Farmers	7	93	0	33	67	0	0
Medium farmers	67	7	26	66	21	0	0
marginal farmers	0	0	100	0	0	0	0

Source: Calculated by the author from the primary survey data collected during March 2017.

Table-5.5 Characteristics of the agricultural land of the farmers (sampled respondents) in the Doodhwa Village				
Mode of work in agricultural land: Yes		Land used for another purpose		
1. Agriculture only	0	Type	Yes	No
2. Agriculture and Forestry	0	1. Digging of soil from the field	0	100
3. Agriculture and Animal husbandry	79	2. Mining around the land	0	100
4. Agriculture, forestry and Animal husbandry	21			
5. Difficult to use land	98	Input into the land (Since five year)		Yes
6. Other	30	i. Decrease in irrigation facility		62
		ii. Equal irrigation facility		28
Occupation	Yes	iii. Increased irrigation Facility		10
Employed in agriculture	100	iv. More fertilizer used		58
Self-employed in non-agriculture	45	v. Equal fertilizer used		34
Regular Wage/Salary	9	vi. Less fertilizer used		8
Casual labourer in agriculture	14	vii. HYV seeds are used		42
Casual labourer in non-agriculture	32	viii. No awareness		28
Others, Specify	100	ix. less awareness		82
		x. More organized agriculture		46
		xi. less organized agriculture		11
Land productiveness (compare to last five year)	Yes	xii. More labour involved		12
a)More productive	12	xiii. Less or equal labour		86
b)Productive as earlier	66	xiv. Pesticide used		68
c)Less productive	22	Soil composition changed (since five years)		Yes
Soil fertility since five years Yes		i. Good from earlier		10
Decreased	68	ii. Bad from earlier		46
Equal	24	iii. Very Bad from earlier		26
Increased	8	iv. Worse from earlier		18
Source: Calculated by the author from the primary survey data collected during March 2017.				

According to the respondents, the land is as productive as it was earlier (66 percent) even though their investment into the land has been increased over the period in terms of fertilizer and HYV seeds, labour, awareness, more organized agriculture etc. (Table-5.5). Though the only 22 percent of respondents have felt that the productivity has decreased than earlier, it also experienced over the period of the time that the soil fertility has been decreased (68 percent respondents) and soil composition changed drastically from the past (90 percent respondents experienced bad to worse quality of soil from earlier) (Table-5.5).

Table-5.6 Characteristics of the soil salinity in the Doodhwa Village based on farmers perception (in percentage to the total sampled respondents)

Cause of Soil Salinity	Yes	Salinity experienced	Yes
i. High temperature	100	No salinity	10
ii. Low rainfall	100	Low	26
iii. Non-scientific (Faulty) agricultural practices	12	Moderate	62
iv. Lack of irrigation facility	100	High	2
v. Lack of Freshwater (saline free)	100		
vi. Irrigation by the saline water without proper distribution on the field	0		
vii. Lack of awareness about the scientific way of agriculture	24	Migration	Yes
viii. water-logging	0	Short term (<3 months)	26
ix. Lack of drainage facility	8	Medium Term (3-6 months)	16
x. overuse of chemical fertiliser	0	Long-term (> 6 months)	8
xi. absence of traditional agriculture	16	Permanent migration	2
xii. Irrigation through saline water	24	Total	52

Source: Calculated by the author from the primary survey data collected during March 2017.

Respondent has the diverse views on the salinity; there are 10 percent respondents who have said that they do not experience the salinity, while 26 percent respondents have verbalized that low salinity, 62 percent moderate salinity and 2 percent high salinity. The respondents have the assumptions that the salinity is high due to high temperature (100 percent), low rainfall (100 percent), lack of irrigation facility (100 percent), lack of fresh water (100 percent), lack of awareness about the scientific way of agriculture (24 percent), irrigation through saline water (24percent) absence of traditional agriculture (16 percent), non-scientific (Faulty) agricultural practices (12 percent) and lack of drainage facility (8 percent) (Table-5.6). The respondents have a stake that the fertiliser is helping in the improving their output so that this would not be responsible for the soil salinity. However, the respondents have the awareness about the health implication of fertiliser, in this aspect, the bad impact of the fertiliser has been seen by the respondent (FGD- 1 in Doodhwa Village).

Out of the sampled respondents, the population migration is reaching to 52 percent of total respondent, out of which 26 percent for the short-term (<3 months), 16 percent for medium term (3-6 months), 8 percent for long-term (>6 months) and 2 percent are going out for the permanent migration (Table-5.6). The causes of the population migration are majorly related to the not satisfactory profit from the agriculture, but additionally, there are some other reasons which lead to the migration e.g. profit on investment in other jobs, holding land is not enough to support the family requirement, more surety of life in other jobs etc. (FGD-2 in Doodhwa Village).

5.3.2 CASE STUDY-2

The Bagundi Village is relatively high soil salinity area in comparison with the adjoining village Doodhwa (Plate-5.4 (a) and Plate-5.4 (b). The village is having 220 households with the very low population density according to the 2011 census. Sex ratio is 951 and the child sex ratio is 1013 (Census, 2011). Female literacy (36 percent) has been recorded very low compared to the male literacy (61 percent). The village is characterized by the significant female participation in the total workforce (47 percent), to the main workforce (52 percent), to the main cultivator (53 percent), to the total main agriculture (32 percent), to the marginal workforce (24 percent), to the marginal cultivator (25 percent) and in marginal agriculture (25 percent). More than 50 percent of the female population comes under the non-working population (Fig.-5.4). Participation of the women in the main workforce is more than the marginal workforce. Compared to the marginal workforce, the participation of the people in the main workforce is very high reaching 75 percent. The main occupation of the village is the cultivation as more than 30 percent of the population is involved in the main cultivation. By adding marginal cultivators the participation to the total population is more than 35 percent. Marginal workforces under the category of 3 to 6 months are having more shares in the total marginal workforces (Fig.-5.5).

Findings of Primary Survey: 50 household surveys have been conducted in the village Bagundi, out of which 18 interviews taken from the large farmers, 24 from the small and medium farmers and 8 from the marginal farmers (Table-5.7). Education among the large farmers is comparatively high to the marginal and small and medium farmers. In the sampled respondents, there is no marginal farmer who is educated to the graduate level (Fig.-5.7 (A). Due to more of the deserted land, the people rarely see the inundated land in the village, though there is some evidence of surface runoff during the monsoon season in the years when they receive rainfall. Due to the groundwater level being comparatively on the upper layer, the salt content of the soil can be seen in the village (FGD-3 in Bagundi Village and Plate-5.7 [B]). Soil quality is very bad to worse because of the soil salinity (*khara mitti* in local term) (Plate-5.4 (b), which is very high in the village (FGD-3 and FGD-4 in Bagundi Village). At the same time, the access to irrigation is not found very well in the region, while some of the large farmers (25 percent) and small and medium farmers (8 percent) have access to irrigation facilities through tube well (Table-5.4). Like Dodhwa, vegetation is very sparse in this village too.

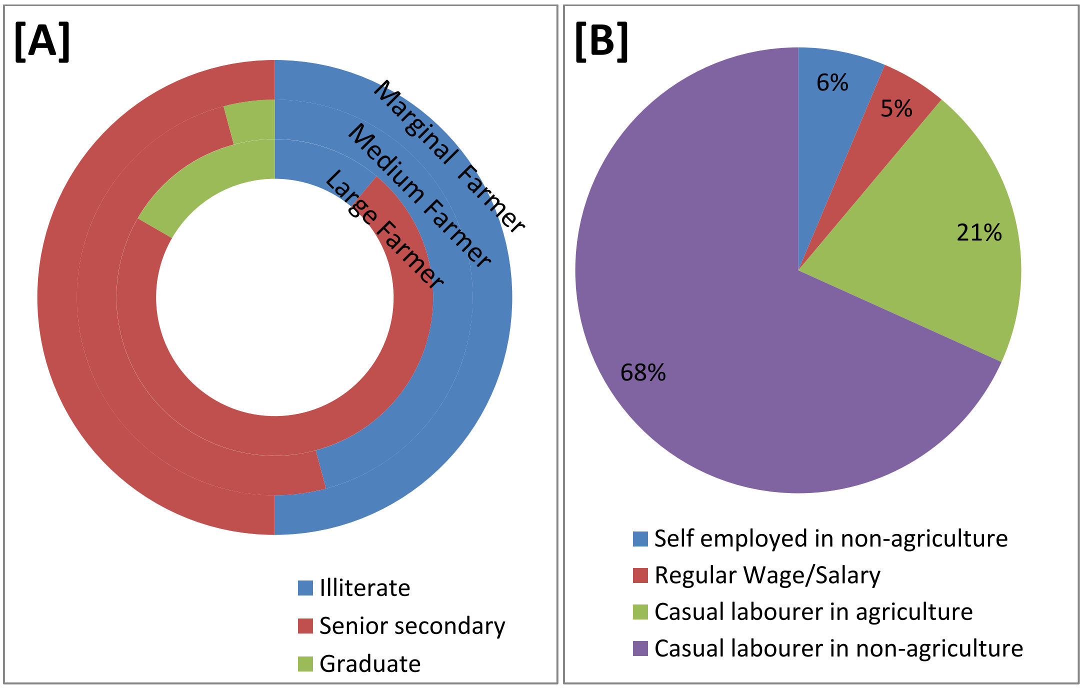


Fig.-5.7 (A) Education level among the sampled Farmers and (B) Occupation of the sampled farmers other than the farming in their own land in the Bagundi Village
Source: The graph prepared by the author by using the data collected from a primary survey in March 2017.

The interviewed farmers are totally dependent on the agriculture for the livelihood, and 8 percent of the respondents are self-employed in the non-agricultural, 6 percent have been receiving the regular wage or the salary, 26 percent are the casual labourer in agriculture and 86 percent is a casual labourer in non-agriculture, which is very high (Fig.-5.7 (B). All the respondent are having the livestock for their livelihood as the region is coming under semi-arid region and the production out of the land is mostly used for the consumption purposes. Very diverse type of livestock has been found in the fieldwork comprising sheep, goats, buffalos, cows and camel as the same has been seen in the Doodhwa Village (Plate-5.6). Because as the land is not being so productive, thus respondents do not prefer to cultivate on the others land because it is not feasible. The earnings from the labourer works would facilitate to buy the grains from the market for their livelihood (FGD-4 in Bagundi Village).

Though all the respondents have been involving into the cultivation in their land, they do farming, not in all the land (Table-5.7) which they hold it because of its high soil salinity which leads to not so productive (FGD-4 in Bagundi Village). The rotation of the farming on the land has been witnessed into the village especially by the large landholders (FGD-3, in Bagundi Village) because of huge availability of the land (Table-5.7), which help them to keep the land productive and fallow land used for the grazing of animals (FGD-4, in Bagundi Village). Moreover, the large farmer has been able to get some profit on the investment to the land compared to the small and marginal farmers. Almost 55 percent of the sampled large farmers are able to manage profit out of the farming (Table-5.7). Additionally, the large farmers compared to the other type of farmers able to sell their product in the market e.g. almost large farmer either manage to sell <25 percent or 25-50 percent of their product. While the majority of small and medium farmers manage to sell <25 percent of farm products and marginal farmers have not able to sell (Table-5.7). The marginal farmers have been even not meeting their yearly need through the farming; they need to work outside mostly as a casual labourer for the better livelihood (Fig.-5.7 (B) and FGD-4 in Bagundi Village).

Most of the respondents (96 percent) have been involved into the mixed farming meaning working in agriculture as well as livestock (Table-5.8) because in the village soil quality is very bad because of the presence of the soil (Table-5.9). Respondents (100 percent) (Table-5.8) found difficulty in using their land because of soil salinity and it's relatively unproductiveness with the difficult climatic condition with the non-availability of the irrigation facilities (Table-5.8 and FGD-3 in Bagundi Village). The presence of salt makes the soil hard locally the respondent in the FGD-3 in Bagundi called it as *"Papadi Mitti"* (Plate-5.8). According to the respondents, the land is as productive as it was earlier (54 percent) and 46 percent respondent has been registered that the productivity of the land has been decreased from earlier (Table-5.7). More so, 88 percent of respondents have mentioned that the soil fertility from the past has been decreased. Soil composition has also recorded the change in terms of being bad from earlier (66 percent respondents) (Table-5.7).

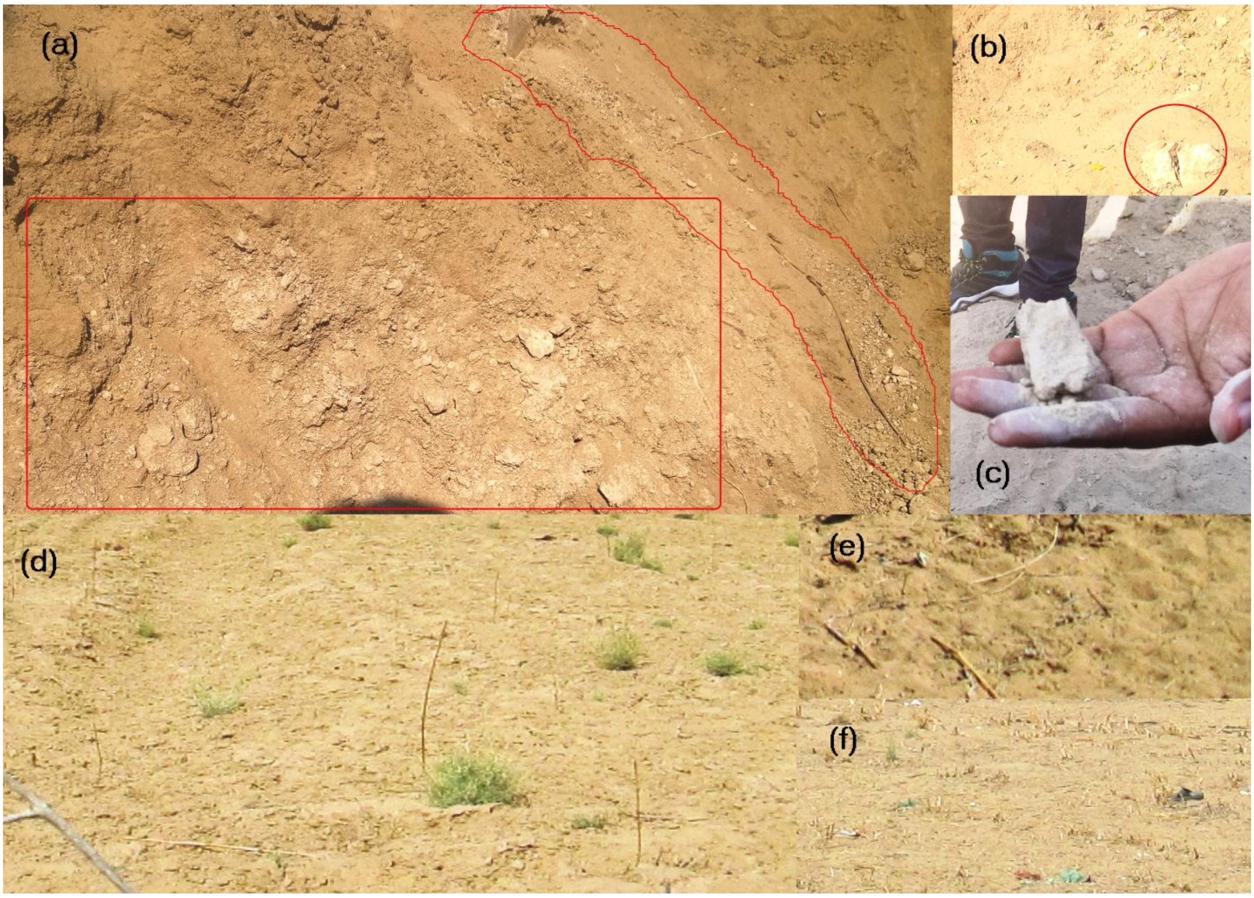


Plate-5.8 Salt content in the soil layer can be seen in picture- (a), (b) and (c), which shows of it being more saline visibility (taken at Bagundi Village). Picture-(d), (e) and (f) are the soils from Doodhwa Village, the soil there is more of sandy and soil moisture is less compared to the Bagundi.
Source: Photograph taken by the author during the field visit in March 2017.

All the respondent have articulated of having salt content into their agricultural land e.g. low salinity (8 percent), moderate salinity (26 percent) and high salinity (66 percent) (Table-5.9).

Table-5.7 General agricultural profile of the sampled respondents of the Bagundi Village of the Pachpadra Tehsil (based on the answer of respondents)							
		Education of the farmers (in numbers)			Land Holding and farming land (%)		
	Sample interviews (No.)	Illiterate (No.)	Senior secondary (No.)	Graduate (No.)	Average land holding size	Average land used in farming	Access of irrigation sources (%)
Large Farmers	18	2	13	3	32	15	25
Medium farmers	24	11	12	1	6	5	8
marginal farmers	8	4	4	0	1.5	1.5	0
Return on investment (% of the respondents)				Sell of the share of the total output (% of the respondents)			
	Total Agricultural Input cost only	Total more than Agricultural Input	Total less than Agricultural Output	0-25 %	25-50 %	50-75 %	75-100%
Large Farmers	42	55	3	45	48	7	0
Medium farmers	52	14	34	86	14	0	0
marginal farmers	48	2	50	0	0	0	0
Source: Calculated by the author from the primary survey data collected during March 2017.							

Table-5.8 Characteristics of the agricultural land of the farmers (sampled respondents) in the Bagundi Village (in percentage to the sampled respondents)				
Mode of work in Agricultural Land Yes		Land Used For Another purpose		
1. Agriculture only	2	Type	Yes	No
2. Agriculture and Forestry	0	1. Digging of soil from the field	0	100
3. Agriculture and Animal Husbandry	96	2. Mining around the land	8	92
4. Agriculture, forestry and Animal Husbandry	2			
5. Difficult to use land	100	Input into the land (since five years)		Yes
6. Other	0	i. Decrease in irrigation facility		36
		ii. Equal irrigation facility		62
Secondary Occupation	Yes	iii. Increased irrigation Facility		2
Employed in agriculture	100	iv. More fertilizer used		50
Self-employed in non-agriculture	8	v. Equal fertilizer used		42
Regular Wage/Salary	6	vi. Less fertilizer used		8
Casual labourer in agriculture	26	vii. HYV seeds are used		28
Casual labourer in non-agriculture	86	viii. No awareness		36
Others, Specify	0	ix. less awareness		8
		x. More organized agriculture		64
		xi. less organized agriculture		36
Land productiveness (compare to five year	Yes	xii. More labour involved		26
a)More productive	0	xiii. Less or equal labour		84
b)Productive as earlier	54	xiv. Pesticide used		22
c)Less productive	46	Soil composition changed (since five years)		Yes
Soil fertility since five years	Yes	i. Good from earlier		2
Decreased	88	ii. Bad from earlier		66
Equal	8	iii. Very Bad from earlier		12
Increased	4	iv. Worse from earlier		20
Source: Calculated by the author from the primary survey data collected during March 2017.				

The respondents have the assumptions that the salinity is high due to high temperature (100 percent), low rainfall (100 percent), lack of irrigation facility (100 percent), lack of fresh water (100 percent), irrigation through saline water (100 percent), lack of awareness about the scientific way of agriculture (36 percent), absence of traditional agriculture (26 percent), Non-scientific (Faulty) agricultural practices (26 percent), lack of drainage facility (12 percent), use of chemical fertiliser (6 percent) and irrigation by the saline water without proper distribution on the field (6 percent) (Table-5.9).

Table-5.9 Characteristics of the soil salinity in the Bagundi Village based on farmers perception (in percentage to the total sampled respondents)			
Cause of Soil Salinity	Yes	Salinity experienced	Yes
i. High temperature	100	No salinity	0
ii. Low rainfall	100	Low	8
iii. Non-scientific (Faulty) agricultural practices	26	Moderate	26
iv. Lack of irrigation facility	100	High	66
v. Lack of Freshwater (saline free)	100		
vi. Irrigation by the saline water without proper distribution on the field	6		
vii. Lack of awareness about the scientific way of agriculture	36	Migration	Yes
viii. water-logging	0	Short term (<3 months)	12
ix. Lack of drainage facility	12	Medium Term (3-6 months)	32
x. overuse of chemical fertiliser	6	Long-term (> 6 months)	28
xi. absence of traditional agriculture	26	Permanent migration	2
xii. Irrigation through saline water	100	Total	74
Source: Calculated by the author from the primary survey data collected during March 2017.			

Out of the sampled respondents, the migration is reaching to 74 percent of total respondent, out of which 12 percent for the short-term (<3 months), 32 percent for Medium term (3-6 months), 28 percent for long-term (>6 months) and 2 percent are going out for the permanent migration (Table-5.9). The causes of the migration are majorly related to high soil salinity, in turn, a low profit from the agriculture, but additionally, there are some other reasons which lead to the migration e. g. profit on investment in other jobs, the same land is not enough to support the family requirement, more surety of life in other jobs etc. (FGD-4 in Doodhwa Village).

5.3.3 COMPARATIVE ANALYSIS OF SOIL SALINITY STATUS IN CASE STUDY VILLAGES

The comparative analysis between the villages has revealed some contrasting as well as similar facts. As the village Doodhwa respondents have asserted that the livelihood is not solely driven by the agriculture-only (Fig.-5.8 (a). Similarly, the respondents of the village Bagundi have the same type of involvement in terms of the mode of work with some exception (Fig.-5.8 (b). Forestry is not preferred work in both the villages (Fig.-5.8 (a) and (b), it probably because of the climatic condition as well as the sandy soil and lack of moisture present in the soil. The only natural vegetation has grown in their agricultural land, not the planted one (FGD-1 and FGD-3).

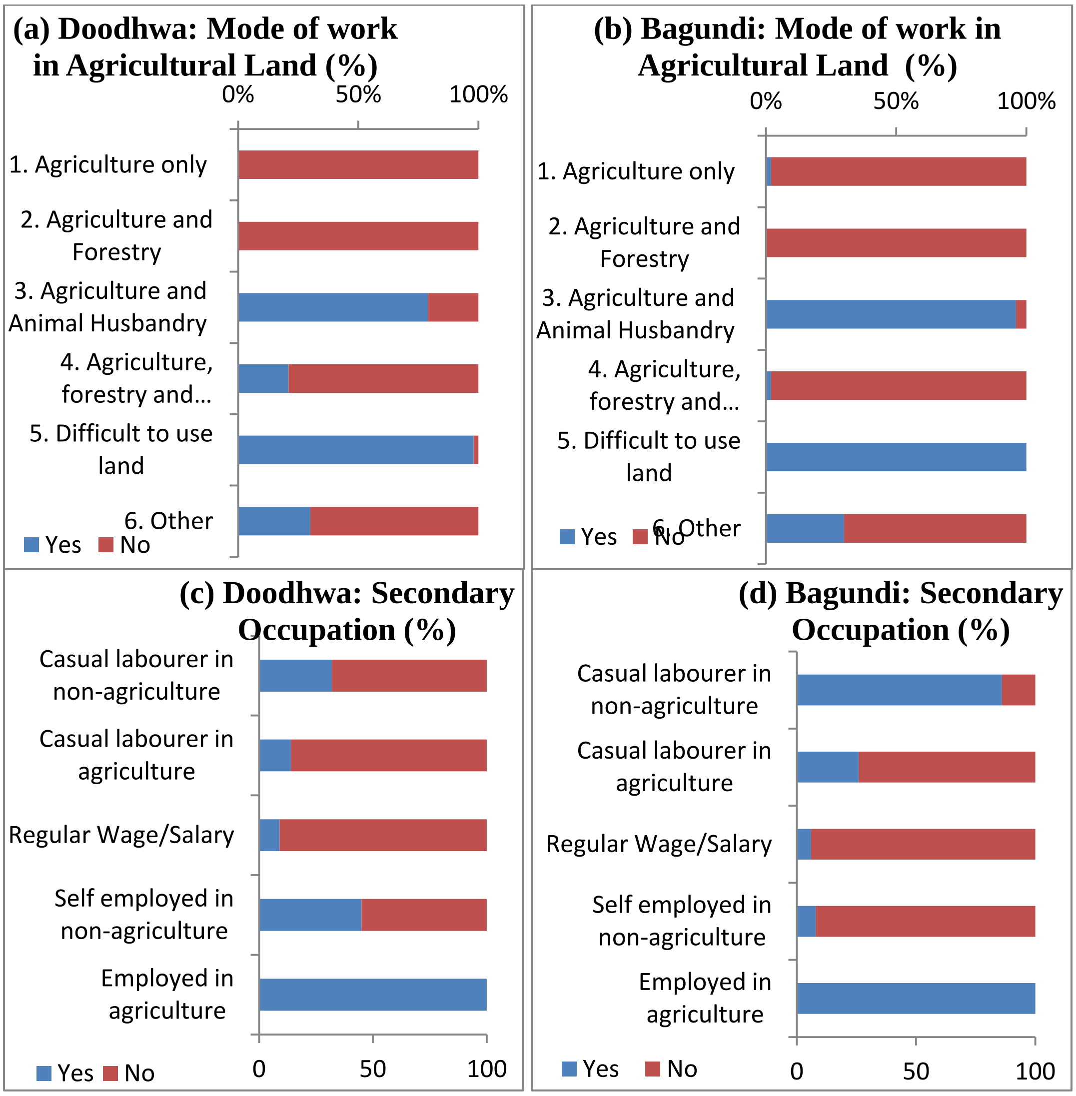


Fig.-5.8 Comparative between the Doodhwa and Bagundi on the basis of occupation

Source: Presentation through graph by the author using the primary survey data collected from the selected respondents of both villages during March 2017.

Majority of land was preferred to use for the both the agricultural and livestock purposes in both villages. Every respondent has found to difficulty in using the land in

Bagundi (100% respondent), while in Doodhwa almost 98 % respondents have registered difficulty in using the agricultural land (Fig.-5.8 (a) and (b).

Though all the selected households have involved in the agricultural practices, the most respondents have been asked for the secondary occupation beside the agriculture. In Bagundi more respondents have involved in casual labour in agriculture and non-agriculture compared to the Doodhwa. However, Doodhwa Village respondents have more self-employed respondent in non-agricultural areas compared to the Bagundi (Fig.-5.7 (c) and (d). It is so because though both the villages are located along the roadsides but the more people have preferred to open shops to the nearby "*Chauraha*" (A central place where four roads meet at a point).

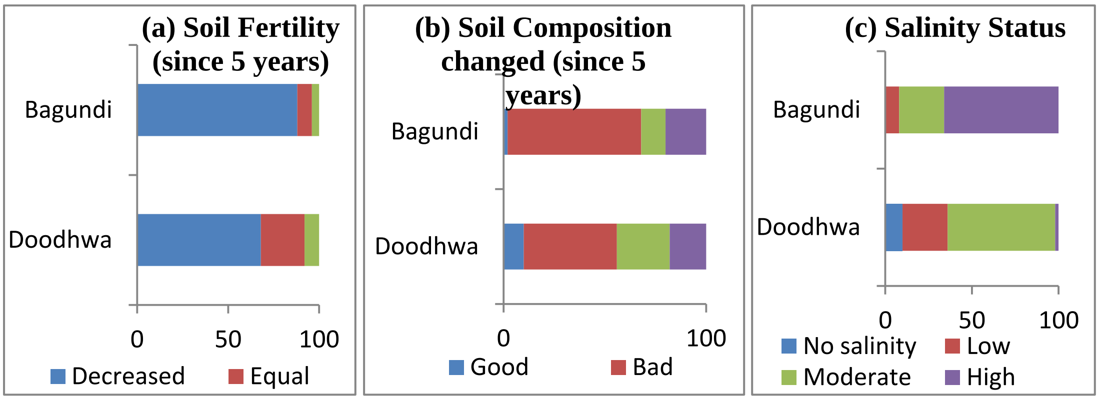


Fig.-5.9 Soil quality status in the village Doodhwa and Bagundi

Source: Presentation through graph by the author using the primary survey data collected from the selected respondents of both villages during March 2017.

The soil quality status has been asked of the respondents. It was found that the respondents of Bagundi have experienced more decreased the soil fertility than Doodhwa. While compared to Bagundi more respondents of Doodhwa feels that their land fertility is intact. However, the majority of the respondents in both villages have experienced the decline in fertility. Conversely, there are respondents in both villages have felt the increase in the fertility over a period of time. When was asked for the reason for the same during FGD-2 and FGD-4, it is found that some section of the respondents have access to the facilities like HYV seeds and Fertilizers from the cooperatives (Fig.-5.4 (a).

The perception of the soil composition varies among the respondents. Equally respondents from the villages agreed on the worse composition of the soil. The bad composition of the soil has been slightly more in the Bagundi compared to Doodhwa because only one respondent variation is recorded (Fig.-5.9 (b). Regarding the salinity status, mostly feels in both the village that it is moderate to high. However, too fewer respondents at Doodhwa have admitted very high salinity (Fig.-5.9 (c). This is because the common peoples believe there that their soil has sweetness (Meetha Miiti) (FGD-2).

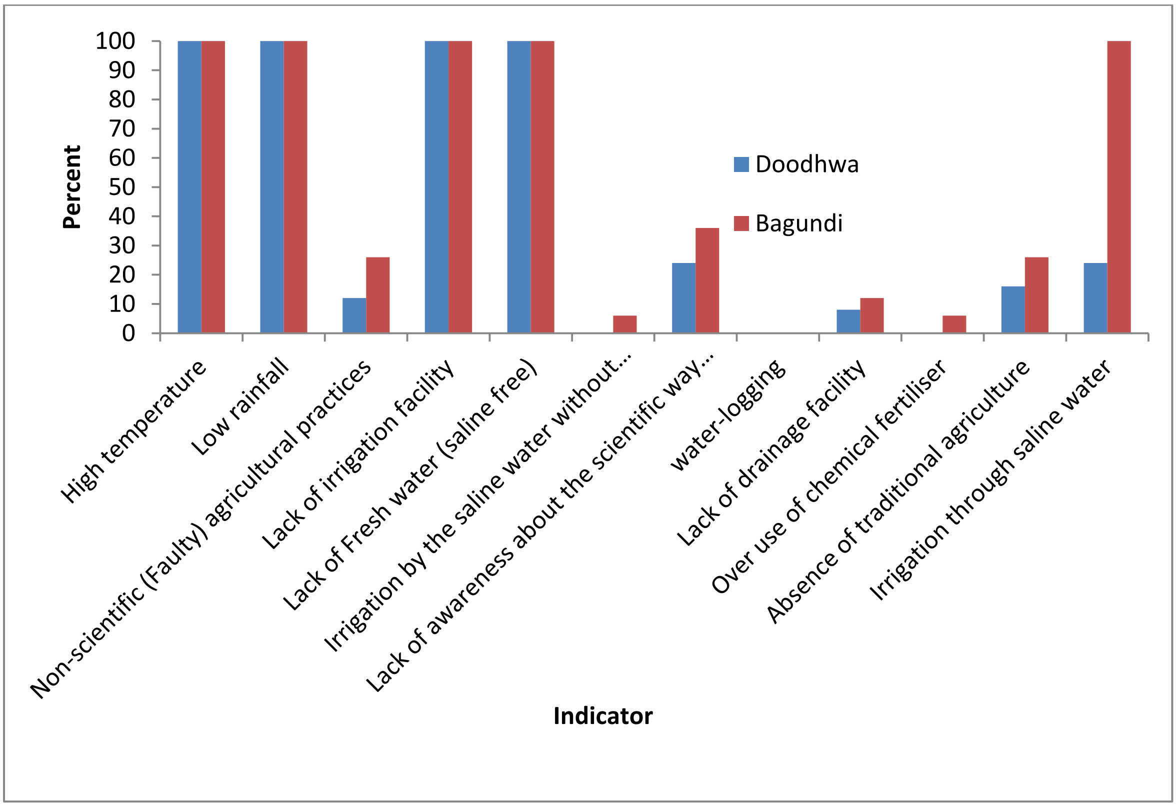


Fig.-5.10 Perception regarding soil salinity by the respondents in village Doodhwa and Bagundi based on their understanding n the land.

Source: Presentation through graph by the author using the primary survey data collected from the selected respondents of both villages during March 2017.

The causes of soil salinity for soil is according to all respondents in both the villages are high temperature, low rainfall, lack of irrigation facility and lack of fresh water (Fig.-5.10). Compared to Doodhwa, more respondents of Bagundi have also mentioned other reason for the salinity e. g. non-scientific agricultural practices, irrigation by the saline water without proper distribution on the field, lack of awareness about the scientific way of agriculture, lack of drainage facility, overuse of chemical fertiliser, the absence of traditional agriculture and irrigation through the saline water.

5.4 CONCLUSION

Rajasthan is one of the prominent regions in India where soil salinity/alkalinity occurred due to natural causes. The state holds almost 10 percent share of total soil salinity area of entire India in the year 2011-13 amounting 363768 hectare areas under the soil salinity (NRSC, 2016). The analysis of the area has shown that the deserted nature of physiography has contributed towards its intensity. The overall conclusion is listed as follow:

1. Degraded land in Rajasthan is majorly concentrated in extreme eastern and extreme western part of the state, while scenario for the soil salinity/alkalinity is very different due to it peculiar formation. The concentration of soil salinity/alkalinity lies into middle and southern-middle part of Rajasthan accounting 2.17 percent of TDA. Barmer District has recorded highest soil under salinity/alkalinity effects.

2. Vegetation distribution is very sparse and uniformly distributed with low vegetation cover except for some concentration into the eastern part of Barmer, where some ruminant of Aravali range is present. Distribution of NDVI, SAVI and NDSI of Barmer can be interlinked spatially (Map-5.4).

3. Pachpadra located into the eastern part of Barmer has the highest soil salinity problem reflected into the satellite imagery analysis through NDVI, NDSI and SAVI. This region also has the least presence of biomass in terms of vegetation (Map-5.4 and field visit observations). The native trees like *Khejri* have been dying, which was not only environmentally important but contained the cultural and economical importance (FGD-1 and FGD-3).

4. In Pachpadra, central regions have been more affected by soil salinity and alkalinity, which is having a predominantly Aeolian origin. In the central region, there has been a drastic increase in grazing land from 2005-06 to 2015-16. The region is also having cattle rearing one of major livelihood means. Hence, the increased grazing leads to the more bare soil to come under direct contact with high temperature prevailing resulting in more evaporation. The visual representation was able to demonstrate that the relation between less vegetation with the soil salinity. More importantly, the chapter-4 has also established that the under-utilised/degraded forest,

degraded land under pasture and plantation and soil salinity/alkalinity has a negative relationship with the agricultural productivity (Table-4.2).

5. Doodhwa Village, which is relatively less salinity affected village, is having mixed education status of farmers which are interviewed. Almost 45 percent interviewed farmers has preferred for self-employment into non-agriculture due to non-benefitting agriculture despite having the large holding size. Majority land left fallow for more than one year. Large farmers are more beneficial compared to small farmers and able to sell significant output from agriculture. Animal husbandry in agriculture is main dominated activities. Sole agriculture has not even preferred by selected large farmers. Input costs have increased over a five-year term.

6. However, the Bagundi Village, which highly affected with soil salinity, has recorded majority large farmer are illiterate, while marginal farmers have mixed results. But some large farmers are graduated. Here majorly interviewed farmers also worked as casual labour into the non-agricultural sector. All the interviewed farmers found difficult to use for agriculture. Some photographs have recorded salt content onto the surface as well as the top layer of the soil. In this village also, the input into agriculture has been increased in the last five year like village Doodhwa. Therefore, it can be said that say that the quality of the land has a strong influence of development and to opt a livelihood means of the village, which some time promote migration.

7. While the comparative study of both the village reveals that soil fertility has decreased since last five year. But more respondents of the Bagundi Village have agreed on compared to the Doodhwa Village. Similarly, more respondents said about the changes regarding soil composition. Further, regarding soil salinity status, all the respondents in Bagundi Village responded to some or other level of salinity in their fields and majority witnessed the high soil salinity level. In contrast, some respondents in Doodhwa Village have witnessed no salinity in their land and majority agrees with a moderate level of soil salinity.

8. Overall, all respondents in two Villages have agreed that high temperature, low rainfall, lack of irrigation facility and lack of fresh water are prominent factors for the soil salinity in the selected area of study. While other minor reasons have recorded by respondents are non-scientific (faulty) agricultural practices, irrigation by saline

water, lack of awareness, and lack of drainage facility, overuse of chemical fertilizer and absence /declining traditional method of farming.

CHAPTER-6

SOIL SALINITY STATUS: STUDY OF PUNJAB

6.1 INTRODUCTION

Fortunately, the state has contributed immensely to the Indian course of development without any doubt in general and to the Indian agriculture in particular. The contribution of Punjab has been counted as more than 83 percent land under cultivation, contributing the majority of central grain pool. The state has been gifted with the five perennial rivers (Sutlej, Beas, Rabi, Chenab and Jhelum) naturally and agricultural structural facilities under green revolution as well as agricultural infrastructures like irrigation etc. All these combined has resulted in cropping intensity at the level of 190 percent in 2009, 86 percent cropped area, 98 percent of it under irrigation (Planning Commission, 2013). Undoubtedly, all these have been very good but not without negative externalities. The problem of waterlogging and soil salinity has become very severe to Punjab (Planning Commission, 2013; Sekhon, 2014; Panday, 2014). The drainage pattern of Punjab is towards the south-west direction in general and soil salinity problem has been recorded in those districts which are suffered not only with the waterlogging problem but also the overuse of irrigation system (Shakya and Singh, 2010).

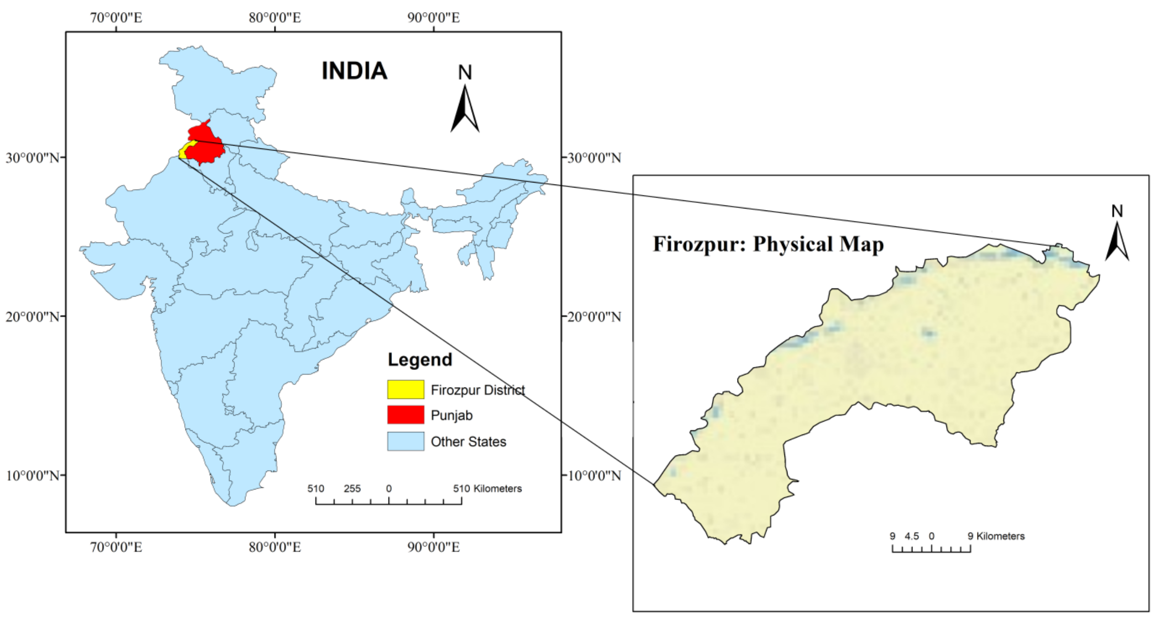
Notably, this chapter has dealt with the objective of assessment of land degradation and soil salinity or alkalinity within Punjab in general and in Firozpur District in Particular.

6.2 STUDY AREA

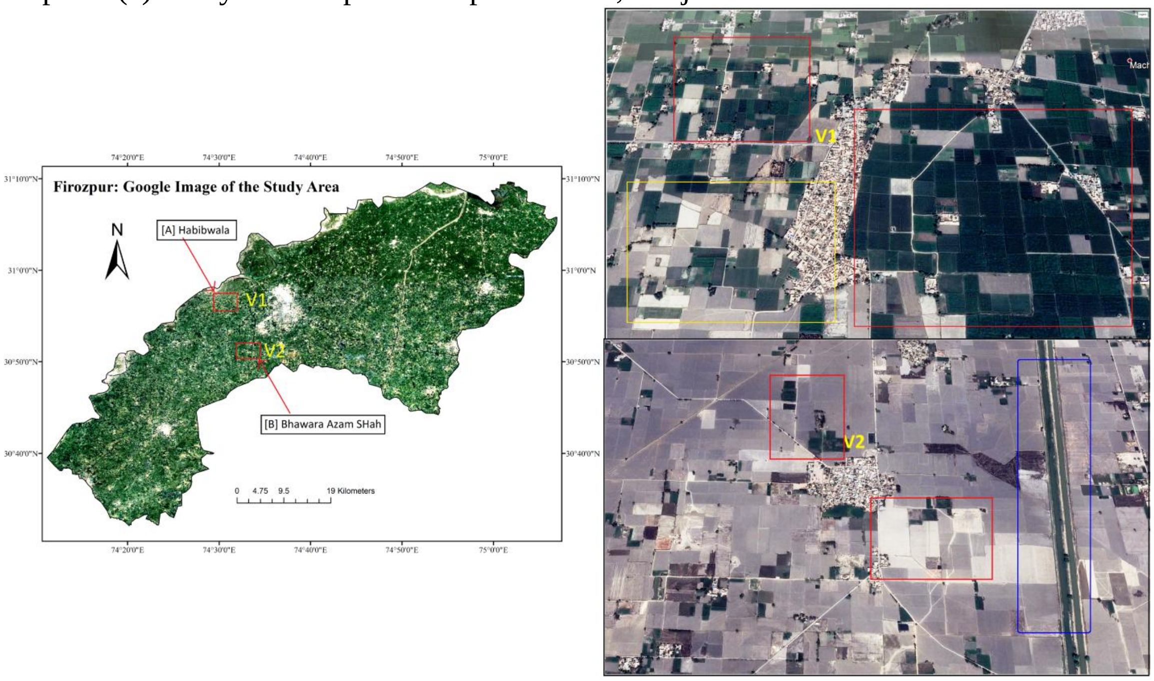
The Firozpur District of Punjab has been situated on the south-west side of Punjab state and it is drained by the Sutlej River. Its extent starts from $30^{o}55^{'}$ $35^{''}$ N and $74^{o}36^{'}36^{''}$ E (Map-6.1 (a). the elevation of the Firozpur District has been recorded as 182 meters from mean sea level. The climatic condition of Firozpur District is characterised by hot summer with short rainy winter. Agro-climatically, as Punjab comes under Trans-Gangetic Plain Region (Planning Commission, 2006), likewise, Firozpur District comes under Western Plain Zone under the agro-climatic classification of Punjab (Department of Revenue, Government of Punjab website, 2018[1]). American cotton is the dominant crop in the region followed by bajara. Now-a-day paddy is emerging as new crop into the region during Kharif season. Wheat has

[1] http://punjabrevenue.nic.in/for%20website/agro-climatic%20zone.htm

been traditionally dominating crop during the rabi season. Average summer temperature has been recorded as 29.7^{o}C, while it drops to 16.9^{o}C during winter. The average rainfall has been registered as 731.6 milliliters.



Map-6.1 (a) Study area map of Firozpur District, Punjab



Map-6.1 (b) Location of study area of the villages selected from the Firozpur Tehsil of the Firozpur District: V1- Habibwala Village, which is not saline affected (intensive agriculture is marked with red colour, sparse or two-cropped commercial agriculture with yellow colour) and V2- Bhawara Azam Shah Village, which relatively high salinity affected villages(saline area marked by red colour and canal demarcated with blue colour)

Source: Map designed and generated by the author through various sources like Google Earth images dated 30 November 2017 and Bhuvan Thematic Service

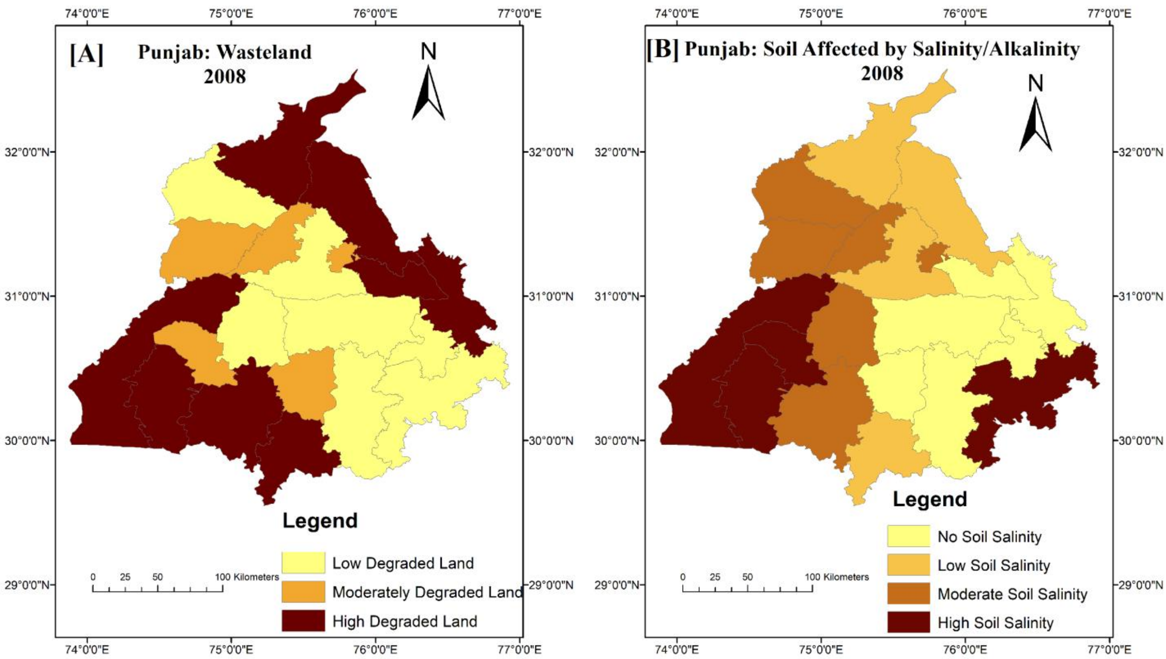
For the study at micro-level two villages from Firozpur Tehsil has been selected- Habibwala (demarcated by V1 in Map-6.1 (b) and Bhawara Azam Shah Village (demarcated by V2 in Map-6.1 (b). Village Habibwala selected as non-salinity/low salinity village, while Bhawara Azam Shah Village is the soil salinity affected village. The distance between the two villages is around 16-18 kilometers. The extent of Habibwala Village is 30°56'34.67"N and 74°31'1.26"E with the household of 532 and population of 2909 (Census, 2011) (Map-6.1 (b). Moreover, the village Bhawara Azam Shah is located on the latitude of 30°51'15.80"N and longitude of 74°33'1.84"E and it is having a household of 430 with 2267 population (Census, 2011).

6.3 RESULT AND DISCUSSION

The Punjab State is having 1.86 percent areas under wasteland to its Total Geographical Areas (TGA). Moreover, the areas under different types of sand degradation contribute highest to the Total Degraded Land (TDA) followed by land with scrub, waterlogging/marshy land, gully/ravines etc. However, when it comes to Firozpur District, it has 2.02 percent of TGA under various degradation types. The degraded area under sand (wind erosion) and land affected with salinity/alkalinity have a large share Firozpur amounting 68.75 percent and 15.86 percent of TDA and 1.39 percent and 0.32 percent of TGA respectively (Table-6.1) (Fig.-6.1).

All the districts of Punjab have been degraded with some types of wastelands problem. Primarily, eight districts are highly degraded spreading into north-eastern and south-western part namely- Rupnagar, Muktsar, Bhatinda, Hoshiarpur, Shahid Bhagat Singh Nagar, Mansa, Gurdaspur and Firozpur (Map-6.2 [A]).

Soil salinity is a very severe problem in Punjab in general and Firozpur in particular (Planning Commission, 2013; Sekhon, 2014; Panday, 2014). 52.15 km^2 areas have been witnessed of the influence of soil salinity/alkalinity in Punjab and as high as 35 percent (18.71 km^2) of the whole land affected with salinity/alkalinity has been recorded only in Firozpur District (NRSC, 2011). 6 percent of TDA and 0.10 percent of TGA of Punjab has been under salinity/alkalinity affected. Extensively, the Firozpur District proportionately highly affected. In this case, 15.86 percent area of TDA and 0.32 percent areas of TGA have been under the effect of salinity/alkalinity (Table-6.1 and Fig.-6.1). Other than Firozpur, the districts like Muktsar, Patiala and Faridkot are highly salinity affected districts (Map-6.1 [B]).



Map-6.2 Spatial distribution of [A] land degradation and [B] Soil salinity/alkalinity in Punjab

Source: The map has been generated by the author by using the data taken from the National Remote Sensing Center, ISRO, in the year 2008.

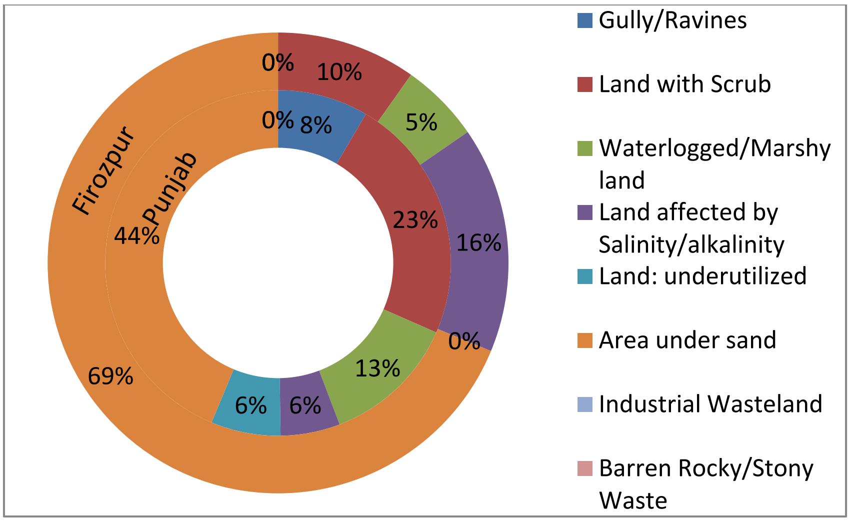


Fig.-6.1 Representation of the resemblances of the land degradation types in Punjab and Firozpur

Source: Prepared by the author by using the data provided by the author using NRSC data-2008

Table-6.1 Share of the different types of land degradation- 2008 (in percentage)				
Wasteland	**Punjab (Share in TDA)**	**Firozpur (Share in TDA)**	**Punjab (Share in TGA)**	**Firozpur (Share in TGA)**
Gully/Ravines	8.48	0	0.16	0
Land with Scrub	23.10	9.79	0.43	0.20
Waterlogged/Marshyland	12.62	5.59	0.23	0.11
Land affected by Salinity/alkalinity	5.57	15.86	0.10	0.32
Land: underutilized	6.52	0	0.12	0
Area under sand	43.71	68.75	0.81	1.39
Industrial Wasteland	0	0	0	0
Barren Rocky/Stony Waste	0	0	0	0
	100	100	1.86	2.02

Source: Wasteland Atlas of India, NRSC, 2011

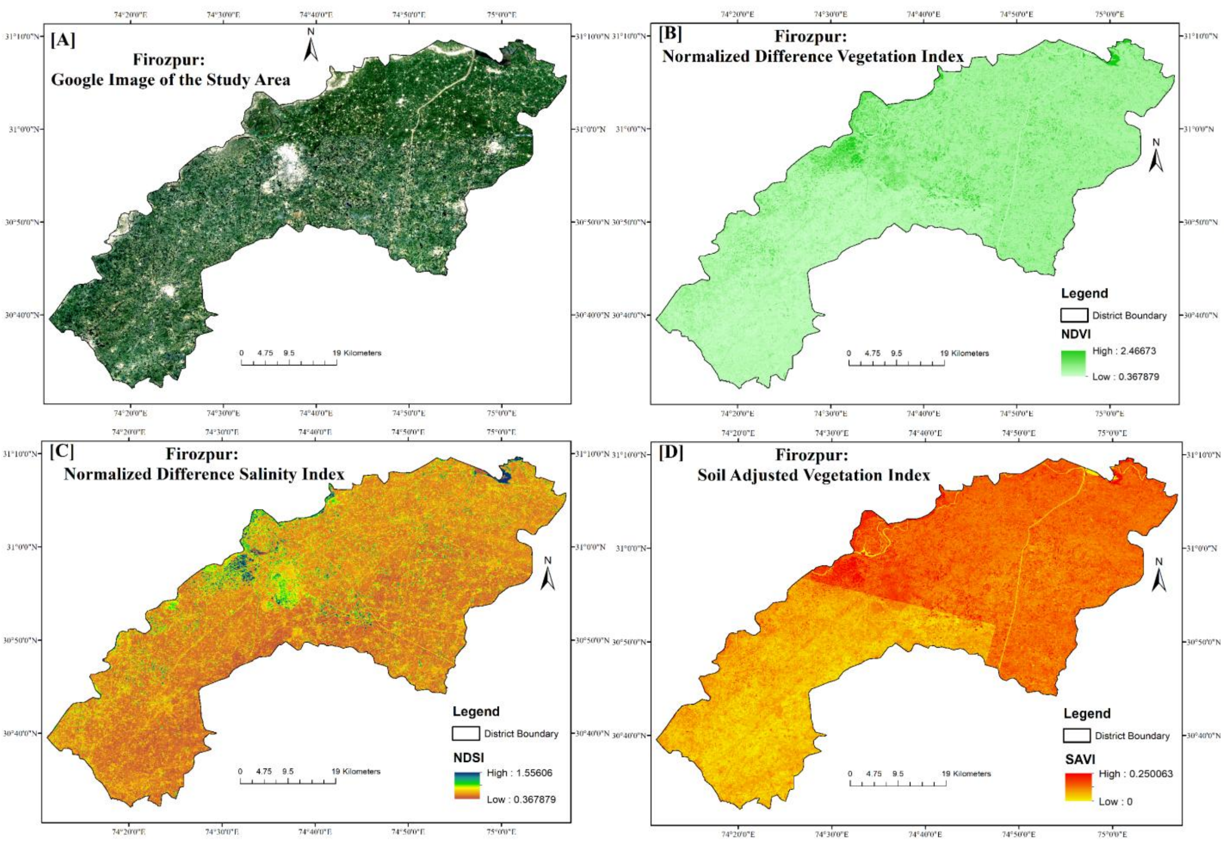
The district of Firozpur is characterised by very low vegetation as indicated by the Normalised Difference Vegetation Index (NDVI). Central regions near the Sutlej River adjoining the border areas are having some evidence of vegetation cover (Map-6.3 [B]). According to Forest Survey of India Report (2015), the Firozpur District has been devoid of *"Very Dense Forest"*, has only 5 km^2 under *"Moderately Dense Forest"* and 24 5 km^2 under *"Open Forest"*. All categories have been accounting only 0.49 percent areas to TGA of the district. Overall, in 2017, the district has recorded no change in total forest cover (FSI, 2017).

Moreover, According to Normalised Difference Salinity Index (NDSI) has revealed that the soil salinity has concentrated in the same zone of significantly high vegetation cover areas (Central regions near the Sutlej River adjoining the border areas) (Map-6.3 [C]). Even at the macro level, it cannot be said that the vegetation has one major factor for the soil salinity existence; it is only the secondary factor. The waterlogged areas have been identified in the same region (Map-6.4 [B]), where soil salinity concentration has been recorded (Map-6.3 [C] and Map-6.4 [C]). Moreover, geomorphologically the region is a low lying area (Map-6.4 [A]), which provides a conducive surficial condition for the waterlogging.

Simultaneously, the anthropogenic interference, especially agricultural infrastructure development e.g. irrigation infrastructure too, has been another factor which visually seems much correlated to the existence of soil salinity/alkalinity into Firozpur District. To demonstrate the same, it can be visualised that the canal expansion from the Sutlej River to central Firozpur areas are very high (Map-6.4 [D] and [E]).

Moreover, the Firozpur District has 298510 hectares area under Gross Cropped Area (GCA) and 152400 hectare is under Net Sown Area (NSA), subsequently, the Net Irrigated area is almost 100 percent accounting 298410 hectare under irrigated and only 100 hectare in unirrigated in the year 2011. Similarly, the Firozpur Tehsil has accounted more than 99 percent area under irrigation with various sources (Agriculture Census, 2011).

Irrigation status since 1995-96 to 2010-11 has changed drastically at three administrative level. Irrigated area has been expanded by 2.14 percent in Punjab, declined by 32.37 percent in Firozpur District and shrink by 16.90 percent in Firozpur Tehsil (Fig.-6.2 [A]). Interestingly, NSA of these administrative levels has gone down by 3.52 percent, 32.52 percent and 16.73 percent respectively [for the mentioned three administrative unit] since 1995-96 to 2010-11 (Table-6.2).



Map-6.3 [A] Google image of the Firozpur District-2017, [B] Map representing the NDVI in the Firozpur District-2016, [C] Map representing the NDSI in the Firozpur District-2016 and [D] Map representing SAVI for the Firozpur District-2016.

Source: The map prepared by the author by using a various band of Landsat-8 imageries provided by the USGS through the url:https://glovis.usgs.gov/app?fullscreen=1, the images acquisition dates were of 26th May 2016 and 4 June 2016 to cover the whole area of Firozpur, Punjab

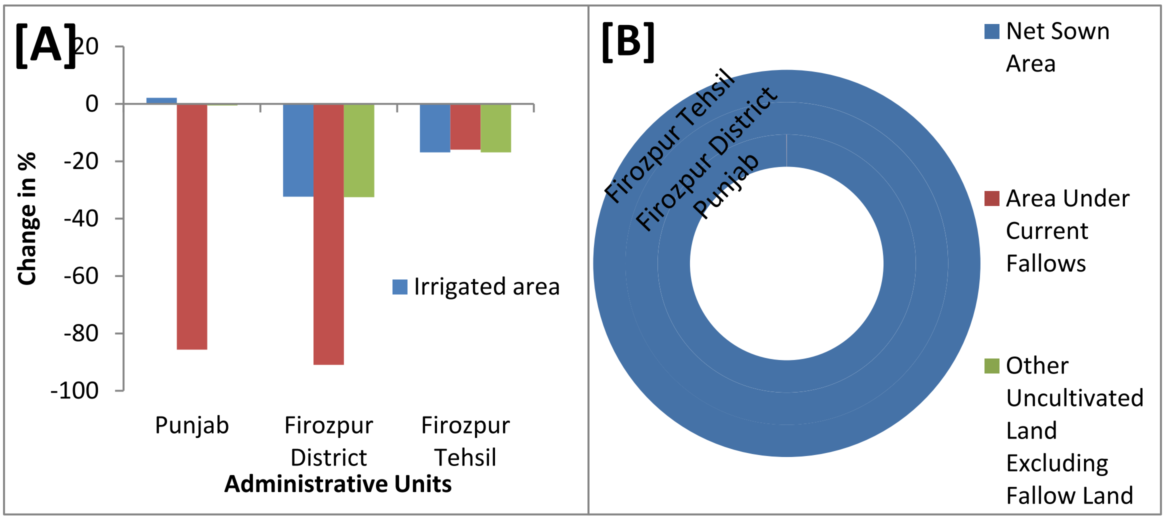


Fig.-6.2 [A] Change in cropping pattern from 1995-96 to 2010-11 and [B] Land-use pattern in the year 2010-11

Source: The graph is designed by the author by using the data provided by the Agriculture Census on various agricultural inputs and the land use pattern.

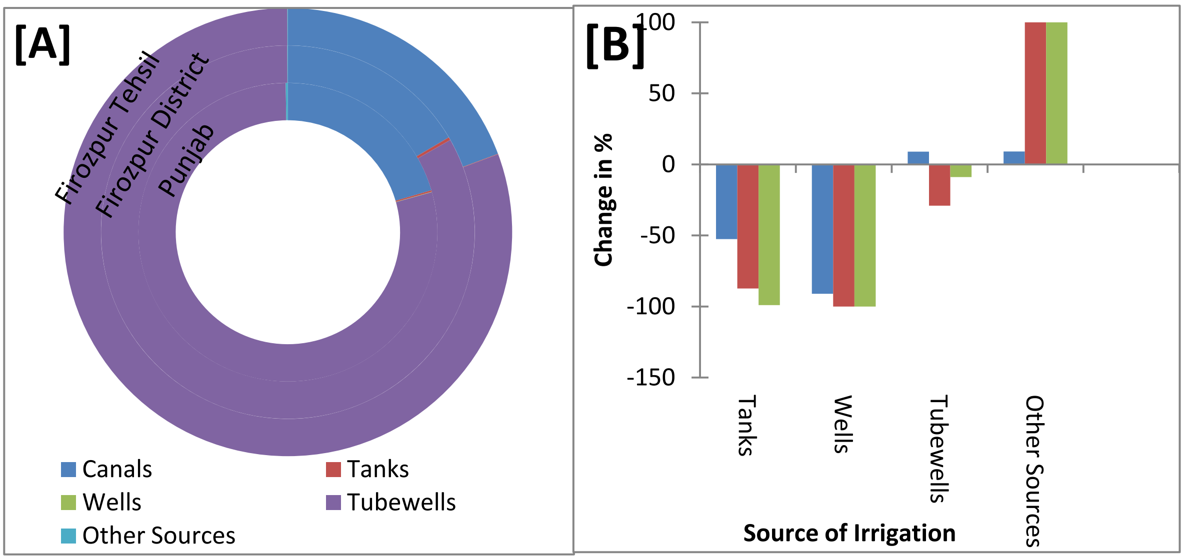


Fig.-6.3 [A] Areas irrigated through different sources in the year 2010-11 and [B] Changes in the irrigated area under different sources from 1995-96 to 2010-11

Source: Graph has been constructed by the author by using data taken from the Agriculture Census of India

As many studies (Datta and Jong, 2002; Fan et al., 2012; Daliakopoulos et al., 2016) have revealed that over-irrigation being one of the major culprits for the soil salinity into agricultural land. The availability of irrigation has been near 100 percent in the state. The major irrigation source at every administrative level of Punjab state, Firozpur District and Firozpur Tehsil had been Tubewells followed by canals (Table-6.3 and Fig.-6.3 [A]). Over-exploitation of groundwater has been an emerging cause for the soil degradation of Punjab (Times of India, 2013) as a whole, because of the majority of farmers opted for the tube wells as irrigation source (Figur-7 [A]). However, there are some positive signs for the tube wells and canal being used by farmers. The canals and tube wells have shown declined in Firozpur District since 1995-96. Thus, farmers are opting for other sources (Fig.-6.3 [B] e.g. micro-irrigation.

Table-6. 2 Land-use changes from 1995-1996 to 2010-11 (in percentage)

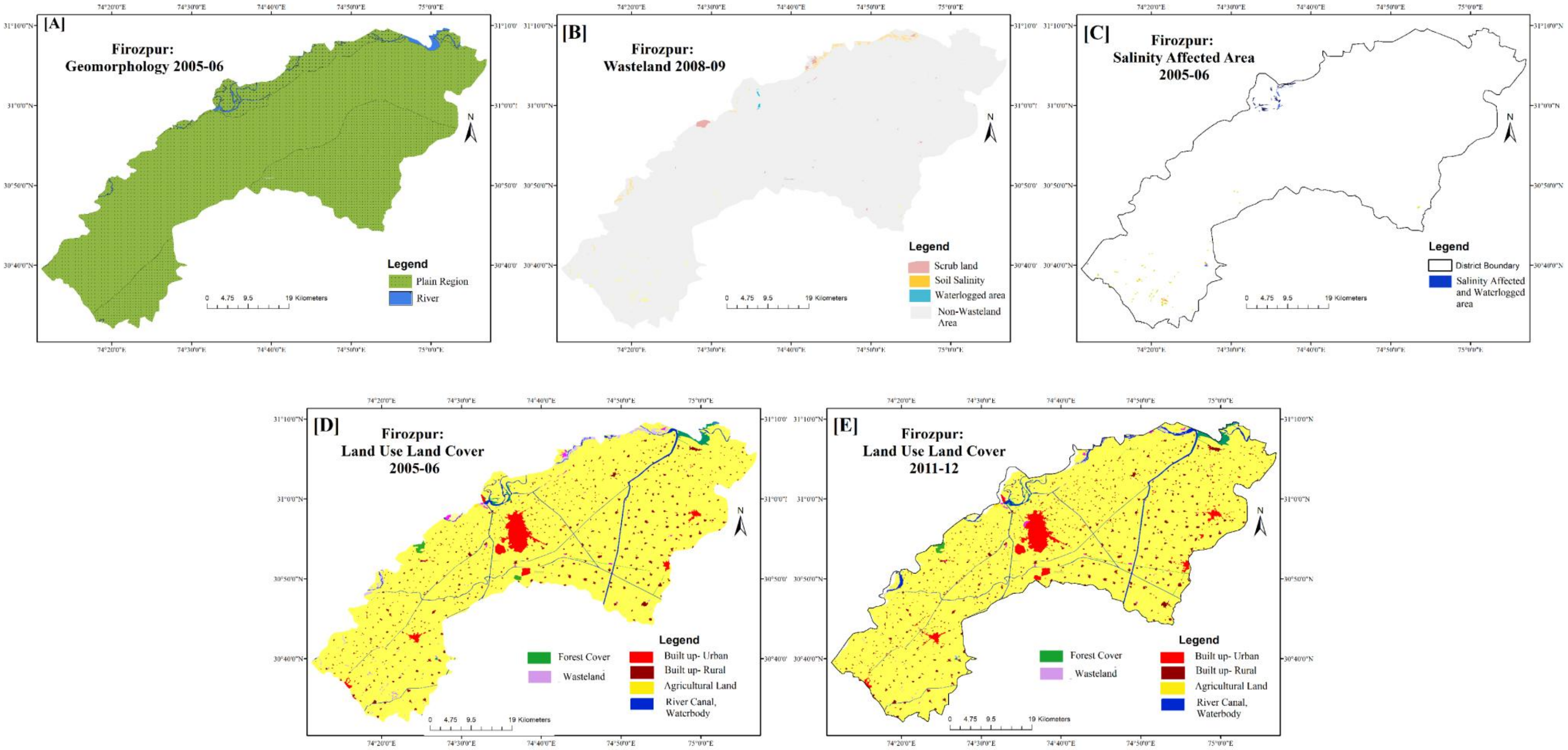
Land Use	Punjab	Firozpur District	Firozpur Tehsil
Net Sown Area	-3.2543	-32.52	-16.73
Area Under Current Fallows	-97.821	-100	0
Net Cultivated Area	-3.9136	-32.56	-16.73
Other Uncultivated Land Excluding Fallow Land	-84.647	0	0
Fallow Land Other than Current Fallows	-99.892	0	0
Culturable Waste Land	-98.213	-100	0
Total Uncultivated Land	-98.786	-100	0
Land Not Available for Cultivation	-91.674	0	0

Source: Calculated by the author by using data provided by the Agriculture Census of India.

Table-6.3 Irrigation characteristics at different administrative level

	Irrigated areas by source 2010-11 (in hectares)			Changes in Irrigated area under different sources from 1995-96 to 2010-11 (in percentage)		
Source	Punjab	Firozpur District	Firozpur Tehsil	Punjab	Firozpur District	Firozpur Tehsil
Canals	808288	25179	16974	-272218	-17697	-7055
Tanks	6689	386	30	-7395	-2649	-2936
Wells	1405	0	0	-14269	-1097	-741
Tubewells	3123573	126762	70836	257233	-51844	-6914
Other Sources	9209	73	33	771	73	33

Source: Calculated by the author by using data provided by the Agriculture Census of India.



Map-6.4 [A] Geomorphology of the Firozpur District with it origin, and characteristics, [B] Wasteland distribution in Firozpur District, [C] Concentration of the soil salinity in the Firozpur District, [D] Land used characteristics in the Firozpur District -2005-06 and [E] Land used characteristics in the Firozpur District -2015-16.

Source: Maps are reproduced by the author by using the ArcGIS online tool to get the various thematic maps from Bhuvan Thematic Service, NRSC, ISRO, URL-http://bhuvan.nrsc.gov.in/gis/thematic/index.php.

The detailed analysis which mentioned before has provided a brief overview to understand the salinity status and agricultural characteristics. Further, to analyse the salinity at micro-level, the two villages namely Habibwala and Bhabra Azam Shahwala have been discussed in detail in the section-6.3.1 and 6.3.2 respectively.

6.3.1 CASE STUDY-1

Habibwala is a no salinity village/less salinity village selected for the micro-level study. The sex ratio of the village is 989, while child sex ratio is much lower to 954 according to Census (2011). Moreover, the literacy rate has been recorded as low as 47 percent. Out of which male literacy has been recorded as 47 percent, while female literacy has been very low to 40 percent (Census, 2011) (Fig.-6.4).

56.84 percent population has been accounted for the total workforce, of 55.88 percent in the main workforce, 29.48 percent in the main cultivation works and 24.21 percent in main agriculture; while, the marginal workforce is very low. Less than 1 percent population has been engaged in the marginal workforce, 0.27 percent into marginal cultivation and 0.55 percent in marginal agriculture (Fig.-6.5) (Census, 2011).

Socioeconomically, female participation in the workforce has two contrary pieces of evidence. For example, female participation in the main workforce is only 9.67 percent, while in the marginal workforce is 79.41 percent. Similarly, female participation in total main agriculture and total main cultivator has been 4.32 percent and 2.49 percent respectively. However, female participation in marginal cultivation has been zero, while in marginal agriculture is 60 percent (Fig.-6.4).

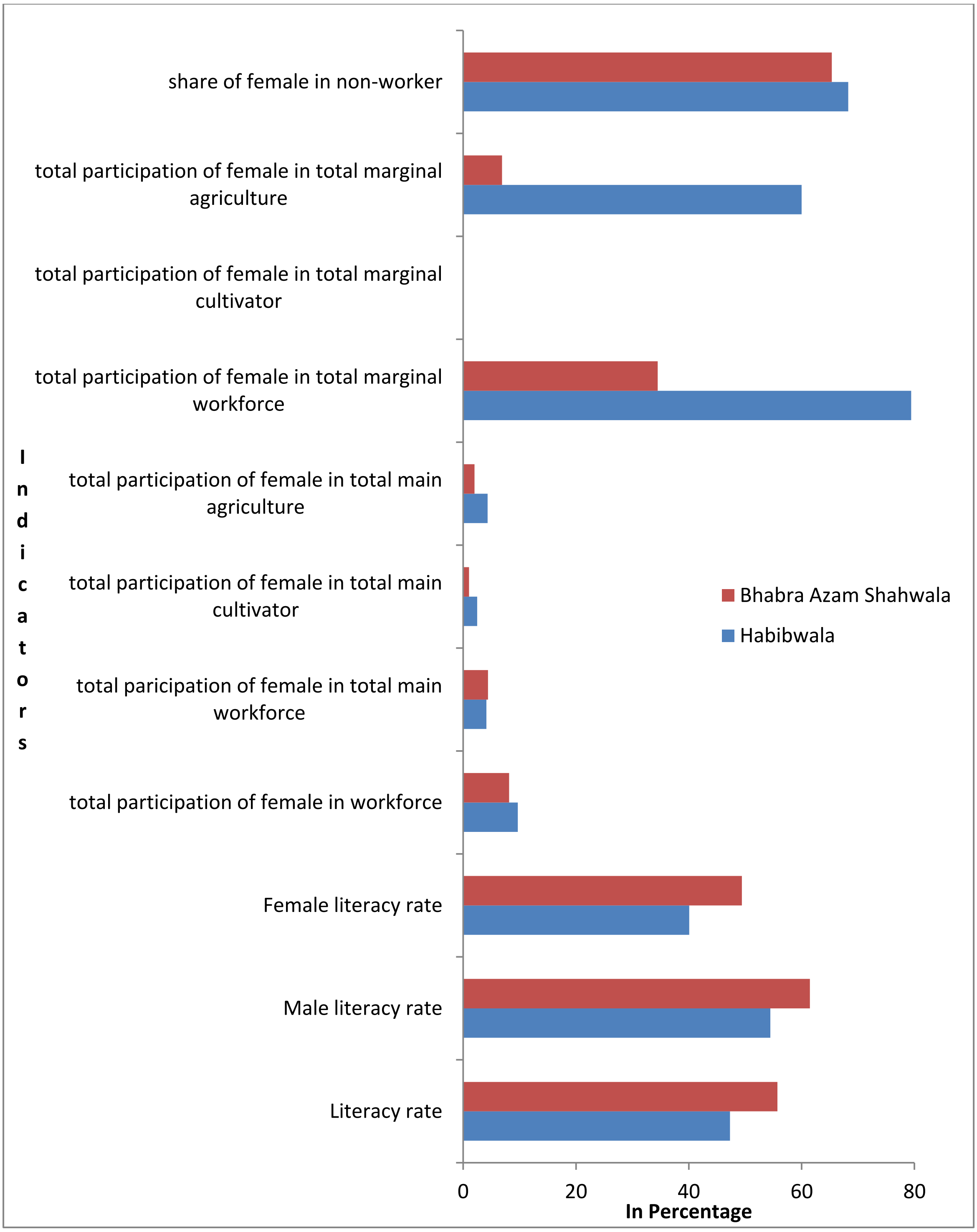


Fig.-6.4 Agro-demographic characteristics of the village Bhabra Azam Shahwala and Habibwala especially focusing on the female participation

Source: Prepared by the author by using data provided by the Census of India, 2011.

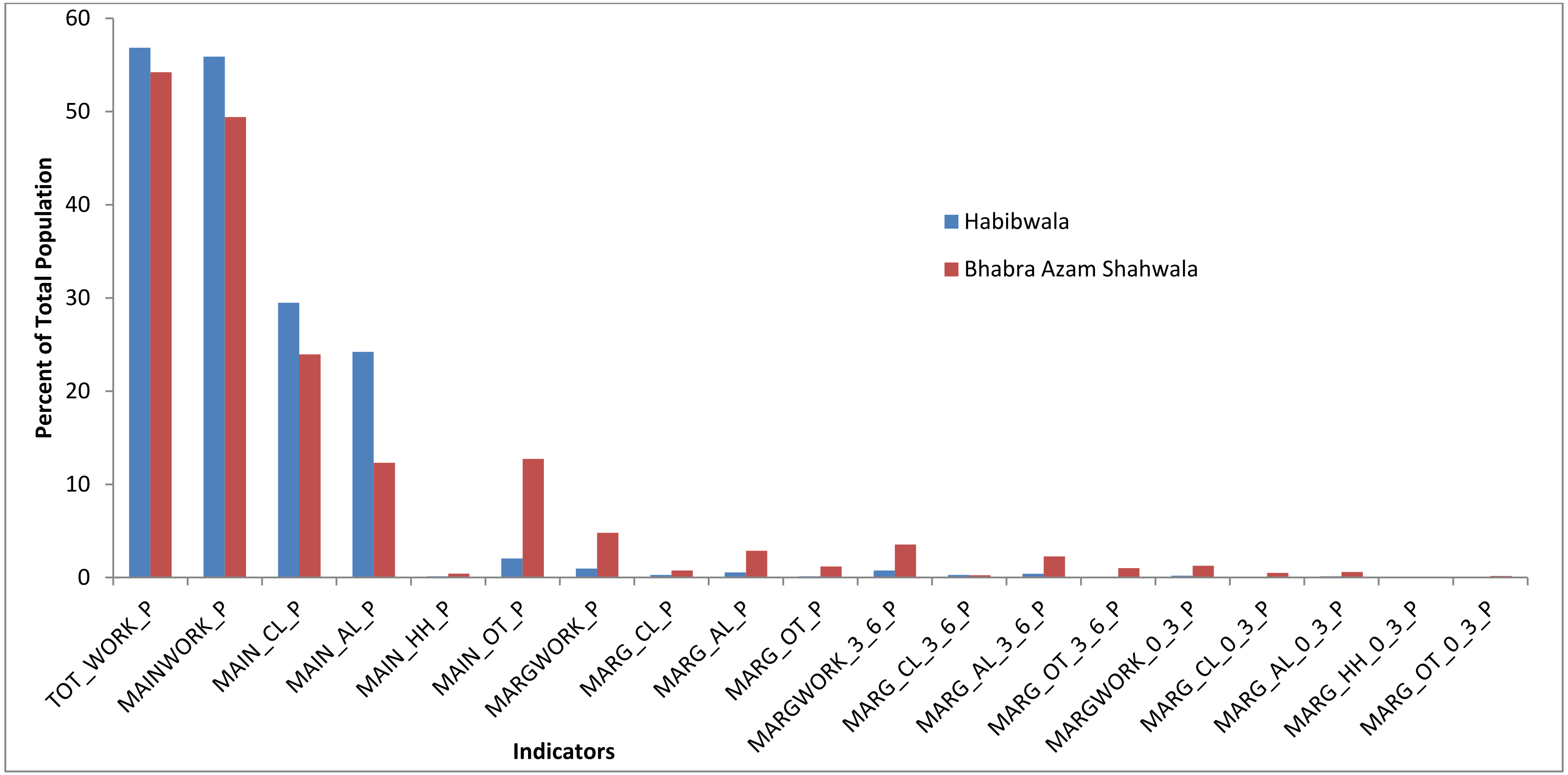


Fig.-6.5 Agro-demographic characteristics of the village Bhabra Azam Shahwala and Habibwala

Source: Prepared by the author by using data provided by the Census of India, 2011.

Findings of Primary Survey: Total 50 household surveys have been conducted in the village Habibwala of Firozpur Tehsil, out of which 14 interviews have been conducted for large farmers, 21 from the small and medium farmers and 15 from the marginal farmers. Majority of respondents have educated at the senior secondary level. Moreover, literacy is comparatively high of the large farmers (Fig.-6.6 (A). Focused Group Discussion (FGD) has enlightened about the physiographic condition. Due to alluvial and plain land, the people rarely found hard to use their land for various agricultural purposes. The village has been usually received rainfall in more than 4 months of the year during monsoonal and western disturbance rainfall (FGD-1 in Habibwala Village). Moreover, the access to the irrigation facility to all respondent has made their agricultural outcome more secure and certain (Table-6.4). The irrigation source of this village has been through tube wells mostly (Fig.-6.3 [A]) (FGD-1 in Habibwala). Cropping intensity is very high in the village. Every respondent has preferred to cultivate the land every year twice (Table four). Usually, other than crops, respondents have cultivated vegetables because it generates better revenue for them (FGD-2 in Habibwala).

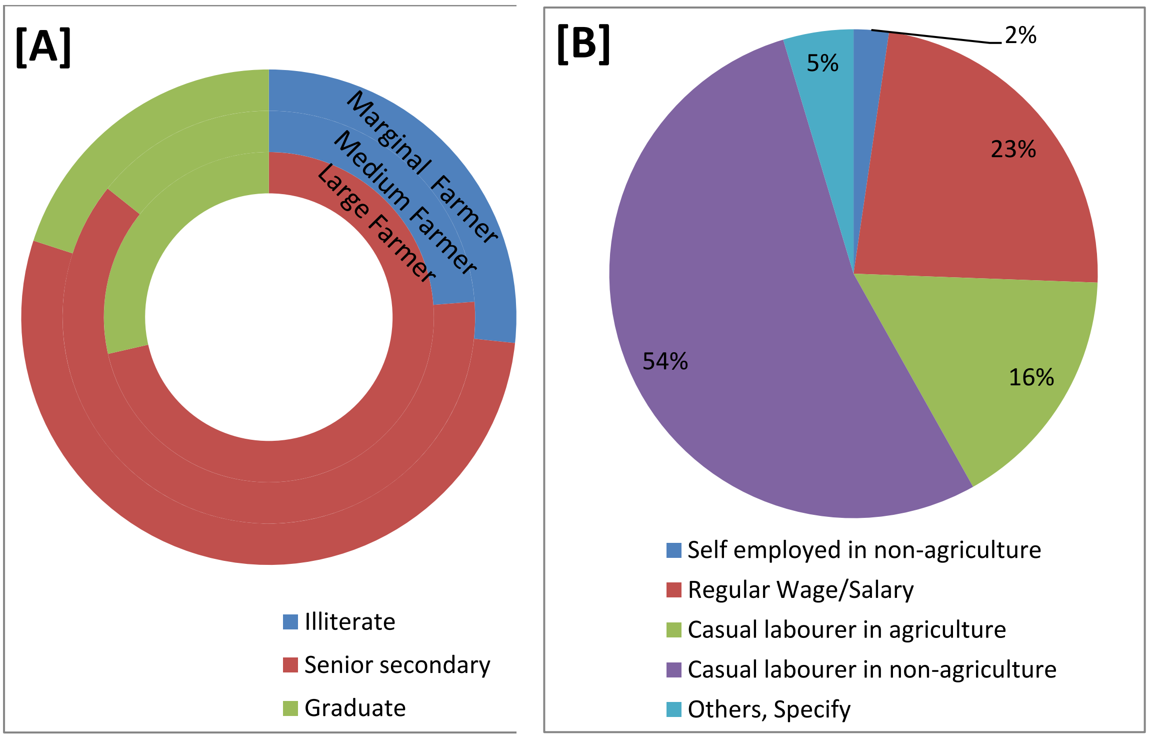


Fig.-6.6 (A) Education level among the sampled Farmers and (B) Occupation of the sampled farmers other than the farming in their own land in the Habibwala Village

Source: The graph prepared by the author by using the data collected from a primary survey in November 2017.

Table-6.4 General agricultural profile of the sampled respondents of the Habibwala Village of the Firozpur Tehsil (based on the answer of respondents)

		Education status of the farmers			Landholding and farming land		
	Sample interviews (No.)	Illiterate (No.)	Senior secondary (No.)	Graduate (No.)	Average land holding size (Hectares)	Average land used in farming (%)	Access to irrigation sources (%)
Large Farmers	14	0	10	4	55	100	100
Medium farmers	21	5	13	3	5.33	100	100
marginal farmers	15	4	8	3	1.53	100	100

Return on investment (% of the respondents)				Sell of the share of the total output (% of the respondents)			
	Total Agricultural Input cost only	Total more than Agricultural Input	Total less than Agricultural Output	0-25 %	25-50 %	50-75 %	75-100%
Large Farmers	0	100	0	0	35.71	35.71	28.58
Medium farmers	9.5	85.8	4.7	23.81	47.62	19.05	9.52
marginal farmers	60	33.33	6.67	60	6.66	0	0

Source: Calculated by the author from the primary survey data collected during November 2017.

Table-6.5 Characteristics of the agricultural land of the farmers (sampled respondents) in the Habibwala Village				
Mode of work in agricultural Land: Yes		Land used for other purpose		
1. Agriculture only	16	Type	Yes	No
2. Agriculture and Forestry	0	1. Digging of soil from the field	0	100
3. Agriculture and Animal Husbandry	84	2. Mining around the land	0	100
4. Agriculture, forestry and Animal Husbandry	0			
5. Difficult to use land	0	Input into the land (since five years)	Yes	
6. Other	0	i. Decrease in irrigation facility	10	
		ii. Equal irrigation facility	68	
Occupation Yes		iii. Increased irrigation Facility	22	
Employed in agriculture	100	iv. More fertilizer used	72	
Self-employed in non-agriculture	2	v. Equal fertilizer used	26	
Regular Wage/Salary	20	vi. Less fertilizer used	2	
Casual labourer in agriculture	14	vii. HYV seeds are used	100	
Casual labourer in non-agriculture	46	viii. No awareness	36	
Others, Specify	4	ix. less awareness	64	
		x. More organized agriculture	88	
		xi. less organized agriculture	12	
Land productiveness (since five years)	Yes	xii. More labour involved	32	
a)More productive	66	xiii. Less or equal labour	68	
b)Productive as earlier	10	xiv. Pesticide used	100	
c)Less productive	24	Soil composition changed (since five years)	Yes	
Soil fertility since five years	Yes	i. Good from earlier	56	
Decreased	22	ii. Bad from earlier	22	
Equal	36	iii. Very Bad from earlier	18	
Increased	42	iv. Worse from earlier	4	
Source: Calculated by the author from the primary survey data collected during November 2017.				

As an occupation, 16 percent of respondents have been doing only agriculture on their land, while 84 percent of respondents have engaged in both agriculture and animal husbandry (Table-6.5). The livestock has been kept for their secondary income and as an assistant to their food supplements (FGD-2 in Habibwala Village). Due to a better quality of the soil structure, all respondents have never preferred for soil mining for any other purposes (Table-6.5) because the mining of soil might leads to removal of topsoil and thus it can impact the productivity (FGD-2 in Habibwala Village). Other than agricultural activities, 2 percent respondents have been engaged into self-employment, 20 percent in regular wage/salary for different sources, and 14 percent into casual labour in agriculture and 46 percent in casual labour in non-agriculture (Table-6.5).

Table-6.6 Characteristics of the soil salinity in the Habibwala Village based on farmers perception (in percentage to the total sampled respondents)

Cause of Soil Salinity	Yes	Salinity experienced	Yes
i. High temperature	0	No salinity	86
ii. Low rainfall	0	Low	12
iii. Non-scientific (Faulty) agricultural practices	12	Moderate	2
iv. Lack of irrigation facility	0	High	0
v. Lack of Freshwater (saline free)	10		
vi. Irrigation by the saline water without proper distribution on the field	0		
vii. Lack of awareness about the scientific way of agriculture	24		
viii. water-logging	0		
ix. Lack of drainage facility	8		
x. overuse of chemical fertiliser	26		
xi. the absence of traditional agriculture	24		
xii. Irrigation through saline water	0		

Source: Calculated by the author from the primary survey data collected during November 2017.

Soil quality has said to be good from earlier by 56 percent respondents, bad by 22 percent, very bad by 18 percent and worse by 4 percent of respondents. The agricultural land is leased out and leased into the village. Interestingly, here, respondents said that the land is always taken on the contractual basis (FGD-2 in Habibwala Village) rather than based on half and one-third crop as found in Rajasthan

(Chapter-5). The unit of land measurement here in the village has been "*Killa*"[2] in which one killa is equivalent to one acre. Availability of irrigation and fertilisers has undermined the degrading soil of the region (FGD-2 in Habibwala Village). Though 86 percent respondents have opined that there is no salinity into the area, however, 14 percent respondents have opined that there is low to moderate level of salinity (Table-6.6), which is very minor and it does not affect productivity (FGD-2 in Habibwala Village).

6.3.2 CASE STUDY-2

The Bhabra Azam Shahwala Village is relatively high soil salinity affected area; the region is getting irrigation from the canal majorly (Plate-6.1). Gang canal from the Sutlej River provides irrigation to the village. Demographically, sex ratio is 911 and child sex ratio is 809 (Census, 2011), which comparatively lower than Habibwala Village. Male literacy is 61 percent and female literacy is 49 percent according to Census 2011. This is higher than the Habibwala Village. Female participation in the total workforce has been very low to 8 percent of the total workforce and it is only 4 percent of the main workforce (Fig.-6.4). More than 65 percent of the female population comes under the non-working population (Fig.-6.5). The total population of the workforce in the village is 49 percent, which is lower than the Habibwala Village. 23 percent population has been engaged mainly in main cultivation activities, 12 percent in main agriculture activities. Which is very low compared to the Habibwala Village (Fig.-6.5). Marginal workforces are comparatively high than the Habibwala Village accounting for 4 percent of the total population of the village. Total female participation in the marginal workforce has recorded 34 percent, which is lower than the Habibwala Village (Fig.-6.5).

Findings of Primary Survey: 16 interviews have been taken from the large farmers, 26 from the small and medium farmers and 8 from the marginal farmers (Table-6.7). Education at graduation level is higher among large farmers than marginal and small and medium farmers. Illiteracy is high in medium farmer (Fig.-6.7 (A). Some of the discussion with respondents has revealed that taking education has not been resulting in any profitable outcome (FGD-3 in Bhabra Azam Shahwala Village). Soil quality has worsened than earlier according to 56 percent of respondents. 12 percent of

[2] Locally used terminology for the measurement of land. One killa is equal to 4 bigha.

respondents have said that the soil quality has been improved from the previous years (Table-6.8). Access to irrigation facility has been available to every respondent (Table-6.8).

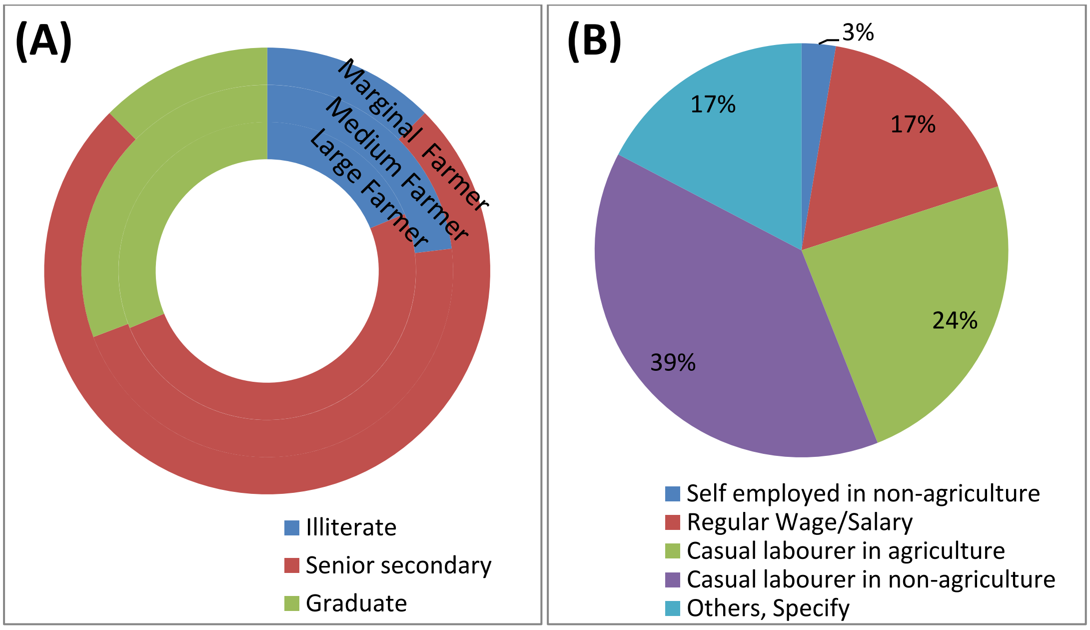


Fig.-6.7 (A) Education level among the sampled Farmers and (B) Occupation of the sampled farmers other than the farming in their own land in the Bhabra Azam Shahwala Village

Source: Source: The graph prepared by the author by using the data collected from a primary survey in November 2017.

The interviewed farmers are totally dependent on the agriculture for the livelihood. Other than agriculture as means for income, 4 percent respondents are self-employed in non-agricultural activities, 26 percent are employed into regular wage or salaried job, 36 percents are a casual labourer in agriculture and 58 percent are casual labour in non-agriculture (Fig.-6.7 (B). 10 percent of respondents have been involved in agriculture only, while 84 percent of respondents have opted agriculture as well as animal husbandry as a mode of work in agriculture (Table-6.8). Respondents have preferred to utilise, reutilise land and then restore it. The commercial cropping has not been so successful in this village compared to the Habibwala Village (Plate-6.2) because of the poor quality of the land (FGD-4 in Bhabra Azam Shahwala Village).

Table-6.7 General agricultural profile of the sampled respondents of the Bhabra Azam Shahwala Village of the Firozpur Tehsil (based on the answer of respondents)							
		Education of the farmers			Landholding and farming land		Irrigation
	Sample interviews (No.)	Illiterate (No.)	Senior secondary (No.)	Graduate (No.)	Average land holding size (Hectares)	Average land used in farming (%)	Access to irrigation sources (%)
Large Farmers	16	3	8	5	40.63	100	100
Medium farmers	26	6	12	8	4.23	100	100
marginal farmers	8	1	6	1	1.5	100	100

Return on investment (% of the respondents)				Sell of the share of the total output (% of the respondents)			
	Total Agricultural Input cost only	Total more than Agricultural Input	Total less than Agricultural Output	0-25 %	25-50 %	50-75 %	75-100 %
Large Farmers	0	81.25	18.75	0	43.75	37.5	18.75
Medium farmers	23.08	61.54	15.38	30.77	34.62	11.54	23.07
marginal farmers	25	50	25	62.5	12.5	25	0

Source: Calculated by the author from the primary survey data collected during November 2017.

36 percent of respondents have faced difficulties while using the land (Table-6.8) due to the relatively low fertility of land (FGD-4 in Bhabra Azam Shahwala Village). Though the two-crop system has opted, no measure initiatives have been started to reduce the soil salinity by farmers as well as by government and non-government agencies (FGD-3, in Bhabra Azam Shahwala Village). 81.25 percent of large farmer respondents are able to get a higher return on investment than their agricultural inputs. However, 23.08 percent of medium farmer respondents and 25 percent of small farmer respondents have neither get profit nor get loss from agriculture. Likewise,

18.75 percent of large farmers, 15.38 percent medium farmer and 25 percent of marginal farmer respondents have faced loss in their last year crops. Large farmer respondents have been able to sell their product to market. 43.75 percent large farmer respondents have sold 25-50 percent of their total agro products. It is very much higher as compared to 34.62 percent medium farmer respondents and 12.5 percent marginal farmer respondents. 37.50 percent large respondents have sold 50-75 percent of their product, while only 11.54 percent medium farmer and 25 percent of marginal farmers have able to sell their 50-75 percent of total product. Moreover, 18.75 percent of large farmer respondents and 23.07 percent of medium farmer respondents have sold their 75-100 percent product, whereas no marginal farmer respondents have able to sell 75-100 percent of total product (Table-6.7).

About the land productiveness, the respondents have a wide range of responses in the village. 56 percent of respondents have mentioned that land has been more productive than earlier (Table-6.8) even the problem of soil salinity has existed at moderate to high level (Table-6.9). In contrast, only 14 percent of respondents have cited that there has been less productiveness from the previous years. Soil Composition has worsened than earlier (56 percent of respondents) but there has been increasing rate of inputs like irrigation (20 percent of respondents), fertiliser (82 percent of respondents), HYV seeds (100 percent of respondents) and pesticides (100 percent of respondents) (Table-6.8).

Majority of respondents (76 percent) have mentioned that the soil is having a moderate level of salt content (Plate-6.1). The major reasons for the soil salinity has been attributed to the lack of fresh water (100 percent) irrigation through saline water (86 percent), not proper irrigation mechanism with saline water (80 percent), lack of awareness about scientific agriculture (46 percent), absence of traditional agriculture (26 percent), waterlogging (18 percent) and non-scientific agricultural practices (16 percent) (Table-6.9).

Table-6.8 Characteristics of the agricultural land of the farmers (sampled respondents) in the Bhabra Azam Shahwala Village				
Mode of work in agricultural land:	Yes	Land used for other purpose		
1. Agriculture only	10	Type	Yes	No
2. Agriculture and forestry	0	1. Digging of soil from the field	0	100
3. Agriculture and animal husbandry	84	2. Mining around the land	0	100
4. Agriculture, forestry and animal husbandry	2			
5. Difficult to use land	36	Input into the land (since five years)	Yes	
6. Other	10	i. Decrease in irrigation facility	8	
		ii. Equal irrigation facility	72	
Occupation	Yes	iii. Increased irrigation Facility	20	
Employed in agriculture	58	iv. More fertilizer used	82	
Self-employed in non-agriculture	4	v. Equal fertilizer used	18	
Regular Wage/Salary	26	vi. Less fertilizer used	0	
Casual labourer in agriculture	36	vii. HYV seeds are used	100	
Casual labourer in non-agriculture	58	viii. No awareness	48	
Others, Specify	26	ix. less awareness	52	
		x. More organized agriculture	66	
		xi. less organized agriculture	44	
Land productiveness (since five years)	Yes	xii. More labour involved	26	
a)More productive	56	xiii. Less or equal labour	74	
b)Productive as earlier	30	xiv. Pesticide used	100	
c)Less productive	14	Soil composition changed (since five years)	Yes	
Soil fertility since five years Yes		i. Good from earlier	12	
Decreased	36	ii. Bad from earlier	56	
Equal	54	iii. Very Bad from earlier	20	
Increased	10	iv. Worse from earlier	12	
Source: Calculated by the author from the primary survey data collected during November 2017.				

Table-6.9 Characteristics of the soil salinity in the Bhabra Azam Shahwala Village based on farmers perception (in percentage to the total sampled respondents)			
Causes of Soil Salinity	Yes	Salinity experienced	Yes
i. High temperature	0	No salinity	6
ii. Low rainfall	6	Low	14
iii. Non-scientific (Faulty) agricultural practices	16	Moderate	76
iv. Lack of irrigation facility	0	High	4
v. Lack of Freshwater (saline free)	100		
vi. Irrigation by the saline water without proper distribution on the field	80		
vii. Lack of awareness about the scientific way of agriculture	46		
viii. water-logging	18		
ix. Lack of drainage facility	4		
x. overuse of chemical fertiliser	14		
xi. the absence of traditional agriculture	26		
xii. Irrigation through saline water	86		
Source: Calculated by the author from the primary survey data collected during November 2017.			

6.3.3 COMPARATIVE ANALYSIS OF SOIL SALINITY STATUS IN CASE STUDY VILLAGES

Majority of the selected respondents have preferred do agriculture and having livestock as an option of occupation in both village of Habibwala and Bhabra Azam Shahwala (Fig.-6.8 (a) and (b). Compared to Habibwala Village, Bhabra Azam Shahwala respondents have been less relying on the agriculture-only (only 10 percent of respondents) (Fig.-6.8 (b). Moreover, 36 percent respondents of the Bhabra Azam Shahwala Village have experienced that the land has been difficult to use (Fig.-6.8 (b) and Table-6.8). Forestry as a means of work into agricultural land has been very less for both the villages (Fig.-6.8 (a) and (b). Other than agricultural occupation, the secondary occupation of respondents is very mixed in nature. In comparison to Habibwala Village, Bhabra Azam Shahwala Village respondents are engaged more as a casual labourer in non-agriculture (58 percent) and casual labour in agriculture (36 percent) and salaried/regular wage (26 percent) and other occupation (26 percent)

(Table-6.7 and Fig.-6.8 (d). Other occupations than with engagement in agriculture have opted more into the Bhabra Azam Shahwala Village (Fig.-6.8 (c) and (d). This might be due to not so productive land as in Habibwala Village.

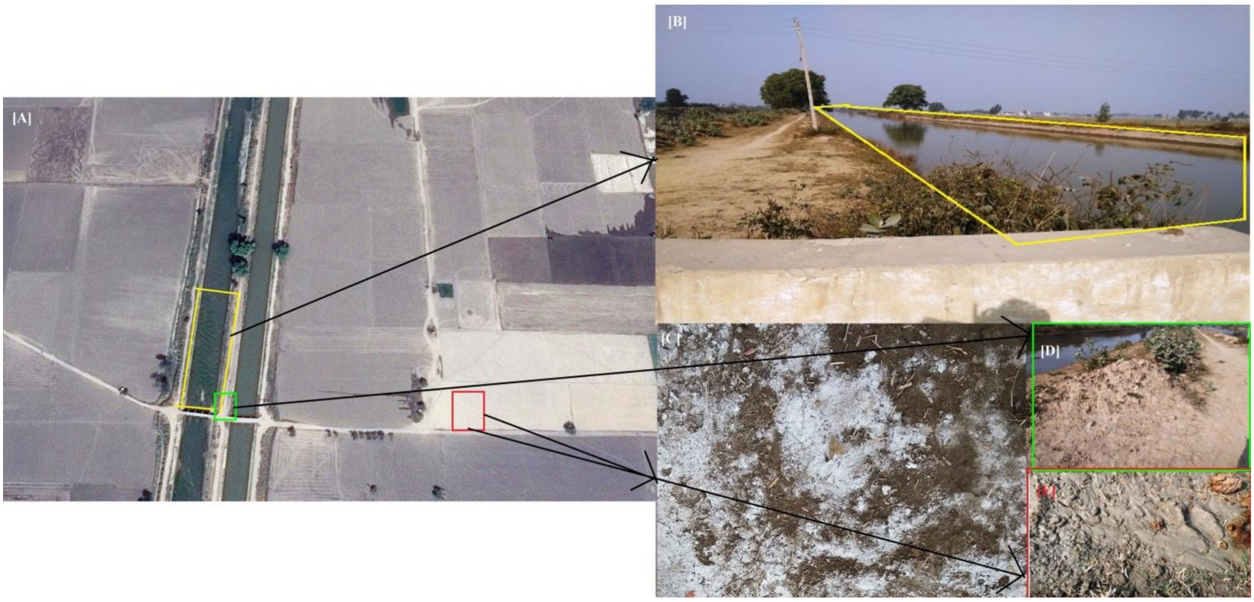


Plate-6.1 [A] Satellite Image of Gang Canal near Bhabra Azam Shahwala Village, [B] Gang canal, [C] Salinity on the soil, [D] Land near the canal and [E] mixing of organic material in the land to revive the soil fertility

Plate-6.2 Image of farming under the cover of plastic to control the soil moisture under commercial farming. Technically called mulching or plasticulture

Source: Photograph taken during the fieldwork by the author on November 2017.

Compare to Bhabra Azam Shahwala Village (10 percent), more respondents in Habibwala Village (42 percent) have mentioned that soil fertility status from earlier has increased, while 36 percent in Habibwala and 54 percent in Bhabra Azam Shahwala Village has made reference to the equal fertility as earlier. In case of decreasing fertility status, both village respondents have observed the declining fertility with variation in responses e.g. 22 percent has mentioned so in Habibwala Village, while 36 percent has mentioned so in Bhabra Azam Shahwala Village (Fig.-6. 13 (a). Soil composition has improved over a period of time in Habibwala Village (56 percent of respondents) as compared to Bhabra Azam Shahwala Village (12 percent of respondents). Conversely, soil composition has become bad from earlier in the Bhabra Azam Shahwala Village (Fig.-6.9 (b).

All respondents have been asked to assess/understand the status of soil salinity. 86 percent of respondents in Habibwala Village have mentioned that there is no salinity issue, while in Bhabra Azam Shahwala Village, only 6 percent respondents have admitted so. 12 percent respondents in Habibwala Village have recorded that low salinity, while 14 percent of respondents in Bhabra Azam Shahwala Village have admitted the same. Moderate level of soil salinity status was said to be very low in Habibwala Village as only 2 percent of respondents have acknowledged the same. Nevertheless, 76 percent of respondents in Bhabra Azam Shahwala Village has experienced a moderate level of salinity in their farming land (Fig.-6.8 (c). When asked about the cause of soil salinity by their experience into agricultural activities, the respondents of the Bhabra Azam Shahwala Village has emphasised more on lack of fresh water, improper irrigation practices with saline water, irrigation with the saline water and waterlogging compared to Habibwala Village. However, in Habibwala Village, more respondents compared to Bhabra Azam Shahwala Village have admitted the lack of drainage facility and over-use of fertiliser might be the reason for the soil salinity (Fig.-6.10).

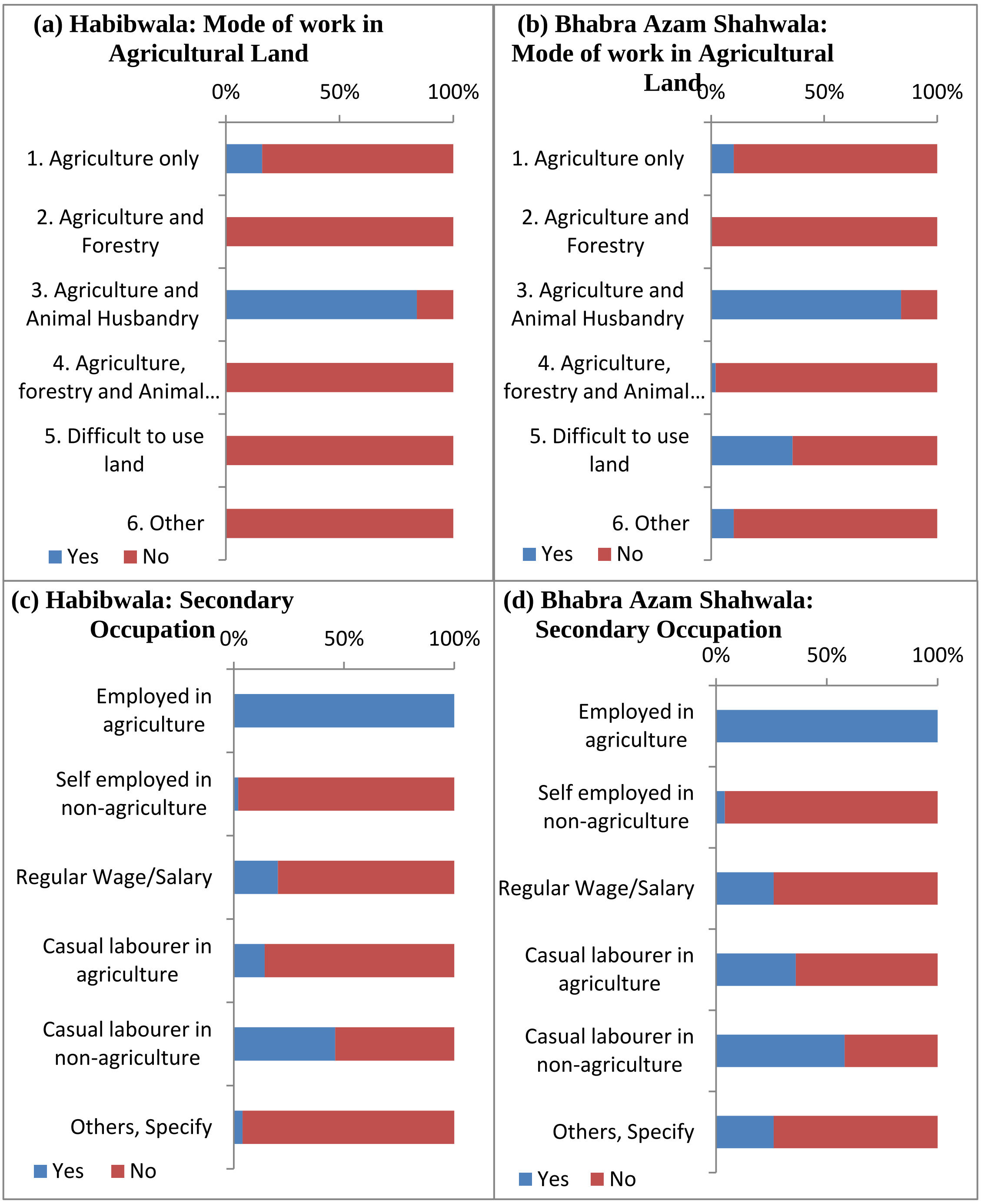


Fig.-6.8 Comparative between the Habibwala and Bhabra Azam Shahwala Village on the basis of occupation

Source: Presentation through graph by the author using the primary survey data collected from the selected respondents of both villages during November 2017.

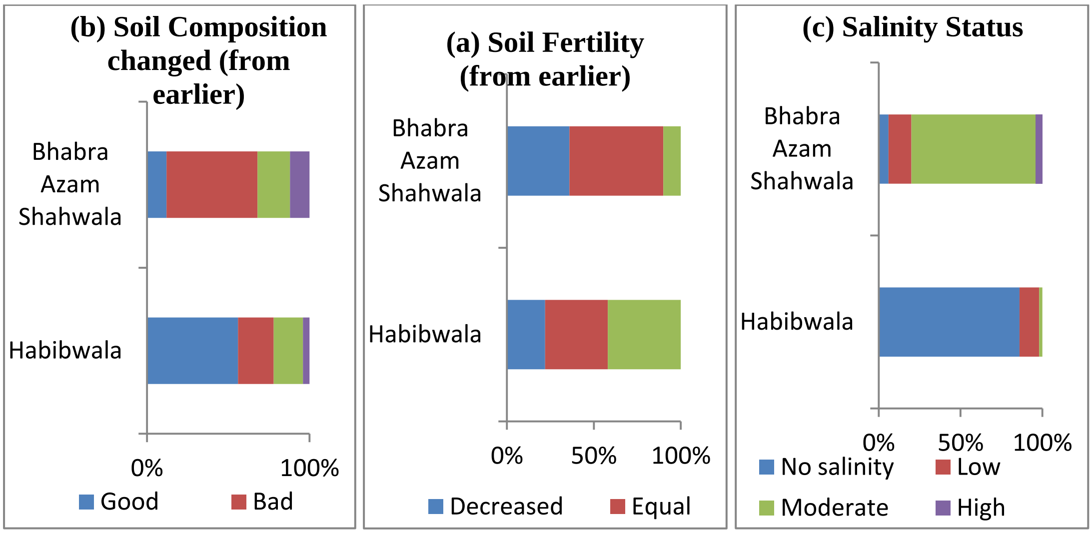


Fig.-6.9 Soil Quality Status in the Village Habibwala and Bhabra Azam Shahwala

Source: Presentation through graph by the author using the primary survey data collected from the selected respondents of both villages during November 2017.

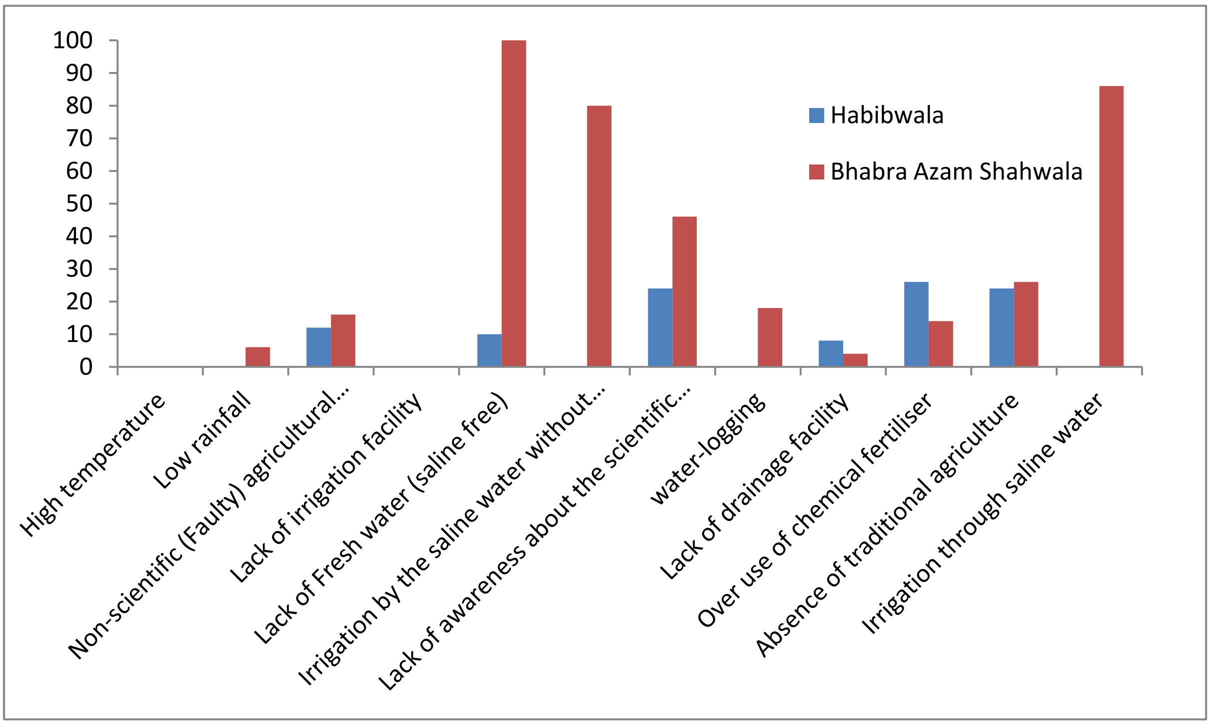


Fig.-6.10 Perception regarding soil salinity by the respondents in Habibwala and Bhabra Azam Shahwala Village

Source: Presentation through graph by the author using the primary survey data collected from the selected respondents of both villages during November 2017.

6.4 CONCLUSION

The chapter has tried to understand the condition of agriculture in the region of high fertilizer consumption along with the soil salinity problem in Punjab. It is said that Punjab is the area on which future of the country lies. The major findings of the chapter can be listed as:

1. Overall land degradation in Punjab is not so prominent. It is only 1.86 percent area of TGA. But the share of wind erosion, land with scrub, waterlogging/marshyland and soil salinity/alkalinity is very high among TDA. A similar scene is experienced in the case of Firozpur.

2. The concentration of land degradation in Punjab has observed in the southern-west region and Northern region, while the concentration of soil salinity/alkalinity is in the south-west region. Forest cover in the region has been recorded very less.

3. The analysis of NDVI map has revealed the very low vegetation cover. There is almost negligible evidence of vegetation from the same in the map (Map-6.3 [B]). Soil salinity concentration has been recorded in the central region of Firozpur near the border of Pakistan. NDSI map has represented a clearer picture of soil salinity/alkalinity concentration compared to SAVI (Map-6.3 [C] and [D]).

4. Physiographically, it has become clear that the region of soil salinity concentration is the region with the river channel as well as canal distribution in those areas. Though the land use-land cover map has not shown drastic changes into use pattern; however over a period of time, misuse and overuse of availability of water have led to the development of salt concentration into the water.

5. Investigation during farmers interviewed has revealed that farmers in Firozpur, Punjab are more educated compared to sample farmer interviewed from Barmer of Rajasthan and Kannauj of Uttar Pradesh. The profit gain from farming has been recorded better for interviewed farmers in Firozpur compared to the farmers interviewed in Barmer and Kannauj. Here in Firozpur, the agriculture has been the primary occupation, unlike Barmer, where it is produced more for the fulfilling their food needs. Land being naturally fertile in Firozpur has not been allowed for mining for any other purposes most of the time, unlike Barmer where it is allowed for the

salt-mining. Like Barmer, this study area has also witnessed increased in agricultural input costs.

6. Many of the respondents in village Habibwala has recorded that soil fertility has increased in the village and changes in soil composition have been good. But respondents of the Bhabra Azam Shahwala Village witnessed equal or decreased soil fertility with the bad quality of soil composition. Regarding soil salinity status, the identification of salt content into the field is difficult for the respondents; still, the Bhabra Azam Shahwala Village respondents admitted the moderate level of soil salinity. Impact of agriculture has not been seen so much because increase fertiliser use might have moderated the same.

7. The scenario related to the cause of salinity here is very opposite to some extent to the Barmer. All Bhabra Azam Shahwala Village respondents suggested the lack of fresh water and irrigation the saline groundwater would be a major cause of soil salinity in the village. However, respondents have been significantly less aware of the real cause being the over-irrigation and increased groundwater level near the canals.

CHAPTER-7

SOIL SALINITY STATUS: STUDY OF UTTAR PRADESH

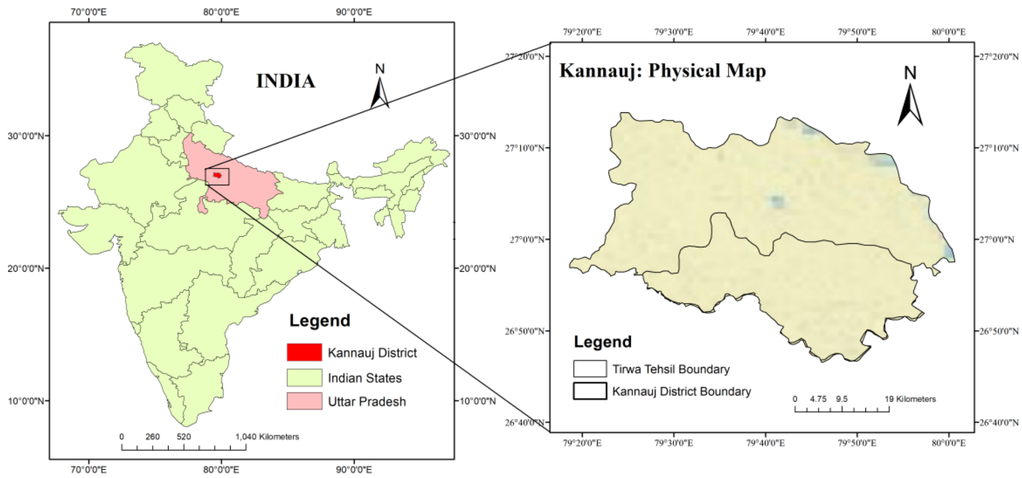
7.1 INTRODUCTION

The process of salinity distribution and pre-distribution govern the process of salt concentration in the soil profile. The fluctuation of groundwater table is also a contributing factor in the same process (Dwivedi and Sreenivas, 1998). In addition to this, rapidly increasing population (Dwivedi and Sreenivas, 1998; Nayak, 2000; Census, 2011) and livestock population in Uttar Pradesh have also posed threats to the sustainability of existing land resources (Nayak, 2000; Priya and Roy, 2015). Thus, we need a balance between ongoing development and environmental conservation to check the increasing soil salinity in the region. Total 2.7 million hectares area is affected by the evils of salinity increment in the Indo-Gangetic region (Singh et al., 2016). The salinization and alkalinisation are the major factors behind this increasing concentration of salt in the soil (Kumar et al., 2015). Waterlogging is a contributing factor in increased salinity in the soil in Uttar Pradesh but the human activity (e.g. Command irrigation) has also held a major stake in the contemporary years (Nayak, 2000). Thus, there is an urgent need to study the status of salinity in the state as well as to assess the perspective of farmers regarding the salinity problem in their land.

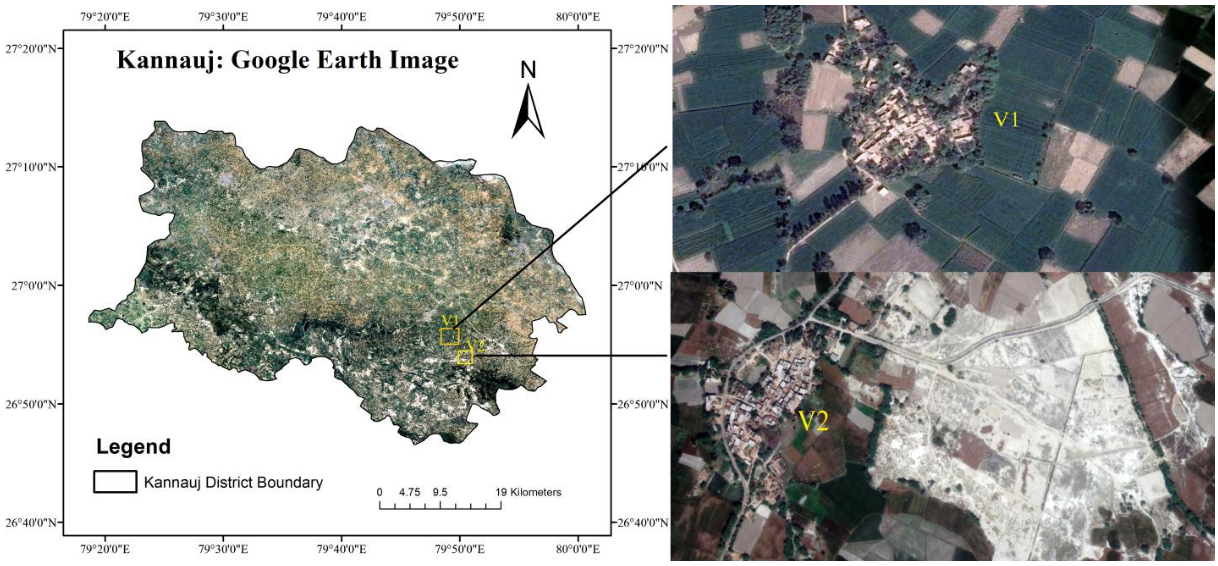
This chapter has tried to analyse the trend and pattern of land degradation in Uttar Pradesh in general and soil salinity in particular. With regard to soil salinity, the district of Kannauj has emerged as the highest soil salinity affected district in the state. In terms of total proportionate to TGA under soil salinity. At the macro level, NDVI, NDSI and SAVI have been calculated to see the spatial distribution of soil salinity and vegetation distribution through analysing satellite imageries of the Landsat-8. Moreover, at micro-level, two villages have been selected for the primary survey of the farmer to look into the experience of soil salinity and their perspective in relation to the agricultural productivity.

7.2 STUDY AREA

Kannauj District is administrative unit along the bank of Ganga River. The district location is at 27^{o} 07' N latitude and 79^{o} 54' E longitude (Map-7.1). The average elevation of the district is 193 meters from mean sea level; with the average rainfall of 80 cm. Kannauj has recorded 7.43 percent of its TGA under various types of land degradations. Out of TGA, 5.96 percent areas have been under soil salinity/alkalinity (NRSC, 2011) (Table-7.1). For the micro level study, two villages have been selected namely- Madanapur and Gurauli into Tirwa Tehsil of Kannauj District. The extent of Madanapur Village is 26°55'43.03"N latitude and 79°48'57.05"E longitude, while of Gurauli Village is 26°52'52.20"N latitude and 79°50'27.92"E longitude (Map-7.2). Madanapur Village has selected under the low salinity category, while Gurauli has taken under the high soil salinity affected village. Total 380 households have been counted with 2031 population under Census (2011), whereas Gurauli Village has 525 households with 3125 population (Census, 2011).



Map-7.1 Study area map of Kannauj District and Tirwa Tehsil



Map-7.2 Study area location of the villages selected from the Tirwa Tehsil of the Kannauj District: V1- Madanapur Village, which is less saline affected (saline area marked by yellow colour) and V2- Gurauli Village, which relatively high salinity affected village (saline area marked by yellow colour)

Source: Map designed and generated by the author through various sources like Google Earth images dated 26 March 2017 and Bhuvan Thematic Service

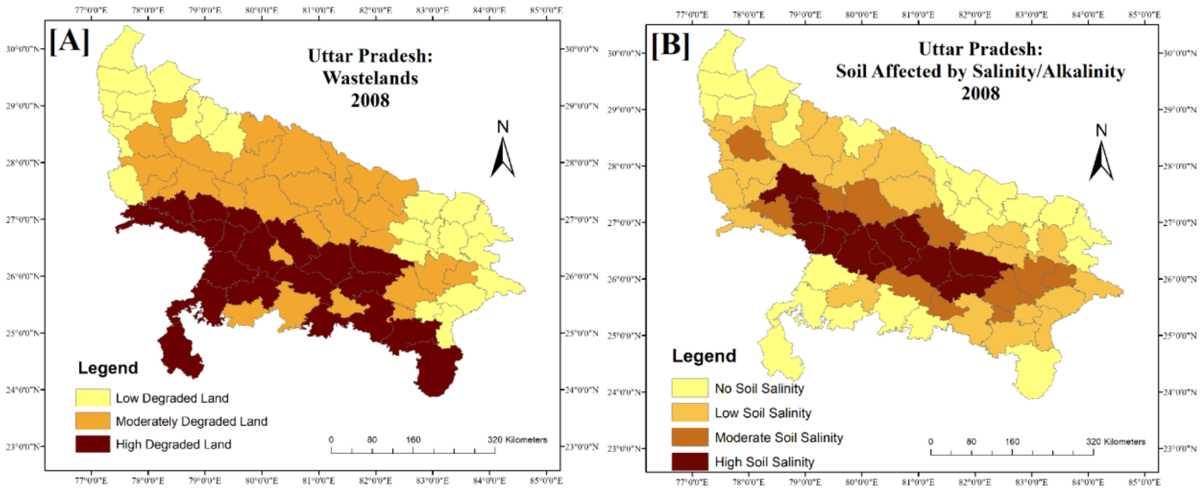
7.3 RESULT AND DISCUSSION

Land degradation problem has been very serious in Uttar Pradesh. Out of TDA, 2.12 percent degraded lands have been witnessed in Uttar Pradesh covering an area of 9881 km^2 in 2008-09. Most significantly, the state of Uttar Pradesh has observed a decline in TDA by 1107.35 km^2 since 2005-06 to 2008-09. From 2005-06 to 2008-09, there has been a reduction of 1269.71 km^2 and an increase of 163.08 km^2 areas (NRSC, 2011). In Uttar Pradesh, land with scrub has the largest share, while in Kannauj the land affected by salinity/alkalinity has the dominance under land degradation categories (Table-7.1). In Uttar Pradesh, the highest land degradation affected districts are Etawah, Jhansi, Agra, Firozabad, Kanpur rural, Lalitpur, Auriya, Jalaun, Kannauj, Mirzapur, Chitrakoot, Raebareli, Allahabad, Pratapgarh, Fatehpur, Sultanpur, Unnao, Sonbhadra, Mainpuri and Hamirpur. These are the districts, which are having more than 5 percent of TGA under the degradation (Map-7.3 [A]). In terms of soil affected with salinity/alkalinity, the high soil salinity affected districts are Kannauj, Raebareli, Unnao, Auraiya, Mainpuri, Pratapgarh, Kanpur Rural, Kanpur Urban, Sultanpur, Lucknow, Etah and Etawah. These districts are having more than 3 percent of its TGA under the soil salinity/alkalinity (Map-7.3 [B]). Kannauj is highly affected by soil salinity/alkalinity with the area of 125.08 km^2 areas. It shares more than 80 percent of TDA and 1.06 percent of TGA. Other than salinity, the Kannauj district has been affected with waterlogging and land with scrub (Table-7.1) (Fig.-7.1).

Table-7.1 Share of the different types of land degradation- 2008 (in percentage)

Wasteland	**Kannauj (Share in TDA)**	**Uttar Pradesh (Share in TDA)**	**Kannauj (Share in TGA)**	**Uttar Pradesh (Share in TGA)**
Gully/Ravines	12.13	0.00	0.50	0.00
Land with Scrub	29.50	9.25	1.21	0.69
Waterlogged/Marshyland	8.76	10.42	0.36	0.77
Land affected by Salinity/alkalinity	25.84	80.32	1.06	5.96
Land: underutilized	19.53	0.00	0.80	0.00
Area under sand	0.49	0.00	0.02	0.00
Industrial Wasteland	0.37	0.00	0.02	0.00
Barren Rocky/Stony Waste	3.39	0.00	0.14	0.00
Total	100.00	100.00	4.10	7.43

Source: Wasteland Atlas of India, NRSC, 2011



Map-7.3 Spatial Distribution of [A] land degradation and [B] soil salinity/alkalinity in Uttar Pradesh

Source: The map has been generated by the author by using the data taken from the National Remote Sensing Center, ISRO, in the year 2008.

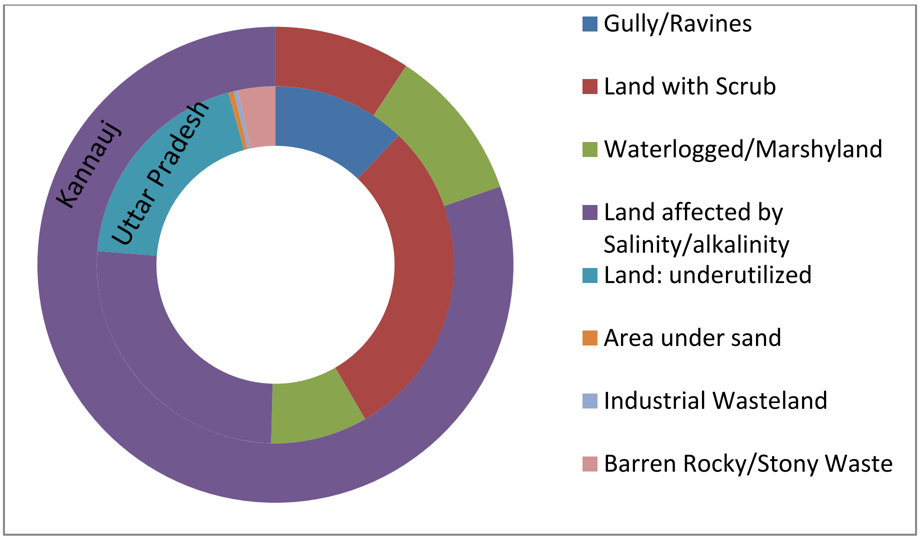


Fig.-7.1 Representation of the resemblances of the Land Degradation types in Uttar Pradesh and Kannauj

Source: Prepared by the author by using the data provided by the author using NRSC data-2008

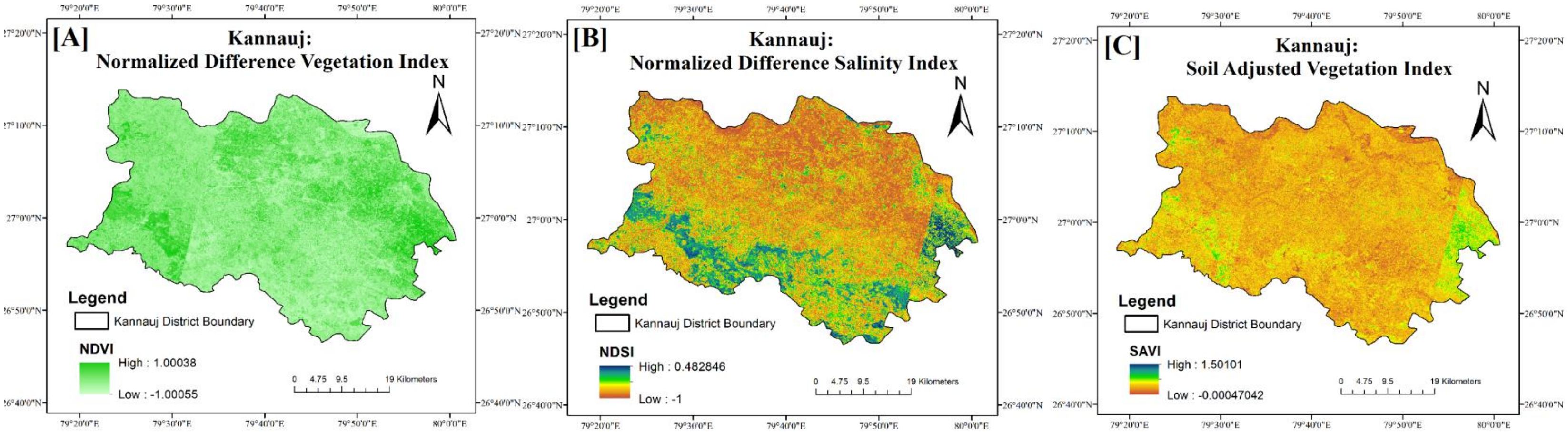
The Kannauj District has not characterised by dense vegetation cover (Map-7.4 [A]). Similar is the case with the Tirwa Tehsil of Kannauj District (Map-7.5 [A]). According to the Forest Survey of India Report (2015), Kannauj has no area under *"very dense forest"* as well as no area under *"moderately dense forest"*. Moreover, only 28 km^2 areas have been under the *"open forest"* category that has covered on

1.34 percent of the TGA. The district has recorded an increase of 1 km square area under forest in 2017 (FSI, 2017).

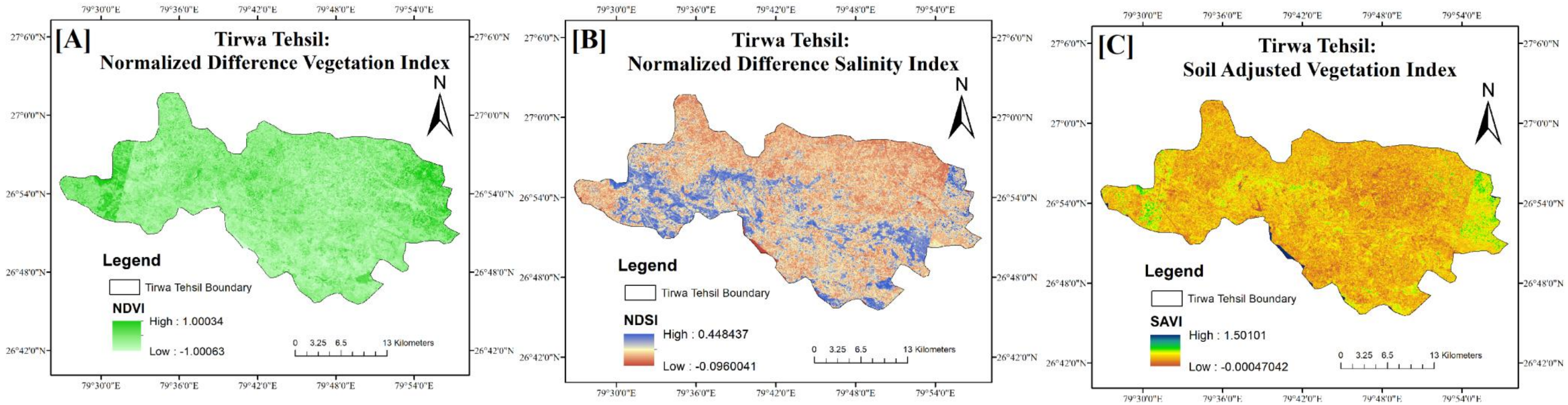
NDSI map (Map-7.4 [B]) has inferred that the Eastern and Southern part of Kannauj District has more soil salinity concentration, especially in Tirwa Tehsil (Map-7.5 [B]). The concentration of soil salinity has witnessed in the Tirwa Tehsil areas (Map-7.4 [B] and Map-7.5 [B]). Geomorphologically, the soil has been largely characterised by the alluvial origin, mostly from the Ganga River. The ox-bow formation has also been witnessed in the Tirwa Tehsil (Map-7.6 [A]). Salt area has extensively affected the land in tehsil and it has been marked with yellow colour in Map-7.6 [B]. Notably, the area is also having the waterlogging problem marked with blue colour on the same map. It the first place, the salinity problem in the tehsil has been categorised into low, moderate and high (Map-7.6 [C]. Lower Ganga Canal has provided extended irrigation facilities (Map-7.6 [D]. the severe saline condition has been recorded near the canal region and the periphery has characterised as moderate salinity and lower salinity. It has not seemed true in every case as the northern area of Tirwa Tehsil has not severely affected by soil salinity problem (Map-7.6 [D]).

Land use land cover map has not sown drastic change in land use pattern from 2005-06 to 2011-12. However, in case of vegetation cover, it has been seen that there has been a decline into forest cover and at the same time, the agricultural area has expanded (Map-7.6 [E] and [F]).

Irrigation expansion has been traced at all administrative level in Uttar Pradesh. There has been an increase of 14.55 percent of irrigation area since 1995-96 in Uttar Pradesh, 9.51 percent of irrigation area since 2000-01. However, the Tirwa tehsil has witnessed 1.61 percent decrease in irrigation area since 2000-01. Regardless of this, there has been a decrease of unirrigated land at all administrative level. Notwithstanding, the regions at every administrative level has witnessed a decline in gross cropped areas (Fig.-7.2 [A]). Thus, it can be inferred that the diversified land cultivation at various season has declined over a period of time (Fig.-7.2 [B]). Under the land use of different agricultural categories, the Net shown area has been declined at all the administrative level (Table-7.2). In case of net cultivation areas, though Uttar Pradesh has witnessed a decline, however, Kannauj District and Tirwa Tehsil has registered increase (Table-7.2).

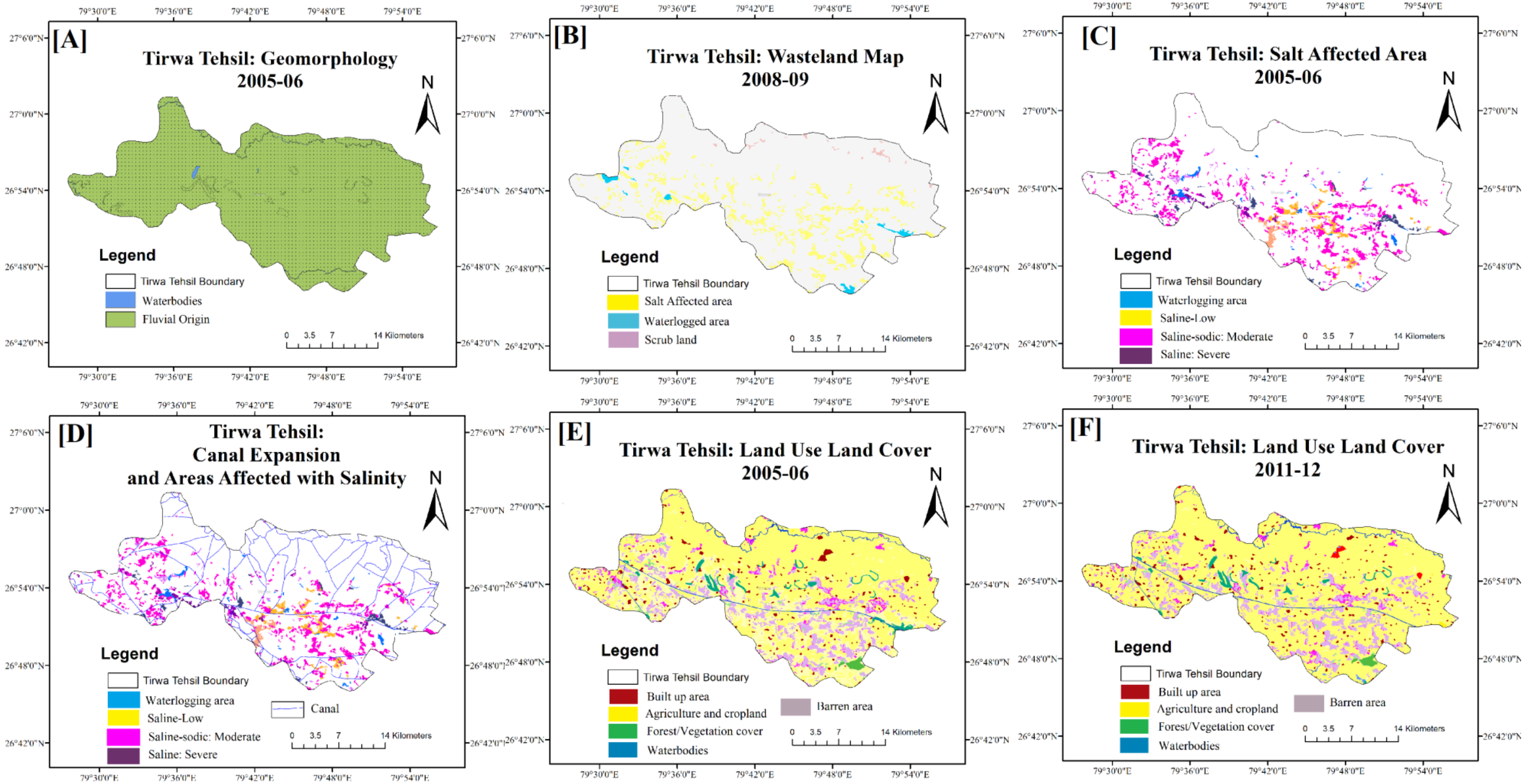


Map-7.4 [A] Map representing the NDVI in the Kannauj District-2016, [B] Map representing the NDSI in the Kannauj District-2016 and [C] Map representing SAVI for the Kannuj District-2016



Map-7.5 [A] Map representing the NDVI in Tirwa Tehsil-2016, [B] Map representing the NDSI in Tirwa Tehsil-2016 and [C] Map representing SAVI for Tirwa Tehsil-2016

Source: The map prepared by the author by using a various band of Landsat-8 imageries provided by the USGS through the url:https://glovis.usgs.gov/app?fullscreen=1, the images acquisition dates were of 7th May 2016 and 21st October 2016 to cover the whole area of Kannauj.



Map-7.6 [A] Geomorphology of the Tirwa Tehsil with it origin characteristics, [B] Wasteland distribution in the Tirwa Tehsil, [C] Concentration of the soil salinity in the Tirwa Tehsil,[D] Canal expansion and soil salinity in the Tirwa Tehsil,[E] Land used characteristics in the Tirwa Tehsil-2005-06 and [F] Land used characteristics in the Tirwa Tehsil-2011-12.

Source: Source: Maps are reproduced by the author by using the ArcGIS online tool to get the various thematic maps from Bhuvan Thematic Service, NRSC, ISRO, URL-http://bhuvan.nrsc.gov.in/gis/thematic/index.php.

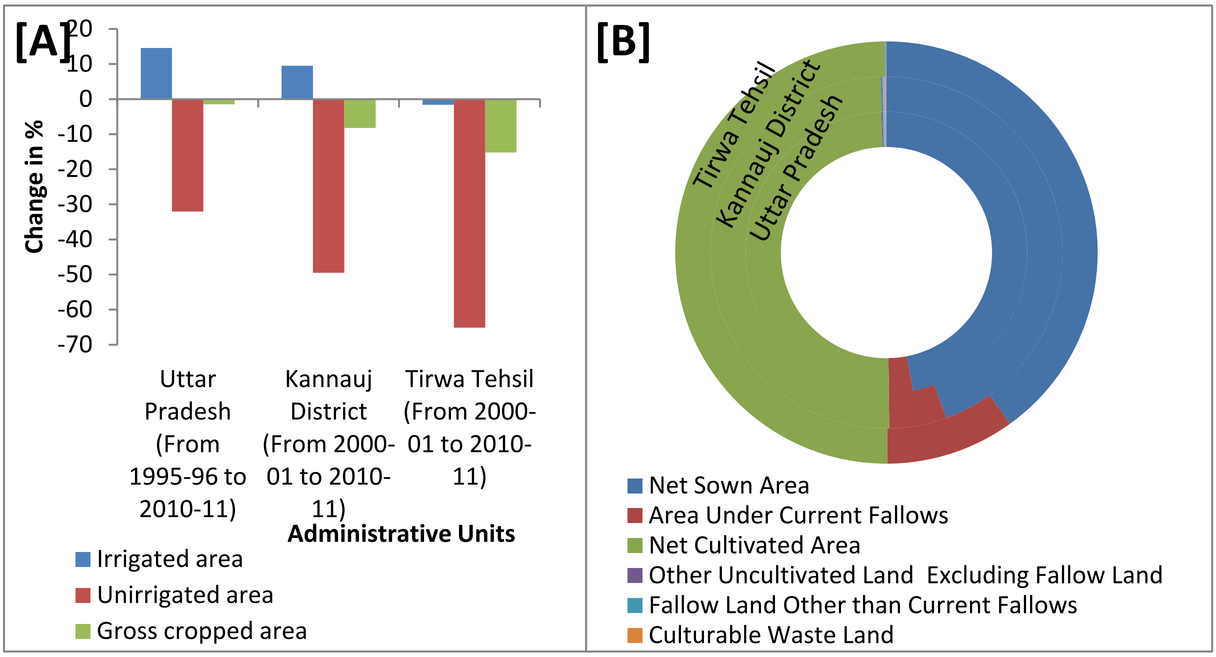


Fig.-7.2 [A] Change in cropping pattern at different administrative levels and [B] Land-use pattern in the year 2010-11 (*Source: The Agriculture Census of India)*

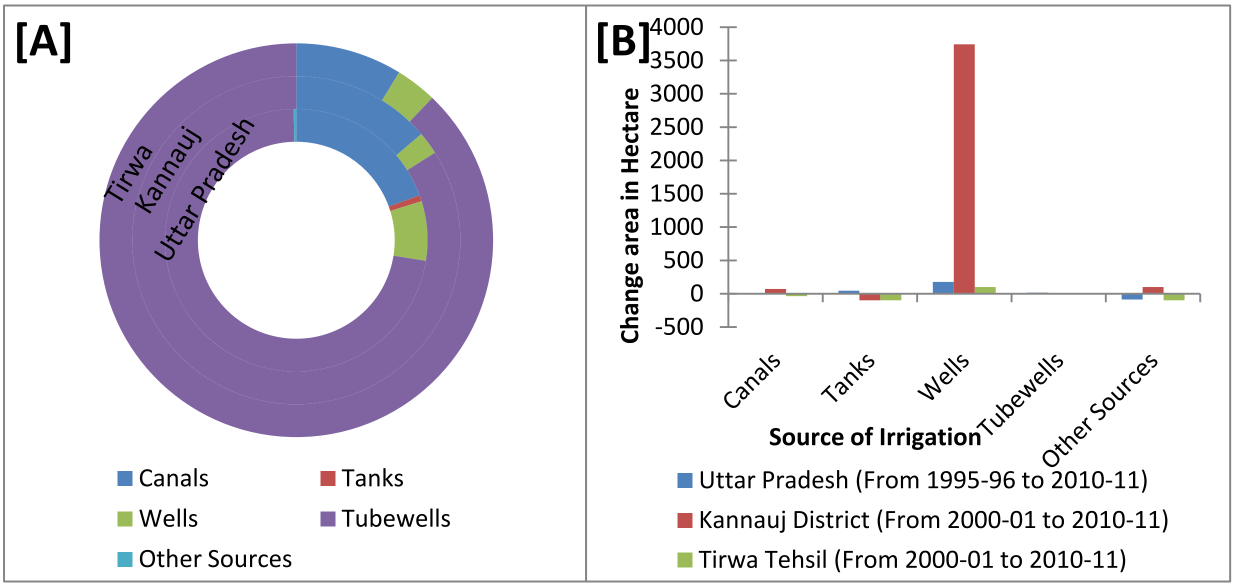


Fig.-7.3 [A] Irrigated areas under different sources in year 2010-11and [B] Changes in Irrigated areas by various sources at different administrative levels

Source: Graph has been constructed by the author by using data taken from the Agriculture Census of India

In the year 2010-11, the net cultivated area has the largest share in total agricultural land use followed by net sown area. The area under current fallow was 10208 hectares and the total uncultivated land was 70 hectare (Table-7.2) (Fig.-7.2 [B]).

Fallow land under various categories in Tirwa tehsil has not changed from 2000-01 to 2010-11 (Table-7.2). In Tirwa tehsil more than 91 percent of Gross Cropped Area (GCA) is under irrigation facility. Monsoonal rainfall facilitates as complimentary for the cultivation of crops. Depending on the well-established irrigation system and its accessibility this region is practiced with extensive agriculture. The tube wells are the major source of irrigation in the study area (87 percent of total irrigated area) followed by canals (8.75 percent of the total irrigated areas), wells (3.39 percent of total irrigated areas) in 2010-11 (Agriculture Census, 2010-11). The Wells as means of irrigation has seen 100 percent from 2000-01 to 2010-11 meaning people are moving towards better irrigation system into the region. While other sources as means of irrigation have shown a decline in Tirwa Tehsil since 2000-01 (Table-7.3).

Table-7. 2 Land-use changes (in Percentage)

Land Use	**Uttar Pradesh (From 1995-96 to 2010-11)**	**Kannauj District (From 2000-01 to 2010-11)**	**Tirwa Tehsil (From 2000-01 to 2010-11)**
Net Sown Area	-3.38	-3.03	-9.75
Area Under Current Fallows	-5.76	218.54	0.00
Net Cultivated Area	-3.52	4.68	7.94
Other Uncultivated Land excluding Fallow Land	-56.55	0.00	0.00
Fallow Land Other than Current Fallows	-74.80	0.00	0.00
Culturable Waste Land	-77.35	-77.58	0.00
Total Uncultivated Land	-68.75	-55.15	0.00
Land Not Available for Cultivation	-84.01	0.00	0.00

Source: Calculated by the author by using data provided by the Agriculture Census of India.

Table-7.3 Irrigation characteristics at different administrative level

Source	Irrigated areas by source 2010-11 (in hectares)			Changes in Irrigated area under different sources (in percentage)		
	Uttar Pradesh	Kannauj District	Tirwa Tehsil	Uttar Pradesh (From 1995-96 to 2010-11)	Kannauj District (From 2000-01 to 2010-11)	Tirwa Tehsil (From 2000-01 to 2010-11)
Canals	2610396	18925	3606	-257382	7960	-2037
Tanks	100702	0	0	31696	-68	-5
Wells	982763	3074	1395	626977	2994	1395
Tube wells	9689276	115186	36200	1332852	-10974	-1583
Other Sources	42949	0	0	-271731	-1364	-1061

Source: Calculated by the author by using data provided by the Agriculture Census of India.

The above analysis has been provided a background knowledge which is essential to further go for the case study at the micro-level. The two villages- Madanapur and Gurauli- have been further studied in section-7.3.1 and 7.3.2 extensively to know about the different dimensions of soil salinity at the ground level among the farmers.

7.3.1 CASE STUDY-1

Madanapur Village has a salinity problem but it is not severe in nature. The village has a skewed sex ratio accounting 895 female per thousand male populations. In the case of child sex ratio, it has a good record of 1056 girl child per thousand boy child. The literacy rate is 61 percent in Census (2011), where male literacy is 72.20 percent while female literacy is 48.59 percent (Fig.-7.4). 34.12 percent of total population has engaged in the workforce (Fig.-7.5). Total participation of female into the total workforce is only 20.77 percent. Though female participation in the total main workforce is very low to 22.06 percent, it is higher than the total marginal workforce, where female participation is very low to 9.72 percent (Fig.-7.4). Similarly, the total marginal population in the village has been very low, only 3.55 percent of the total population has engaged in the marginal workforce. Out of which majority of them engaged in marginal agriculture. Conversely, most of working population has engaged in the main workforce (30 percent of the total population into the main workforce).

Interestingly, more than 90 percent of them have been engaged as main cultivators (Fig.-7.5).

Findings of Primary Survey: Out of 50 household surveys with the farmers, 6 large farmers, 12 medium farmers and 32 small and marginal farmers have been selected for the interviews. Out of all respondents, 12 were illiterate, 28 were educated up to senior secondary level and 10 are graduated. Major illiteracy has been found in small and marginal farmers because out of 12 total illiterate respondents, 12 are small and marginal farmers (Fig.-7.6 [A] and Table-7.4). Other than agriculture, respondents have also preferred to work in other fields of employment because of agriculture not being profitable or sufficient for livelihood (FGD-2 in Madanapur Village). No respondent has engaged in the self-employment. 2 percent of the respondent has taken regular/salary jobs, 56 percents of respondents have worked as a casual labourer in agriculture other's field and 26 percent of respondents have opted for work into non-agricultural areas. 16 percent of respondents have worked for other works either within the village or outside the village (Fig.-7.6 [B] and Table-7.5).

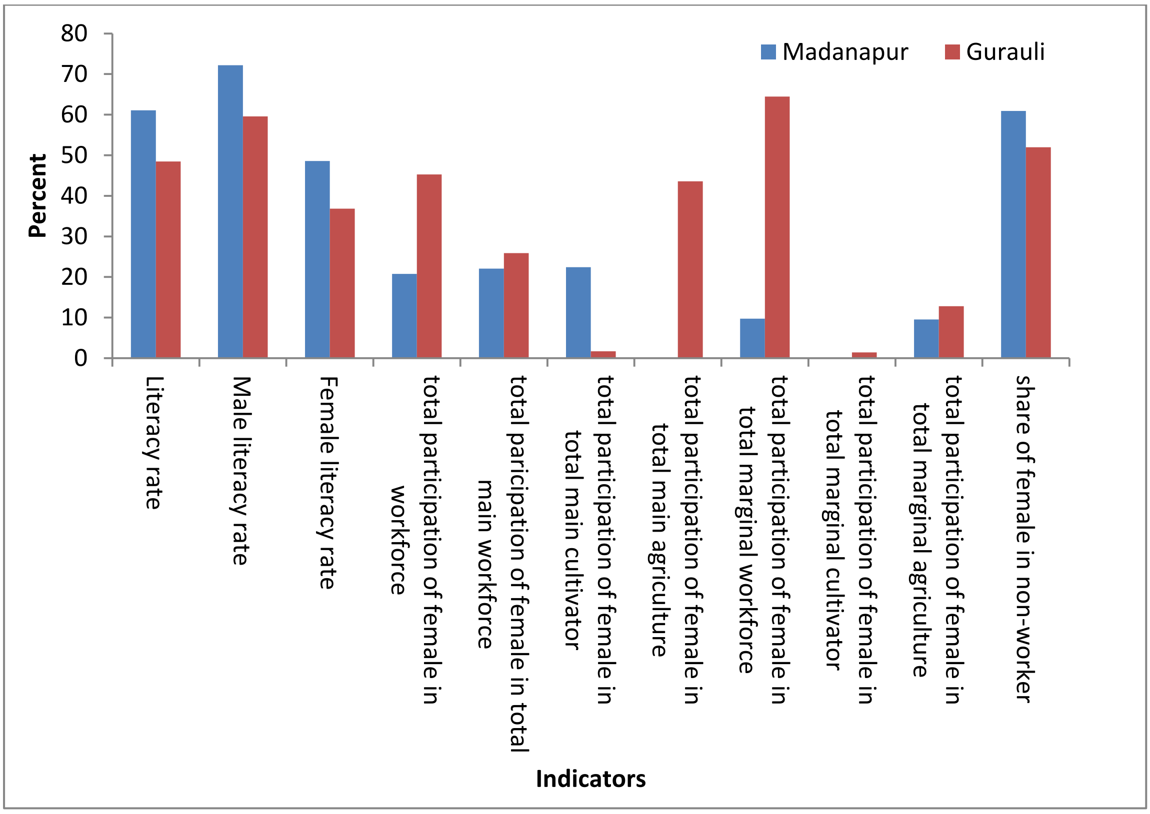


Fig.-7.4 Agro-demographic characteristics of the village Madanapur and Gurauli especially focusing on the female participation

Source: Prepared by the author by using data provided by the Census of India, 2011.

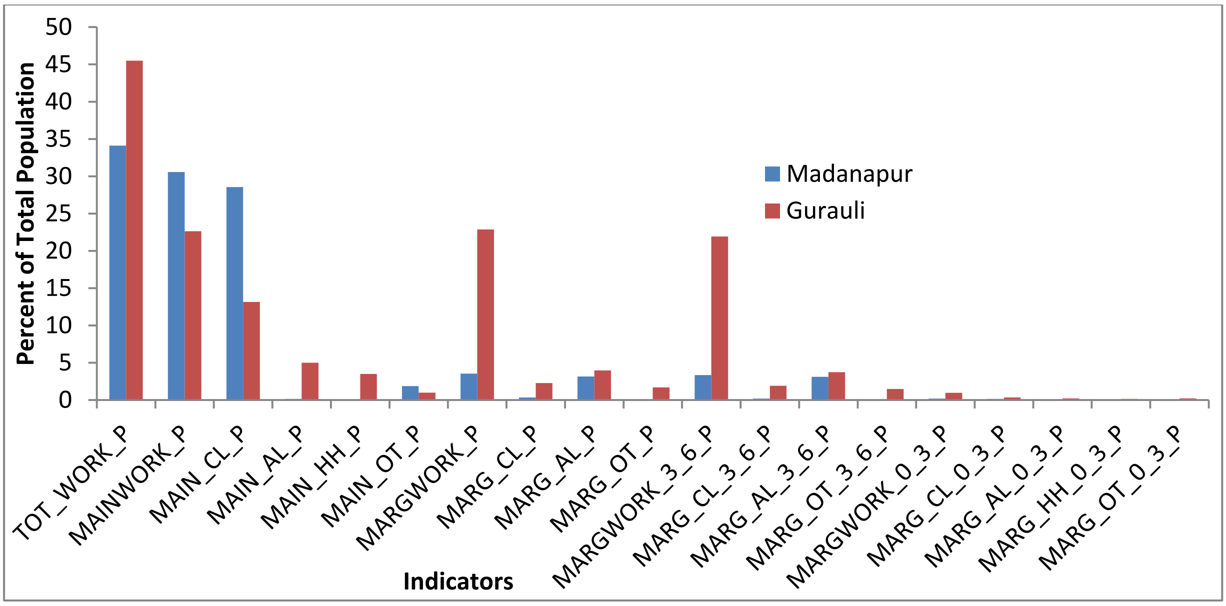


Fig.-7.5 Agro-demographic characteristics of the village Madanapur and Gurauli

Source: Prepared by the author by using data provided by the Census of India, 2011.

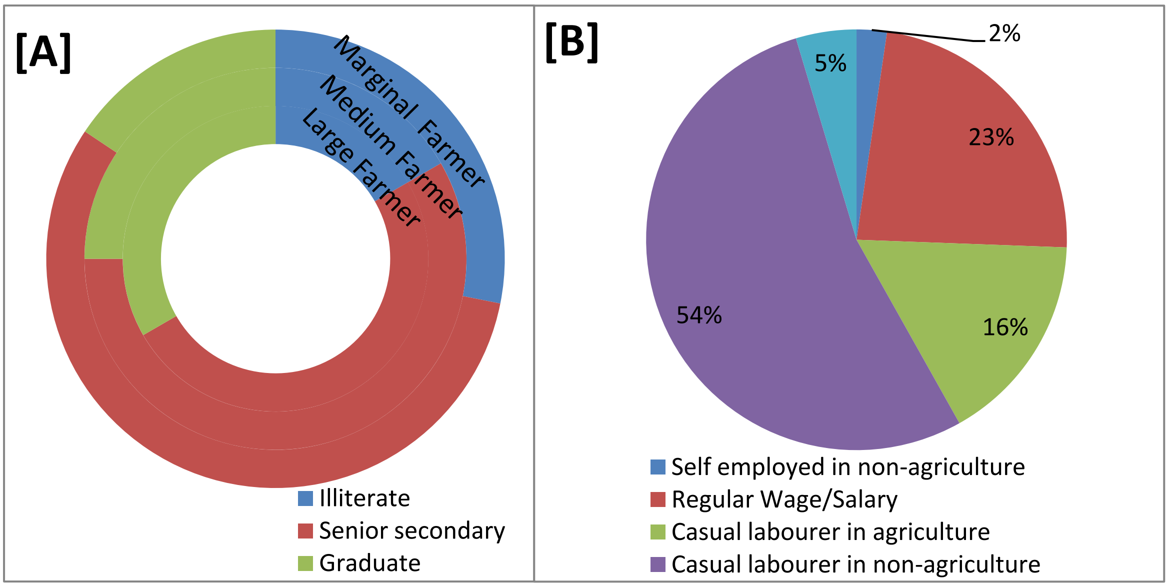


Fig.-7.6 (A) Education level among the sampled Farmers and (B) Occupation of the sampled farmers other than the farming in their own land in the Madanapur Village

Source: The graph prepared by the author by using the data collected from a primary survey in December 2017.

Table-7.4 General agricultural profile of the sampled respondents of the Madanapur Village of the Tirwa Tehsil (in percentage to the total respondents)

Educational status of the farmers				Landholding and farming land			
	Sample interviews	Illiterate	Senior secondary	Graduate	Average land holding size (Hectares)	Average land used in farming (%)	Access to irrigation sources (%)
Large Farmers	6	1	3	2	14	94	100
Medium farmers	12	2	7	3	4.5	98	100
marginal farmers	32	9	18	5	1.1	100	100
Return on investment (% of the respondent)				Sell of the share of the total output (% of the respondents)			
	Total Agricultural Input cost only	Total more than Agricultural Input	Total less than Agricultural Output	0-25 %	25-50 %	50-75 %	75-100%
Large Farmers	16.67	66.66	16.67	0	66.67	33.33	0
Medium farmers	25	66.67	8.33	41.67	58.33	0	0
marginal farmers	21.88	28.12	50	84.37	15.63	0	0

Source: Calculated by the author from the primary survey data collected on December 2017.

Average land holding size of sampled large farmers was 14 hectares, for medium farmers were 4.5 hectares and 1.1 hectares for the small and marginal farmers. The average land holding uses was 94 percent for large farmers, 98 percent for medium farmers and 100 percent for the small and marginal farmers. Access to irrigation facilities are 100 percent to all farmers (Table-7.4) through various means but majorly through wells, tubewell and canals (FGD-1 in Madanapur Village). 16.67 large farmer responded that their return on investment equal to the input cost only, while 25 percent and 21.88 percent medium farmer and small and marginal farmer respondents respectively got the equal return on investment to input cost only. 66.66 percent of large, 66.67 percent of medium and 28.12 percent of small and medium farmer respondents has incurred returns more than their agricultural inputs. 16.67 percent of a large farmer, 8.33 percent medium farmer and 50 percent of small and medium farmer respondents have obtained less return than their investment into the land (Table-7.4).

The loss of crops due to various calamities and no security of the crops have been attributed to the reason behind not getting a better return on investment by respondents. Marginal farmer respondents have to seek cultivation for the livelihood even it has not resulted profitable (FGD-2 in Madanapur Village).

The large and medium farmer respondents have able to sell their product because they would able to produce more compared to small farmers. 66.67 percent of large farmer respondents have sold their 25-50 percent total output, while in same category 58.33 percent medium farmer and only 15.63 percent small and marginal farmer respondents are able to sell their product. Not farmer respondent has sold 75-100 percent of the total output (Table-7.4) as no-commercial farming has extensively practiced in the village (FGD-1 in Madanapur Village).

36 percent of respondents have practiced agriculture only on land, while 56 percent of respondents have done both agriculture and livestock. Moreover, only 2 percent of respondent prefers to do agriculture with animal husbandry and 6 percent find their land very difficult to use. 76 percent has observed the present condition of land as more productive than earlier, while 6 percent responded for the same productiveness and 18 percent for the less productive land (Table-7.6).

Table-7.5 Characteristics of the agricultural land of the farmers (sampled respondents) in the Madanapur Village				
Mode of work in agricultural land	Yes	Land used for other purpose		
1. Agriculture only	36	Type	Yes	No
2. Agriculture and forestry	0	1. Digging of soil from the field	2	98
3. Agriculture and animal husbandry	56	2. Mining around the land	0	100
4. Agriculture, forestry and animal husbandry	2			
5. Difficult to use land	6	Input into the land (since five years)		Yes
6. Other	0	i. Decrease in irrigation facility		0
		ii. Equal irrigation facility		56
Occupation	Yes	iii. Increased irrigation Facility		44
Employed in agriculture	100	iv. More fertilizer used		86
Self-employed in non-agriculture	0	v. Equal fertilizer used		14
Regular Wage/Salary	2	vi. Less fertilizer used		0
Casual labourer in agriculture	56	vii. HYV seeds are used		100
Casual labourer in non-agriculture	26	viii. No awareness		78
Others, Specify	16	ix. less awareness		12
		x. More organized agriculture		2
		xi. less organized agriculture		98
Land productiveness (since five years)	Yes	xii. More labour involved		24
a)More productive	76	xiii. Less or equal labour		76
b)Productive as earlier	6	xiv. Pesticide used		100
c)Less productive	18	Soil composition changed (since five years)		Yes
Soil fertility since five years Yes		i. Good from earlier		72
Decreased	46	ii. Bad from earlier		18
Equal	48	iii. Very Bad from earlier		10
Increased	6	iv. Worse from earlier		0
Source: Calculated by the author from the primary survey data collected during December 2017				

Regarding soil composition, the 72 percent respondent found it better from earlier, 18 percent found bad from earlier and 10 percent found very bad from earlier. In the case of soil fertility, it has been noticed decreased by 46 percent, equal by 48 percent and increased by 6 percent by the respondents (Table-7.5). Moreover, 50 percent respondents have marked no salinity in their land, while 14 percent noted low salinity, 18 percent moderate salinity and 18 percent high salinity (Table-7.6) (Plate-7.1).

Table-7.6 Characteristics of the soil salinity in the Madanapur Village based on farmers perception (in percentage to the total sampled respondents)

Causes of soil salinity	Yes	Salinity experienced	Yes
i. High temperature	0	No salinity	50
ii. Low rainfall	0	Low	14
iii. Non-scientific (Faulty) agricultural practices	20	Moderate	18
iv. Lack of irrigation facility	0	High	18
v. Lack of Freshwater (saline free)	52		
vi. Irrigation by the saline water without proper distribution on the field	0		
vii. Lack of awareness about the scientific way of agriculture	48		
viii. water-logging	52		
ix. Lack of drainage facility	12		
x. overuse of chemical fertiliser	22		
xi. the absence of traditional agriculture	12		
xii. Irrigation through saline water	42		

Source: Calculated by the author from the primary survey data collected during December 2017.

Plate-7.1 "Usar" Soil in the village Madanapur containing salt content. It is demarcated into a red line in the photograph which is largely between the two lands. Other than demarcated land is agricultural land, which is being reclaimed by the locals.

Source: Photograph taken during the fieldwork by the author on December 2017.

7.3.2 CASE STUDY-2

The Gurauli Village has a population of 3125, where the sex ratio is 958 and child sex ratio is very poor to 919 according to Census (2011). The literacy rate is 48.45 percent, where male literacy is 59.59 percent and female literacy is 36.82 percent (Fig.-7.4). 45 percent population is working for the population. 22.62 percent of total population is into the main workforce and 22.88 percent are into the marginal workforce. Compared to Madanapur Village, people participation in main agriculture is higher (4.99 percent of the population), while participation marginal agriculture has been equal. Non-working population in Gurauli was lower (17.38 percent) compared to Madanapur Village (31.07 percent) (Fig.-7.5). Female participation in the total workforce has been 45 percent in 2011, wherein total main workforce is 25.88 percent and 64 percent in the total marginal workforce. Female participation in main agriculture is 43.59 percent. This reflects the feminisation of agriculture in the village (Fig.-7.4).

Findings of Primary survey: Total 50 respondents have been taken from the village Gurauli. Out of which 4 were large farmers, 13 were medium farmers and 33 were small and marginal farmers. Contrary to Madanapur, Gurauli has high soil salinity problem and the village is having located around the canal through which it gets the irrigation facility (Plate-7.2). Saline affected land usually calls "*Usar*" (barren) into local language in the village (FGD-3 in Gurauli Village).

The respondent informed that there are two types of "*Usar*"- "*Nunila Usar"* (Salty Usar) and Other *Usar.* The first type of *Usar* is very prominent in the village, which is more harmful to the fertility and it is very difficult to restore this type of soil (FGD-4 in Gurauli Village). There has been seen the "*Kankar pan*" layer of calcium carbonate into sub-soil layer (Plate-7.3), which do not support the vegetation to grow maturely (FGD-4 in Gurauli Village).

Plate-7.2 [A] Canal adjacent to village Gurauli, [B] Agricultural land affected by the soil salinity near the canal, which is marked by red colour, [C] The Red color marked land is highly affected with soil salinity compared to the adjoining land. It is the zoomed image of the red color marked in section-[B], and [C] Land reclaiming process have a different effect as some area are still non-productive in the same vicinity marked by the yellow arrow, red arrow denotes the reclamation being relatively successful and green arrow represent still highly saline and non-reclaimable.

Source: Photograph taken during the fieldwork by the author on December 2017.

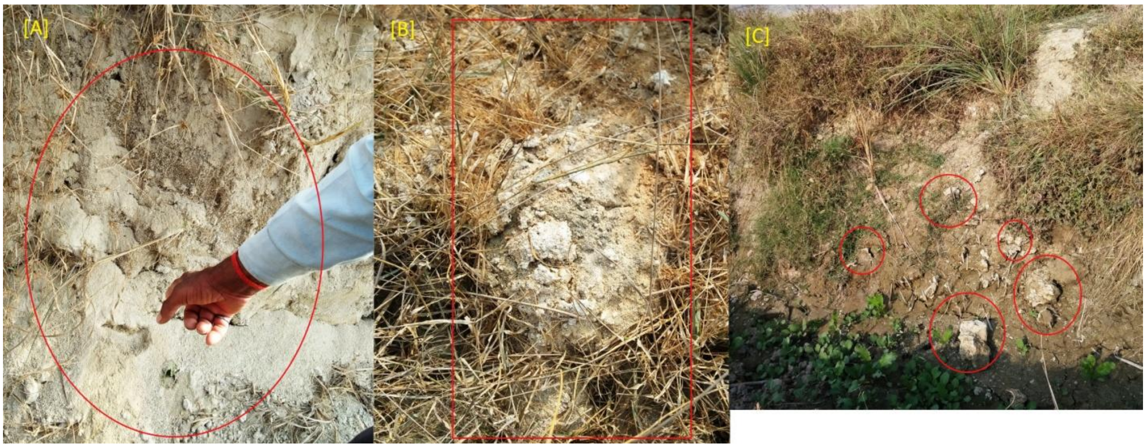


Plate-7.3 [A] Salty "Usar", in taste also it is found salty (according to a local farmer), [B] Big "Kankar" formation and [C] Red circle is the area of "Kankar" formation below the top layer of the soil.

Source: Photograph taken during the fieldwork by the author on December 2017.

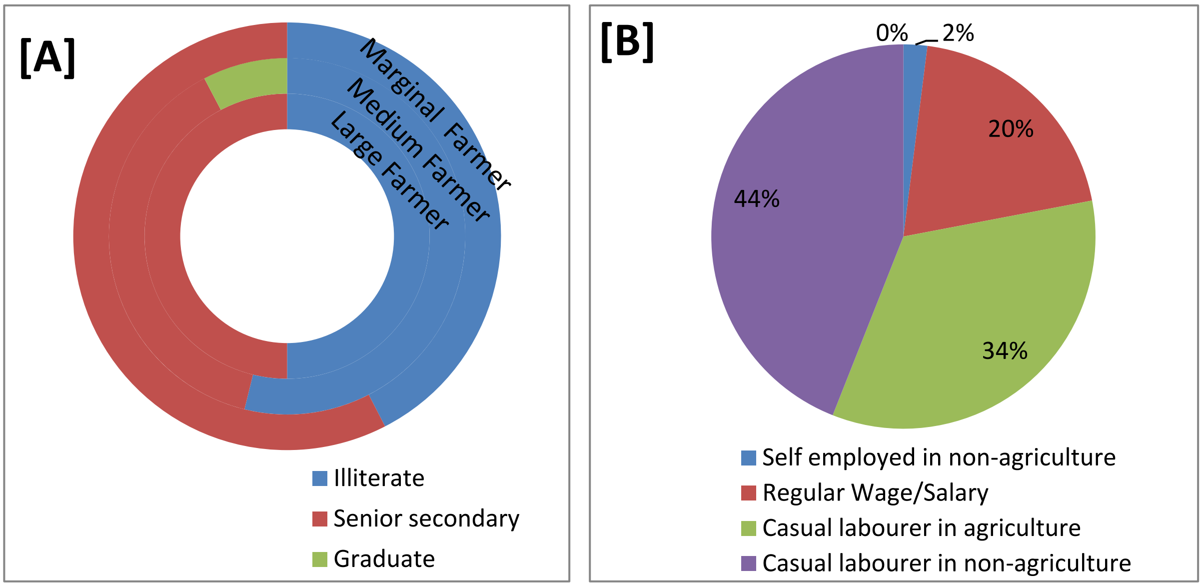


Fig.-7.7 (A) Education level among the sampled Farmers and (B) Occupation of the sampled farmers other than the farming in their own land in the Gurauli Village

Source: The graph prepared by the author by using the data collected from a primary survey in December 2017.

In all the interviews, the education level of farmers has been asked. 2 out of 4 large farmers were illiterate, 2 were educated at the senior secondary level and no one to graduate level. Only 1 respondent out of total 50 sampled farmers has education up to graduation level. Average land holding size of the large farmer was 12.5 hectares, of the medium farmer was 4.91 hectares and of small and marginal farmers was 0.65 hectares. On an average, large farmer respondents have used their 95 percent land for farming, medium farmer and small and marginal farmer respondents have been using their land 100 percent for cultivation. Thus, the extensive intense cultivation has practiced in the village (Table-7.7).

Access to irrigation for large farmer respondent was 100 percent, for medium farmer 84.61 percent and small and marginal farmers was 87.88 percent (Table-7.7). The status of access to irrigation is at the medium level in the selected village. It is on average more than the access to irrigation in villages selected from Rajasthan (Chapter-6) and less than the villages selected from Punjab (Chapter-6).

Table-7.7 General agricultural profile of the sampled respondents of the Gurauli Village of the Tirwa Tehsil (in percentage to the total respondents)

Educational status of the farmers					Landholding and farming land		
	Sample interviews	Illiterate	Senior secondary	Graduate	Average land holding size (Hectares)	Average land used in farming (%)	Access to irrigation sources (%)
Large Farmers	4	2	2	0	12.5	95	100
Medium farmers	13	7	5	1	4.91	100	84.61
marginal farmers	33	14	19	0	0.65	100	87.88
Return on investment (% of the respondent)				Sell of the share of the total output (% of the respondents)			
	Total Agricultural Input cost only	Total more than Agricultural Input	Total less than Agricultural Output	0-25 %	25-50 %	50-75 %	75-100%
Large Farmers	0	100	0	0	75	25	0
Medium farmers	15.38	61.54	23.08	61.54	30.77	7.69	0
marginal farmers	24.24	45.45	30.31	84.85	15.15	0	0

Source: Calculated by the author from the primary survey data collected during December 2017.

Table-7.8 Characteristics of the agricultural land of the farmers (sampled respondents) in the Gurauli Village				
Mode of work in agricultural land:	Yes	Land used for other purpose		
1. Agriculture only	8	Type	Yes	No
2. Agriculture and forestry	0	1. Digging of soil from the field	0	100
3. Agriculture and animal husbandry	82	2. Mining around the land	0	100
4. Agriculture, forestry and animal husbandry	0			
5. Difficult to use land	46	Input into the land (since five years)	Yes	
6. Other	0	i. Decrease in irrigation facility	10	
		ii. Equal irrigation facility	56	
Occupation	Yes	iii. Increased irrigation Facility	34	
Employed in agriculture	100	iv. More fertilizer used	92	
Self-employed in non-agriculture	2	v. Equal fertilizer used	8	
Regular Wage/Salary	20	vi. Less fertilizer used	0	
Casual labourer in agriculture	34	vii. HYV seeds are used	100	
Casual labourer in non-agriculture	44	viii. No awareness	62	
Others, Specify	0	ix. less awareness	38	
		x. More organized agriculture	58	
		xi. less organized agriculture	42	
Land productiveness (since five years)	Yes	xii. More labour involved	24	
a)More productive	22	xiii. Less or equal labour	76	
b)Productive as earlier	26	xiv. Pesticide used	100	
c)Less productive	52	Soil composition changed (since five years)	Yes	
Soil fertility since five years	Yes	i. Good from earlier	36	
Decreased	46	ii. Bad from earlier	34	
Equal	32	iii. Very Bad from earlier	16	
Increased	22	iv. Worse from earlier	14	
Source: Calculated by the author from the primary survey data collected during December 2017.				

Moreover, 100 percent of large farmer respondents could incur returns more than their investment into the agriculture. However, this has not been like the medium farmer and small and marginal farmer respondents. 15.38 percent medium farmer respondents have incurred return equal to the input cost only. In a similar category, 24.24 percent small and marginal farmer respondents have agreed. 61.54 percent of a medium farmer and 45.45 percent of small and marginal farmer respondents were able to get more return than their input costs. But, 23.08 percent of a medium farmer and 30.31 percent of small and medium farmer respondents have met with a loss in agriculture. Interestingly, in sampled farmers, no farmer respondents have managed to sell their 75-100 percent of their total agricultural products. Moreover, only 25 percent of a large farmer and 7.69 percent of medium farmer respondents have carried out selling off 50-75 percent of the total product. Majority of medium, small and marginal farmer respondents comes into the category, where either does not manage to sell or can sell only up to 25 percent of the total product (Table-7.7).

Table-7.9 Characteristics of the soil salinity in the Gurauli Village based on farmers perception (in percentage to the total sampled respondents)

Causes of soil salinity	Yes	Salinity experienced	Yes
i. High temperature	0	No salinity	2
ii. Low rainfall	0	Low	20
iii. Non-scientific (Faulty) agricultural practices	26	Moderate	44
iv. Lack of irrigation facility	0	High	34
v. Lack of Freshwater (saline free)	100		
vi. Irrigation by the saline water without proper distribution on the field	20		
vii. Lack of awareness about the scientific way of agriculture	26		
viii. water-logging	46		
ix. Lack of drainage facility	16		
x. overuse of chemical fertiliser	48		
xi. the absence of traditional agriculture	12		
xii. Irrigation through saline water	100		

Source: Calculated by the author from the primary survey data collected during December 2017.

7.3.3 COMPARATIVE ANALYSIS OF SOIL SALINITY STATUS IN CASE STUDY VILLAGES

Regarding the mode of work in the agricultural land between both villages, the more respondents of village Madanapur has preferred to do agriculture only, while more respondents of Gurauli Village has opted for the agriculture with livestock compared to village Madanapur (Fig.-7.8 (a) and (b). Moreover, in the case of occupation, both villages have contrasting features. More casual labour in agriculture has found in Madanapur Village than Garauli Village. However, casual labour in non-agriculture has found in Gurauli Village (Fig.-7.8 (c) and (d).

Soil fertility has been decreased in both the villages (as 46 percent of respondents in both villages). In Madanapur, 48 percent of respondents have observed equal fertility, while in case of Gurauli Village it is only 32 percent of respondents said so. In Madanapur Village, only 6 percent of the respondents have found an increase in fertility. Conversely, in Gurauli Village, 22 percent of respondents have found land is having more fertility than earlier (Fig.-7.9 (a). Soil composition has been said to be good by 72 percent in Madanapur, while by 36 percent respondents in Gurauli Village. 14 percent respondents in Gurauli Village rated the soil composition bad from earlier, while no one in Madanapur has rated their land composition to worse (Fig.-7.9 (b).

When asked about the salinity status into the land of the farmers, 50 percent respondents of Madanapur have not found salinity in their soil, while in case of Gurauli only two percent respondent observed this. 14 percent respondents of Madanapur have mentioned low soil salinity, which is a lower compared to Gurauli (20 percent respondents). Moderate soil salinity has been found in 18 percent of respondents in Madanapur Village, drastically lower than Gurauli where 44 percent of respondents have found moderate soil salinity. High salinity has been marked by 18 percent of Madanapur Village, while by 34 percent respondents into Gurauli Village (Fig.-7.9 (c).

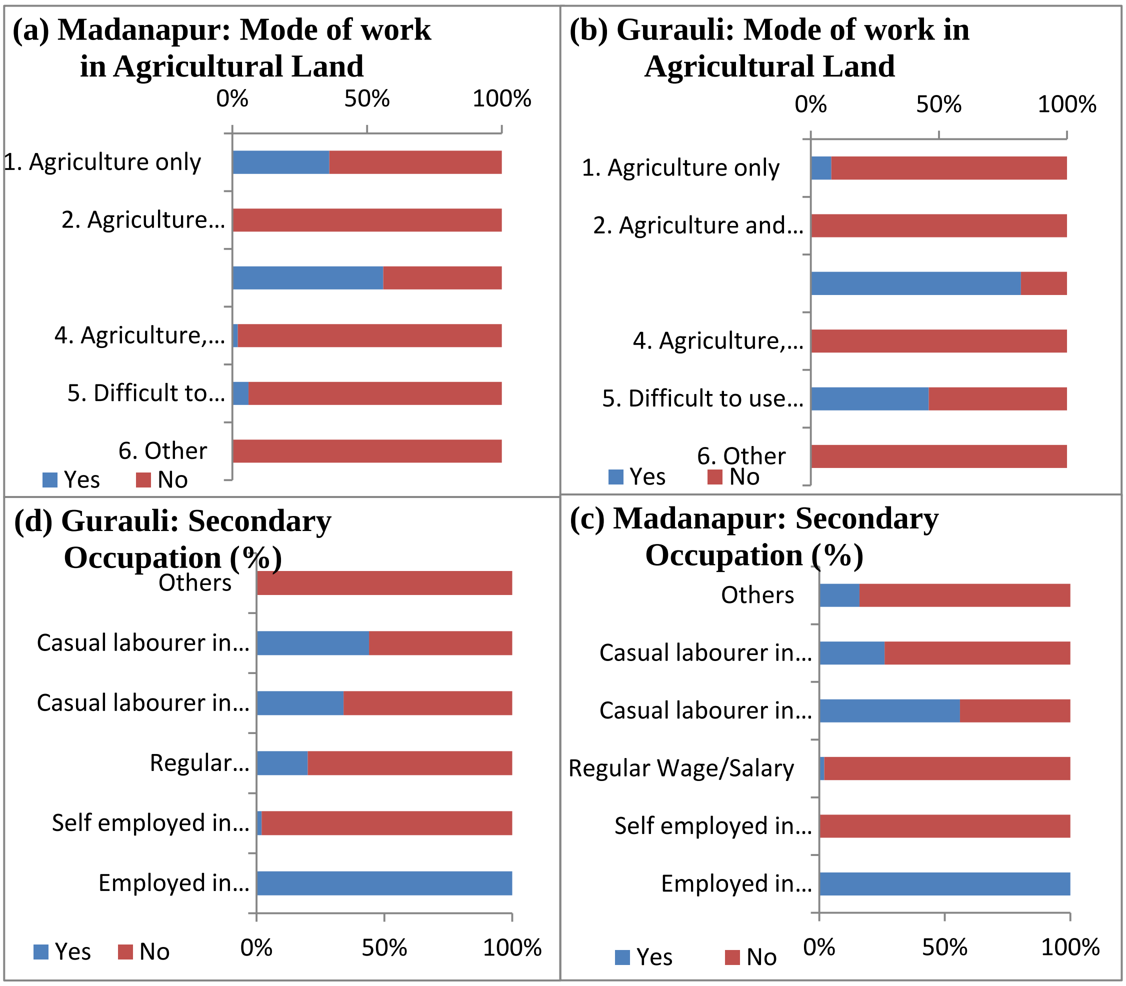


Fig.-7.8 Comparative between the Madanapur and Gurauli on the basis of Occupation

Source: Presentation through graph by author using the primary survey data collected from the selected respondents of both villages during December, 2017.

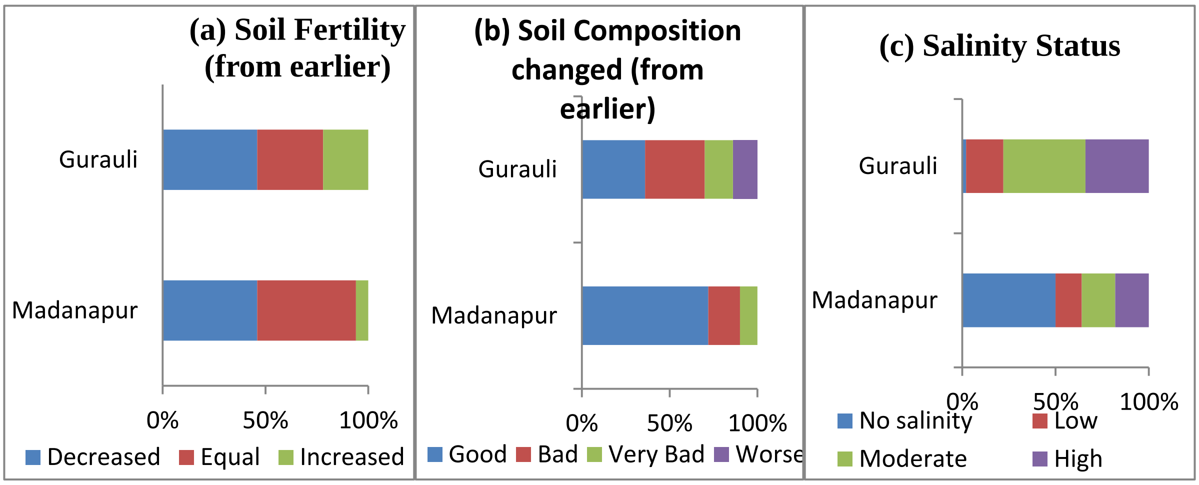


Fig.-7.9 Soil quality status in the village Madanapur and Gurauli

Source: Presentation through graph by the author using the primary survey data collected from the selected respondents of both villages during December 2017.

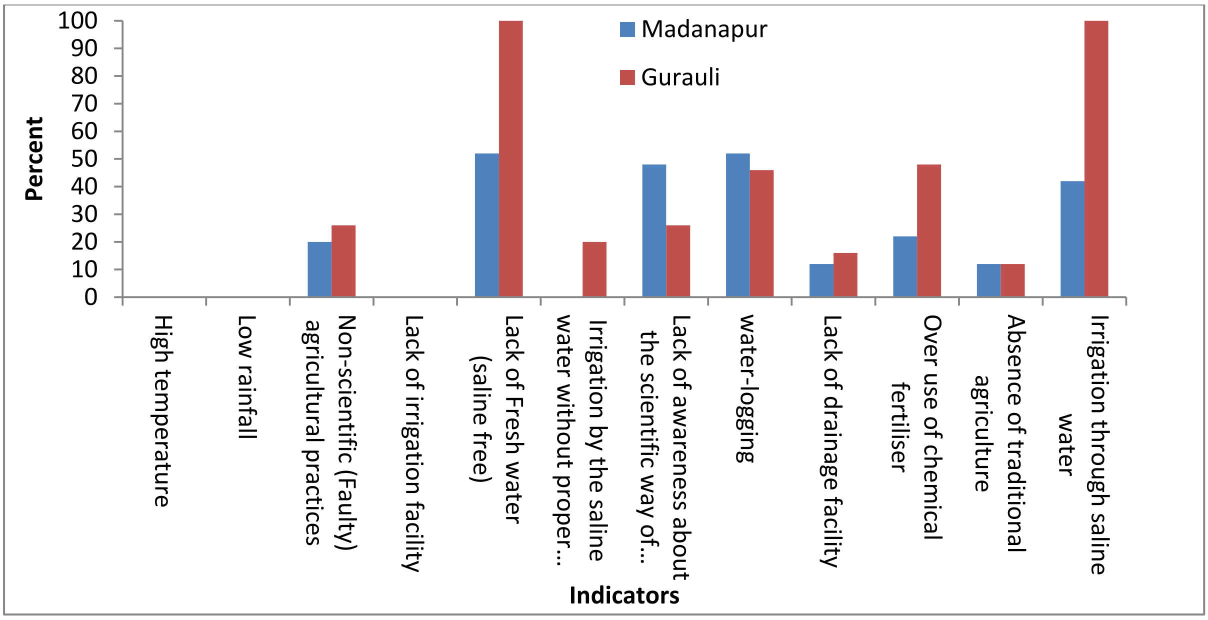


Fig.-7.10 Response on the cases of salinity by the respondents in village Madanapur and Gurauli

Source: Presentation through graph by the author using the primary survey data collected from the selected respondents of both villages during December 2017.

Generally asked about the causes of soil salinity, the major reason has emerged is irrigation through the saline water as well as improper irrigation through saline water into both the villages. Other reasons have been attributed to the lack of awareness, non-scientific (Faulty) agricultural practices, waterlogging, overuse of fertiliser etc. (Fig.-7.10). The impact of soil salinity has discussed with various farmers in villages. The Kankar formation into the sub-surface level is visible while digging the land. Some farmers have continuously engaged in the restoration of salt-affected land for more than 20 years and some of the lands has restored successfully. "*Hari Khad*" (organic fertiliser) has been used by the farmers into locality; mixing gypsum in the land has tried as another method. But the availability of gypsum has not been easy for all. One unique method has opted to minimize the impact of soil salinity was the stubble of the paddy has been spread over the field followed by the irrigation into the land (FGD-2 and 4 in Madanapur and Gurauli Village respectively).

7.4 COMPARATIVE ANALYSIS OF SOIL SALINITY STATUS IN CASE STUDY VILLAGES

As the perception of the farmers regarding the soil salinity of their land is quantified into four categories-'no soil salinity' in the land, 'low soil salinity', 'moderate soil salinity' and 'high soil salinity' based on their understanding about the level of soil salinity in their landholdings. As satellite imageries helped in identifying the low and high salinity villages, the same has been revealed by the perception about the soil salinity level in the villages under this study. It is the Habibwala Village, which recorded the highest no salinity status. 86 percent of all the respondents of the sampled farmers in the village have observed no soil salinity. Conversely, no respondents in Bagundi Village have observed salinity in their land. But, the 66 percent of respondents of the same village have recorded high salinity status, which is highest among the all other study areas. Moreover, 76 percent of respondents of Bhabra Azam Shahwala Village have perceived moderate soil salinity in their land holding, which is the highest among all villages in the same categories (Table-7.10).

Overall, soil salinity has been observed high by 21 percent of total respondents, while 38 percent of respondents have recorded moderate level soil salinity. Moreover, 16 percent of respondents have indicated a low level of soil salinity and 26 percent of respondents have communicated no level of soil salinity. It is revealed that people perception regarding the salinity status might be more grounded e.g. majority respondents of low soil salinity villages have recorded no soil salinity and majority respondents of high soil salinity villages have witnessed moderate to high level of soil salinity (Table-7.10).

Table-7.10 Comparison of perception among the six case studies regarding soil salinity status (in percent of respondents)

	No salinity	**Low**	**Moderate**	**High**
Doodhwa	10	26	62	2
Bagundi	0	8	26	66
Habibwala	86	12	2	0
Bhabra Azam Shahwala	6	14	76	4
Madanapur	50	14	18	18
Gurauli	2	20	44	34
Total	26	16	38	21

Source: Calculated by the author from the primary survey data collected from all the six study villages at various months in the year 2017.

The perception regarding soil salinity in Barmer has been comparatively stronger in terms of awareness about it and its availability into the soil (through various FGDs). This can be attributed to the physically more presence of salinity into the top of the layers (through various photographs). Therefore, further to understand their perception regarding the causes of soil salinity into the land of the farmers of all the villages, a comparative cross-tabulation has been done. All the respondents of both villages of Bramer Districts have perceived that the high temperature, low rainfall, lack of irrigation facility as well as lack of fresh water are the prime cause of the soil salinity in their land holding. While in cases study of Firozpur District, the perceptions are contradictory as rightly the cause is also diametrically opposite for the soil salinity in these areas (Table-7.11) as many literatures confirm like Verma et al. (1996), Raina et al. (2009), Thakur et al. (2016).

The respondents of Firozpur District have mainly attributed the lack of awareness, overuse of chemical fertiliser, the absence of traditional agriculture as the cause for the increasing soil salinity into their land (Table-7.11 and FGDs into villages). However, the respondents of high salinity and low salinity villages (Bhabra Azam Shahwala and Habibwala respectively) have perceived contradictory on the lack of fresh water and irrigation through the saline water as a cause for the soil salinity (Table-7.11). High salinity affected village respondents have admitted that the water available into the vicinity are too salty in taste. Therefore, this might be the main reason for them; while in the low salinity affected village, the groundwater is not salty in nature (FGDs into both villages).

The similar kinds of responses have been found in the selected village of the Kannauj District. Overall in both the villages, lack of fresh water, lack of awareness, waterlogging, overuse of fertiliser and irrigation through saline water are perceived to be the major cause of soil salinity into the case study areas. However, in the Gurauli Village, where the soil salinity is very high, the emphasis on the lack of fresh water and irrigation through saline water has been seen comparatively more. In both villages Madanapur and Gurauli, the waterlogging has been perceived to be one of major cause for the soil salinity (Table-7.11). Many literatures support for the waterlogging as the cause for the soil salinity (Datta et al., 2000; Datta and Jong, 2002; Singh, 2007).

Table-7.11 Comparison among case study regarding perception related to causes of soil salinity (in percent of respondents)

Units (total respondents)	**Doodhwa (50)**	**Bagundi (50)**	**Habibwala (50)**	**Bhabra Azam Shahwala (50)**	**Madanapur (50)**	**Gurauli (50)**	**Total (300)**
1. High temperature	100	100	0	0	0	0	33
2. Low rainfall	100	100	0	6	0	0	34
3. Non-scientific (Faulty) agricultural practices	12	26	12	16	20	26	19
4. Lack of irrigation facility	100	100	0	0	0	0	33
5. Lack of Fresh water (saline free)	100	100	10	100	52	100	77
6. Irrigation by the saline water without proper distribution on the field	0	6	0	80	0	20	18
7. Lack of awareness about the scientific way of agriculture	24	36	24	46	48	26	34
8. Water-logging	0	0	0	18	52	46	19
9. Lack of drainage facility	8	12	8	4	12	16	10
10. Over use of chemical fertiliser	0	6	26	14	22	48	19
11. Absence of traditional agriculture	16	26	24	26	12	12	19
12. Irrigation through saline water	24	100	0	86	42	100	59

Source: Calculated by the author from the primary survey data collected from all the six study villages at various months in the year 2017.

In all the sampled respondents (300), the lack of fresh water and salinity through saline water have been perceived as the major cause for the soil salinity by 77 percent and 59 percent respondents respectively. Other than these, lack of awareness, low rainfall, lack of irrigation facility and high temperature have been found to be further reason for the soil salinity by 34 percent, 34 percent, 33 percent and 33 percent of respondents respectively. The characteristics of the causes in Firozpur and Kannuaj Districts have been comparatively more similar than the Barmer District. The respondents have very mixed responses regarding the causes of soil salinity into Firozpur and Kannuaj Districts, where causes of soil salinity are more human-induced in nature (Table-7.11) (Datta et al., 2000; Datta and Jong, 2002; Qadir and Oster, 2004). However, in Barmer District, the natural causes are rightly perceived by the people and it is much clearer to respondent farmers (Table-7.11) (Datta et al., 2000; Qadir and Oster, 2004; the Wicke et al., 2011; Daliakopoulos et al., 2016).

7.5 RELATION BETWEEN AGRICULTURE AND SOIL SALINITY

To analyse the relationship between the soil salinity and agricultural productivity especially wheat productivity, the linear regression model has been run. The two models have been performed. Where, wheat productivity per bigha has been taken as the dependent variable for both the model-1 and model-2 (Table-7.12). Some independent variables are similar for both the model. In this respect, the independent variables are fertiliser used (yes/no), farmer experience (square of the age), education level (literate/illiterate), labour per season, irrigation (yes/no) and soil salinity status in the land (yes/no). Three more additional variables have been taken for the model-2. These are the three-state dummy for three different states- Rajasthan, Uttar Pradesh and Punjab. The additional variable as state dummy has been incorporated to understand the state specific reasons, which might not have been covered through the other variables. For the state dummy, the particular state related observations have been given dummy as 1 and other observations from the other states have been given 0. A similar exercise has been done for each three-state dummy. Overall 211 observations of farmers have been selected from all the study areas. All samples from Uttar Pradesh and Punjab have been taken, while from Barmer only 11 observations have been taken. This is because the village, which is selected for the study in Barmer, has not cultivated wheat extensively. The bajra crop is the main crop into the village. Farmers who have the relatively good quality of land with their own irrigation sources only go for the wheat cultivation.

The r-square for the model-1 was 0.377. This has been reflecting that the relation among salinity, agricultural input and wheat productivity are significant but not stronger for the selected variable in the model-1. The f-value, which express about the model of fitness, is significant at the level of <0.001. Among all the selected independent variables for model-1, fertiliser (b-value is 313.99) has been having major control on the wheat productivity per bigha, followed by irrigation (b-value is 134.98), salinity status in land (b-value is 37.27), education level (b-value is -10.325), labour input (b-value is 2.62) and farmers' experience (b-value is -0.001). It reveals that the role of farmers' experience has a negligible influence on the wheat productivity and the education level of farmers has a negative impact over the same. Contrary to this, the fertliser and irrigation have been the main driver for the wheat productivity (Table-7.12). Interestingly, the soil salinity status has shown a positive relationship with the agricultural productivity; however, in theories and in earlier studies it is said that the impact of land degradation has been negative on agricultural productivity (Barbier, 2000; Datta et al., 2000; Datta and Jong, 2002).

Model-2 has been performed with state dummies as the independent variable. The b-value for the Rajasthan dummy (b-value is -414.49) has been recorded higher compared to other variables. This reflects that the state unique factors are more dominating in Rajasthan state compared to other states. In the case of Punjab, it is recorded 0, means there have not been stating factors dominating into agricultural productivity. The overall, correlation has been more than 50 percent and adjusted r-square has been 0.261. Compared to model-1, it has recorded a higher correlation. Therefore, it has been inferred that the state-specific factors are too a major player while determining the wheat productivity (Table-7.12).

Table-7.12 Determinants of wheat productivity into the case study areas[1]

Model-1 Without State Dummy*		Model-2 With State Dummy *	
Determinants	**B-value**	**Determinants**	**B-value**
(Constant)	104.78	(Constant)	522.89**
Fertiliser used	313.99**	Fertiliser used	-15.42
Farmer experience[2]	-0.001	Farmer experience[2]	-0.004
Education level [3]	-10.325	Education level[3]	-9.24
Labour per season[4]	2.620	Labour per season[4]	1.32
Irrigation	134.98***	Irrigation	30.95
Salinity status[5]	27.27	Salinity status[5]	94.70**
		Rajasthan_dummy[6]	-414.49**
		UP_dummy[7]	35.44
		Punjab_dummy[8]	0

*Dependent Variable: Wheat production per hectare.
1. Adjusted r-square for the model-1 is 0.117.
2. Adjusted r-square for the model-2 is 0.261.
* F-value is significant at the level of < 0.001
** T-value is significant at the level of < 0.001
*** T-value is significant at the level of < 0.010
Note- Number of observations has been 211.

Source: Calculated by the author from the primary survey data collected from all the six study villages at various months in the year 2017.

Though, the b-value for the soil salinity has been recorded positive with high impact. This reflects the distorting nature of other factors of wheat production, which has been able to undermine the salinity impact successfully. The other literature too has been supporting the idea that along with agricultural inputs, the soil salinity (one of the types of land degradation) too has played a significant role into agricultural productivity (Singh and Singh, 1995; Jena, 2011; Priya, 2014; Priya and Pani, 2017).

[1] Some observations (55 interviewed data from Barmer District) regarding agricultural productivity has been excluded from the analysis to maintain the uniformity regarding wheat cultivation by the farmers. By doing so, it enabled to measure the various determinants for the wheat productivity especially soil salinity.

[2] Square of the age of interviewed farmers are used as farmers experience.

[3] It is taken as dummy for literate and illiterate.

[4] It includes the family member also.

[5] It is taken as presence and absence of soil salinity as one value for the whole village through satellite imageries data.

[6] Dummy for the Rajasthan has been used to analyse the intensity of the unique factors prevailing into state, which has not been covered through interview. Yet, it is playing key role in wheat productivity.

[7] Dummy for the Uttar Pradesh has been used to analyse the intensity of the unique factors prevailing into state, which has not been covered through interview. Yet, it is playing key role in wheat productivity.

[8] Dummy for the Punjab has been used to analyse the intensity of the unique factors prevailing into state, which has not been covered through interview. Yet, it is playing key role in wheat productivity.

7.6 CONCLUSION

Kannauj has the highest area under the salinity effect (NRSC, 2011). It is having a second highest area of TGA under soil salinity/alkalinity, which is having highest share among TDA. The middle-southern portion of Uttar Pradesh, which is adjacent to the southern Peninsular, has been highly degraded. While in case of soil salinity/alkalinity, it is concentrated into the middle of Uttar Pradesh especially along the Gangetic river belt. The conclusion of the chapter can be listed as:

1. Central areas around the Ganga River area are highly affected by the soil salinity and alkalinity. As one move away from the river basin area, the soil salinity level has recorded decrease. Similarly, Kannauji has been facing a major problem of soil salinity. Areas near to canal has recorded high problem of soil salinity/alkalinity because of a waterlogging problem near canal and over-irrigation. The forest cover also holds a check into soil salinity, but the less availability of forest cover has helped to increase the pace of *"kankar"* formation into soil layers.

2. The intense level of soil salinity problem has been observed in southern and eastern part of the Kannauj, especially in Tirwa Tehsil. The canal expansion has been extensively done in the region. It can be visually observed through the map that the areas of the canal irrigation facility are having the soil salinity problem. The extensive tube well irrigation also has contributed to the soil salinity crisis in the region. Interestingly, there has been a decline in the gross cropped area of the Tirwa Tehsil from 2000-01 to 2010-11 (Table-7.3).

3. The two types of *"Usar"* has been recorded, between the two *"salty Usar"* has been found widespread into the region. There have been many efforts are being done by local people for the reclamation. But some of the efforts are too long to reclaim these lands. Many have given 15-20 years in this, but still struggling to get the real reclaimed status of soil means still not come back to the normal soil structure.

4. Soil fertility has been declining into the selected sample villages. Many have increased their investment into the agriculture since last five years. Majority of respondents have attributed to the lack of fresh water and the irrigation through the saline water as a major cause for the widespread soil salinity.

5. It can be concluded from the above study that although soil salinity has not able to affect agricultural productivity directly because of the use of fertilizer and irrigation. However, it has the role to play as one of the significant determinants of wheat productivity.

6. It is evident through the analysis that not only man-made environment affects the high productivity, but also in some extent soil degradation impacts on production of wheat (yield/bigha). While we can also say that the striking effect of soil salinity on wheat did not come into appearance clearly due to use of fertilizer and availability of irrigation system.

CHAPTER-8

SUMMARY AND CONCLUSION

8.1 SUMMARY AND CONCLUSION

Degradation of natural resources in terms of quantity and quality is very alarming at present days in India. This degradation of one resource causes the degradation of others. As for example, the degradation of forest resources can also cause the degradation of land. The land has been the most precious resource after the air and water. Presently, it is under threat which is caused by the major land degradation processes. Among all of the degradation processes, the forest degradation has been more significant (Munsi et al., 2012; Priya, 2014; Priya and Pani, 2015), which is widespread across the country (Map-3.6 in Chapter-3).

Degradation of the forest has not only impacting the land quality but also having a control over the water level and water quality in the vicinity (United Nation, 2007). Declining vegetation accelerates the pace of land degradation process (Gabathuler et al., 2009). Moreover, gully or ravines have been recorded as an important type of land degradation in India (Joshi, 2014; Pani, 2016). There are four severely affected ravine zone in India (Sharma 1980). The largest one is Yamuna-Chambal ravine zone. The Yamuna-Chambal Ravine is the largest zone in the country. Another aspect of land degradation is that it is severely hampering the Indian agricultural output (Department of Agriculture and Cooperation, 2011).

The salinity or alkalinity has been concentrated into major three area- middle Gangetic plain, Western India and South-East India. Its' concentration in the Gangetic Plain is very high, which is affecting the agricultural productivity of the region (Chapter-4). This can be a serious problem for the total productivity of India as the Gangetic plain is the land of food granary for India on which millions of the life is dependent. Inefficient water-use in study areas of Punjab and Uttar Pradesh has been found to be a major reason. The FGDs into the study villages of both states have found that the salt content into the groundwater, which is used for irrigation, has been the major cause for the soil salinity (Department of Agriculture and Cooperation, 2011; Min et al., 2014). The reason for the same has been attributed to the shallow groundwater level in another part of the world (Zewdu et al., 2015).

There are different types of land degradation processes. Each process has its' own characteristics as it exists in a specific agro-climatic region.The land is continuously exposed to the specific climate and developed through certain stages. The various factors particular to the agro-climatic region cause the unique degradation and develop into a present form of land degradation (Zhang et al., 2011) Bautista Solís et al., 2012). The linkage between land degradation and the climate cannot be evaluated direct observation, but the biotic factors might be used as an indicator to understand the same for clear understanding (Bautista Solís et al., 2012). In the analysis, the clear domination of soil salinity problems has been clearly identified with the arid and semi-arid region. Similarly, in the case of Rajasthan, the climate plays a dominant role (Chapter-5). However, in case of Punjab and Uttar Pradesh soil salinity has not had the same reason for soil salinity. Instead, it is human activities which have been found to be a more prominent factor for soil salinity (Chapter-6). Similar findings have been reported in various developing countries like Pakistan, China (Ahmad et al., 2012; Min et al., 2014; Qiu et al, 2017)

This problem is majorly found in the arid and semi-arid region, where climate plays a dominating role in land degradation. However, the same problem has also been recorded into the different climatic zone in Upper and Middle Gangetic Plain. It has also been found that there is a relation of land degradation with the climate. But in this case of an arid and semi-arid region, the human activities have been emerged as the biggest threat to their own humanity through its unreasonable, discriminated use and overexploitation of the land (Bautista Solís et al., 2012; Min et al., 2014; Qiu et al, 2017).

Land Degradation Index is calculated (Chapter- 3) for a better understanding of the concentration of land degradation. The Index largely represents those more than seventy percent variations of various selected types of land degradation for study. It has reflected that uniformity is not even true for the problem like land degradation in India. The clusters of land degradation found in India really need a special attention. The various types of degradation must be dealt with proper policy formations as it is directly related to the agriculture in India (Puri and Shahay, 2003).

Another important aspect of land degradation is soil salinity. Soil salinity has different dimensions in terms of the physiographical formation with the prevailing climatic condition e.g. the aridity has a direct relation with salinity. Human factors into the formation of soil salinity cannot be ignored as the world is going through of rapid social transformation. The technological innovations are taking places resulting in major degradation. Such as the development of drip irrigation can be very beneficial for agricultural productivity but on the other hand, it can increase the soil salinity problem into the field. There are various models to assess the soil salinity/alkalinity through remote sensing with high accuracy; but these are still not able to demonstrate the precise ground existence of soil salinity (Ravi & Huxman, 2009; Singh et al., 2011; Velmurugan et al., 2015; Dagar et al., 2016).

Thus, with the use of remote sensing analysis the the salinity analysis has been found helpful and it helped to get a spatial distribution of the salinity status. However, the micro-level study about soil salinity has demanded the field-based study to get a clear and compact understanding of it at the village level. Therefore, this study has included the integrated approach, where the data provided by NRSC (based on LISS-III with the resolution of 23.5 meters) has enabled for the macro-level and meso-level study. Moreover, the Landsat-8 (2016) imageries have helped to comprehend the soil salinity status at the administrative level. At meso-level, the study has found that the vegetation cover has visually positive relation with the soil salinity through NDSI, NDVI and SAVI (Chapter -5, 6 and 7). Satellite imagery based salinity assessment at such a large scale has proven effective to evaluate for a vast area. Finally, these studies have been integrated with ground validation and primary survey of farmers perception related to soil salinity (Chapter-5, 6 and 7). Among all, the field-based study on soil salinity/alkalinity has remained the best complementary in soil salinity understanding especially to get the farmer's perception about their own field.

Soil salinity/alkalinity has emerged as a threat to the sustainability of the agricultural land as well as the food security. It is very profound in India as India is the second largest in terms of population in the world. The overpopulation demands for better food security through better agricultural production. It involves greater economic costs than thoughts. The studies from various regions of India have found that the severity of soil salinity has been increasing due to many human-induced factors. The examples are unscientific agricultural practices, over-irrigation, and irrigation by saline water due to non-availability of fresh water etc. In the high soil salinity affected villages, people have the good knowledge of the fact about the soil salinity status to great extent (e.g. in case of Bagundi in Rajasthan, Bhabra Azam Shahwala in Punjab and Gurauli in Uttar Pradesh). Even if they are not much aware, they have the traditional knowledge to overcome or reclaim the salty land. However, the people, of the less soil salinity affected villages, do not have much knowledge of the problem as those regions are less affected and do not have a direct appearance on the land (e.g. in case of Doodhwa in Rajasthan, Habibwala in Punjab and Madanapur in Uttar Pradesh). It might be due to the availability of various inputs to agriculture, which undermine the land degradation problems especially soil salinity (especially in case of Punjab and Western Uttar Pradesh, where Green Revolution has been a major player into agricultural output) (Posgate, 1974; Ranade, 1986).

Although research shows that land degradation has a implication on agricultural productivity, but this analysis has revealed that to prove is a complex process on the ground (Table-4.1 in Chapter-4 and Table-7.12 in Chapter- 7). This happens because of the complexity of the nature of agriculture due to various technological innovations in the field of agricultural inputs (Easter et al., 1977).

The relation between the agriculture and land degradation changes with the change in the variables into the various regression models. This has revealed that it requires the careful selection of the variables to get the real level impact of land degradation on agriculture. Agricultural inputs into the field have been playing a crucial role in increasing and sustaining the productivity. As beta coefficients of all model show (Table-4.1 in Chapter-4 and Table-7.12 in Chapter-7) a higher value for the agricultural inputs indicators with a high significance level of the t-test. It can be deduced that penetration and increased use of various agricultural inputs like fertiliser per hectare, the irrigated area per hectare and a number of tube wells per hectare have a direct and positive impact on productivity.

Land Degradation Index has comparatively greater in negative relation with the agricultural output than the soil salinity/alkalinity (% of TGA) (Table-4.1 in Chapter-4). This is due to the broader coverage of problems related to soil degradation compared to soil salinity. The impact of land degradation and soil salinity/alkalinity on agriculture is not so significantly established. It might be because agriculture is subject to the various other factors of the agricultural inputs (Table-4.1 in Chapter-4). Though the implication of land degradation and soil salinity/alkalinity with other inputs have been clearly seen on wheat and rice productivity; however, within the limited variables (selected one) the land degradation and salinity/alkalinity are significantly impacting the wheat productivity to the greater extent. Specifically, the land degradation is having a greater correlation with rice productivity compared to wheat; similar is the case with soil salinity. However, soil salinity has greater relation with wheat compared to the overall land degradation; though both relations are not so strong (Table-4.2 and Table-4.3 in Chapter-4).

The identification of soil salinity has been more difficult in the area of intense agricultural practices e.g. in Firozpur (Punjab) and Kannauj, (Uttar Pradesh). The soil salinity problem has not been so intense in these areas compared to Barmer because of the soil nature (Plate-5.4 in Chapter-5 and Plate-7.2 in Chapter-7). The salinity existence has not been even felt into the agriculturally intensive area (Punjab and Uttar Pradesh) (Table-6.4 & 6.7 and Table-7.4 & 7.7). It is because of the high use of chemical fertilizer into the region (Table-6.5 & 6.8 and 7.5 & 7.8). In this way, it undermines the real impact of salinity on output because nitrogenous fertiliser helps to increase production drastically (Chhabra, 2004).

The livelihood in Barmer areas is not totally dependent on the agricultural land. Farmers have adapted to the other means of livelihood majorly animal husbandry (Table-5.5 and 5.8 in Chapter-5). But importantly, at least one family from the family migrate to the nearby town or distant cities like Surat and Mumbai (FGDs in Barmer). However, the nature of migration is very different in Punjab and Uttar Pradesh, where farmer's livelihood is highly dependent on agriculture. Rural Punjab is known for the international outmigration (Ghuman et al., 2007). Migration nature in Kannauj is more of inter-regional migration into big cities of the adjoining state like Delhi or developed state like Maharashtra. The population pressure in Kannauj might be one region for the pressure on land and out-migration (FGDs in Kannauj). Therefore, the increasing pressure on the land resources might contribute to a push factor of migration (Kangalawe et al., 2010).

The coping mechanism with soil salinity has been found to more suitably with large farmers. For example, in Barmer District, the large landholder has been able to leave their land abandoned and fallow for few years so that it can be reclaimed and further it could be cultivated after few years. However, in the case of small landholders are cultivating it frequently every year (FGDs in Barmer). Interestingly, in Barmer, the farmers abandoned the land at large scale compared to Punjab and Uttar Pradesh. It might be attributed to the quality and fertility of the land, income status of farmers, government policy toward the region (disparity created by Green Revolution) and climatic conditions (Kalaiselvi and Sundar, 2011).

Thus, sometimes conservation of locally good valued vegetation helps into the recovery of the soil. The selected study reveals that the experiences of the farmers have values but they do not get proper attention to implement those in the field on the large scale of the experiment. Thus, the reclamation related subsidy assistance program is necessary to encourage the farmers to opt their own ways of the reclamation process. In the case of Kannauj, farmers have applied their own traditional way to reclaim the land at the individual level. Additionally, the application of gypsum in salinity affected field has been adopted by some farmers in Kannauj (Chapter-7). However, it has taken 20-25 years to reclaim the land. Therefore, the government support is necessary at the policy level as well as implementation level.

Locally, it is needed to identify or record the suited methods and it can experiment at the other places too. The successful method should be applied to other areas. Similarly, the subsidies should be provided for the easy and affordable access to the gypsums and other technology to reclaim the land. On contrary, in case of Western Uttar Pradesh and Punjab, there is a need for rationalizing the subsidy provided to available electricity, which has resulted into over-irrigation and over-exploitation of groundwater (Dagar et al., 2016).

Some of the local vegetation e.g. *Khejri* in Pachpadra region has greater ecological importance but has been recorded declining which is of a great concern (Plate-5.2 in Chapter-5). Therefore, there is need to promote the biological means e.g. salt tolerant tree, plant, crops and agroforestry etc. to reclaim the degraded land (Yuvaniyama, 2001, Bell, 2002; Sharma and Minhas, 2005; Lakhdar et al., 2009) (Appendix-I).

Though, there have been differences in the characteristics of the land in Sandy dominated Rajasthan and alluvial soil dominated Punjab and Uttar Pradesh. As the food security of the country dependent on the plain region of north India, it should not be the approach to ignore the arid land of Thar Desert. On one hand, Punjab and Uttar Pradesh are important for the sustainability of the need of population, on another hand; the ecological importance of Rajasthan should need to be protected. Therefore, the approach of the government should to take soil salinity problem of each region with the greatest care and avoid for opting ad hoc measure, which usually leads to disparity.

8.2 SUGGESTIONS

As the food is indispensable for the human being, the soil health is also indispensable for the food security. The different unconscious development has been contributed to the soil salinity, additional to its natural contributing factors. This is alarming for the country as well as the policymakers to focus towards the soil salinity problem in a specific manner and towards land degradation in general. This country cannot afford to be a mute spectator of this problem; otherwise, the food insecurity would mount to the head of it. Economically and ecologically, the gravity of the problem demands a strong recognition of the problem. This should include the great political interest in the country for systematical action against the problem of degradation with taking all the stakeholders on the board. Indian land quality is in the grave situation because food security is being under threat that seeks the attention of all from the farmers to policymakers. The country still does not have any land degradation policy; forget about the soil salinity specific policy. The government in 2014 was planning to have a plan to make India land degradation neutral by 2030. However, the developing common minimum strategy requires the major ministries at the board e.g. Ministry of Environment, Ministry of Agriculture, Ministry of Water Resources and Department of Land Resources under the Ministry of Rural Development. But till now it is under consideration.

The planning for salinity reclamation required an integrated approach with the needful higher yield and sustainability. The ever-increasing expectation from the land and water resources should only be fulfilled when each stakeholder keeping the knowledge of own responsibility to contribute to the management with comprehensive manner. Though many researchers have been done important analysis in the different fields related to soil salinity, there is missing the part in the identification of the problem in the resultant land. This includes the attention towards the farmers' actions after the deserted land, its different uses afterward and further its feasibility for the sustainable land environment. Thus, comprehensive remedies and management of the land degradation is need of the hour. All stakeholders should be involved in the management by combining the advanced technological method of remedies with the traditional one. This study has provided the extensive understanding of the policy formulation in a different part of India. Therefore, this study has segregated the different micro level and national level policy and strongly advocate for the decentralized and bottom-up approach for the neutralization of land degradation/soil salinity and reclamation of the degraded/soil salinity affected land.

8.2.1 MACRO-LEVEL SUGGESTION

First and for the most important, the government should opt for an inclusive and comprehensive land degradation policy; the importance is having policies shows the attitudes, approaches and priority-level of the government. Secondly, the policy makes the committee should not only include the high qualified academicians and agriculturists but also include all the major and minor stakeholders. The stakeholders can be from ground level such as a representation of farmers, representation of those who implement the policy, ministries representation etc. Features of policy related to land degradation at national-level (macro-level) can be listed as:

1. The macro-level policy should have broad separate scientific objectives for the separate prominent types of land degradation e.g. Gully erosion, soil salinity, desertification and degradation of forest etc. The government should prioritize each of the types because each type of land degradation cannot be allotted the same finances. Priority of types of land degradation should be based on the need for food security, environmental concerns and resource utilization.

2. Regional objectives can be set because different regions are not having different types of land degradation problems. It will be good if decides according to the agro-climatic region and fix the specific objectives for the reclamation of land degradation. This would help into the regionally balanced approach for the solving existing problem of land degradation.

3. Coordination among the ministries and among the states is at most important for the implementation of land degradation policy due to various stakeholders' involvements. A separate body or Department of Land Resources can be declared as the nodal agency to track the efficient and effective performance of policy through coordination among the stakeholders.

4. The policy should be formulated at the national level in a way that it can provide the scope for the states and district and even further down the level of administration to change it according to the demand of their regional and local need.

5. Research and Development into a different field of land degradation should be promoted especially in technological innovation sectors which have the solution approach to land degradation. At the same time, the traditional knowledge should be recognized with the best practices across the country. The special focus should be towards clubbing the technological advancement with the traditional knowledge to cope up with the land degradation problems.

6. More importantly, the awareness and education program for the farmers should be organized focusing towards the intensity and effectiveness of the land degradation problem. These can be the characteristics of different types of land degradation, implication on their land and socio-economic status of the farmers, the best practices followed to reclamation or sustenance of land, best practices of sustainable farming, scientific approach of farming etc.

These are the minimum policy related recommendation at the national level, which can give the panoramic framework to be followed.

6.2.2 MICRO-LEVEL SUGGESTION

A. Rajasthan: Rajasthan has been suffering from the desertification and soil salinity both. However, the policy recommendation has provided here by focussing on soil salinity due to the objective of the study. Thus policy at District-level and below administration level should be:

1. As the nature of causes of land degradation is natural more rather than human-induced, the focus should be more on adaptation rather than mitigation of soil salinity. The introduction of salt-tolerant crops and vegetation can be recommended for this region (Appendix-I).

2. The farmers are resource-poor, but they do have local knowledge that might be involved into remedy process of soil salinity. Assured water supply through rain-harvesting/canal extension can be useful for the percolating down the salt content of the soil in the region.

3. To control high evaporation increasing vegetation cover would be helpful. Agroforestry could be another alternative because it will not only help in reclaiming the land but also provide a sustainable livelihood.

B. Punjab and Uttar Pradesh: Nature of soil salinity in this region is rather human-induced. So, the more focus should be on the mitigation primarily. Here, the unbalanced water situation and its use have been the major causes. The policies can be listed as:

1. As region cannot afford for the mass fallow, the emphasis should be towards the providing physically accessed mechanism to reduce salinity in short-term. These can include the subjects like providing gypsum, Calcium chloride and limestone at the subsidized rate without compromising the quality of it.

2. The monitoring of the soil salinity should be done on a periodic basis to check the progress. At the same time, the training and awareness are required for the farmers about the proper ways of irrigation if the land is the salt-affected and proper use of chemical fertilizer.

3. The planner must take the surface and subsurface into consideration for the drainage planning with the connection of the farmer's conditions in the region. This is important because subsurface drainage management is capable of the twin problem: salinity with waterlogging.

4. Some traditional and cultural practices at the local level can be adopted by our own experience as well as experience around the world. As for Example irrigation with the mixed sources like canal and groundwater or alternatively irrigating with canal and groundwater. The other methods are even distribution of irrigation water, mixing up of saline/alkali water with fresh water for irrigation to control salinity at the threshold, crop rotation, traditional and local irrigation methods etc.

Finally, the integrated approach of modifying the plant according to the environment and modifying soil to the need of plant could be more helpful. Indian farmers should be encouraged to take the steps by following the footstep taken by the government for solving the problems of land degradation.

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APPENDIX-I NEWS CLIPPINGS

NOIDA/DELHI THE HINDU
SUNDAY, JULY 15, 2018

Scientists decode how mustard plants tolerate salt

Thiourea is used to minimise bad effects of salt stress

ASWATHI PACHA


We identified four key genes responsible for the adaptation, says Ashish Srivastava (standing)

High salinity is one of the major problems in agricultural fields and many countries, including India, use an organic sulphur compound thiourea to minimise the negative effect of salt stress. Now, using molecular biology tools, scientists from Bhabha Atomic Research Centre (BARC), Mumbai have reported how this treatment altered the plant RNA and hormones to facilitate this survival in mustard plants grown with high salt stress (125-150 milliMolar NaCl).

Anthropogenic factors, irregular irrigation and proximity to the sea can cause high salinity in the agricultural fields and this induces redox imbalance and damages the plant. Various studies have shown that thiourea is a good redox stabiliser as it scavenges multiple reactive oxygen species including hydrogen peroxide. The researchers carried out studies to understand how this thiourea activates the tolerance mechanisms.

Mustard seedlings, just 20-day-old plants, grown in a liquid nutrient medium, were given saline treatment with and without thiourea, and their growth was studied for seven days. The plants which were supplemented with 75 micromolar of thiourea showed increased survival and better phenotype with larger leaves compared with the group grown in saline medium.

The researchers then studied the microRNA of the plant as it is an important component that regulates plant transcriptomes according to the environmental conditions.

"We found that down-regulated microRNAs were enriched in the thiourea group to facilitate transcriptional activation and adaptation under salt stress conditions," explains Dr. Ashish Kumar Srivastava, at BARC and first author of the paper published in *Scientific Reports*.

They also studied different genes and plant hormones that are involved in stress management and identified four key genes responsible for the adaptation. Plant hormones such as ABA, Auxins, jasmonates which have been shown to play important roles in salt tolerance were all found to be co-ordinately regulated upon thiourea treatment.

The team also studied the effect on spraying diluted thiourea directly on the shoot of rice plants grown in arsenic contaminated soil and found it effective in reducing arsenic accumulation in rice grains.

Further studies are underway to validate the effects of thiourea in rice and multiple different crops under varied environmental conditions.

"Thiourea based technology can sprovide easy-cum-affordable solution to the farmers for minimizing abiotic stress induced losses in crop plants," explains Dr. Penna Suprasanna at BARC one of the authors of the paper.

APPENDIX-II
SURVEY QUESTIONNAIRE

PURPOSE: FOR RESEARCH USED IN PH.D.			
Country Name: India		**State Name:**	
District Name:		**Tahsil Name:**	
		Village Name:	
GPS Coordinates of the Village:	**Latitude:**		
	Longitude:		
Name of the Interviewer:		**Date:**	
		Questionnaire No.:	
Respondent Name:		**Relation With the head of the Family:**	
Name of the Head of the Family:			

FAMILY DETAILS				
Personal/Family Characteristics				
ID No.	**Name of Family member**	**Age Completed (in Years)**	**Marital Status ***	**Relation with the head of the Family****
i	***ii***	***Iii***	***iv***	***v***
1				
2				
3				
4				
5				
6				
7				

8				
9				
10				

FAMILY DETAILS Continue…….

ID No.	Sex (0. Male, 1. Female)	Duration of stay outside family. (in Months)	What is the reason of migration?*** and how much far to your family*#	Education Level at current time****	Current Occupation*+
i	*vi*	*vii*	*viii*	*ix*	*v*
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

***1 *for work*
2 *Other economic reason*
3 *Illness*
4 *Education*
5 *marriage*
6 *Working in Job as labour*
7 *Working in Job in manufacturing*
8 *Working in Job in services*

*1 *Unmarried*
2 *Married*
3 *Divorced/separated*
4 *Widow/ Widower*

****1 *Never attended*
2 *Left School*
3 *Nursery*

*+1 *Retired*
2 *Student*
3 *Housewife*
4 *Unemployed*
5 *Farmer*
6 *Craftsman*
7 *Merchant*
8 *Labour/worker*

9	Others Specify.	4	Primary	9	Teacher
**1	Head	5	Secondary	10	Doctor
2	Spouse	6	High School	11	Other, Specify
3	son/daughter	7	Intermediate		
4	Grand child	8	Graduate	*#1	Nearby village
5	Parent of the head	9	PG	2	Nearby town
6	Nephew or niece	10	Diploma course	3	City in district
7	in-laws	11	Other, Specify	4	Outside district
8	other relative			5	Outside state
9	servant			6	Outside country
10	Others, specify				

1. Farmer's Details

1.1 How long in Farming?*		1.2 Education Level of the main farmer:			
1.3 Farming type#		1.4 Land owned:			In Acres/Bigha
1.5 (a) Land leased in	In Acres/Bigha	1.5 (b) Land leased out			In Acres/Bigha
1.6 No. of Family member dependent on agriculture					
1.7 No. of Family member directly involve in agricultural activity					

*1	From birth/entire life	#1.	Subsistence Farming
2	After Schooling	2	Commercial Farming
3	After Graduates	3	Combined (1+2) Farming
4	Other, Specify	4	Mixed Farming
		5	Intensive Farming
		6	Other, Specify:

2. What is your financial status?				
A. Below poverty line	B. Above poverty line			
Monthly Income (in Rs.)	1. <5000	2. 5000-10000	3. 10000-20000	4. > 20000
3. Main Occupation*				
(i) Employed in agriculture	(iv) Casual labourer in agriculture			
(ii) Self employed in non-agriculture	(v) Casual labourer in non-agriculture			

(iii) Regular Wage/Salary		(vi) Others, Specify		
Answer: Yes or No.				
4. Is Livelihood depending on the livestock also?		**i. YES**		**ii. NO**
4.1 If yes, then what type of livestock is raised?				
A. Cows			No.	
B. Sheep and goats			No.	
C. Pigs			No.	
D. Poultry and eggs			No.	
E. Camel			No.	
F. Buffalo			No.	
G. Others, Specify			No.	

5. Investment in the farms:	**Average Investment in whole land**	
No.	**Items**	**Investment (in Rs. Approx) in a year**
1	Land preparation (machinery/labour cost)	Rs.
2	Seeds and plants	Rs.
3	Fertilizers	Rs. Kg. per bigha/hec.
4	Pesticides / herbicides	Rs. g/hec or bigha
5	harvest (machinery/labour cost)	Rs.
6	Transportation during harvest	Rs.
7	Energy (Electricity, gas etc.)	Rs.
8	Rent (if taking some facility in rent)	Rs.
9	Licenses, fees	Rs.
10	Other	Rs.
11	Total Costs	

6. What share of your production do you and your family sell?			
A. <25%	B. 25-50%	C. 50-75%	D. 100%

7. If Leasing in or out, then terms & conditions*	**Leased In**	**Leased Out**

a) 1/3rd of the crop without getting half inputs	
b) 1/2 of the crop with getting half of the inputs	
c) 1/2 of the crop without getting half of the inputs	
d) Fixed money…………………	
e) Others………………………	

**Answer: Yes or No.*

8. Return on Investment			
i. Total Agricultural Input cost only	*1. Yes*	*2. No.*	*In Rupees (Approx.)*
ii. Total more than Agricultural Input	*1. Yes*	*2. No.*	*In Rupees (Approx.)*
iii. Total less than Agricultural Output	*1. Yes*	*2. No.*	*In Rupees (Approx.)*

9. Agricultural land Characteristics					
9.1 Physical Dimension	Inundated land	*i. YES*		*ii. NO*	
	Time period (Duration in days)				
	Soil Quality	*1. Very good* *2. Good*		*3. Bad* *4. Very bad*	
	Access of irrigation sources	*i. YES*		*ii. NO*	
	If Yes, then type *1. Well* *2. Canal* *3.River* *4. Tube well* *5. Micro-irrigation* *6. Others*				
	Land used for (in a year)	*1. Single crop*	*2. Double crop*	*3.Multiple Crop*	
	Is there vegetation around the field?			*1. Yes*	*2. No*
	Vegetation Type	1. Dense		2. Tree cover	
		3. Scrub		4. No vegetation	

9.2 Environmental dimension	Rainfall experience	1. Erratic 2. Regular		
		Is rainfall sufficient for agriculture? 1. Yes 2. No		Duration of rainfall in a year (in days):
	Rainfall	1. Good		2. Moderate
		3. Bad		4. no rainfall
	Soil Type	1. Fluvial 2. Sandy-fluvial		3. Sandy 4. Rocky
		1. Khadar		2. Bangar
	Surface runoff Condition	1. Good 2. Bad		1. Seen 2. Not Seen

	Land is near to	1. Settlement/village	2. Road	3. River/water source	4. Surrounding field	5. Other	
10. Cropping Pattern (in a year)							
Crop 1_Name		Area (in Acre/bigha)			Yield		
Crop 2_Name		Area (in Acre/bigha)			Yield		
Crop 3_Name		Area (in Acre/bigha)			Yield		
Crop 4_Name		Area (in Acre/bigha)			Yield		
11. Mode of work in Agricultural Land							
1. Agriculture only					4. Agriculture, forestry and Animal Husbandry		
2. Agriculture and Forestry					5. Difficult to use land		
3. Agriculture and Animal Husbandry					6. Other		
12. Land Used For Other purpose							
1. Digging of soil from the field				1. Yes	2. No.		
2. If digging of Soil, then used for				i. brick making	ii. Detergent		
3. If digging for other purpose, then specify:							
4. Mining around the land				1. Yes			2. No.
For what:							
13. Land productiveness (compare to earlier)							
a)More productive				1. Yes			2. No.
b)Productive as earlier				1. Yes			2. No.
c)Less productive				1. Yes			2. No.
14. If More Productive, have you taken the following steps: Answer in Yes or No							
i. Increase in irrigation facility				v. More organized agriculture			
ii. More fertiliser used				vi. More labour involved			
iii. HYV seeds are used				vii. Pesticide used			
iv. More awareness				viii. Other, if any,			

15. If equal productive, then have you taken the following steps: Answer in Yes or No	
i. Increase in irrigation facility	v. More organized agriculture
ii. More fertiliser used	vi. More labour involved
iii. HYV seeds are used	vii. Pesticide used
iv. More awareness	viii. Other, if any,

16. If less productive than earlier, then it is due to or conditions is available (compare to earlier): Answer in Yes or No	
i. Decrease in irrigation facility	viii. No awareness
ii. Equal irrigation facility	ix. less awareness
iii. Increased irrigation Facility	x. More organized agriculture
iv. More fertilizer used	xi. less organized agriculture
v. Equal fertilizer used	xii. More labour involved
vi. Less fertilizer used	xiii. Less or equal labour
vii. HYV seeds are used	xiv. Pesticide used
xv. Other, if any,	

17. Have you able to measure the declining fertility of land, if declining: Yes		**No**
If Yes…..		
i. Assumption	1. Yes	2. No.
If Yes, then explain how:		
ii. Approximate calculation	1. Yes	2. No.
If Yes, then explain how:		
iii. Proper calculation through cost-benefit on the basis of input-output. 1. Yes	2. No	
If Yes, then explain how:		
18. Is soil composition changed over a period of time?	**1. Yes**	**2.No**
19. Land condition is getting:		**Source of Indication**

i. Good from earlier	1. Yes	2. No.	
ii. Bad from earlier	1. Yes	2. No.	
iii. Very Bad from earlier	1. Yes	2. No.	
iv. Worse from earlier	1. Yes	2. No.	

20. Is soil salinity felt according to your experience: : Yes No

20.1 When, you witness soil salinity for the first time:

How you got to know: (symptom)

20.2 Is soil salinity increasing? Yes No

If Yes, then, how are you experiencing these changes or getting sense of increasing salinity?:

21. In your opinion, what is the major factor due to which the soil salinity is increasing?-

i. High temperature	1. Yes	2. No.
ii. Low rainfall	1. Yes	2. No.
iii. Non-scientific (Faulty) agricultural practices	1. Yes	2. No.
iv. Lack of irrigation facility	1. Yes	2. No.
v. Lack of Fresh water (saline free)	1. Yes	2. No.
vi. Irrigation by the saline water without proper distribution on the field	1. Yes	2. No.
vii. Lack of awareness about the scientific way of agriculture	1. Yes	2. No.
viii. water-logging	1. Yes	2. No.
ix. Lack of drainage facility	1. Yes	2. No.
x. over use of chemical fertiliser	1. Yes	2. No.
xi. absence of traditional agriculture	1. Yes	2. No.
xii. Other, if any.		

22. Is there attempt to reduce the salinity or maintain the soil fertility? Yes. No. **22.1 What are the methods used in the area to reclaim or reduce the soil salinity impact on the crops (in general):**				
Specific Details of the method:				
22.2. Is there any private attempt by the farmer individual or family to reclaim the saline land? **Yes.** **No.**				
If Yes, then What:				
22.3. Is there any, Community attempt by Farmer's community or village for reclamation of soil? **Yes.** **No.**				
If Yes, then What:				
23.4. Is any Step taken by the Government? **Yes.** **No.**				
If Yes, then What:				
23. 5. Are any private institution, corporative or NGOs helping for the reclamation or soil salinity reduction? **Yes.** **No.**				
If Yes, then What:				
24. Which one is more beneficial?				
1. Personal attempt		1. Yes	2. No.	
2. Government attempt		1. Yes	2. No.	
3. Private, corporative sector or NGOs attempt		1. Yes	2. No.	
4. Community Attempt		1. Yes	2. No.	
25. What is the Effective Ratio? (on personal experience basis):				
1. Personal attempt	0-25%	25-50%	50-75%	75-100%
2. Government attempt	0-25%	25-50%	50-75%	75-100%
3. Private, corp. sector or NGOs attempt	0-25%	25-50%	50-75%	75-100%

4. Community Attempt	0-25%	25-50%	50-75%	75-100%

26. Does saline soil support to any particular crop more?	**Yes.**	**No.**
If Yes, then What type of crop:		
26.1. If answered any crop, then: Is the above said crop/crops led to:		
1. Maintaining fertility of the soil only, no impact on income	1. Yes	2. No.
2. increase the income and maintain the fertility	1. Yes	2. No.
3. Decrease the income and maintain the fertility	1. Yes	2. No.
4. increase the income only, no impact on fertility	1. Yes	2. No.
5. increase the income, decrease the fertility	1. Yes	2. No.
6. Income and fertility both decrease	1. Yes	2. No.
7. Above crop necessary for livelihood	1. Yes	2. No.
8. Other, if any		
26.2. Is any specific Plants have ever been used for the reclamation of the saline soil?	**Yes.**	**No.**
If Yes, then What type of plants:		
27. According to your experience, what may be the best method to reduce soil salinity, if you have any-		
28. Have any Land ever successfully reclaimed from the soil salinity?	**Yes.**	**No.**

28.1 How, through:	
1. Forestation	2. Proper Irrigation through non-saline water
3. Proper Irrigation through saline mixed with non-saline water	4. Use of Gypsum
5. use of Calcium ions, sulphur, ferrous sulphate or limestone	6. Deep ploughing of land
7. Application of green manures of Dhaincha, guar, jantar (Sesbania aculeata)	8. Spreading of straw and dried grasses and leaves
9. Growing salt tolerant crops	10. Crop rotation method

11. Mechanical shattering of clay pans	12. Irrigation with maintaining proper drainage	
13. Green manure	13. Others If any:	
29. 1. Have you or your one of the family member prefer to work in agriculture in future: Yes.	**No.**	
If no or yes then why?		
29. 2. Have you or your one of the family member prefer to work other than agriculture: Yes.	**No.**	
If Yes then, why you would like to choose the job other than agriculture:		
i. Due to no profit in the agriculture	1. Yes	2. No.
ii. Due to more profit on investment in other job	1. Yes	2. No.
iv. Due to the same land is not enough to support to the family requirement.	1. Yes	2. No.
v. Due to more surety of life	1. Yes	2. No.
vi. Other, if any.		
30. Have due to soil salinity distress led ever to migrate from here for other jobs? Yes.	**No.**	
If yes, then what was the duration and the year frequency:		
i. For 3 months	v. permanent (of some part of family)	
ii. For 6 months	vi. uncertain	
iii. For a year	vii. Other	
iv. 2 year		
31. Any comments or suggestions for the quality of soil and soil salinity:		

32. Remarks by the Respondent about the experience on agriculture:
33. Remarks by the Respondent about the experience on Soil salinity or declining soil fertility:
34. Remark by the interviewer, if he/she feels that something said by the respondent but not recorded properly and require mention on the spot: