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Impact of Dry land Salinity on Agriculture and Drinking Water
A Study from the Coastal Gujarat

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Foreword

The Centre for Economic and Social Studies (CESS) was established in 1980 to undertake research in the field of economic and social development in India. The Centre recognizes that a comprehensive study of economic and social development issues requires an interdisciplinary approach and tries to involve researchers from various disciplines. The Centre's focus has been on policy relevant research through empirical investigation with sound methodology. Being a Hyderabad based think tank, it has focused on, among other things, several distinctive features of the development process of Andhra Pradesh, though its sphere of research activities has expanded beyond the state, covering other states apart from issues at the nation level. In keeping with the interests of the faculty, CESS has developed expertise on several themes which included, among others, growth, equity, rural development, poverty, agriculture, food security, irrigation, water management, public finance, health, and environment. It is important to recognize the need to reorient the priorities of research taking into account the contemporary and emerging problems. Social science research needs to respond to the challenges posed by the shifts in the development paradigms like economic reforms and globalization as well as emerging issues such as optimal use of environmental and natural resources, role of new technology, and inclusive growth. Dissemination of research findings to fellow researchers and policy thinkers is an important dimension of policy relevant research which directly or indirectly contributes to policy formulation and evaluation. CESS has published several books, journal articles, working papers and monographs over the years. The monographs are basically research studies and project reports done at the Centre. They provide an opportunity for CESS faculty, visiting scholars and students to disseminate their research findings in an elaborate form.

The present monograph by Dr. Jyothis Sathyapalan is an attempt to understand the impact of salinity ingress due to groundwater depletion on rural households living in the coastal areas of Gujarat which has the longest coastal line amongst the maritime states of India. Gujarat is a water scarce state with groundwater as a major source of irrigation in the state. Apart from the demand for water for irrigation and domestic uses, a fairly high pace of industrialization also exerts pressure on the existing water resources available in the state. As a result, several parts of the state, specially Kutch and Sourashtra regions, have been witnessing excessive drafting of groundwater resources, well above the recharge rates. Excessive withdrawal of ground water has not only resulted in the depletion of water tables but also deterioration of water quality due to salinity ingress. The impact of salinity can manifest itself in the form of scarcity of drinking water to the rural households and deterioration of soil structure affecting agricultural production.

In this context, the author examines the relationship between population, poverty and natural resource base and estimates defensive expenditure the rural households have to incur for accessing better quality water for drinking and other domestic uses. Salinity being invariably a problem of land degradation has implications for costs and returns arising from agriculture. The data required for the study have been collected by conducting a primary survey.

The study assesses the impact of salinity on agriculture mainly in terms of costs and returns arising from different crops. Examining the differences in production, productivity and profitability of crops across saline and non-saline farmers, the author observes that if cultivation under present conditions continues, most crops like wheat, sugarcane and groundnut might soon become unviable. He draws attention to the need for controlling indiscriminate extraction of groundwater by promoting less water intensive crops in the water scare region together with better water harvesting facilities. In order to minimize the effects of salinity intrusion, it is important that we carefully plan water use and management, factoring in both demand for and supply of water. There is a need for undertaking measures to control salinity propagation as well as for mitigating its effects. The study argues that public action is required in terms of improving the drinking water sector of the coastal area rather than leaving it to the market forces. Mitigation measures point towards need for planning cropping patterns and adoption of less water intensive and more salt resistant crops

This monograph thus contributes to our understanding of various dimensions of the salinity problem emerging as a major factor for soil degradation in several parts of the country. I hope that the research community, policy makers and development practitioners shall find it useful.

Manoj Panda
Director, CESS.

CONTENTS

Page No.

List of Figures

List of Tables

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Tuesday, August 30, 2010 **Jyothis Sathyapalan**

Chapter. 1
Introduction

Salinity in Dry lands: Its consequence and the issues
Dry land is an ecological concept classified as a region where annual potential evaporation and plant transpiration exceed annual average precipitation (Hassan and Dregne, 1997). A salient feature of dry land ecosystem is low rainfall associated with variability. Geographically, dry lands are divided into four climatic zones: hyper-arid, arid, semi-arid and dry sub-humid[1]. Hyper-arid areas are natural deserts that are relatively uninhabited. Arid regions are almost exclusively used for extensive grazing. Semi-arid lands are largely pastoral in nature, and include extensive rain-fed cropping. Dry sub-humid zones are woodlands and forested lands where intensive cropping is practised, along with livestock rearing. The Millennium ecosystem assessment (MA, 2005) reports that dry lands cover 41 per cent of the Earth's surface inhabited by more than 2 billion people. It is also reported that the dry land population, on the whole, lags behind the rest of the world in terms of human well being and development indicators. The current socio-economic conditions in dry lands show that about 90 percent of the dry land people live in developing countries.

The MA presents the dry land and dry land people not as homogeneous entities but as a continuum of ecosystem with human inhabitants spread along a global aridity gradient in which life and livelihoods are constrained by water. The magnitude of this constraint determines the make-up of the flow of services provided by ecosystems and, the land uses by the people and their respective livelihoods. The existing water shortages especially in dry lands are projected to increase overtime due to population growth, land cover and climate change (MA, 2005). Therefore, issues related to water resource management in dry lands merit greater attention in the near future.

Today water scarcity and soil salinization are two main constraints coming in the way of improving human wellbeing in these regions which can be explained in terms of

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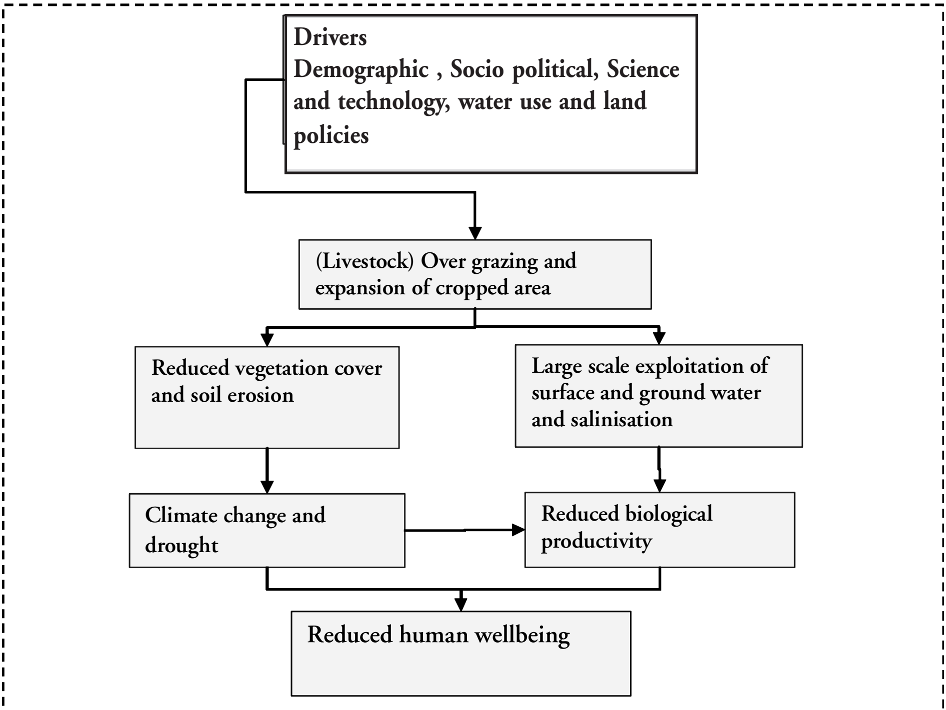
[1] The classification is based on UNEP terminology. Dry land sub types can also be described in terms of land uses: range land, croplands and urban areas. Rangelands and croplands together constitute 90 per cent of dry areas and are often interwoven with agro pastoral livelihood systems (MA, 2005)

desertification paradigm (Figure 1). The desertification paradigm focuses on the negative interactions of human with dry land ecosystems. The paradigm shows that demographic and socio political factors drive the trends in ecosystem degradation which, in turn, further affect human well being (MA, 2005). The figure also reveals that the soil structure and water salinity play a significant role in bringing down human welfare in dry land areas[2]. Salinity affects agriculture productivity and drinking water, thereby human welfare and hence the issue also differ.

Figure 1 Desertification paradigm and its links with human welfare



Source: (MA, 2005)

As far as the agriculture is concerned, the most important issue is the loss of agricultural productivity of farm lands due to water and soil salinity. Because, dry land areas face extreme temperatures with low relative humidity resulting in high rates of evaporation which in turn leads to deposition and accumulation of salt in the soil profile affecting the growth of plants. Dissolved salts increase the osmotic potential of soil and water. An increase in osmotic pressure on the soil structure increases the amount of energy which

[2] Salinity is the presence of soluble salts in or on soils, or in waters. High levels of soluble salts may result in reduced plant productivity or the distruction of vegetation (QDPI, 1987).

plants must expend for absorbing water from the soil. As a result, respiration increases resulting in the growth and yield of most plants declining progressively (FAO, 1985). In such situation, small, and marginal farmers are the worst affected category. With salinisation of water and soil, the surface eco-landscape particularly biodiversity, soils, and vegetative cover also undergo drastic, and often irreversible changes. This implies that the salinisation manifests in the reduced agricultural production and loss of biodiversity.

The second issue is related to the use of saline water for domestic purposes, especially for drinking and its impact on human health. Drinking of saline water can cause health problems like knee pain, kidney stone, tooth decay etc. Many examples are available in the medical and toxicological literature regarding acute effects of "salt poisoning". It is observed that a relatively small quantity of sodium chloride in solid form may produce profound hypernatremia and critical sequelae in pediatric patients. Magnesium salt concentrations in water exceeding 50 mg/L may cause laxative effects in users; however, these effects are likely to be transient. Similarly, sulphates of several forms (e.g., calcium, magnesium, sodium) may cause gastrointestinal irritation and laxative effects at greater than approximately 500 mg/L, coupled with disagreeable taste. The presence of each of these minerals in saline water supplies is likely, with relative quantities being dependent upon the specific geographic area and ancillary sources (WHO, 2003).

In order to avoid these health risks, people either buy fresh water from the market or walk long distances to collect fresh water at the cost of other productive activities. Finally, labour allocation decisions at household level will also change due to changes in production and consumption. This indicates that the problem of salinisation manifests not only in reduced agricultural production and loss of biodiversity but also increased cost of drinking water and human health care. The present research study examines these issues by carrying out an economic valuation of ecosystem changes due to salinity ingress in coastal dry land areas of Gujarat State in India.

Sources of salinity in dry lands

The salinisation of water and soil can occur due to various human induced activities in which agriculture stands first. The important reasons for salinity in the soil are capillary rise from sub soils containing salt, indiscriminate use of canal water for irrigation, weathering of rocks in salts deposited by rivers from upstream regions to plains, salt impregnated sands transported by coastal winds, underground decomposition of soil minerals, intrusion of sea water, excessive use of chemical fertilisers and pesticides. In short, intensive agriculture practices might cause salinity in water and soil. Many studies reveal that excessive use of both surface and ground water for irrigation in arid and semi arid regions leads to salinity problems. As far as surface water irrigation is concerned, perennial canal systems continue to raise subsoil water tables that can cause salinity in water and soil. Land use changes without proper understanding of the local ecosystems are also a reason for increasing salinity in water and soil. For example, Glean and Mark (2007) reports clearing of native deep rooted perennial vegetation and its replacement with annual crop and pasture species resulting in ground water salinity. The vegetation change, and the associated differences in plant water-use, has led to an altered water-balance and rise in groundwater tables, ultimately bringing salts stored deep in the soil profile to the surface (Glenn and Mark, 2007). In irrigated areas, groundwater salinization can result from irrigation with saline water, salt water intrusion owing to pumping of groundwater, downward movement of salts in the unsaturated zone or dissolution of saline minerals, and the unavoidable concentration of salts owing to plant water uptake. In non-irrigated areas, agriculture often leads to increased recharge, sometimes resulting in the leaching of salts from the unsaturated zone into groundwater (Saurez, 1989). It is also reported that excessive ground water exploitation for agriculture purposes can cause intrusion of sea water into aquifers in coastal areas resulting in ground water salinity (Goudie, 2000).

Ground water depletion and Sea water intrusion

Groundwater is one of the components of the hydrological cycle, stored underground in geological layers called aquifers; it is a result of rainfall and surface water, with which it maintains a close relationship (Yogesh, 2005). Today, increasing depletion of ground water is identified as a major problem especially in dry land areas in terms of sustaining human welfare. Two types of ground water depletion have been identified: secular depletion and seasonal depletion. The secular depletion is due to uncontrolled withdrawal of groundwater at rates that exceed those of natural replenishment over substantially long periods of time. Seasonal depletion of groundwater levels occurs due to faster rates of extraction of groundwater in hard rock areas between two monsoons resulting in drying up of wells. The excessive withdrawal of groundwater from deep aquifers also leads to quality deterioration in terms of increase in fluoride content and salinity levels. In the coastal areas, excessive withdrawal of ground water leads to hydrostatic imbalances between freshwater aquifers and seawater. The reason is that fresh water has a lower density than salt water, in that a column of sea water can support a column of fresh water approximately by 2.5 per cent higher than itself (or a ratio of about 40:41). So where a body of fresh water has accumulated in a reservoir rock which is also open to sea water ingress, doesn't simply lie flat on top of the salt water but forms a lens, whose thickness is approximately 41 times the elevation of the piezometric surface above sea level (Goudie, 2000). This is called Ghyben-Herzenberg principle. The corollary of this rule is that if the hydrostatic pressure of fresh water falls as a result of over pumping of a well, then the underlying salt water will rise by 40 times for every unit of fresh water table is lowered. With groundwater extraction, there is a risk of the lowering of water tables, thus disturbing the dynamic balance between fresh and seawater, apart from permitting the saline interface to progress inland. As a result, in the Coastal areas, the total dissolved solid (TDS) levels in groundwater far exceed the permissible levels accepted for irrigation and drinking, and hence adversely affect human welfare.

Therefore, in this study, we have examined two types of welfare implications: (a) welfare impact through reduced agriculture production; (b) welfare impact due to the use of saline water for domestic and drinking purposes. We have used economic valuation approach to understand welfare implications of saline water consumption for both agriculture and domestic purposes.

An Economic case for valuing welfare loss in the presence of salinity

An important question that arises here is there a need for valuing welfare loss due to salinity ingress resulting from ground water extraction. A basic premise is that assigning economic values to ecosystem externalities helps take rational decisions with regard to conserving natural resources like soil and water. The study considers salinity ingress from seas to aquifers as an 'externality' due to excess drafting of ground water for agriculture and domestic purposes. The presence of externalities reflects the failure of the economic system to recognise and register the relative scarcity of resource through prices (Swanson, 1996)[3]. Therefore, a proper economic valuation of environmental externalities helps society make informed decision with regard to the use and conservation of natural resource. This view on valuation going back to the early literature on environmental economics (Pigou, 1920) (Mäler K. , 1974) as an important reason for 'market failure'. Later, it was argued that market failure was one type of 'institutional failure', and that it was the prime cause for all ecological problems[4] (Dasgupta, 1996). It perceived market as an institution making available to interested parties the opportunity to negotiate mutually advantageous courses of action. Its functioning is closely linked with the structure of property rights. In order that someone is able to negotiate, they need to know the extent to which they are empowered to negotiate, the extent to which other parties are empowered to negotiate, and so on. In other words, for one to be able to negotiate, one need to know what one can negotiate with, what the other parties can

[3] If a resource is becoming relatively scarce on account of lack of management, then its relative price should be increasing and the incentive to increased management should increase like-wise (Swanson 1996:11).

[4] Market failure, government failure, micro institutional failure and political instability together reflect the environmental consequences of *institutional failure* (Dasgupta 1996).

negotiate with, and so forth. Therefore, it is not a surprise that the functioning of market is linked closely to the structure of property rights. Therefore, our enquiry into the issue of ground water depletion as an externality also considers various property right issues associated with the use and conservation of resources. This approach can be further substantiated by the property right argument related to common pool resource (Ostrom, 2005). This argument highlights the fact that the issue of controlling landowners from over exploiting ground water lies with the 'non-excludability' and subractability character of the resources[5]. The withdrawal of water from aquifers by one farmer implies that there is that much less water available for anyone else to use. Theoretically, it is hard to exclude beneficiaries, but each person's use of the resource system subtracts units of that resource from a finite total amount available for harvesting. It is also pointed out that, where exclusion is costly, those wishing to provide a good or service face a potential 'free rider' problem (Olson, 1965). When the flow of service by one individual subtracts from what is available to others and when the flow is scarce relative to demand, users will be tempted to try to obtain as much as they can of the flow for fear that it will not be available later (Ostrom, 2005). Today, in the semi arid parts of the country, good quality ground water is an extremely scarce commodity in relation to demand for it. It is also important to point out that at the national level, ground water irrigation system registered first position in terms of area irrigated by a single source as compared to its third position in 1950-51. Nevertheless, individuals gaining from ground water irrigation system may not wish to contribute labour or taxes towards groundwater replenishment activities subject to a potential free rider problem in the absence of proper institutions for monitoring ground water use. Therefore, it is necessary to understand the property right issues with respect to ground water resource so as to value the impact of its depletion on human welfare. This would help us take considered decisions regarding ground water conservation and use.

The Study Area: Gujarat State, India

In India, the dry land regions comprise about 228.3 million ha (69.6%) of the total geographical area (328 m ha) of the Country (Mandal, Mandal, Srinivas, Sehgal, and Velayutham, 1999). Gujarat is one of the Dry land States of India with a considerable proportion of saline land due to sea water intrusion. Gujarat coast is situated on the west coast of India between 20o 2'-24'' N latitude, and 68o 8'-74o 23' E longitude with a 1650 KM long coastal line (Figure 2). This is the longest coastal line amongst the maritime

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[5] Non-excludability relates to the difficulty in restricting those who benefit from the provision of a good or service. Subtractability refers to the extent to which one individual's use subtracts from the availability of a good or service for consumption by others. (Ostrom, 2005)

states of India, constituting nearly 21 per cent of the total coastal line of India. There are about 2802 villages and 59 towns located within 20 kilometres inland from the seashore (Gupta and Deshmukhe, 2000). In terms of agro-climatic features, Gujarat comes under arid and semi arid zones (Figure 3), with longest stretches of saline area known as the Rann (GOI, Drought: Sate Report (Gujarat, Maharashtra and Rajasthan), 2002).

The climate of Gujarat is highly varied. The north-western part of the state is dry, with less than 500 mm (20 in) of annual rainfall. In the more temperate central part of the state, the annual rainfall is more than 700 mm (28 in) while in the southern part of Gujarat, rainfall averages 2000 mm (79 in) a year. During winter although temperatures generally average between 12° and 27° C (between 54° and 81° F), freezing levels have also been recorded in the state. In the summer, temperatures vary between 25° and 43° C (77° and 109° F) and have been known to reach as high as 48° C (118° F). In many parts of the state, the drafting of groundwater is much above recharge rates. It is reported that every year, on an average 0.5 to 1.0 km stretch from the coast lines gets affected by salinity ingress. Thus, about 5 to 7.5 km wide strip of the inland area had been rendered saline till 1996. The groundwater quality has deteriorated to more than 2000 ppm of TDS in many places of coastal Gujarat (Barot, 1996). Gujarat being a water scarce region, groundwater has gained prominence as a major source of irrigation. The total net irrigated area in Gujarat is reported to have risen from 700,000 ha in 1962-63 to 2,989,000 ha in 2002-03. Around the same period, the area irrigated by groundwater increased from 463,000 ha to 2,544,000 ha indicating that the share of ground water in total net irrigated area has been on the increase. The annual growth rate of ground water irrigation in terms of net area irrigated showed a high growth rate of 6.50 per cent during the first green revolution phase, 1960-61 to 1980-81. During the second phase it grew at the rate of 2.35 per annum. The overall growth rate for the perioid 1961 to 2002-03 was 4.05 per cent per annum. The high growth rate of groundwater irrigated area was due to higher water requirements of high yielding verities (HYV) of rice and wheat during this period (Singh and Singh, 1995). Apart from high irrigation requirements, rapid spread of industrialisation and domestic requirements have also been exerting pressures on the water resources in the state. The Gujarat Ecology Commission observes that the degradation of land has resulted in increased use of other agricultural inputs like chemical fertilisers (GEC, 2001). This certainly indicates that there are implications for agricultural production and productivity along with potentially harmful consequences on human and animal health. Although, this issue has been documented, there appears to be few scientific studies carried out for understanding the magnitude of damages caused by salinity ingress in the coastal areas of Gujarat State. Since the overexploitation of groundwater and the resultant land degradation in terms of salinity ingress being largely the result of a lack of proper water resource management regime, there is a real need for understanding the magnitude of economic losses caused by salinity ingress in Gujarat, so that appropriate measures are adopted for desalinization and groundwater replenishment.

Figure 2 Location Map of Study Area

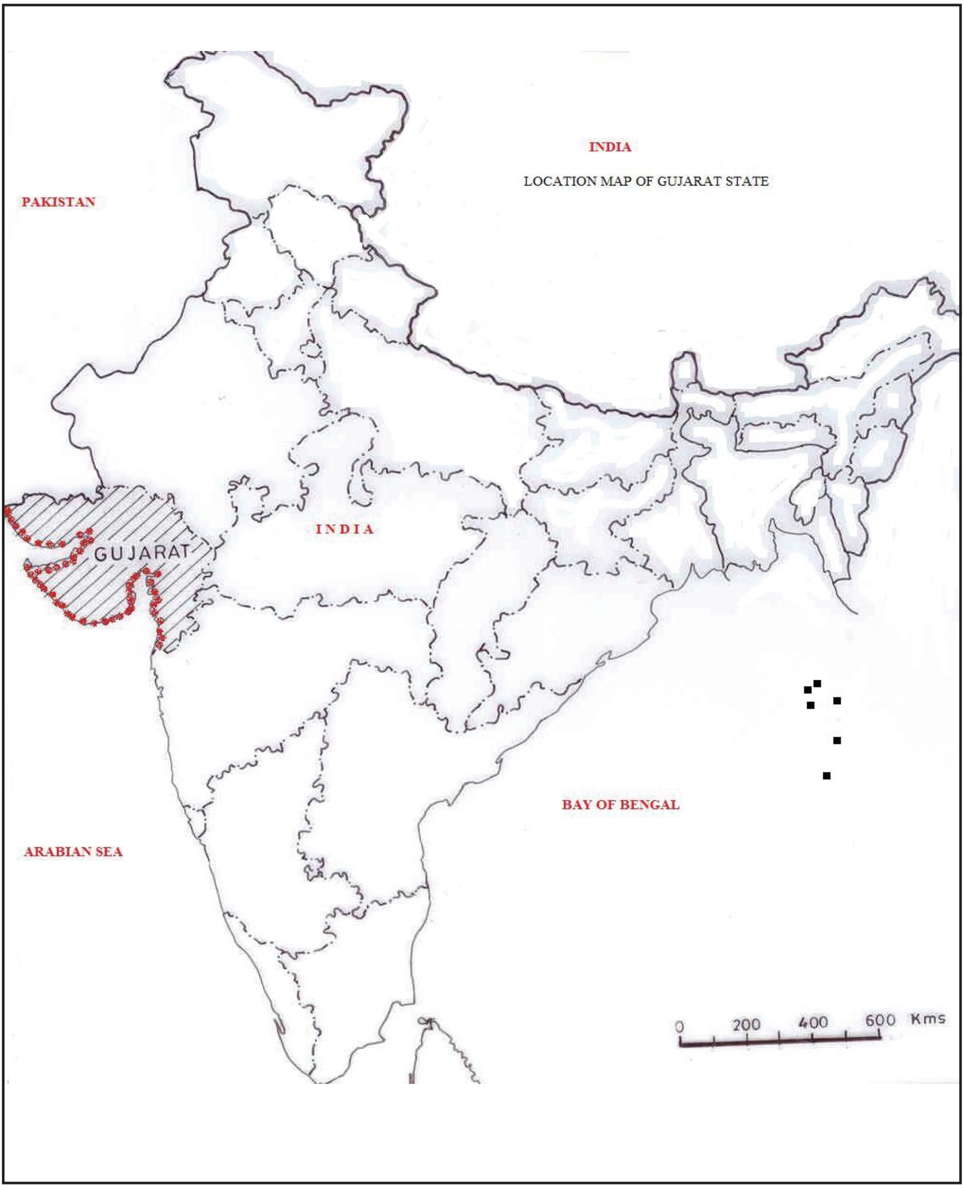
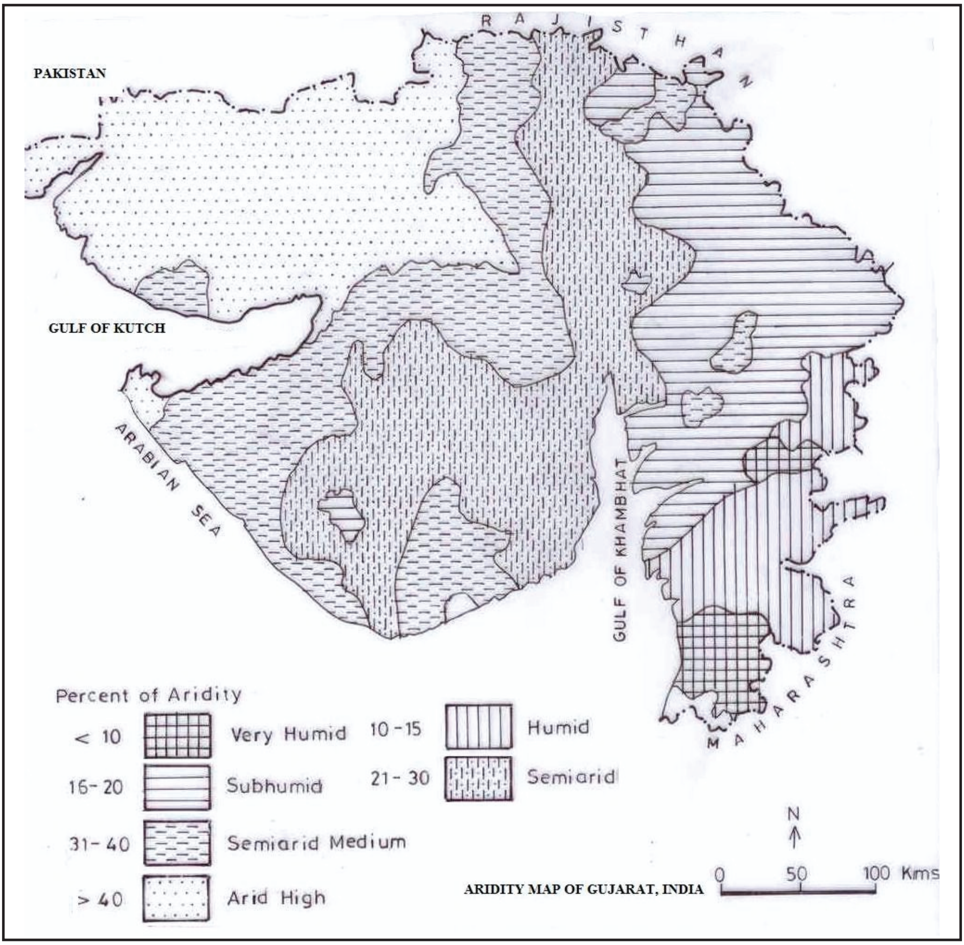


Figure 3 Aridity Map of Gujarat



Source: Patel 1997.

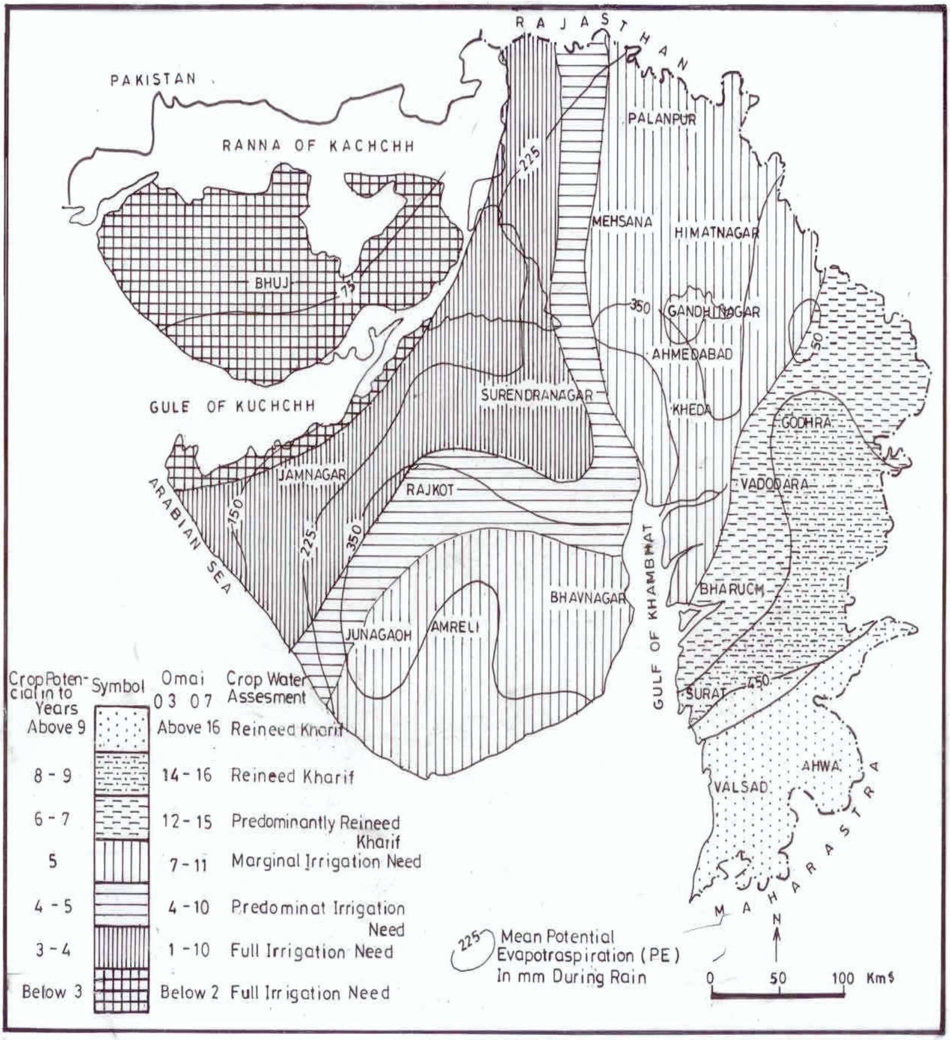
Review of Literature

While there is no dearth of literature on salinity and water logging caused by perennial canal irrigation and its impacts on income and employment generation in irrigated agriculture, economic valuation studies on coastal salinity ingress due to over exploitation on ground water is relatively less. For our analysis, we concentrate on studies focusing on the impact of salinity on agriculture production and human health.

Impact of Salinity on agriculture

We have already explained that dissolved salts in water increase the osmotic potential of soil in that an increase in osmotic pressure of the soil solution increases the amount of energy plants must expend to draw up water from the soil. As a result, respiration is

Figure 4 Map showing agro climatic regions of Gujarat State



Source: Patel, 1997

increased and the growth and yield of most plants decline progressively. Although most plants respond to salinity as a function of the total osmotic potential of soil water, some plants are susceptible to specific ion toxicity. Many of the ions which are harmless or even beneficial at relatively low concentrations, may become toxic to plants at high concentrations, either through direct interference with metabolic processes or through indirect effects on other nutrients, which might be rendered inaccessible (FAO, 1985). Important agricultural water quality parameters include a number of specific properties of water that are relevant in relation to the yield and quality of crops, maintenance of soil productivity and protection of the environment. These parameters mainly consist of certain physical and chemical characteristics of water. Table 1 presents a list of some of the important physical and chemical characteristics that are used in the evaluation of agricultural water quality (Kandiah, 1990). It has been reported that irrigation with nitrogen-enriched polluted water can supply a considerable excess of nutrient nitrogen to growing rice plants resulting in a significant yield loss of rice through lodging, failure to ripen and increased susceptibility to pests and diseases as a result of over-luxuriant growth. The study further reports that non-polluted soil, having around 0.4 to 0.5 ppm cadmium, might produce about 0.08 ppm Cd in brown rice, while only a little increase up to 0.82, 1.25 or 2.1 ppm of soil Cd has the potential to produce heavily polluted brown rice with 1.0 ppm Cd.

Most of the case studies focusing on water logging and salinity conclude that salinity affects the fertility of soil structure which in turn might lead to a decline in agriculture productivity. The main source of this sort of salinity is the rise in subsoil water table resulting from perennial canal systems (GOI, Report of the Irrigation Commission, 1972). As a result, the investments made on the development of canal irrigation in the salinity affected areas become economically unviable to the society. Some of the case studies focusing on the decline of agriculture output due to salinity are presented in Table 2. Labour unrest and unemployment are also observed in various parts of salinity affected areas (Singh and Singh, 1995). These studies bring out enormous risks farmers take in terms of crop loss in salinity affected areas. One prominent question is how to tackle these risks and what benefits it can ensure. A risk assessment approach points out that staging salinity management and prevention require an assessment of the timeline of salinity development, the level of risk and the value of assets under threat (Michael, Silburn, and Chamberlain, 2007).

Although studies focusing on salinity ingress due to ground water depletion and its impacts on human welfare are relatively few, some case studies cover different dimensions of this problem, such as extent of depletion, cost of depletion, property right issues etc. Several studies have observed that ground water in India is left unmanaged (Singh K. , 1995) (Chandrakanth and Arun, 1997). An important reason is the absence of ground water institutions and markets at the local level (Chandrakanth and Arun, 1997) (Satyasai, Kumar, and Mruthyunjaya, 1997) (Nagaraj, Marshall, and Sampath, 1999). It is perceived that ground water depletion is an important issue of negative externality due to lack of institutions to monitor ground water use for irrigation. Its magnitude in terms of farmer's willingness to mitigate the negative effect is calculated to be around Rs 48,370 per framer in Karnataka State (Chandrakanth and Arun, 1997). Another study that examines ground water market concludes that small farmers have limited access to ground water as compared to large farmers. The study finds small farmers buying ground water from

Table 1 Water Quality Parameters

Parameters	Symbol	Unit
Physical		
Total dissolved solids	TDS	mg/l
Electrical conductivity	Ec_w	dS/m[1]
Temperature	T	°C
Colour/Turbidity		NTU/JTU[2]
Hardness		mg equiv. aCO_3/l
Sediments		g/l
Chemical		
Acidity/Basicity	pH	
Type and concentration of anions and cations:		
Calcium	Ca^{++}	me/l[3]
Magnesium	Mg^{++}	me/l
Sodium	Na^{+}	me/l
Carbonate	CO_3^{--}	me/l
Bicarbonate	HCO_3^{-}	me/l
Chloride	Cl_{-}	me/l
Sulphate	SO_4^{--}	me/l
Sodium adsorption ratio	SAR	
Boron	B	mg/l[4]
Trace metals		mg/l
Heavy metals		mg/l
Nitrate-Nitrogen	NO_3-N	mg/l
Phosphate Phosphorus	PO_4-P	mg/l
Potassium	K	mg/l

Note: [1] dS/m = deciSiemen/metre in SI Units (equivalent to 1 mmho/cm)
[2] NTU/JTU = Nephelometric Turbidity Units/Jackson Turbidity Units
[3] me/l = milliequivalent per litre
[4] mg/l == milligrams per litre = parts per million (ppm); also,
mg/l ~ 640 x EC in dS/m

Source: (Kandiah, 1990)

large farmers at the cost of 7.70 per hour (Satyasai, Kumar, and Mruthyunjaya, 1997). In India, the ownership of ground water is linked to land ownership, which is found skewed in various parts of the country. The linking of ground water and land rights makes the resource relatively an open access to those landowners who have financial capacity to invest in water pumping technology. This has led to a situation of overexploitation of the resource in many parts of the country (Reddy, 2005).

Table 2 Different Estimates of agriculture production loss due to salinity

Source	Methodology	Yield decline due to salinity in per cent
Joshi and Agnihothri, 1984		
Joshi 1987		
Chopra 1989		
Joshi and Jha 1992 (Singh and Singh, 1995)	Cobb-Douglas production function estimates at the farm level in the case of Hariyana state	Paddy 29.9 What 31.8 Cotton 62.0 Sugar cane 37.7
(Nayak, 2002)	Cost benefit Analysis	Decline in benefit cost ratio from 2.39 to 2.15

Source: Compiled from different studies

Controlling salinity ingress in agriculture

A risk assessment approach similar to the concepts of 'diagnosis and staging' used by physicians for diseases such as cancer shows the importance of an information base at the micro level to design management strategies with local community investment for preventive actions in the Fitzroy Basin, Australia. It is proved that preventive actions like afforstation in the catchment areas of river basins help reduce the risk of salinisation in down streams (Michael, Silburn, and Chamberlain, 2007). An interesting case study on preventing salinity risk in the Murray Darling Basin (Australia) using salt and drought tolerant eucalyptus hybrid species (E. Camaldulensis) report a significant opportunity existing for private investors to partner with natural resource management agencies in projects with commercial and environmental benefits in terms of preventing salinity and improving biodiversity (Glenn and Mark, 2007). However, in many cases, the responsibility of implementing preventative measures will rest with individual landholders, as the impact of salinisation tends to get localised. These measures are most likely to be applied if they could be shown to be economically viable. This requires understanding of the impacts on farm incomes as a result of continuing with, or changing from, current land management practices.

An analysis of the economic damages resulting from high soil salinity levels in the irrigated lands' of Bardenas I in Zaragoza, Spain is presented in Zekri and Albisu (1993). In this area, the principal sources of salinity are salts arising from meteorisation in combination with secondary salinisation in areas lacking in natural drainage. The study uses an interactive multi-objective programming technique, to represent the current situation with the corresponding salinity levels and demonstrates the benefits and feasibility of salt-affected land reclamation projects in Spain (Zekri and Albisu, 1993).

Salinity impact on human health

We have already introduced the issues related to the use of saline (marginal quality) water for domestic purposes, especially for drinking and its impact on human health. Some of the diseases, due to drinking of saline water are knee pain, kidney stone, tooth decay, hypertension etc. We have also mentioned that magnesium salts concentration in water exceeding 50 mg/L may cause laxative effects in naïve users; however, these effects are likely to be transient. Similarly, sulphates of several action (e.g., calcium, magnesium, sodium) may cause gastrointestinal irritation and laxative effects at greater than approximately 500 mg/L, coupled with disagreeable taste (WHO, 2003). There are case studies focusing on these health risks that use both direct and direct methods to estimate the costs of saline water use for domestic purposes. An early study reports that much of the ground water in Gujarat is saline or contaminated with fluoride and nitrates that limit its usability (Matzger and Moench, 1994). The increasing fluoride content of water eventually creates health problems. A recent study conducted in junagadh region of Gujarat reports that most significant health hazards in the salinity ingress areas include kidney stone (Indu and Rawal, 2006). The study reports 6 percent of the population in Junagadh suffering from kidney stone. A sample of 156 households covered under this study reports an average medical expenditure of Rs 5790 and an average wage loss of Rs 3520 per person. Since studies covering the entire coastal area are very few, it is difficult to generalise this phenomenon.

Objective of the Study

The lead objective of the study is to understand the impact of salinity ingress (due to ground water depletion) on rural households living in the coastal belts of Gujarat State. The other specific objectives of the study are as follows:

1. To analyse the characteristic features of the coastal regions of Gujarat with special emphasis on exploring population, poverty and resource base linkages.
2. To study the impact of salinity propogation or ingress on the rural households in terms of their defensive expenditure in the household budget.
3. To estimate the impact of salinity ingress on agricultural production in the coastal areas of Gujarat.
4. To draw policy implications for mitigating the effects of salinity ingress on the rural households in the Coastal regions of Gujarat.

Data sets, sources and approach

The study is based on both secondary and primary data. In order to provide a backdrop to the analysis, secondary data have been used. The data required for the economic valuation were collected by conducting a primary survey among 24 households located within 20 kms from the shore line of Gujarat Coast. The study followed a stratified random sampling for selecting households from the selected villages of Gujarat coast. These villages included both agriculture and fishing villages. In the absence of reliable sample frames, we adopted a census survey to list all the households of these villages. In the census survey, we collected basic information on the households like total number of people, primary source of income, number of wells and the area of land owned, presence of salinity in land or water, drinking water source etc. In the first stage of sampling, we categorised villages into three groups based on elevation and distance from the sea as villages near to the sea were more prone to salinity ingress. The total number of households enumerated from the 24 villages comes to 12501, of which, 56.2 per cent of households were living in lowland areas that is, villages located less than 6 metres of elevation (11 villages). The middle land villages were located at an elevation of 8.8 to 12.7 metres from the sea level, constituting 29.2 per cent of the households (6 villages). The upper land villages, located at an elevation of 17 to 50 metres (7 villages), constituted 14.6 per cent of the total households.

In the second stage of sampling, households were categorised into salinity affected and not affected households. The census data shows that 71.5 (8940) per cent of the households were salinity affected of which 41.4 per cent were in the low land, 22.3 per cent in the middle land and 7.8 per cent in the upper land range. The remaining 28.5 per cent (3561) were not affected by salinity. The samples were drawn proportionately from both the group of households based on the landholding size. In the third stage, the sample size was determined at a five percent margin of error. The sample was drawn using random number tables.

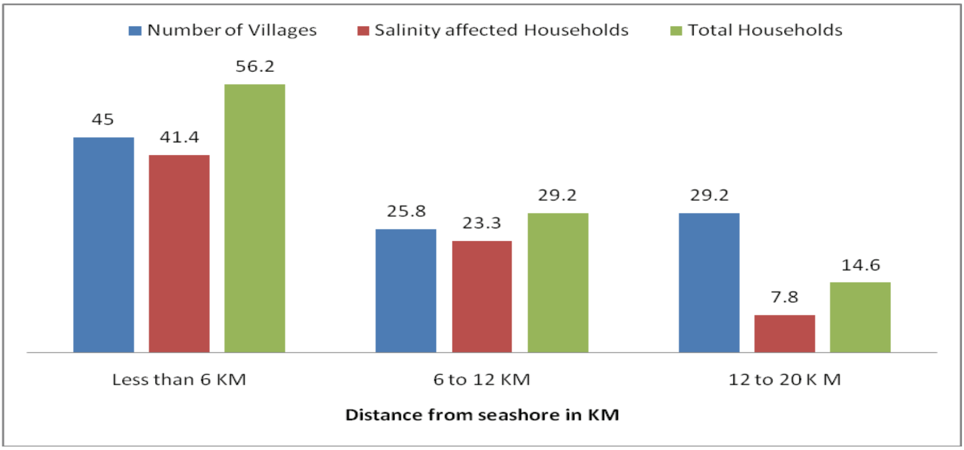
Table 3 Distribution of sample households by district, taluka and village

District/Regions	Taluk	Village	Total number of Sample households	Total number of households
Junagadh (Saurashtra)	Kodinar	Panch Pippalava	36	347
		Kaj	67	687
		Velan	125	1304
		Velva	24	220
	Keshod	Pankhan	34	440
		Eklera	16	163
	Mangrol	Nandrakhi	37	398
		Chandvana	53	542
		Shapur	56	563
	Veraval	Jaleswar	17	210
	Sutrapada	Damlej	153	1627
	Talala	Vadala	29	295
Bhavnagar (Saurashtra)	Shihor	Jashpara	27	278
	Shihor	Pipli	16	170
	Vallabhipr	Vavdi	31	310
Surat (Gujarat Eastern)	Olpad	Sondlakhara	17	180
	Jinod	26	244	
	Delasa	23	228	
	Sithan	20	200	
Navsari (Gujarat Eastern)	Jalalpur	Bhattai	20	236
	Onjal	89	1079	
	Mandir	29	367	
Kachchh (Dry Region)	Mandvi	Bidada	153	2000
	Nagalpur	31	413	
Total	**10**	**24**	**1129**	**12501**

Source:: Based on primary Survey data

Data analysis has been carried out for different regions of Gujarat State. A systematic and well-accepted regionalisation of Gujarat based on the NSS classification (in terms of ecological and economic factors) was followed. We therefore, chose to undertake the regional level analysis using the regionalisation classification undertaken by the National Sample Survey Organisation (NSSO). The NSS regions included all or some blocks in a district in its scheme of regionalisation, but for simplicity, we classified the entire districts of Gujarat in one particular region avoiding overlapping of districts in more than one NSS region. Census data comparisons have been made in accordance with NSS regions

Figure 5 Distribution of sample villages and households (in percentages) based on distance from Seashore



Source: Based on primary census data collected from 24 coastal villages

of Gujarat State as suggested in a study on the comparability of NSS and Census data in India (Murthi, Srinivasan, and Subramanian, 1999). The classification of districts based on census in conjunction with NSS regions is presented in Table 4.

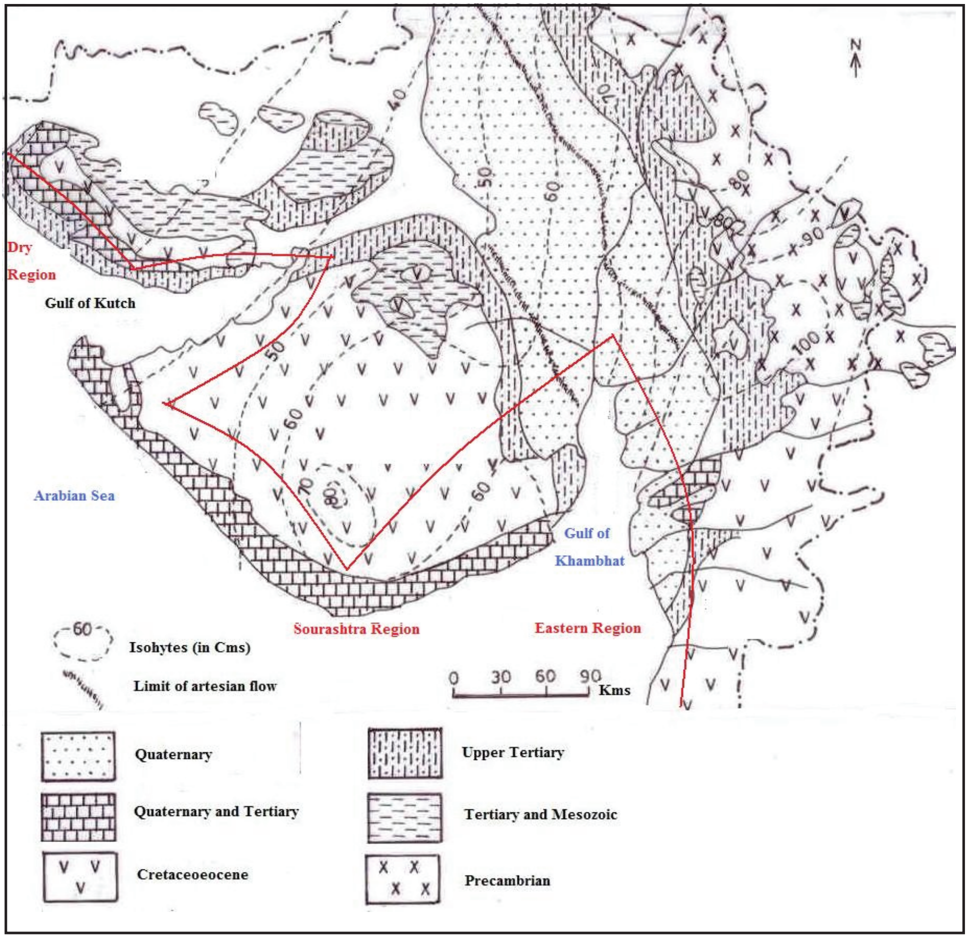
There are mainly five NSS regions for Gujarat state, namely the Gujarat Eastern comprising Surat, Valsad, the Dang and Navasari districts; Gujarat Plain Southern including districts such as Bharauch, Panchamahals, Dahod, Narmada and Vadodara; Gujarat Plain Northern with districts such as Ahmedabad, Anand, Sabarkantha, Mehsana, Gandhinagar and Kheda. The other NSS regions are Dry region, with Kutch, Banaskantha, Patan, Surendranagar; and Saurashtra region including Jamnagar, Junagadh, Bhavnagar, Amreil, Porbandhar and Rajkot districts. Among the different districts in Gujarat, the Dangs, Panchmahals, Dahod, Narmada, Vadodara, Sabarkantha, Mehsana, Gandhinagar, Kheda, Banaskantha, Patan, and Surendranagar do not have coastal regions. The climatic conditions of these regions range from humid to semi arid and arid. For the convenience of sampling and analysis, we have merged the Gujarat plain regions (northern and central plain regions) with Eastern region. Therefore, results of this study cover three regions shown in (Table 5). Data used for all maps in this study are from the publications of Gujarat Ecological Commission (Patel, 1997). The distribution of sample households and basic demographic characteristics of the sample population are presented in Table 5.

Table 4 Classification of Census districts in conjunction with NSS regions of Gujarat State

NSS regions of Gujarat State	Census Districts having coastal area	Census Districts not having coastal area	Key Characteristics of the Region
Gujarat Eastern	Surat (3), Valsad (3), Navsari (4)	The Dangs	Tribal Area with degraded forest resource base. Tribal talukas covered under Tribal sub-Plan. Humid climate, Normal rainfall1986mm per year
Gujarat Plain Southern	Bharuch (5),	Panchmahals Dahod, Narmada, Vadodara	Tribal Area with degraded forest resource base. Tribal talukas covered under Tribal sub-Plan. Normal rainfall 813mm per year
Gujarat Plain Northern	Ahmedabad(2) Anand(2)	Sabarkantha, Mehsana Ghandhinagar, Kheda	Except Sabarkantha, other districts are non tribal districts
Dry Region	Kutch(6),	Banaskantha, Patan, Surendranagar	Arid and semi arid Region Covered under Drought Prone areas Programme and Desert Development Programme.
Saurashtra Region	Jamnagar (6) Junagadh (6) Bhavnagar (4), Amreli (2) Porbandar (1) Rajkot (2)		Semi Arid Region. Covered under Drought Prone areas Programme and Desert Development Programme.

Classification based on (Murthi, Srinivasan, and Subramanian, 1999)
Note: Figures in parenthesis denote the number of sub-districts within 20 kilometers from the coastal line (total 51sub-districts).

Figure 6 Hydrological map of Gujarat (with different sample regions of villages)



Source: Patel 1997

Table 5 Demographic details of sample households within 20 kilometres of shoreline of the coastal area of Gujarat

Regions	Male	Female	Total Population	Sex Ratio	Literacy level	Household size	Sample size
Gujarat Eastern	515	536	1051	1041	82.8	4.7	255
Saurashtra	2228	2038	4266	915	60.8	5.9	721
Dry Region	479	435	914	908	68.0	5.0	184
Gujarat (Total)	3222	3009	6231	934	60.1	5.5	1129

Source: Primary survey

Structure of the Report

The study is presented in five chapters. The following chapter 2 presents the characteristic features of the coastal regions of Gujarat and explores the linkages between resource base population and poverty. Chapter 3 provides the socio economic characteristics of the sample households surveyed. The chapter 4 analyses the impact of salinity on drinking and domestic water use. This chapter also deals with the results of the defensive expenditure incurred by households for mitigating the effects of poor quality of water used for drinking and other domestic purposes. Chapter 5 highlights the impact of salinity ingress on agriculture production followed by summary and policy implications in chapter 6.

Chapter 2

Population, poverty and coastal ground water resource base

Introduction

As is known, Gujarat is one of the economically developed states in India and it ranks fourth in terms of per capita State Domestic Product when only major states are considered (Iyengar, 1998). The high net state domestic product (NSDP) and its growth rate also keep the state among the first few progressive states in India. A study on the performance of Gujarat state reports a growth rate of (NSDP) around 4.6 per cent both in the 1970s and 1980s and further to 6.6 per cent in the 1990s. The entire period from 1970-71 to 2000-01 shows a growth rate of 5.3 per cent (Baghi, Das, and Chattopadhyay, 2005). Today the state ranks as the second most industrialised, the third most urbanised and the fifth richest state (in terms of per capita income) among the major states of India. It is also evident from the poverty figures in various rounds of the National Sample Survey (NSS) that although the poverty levels in Gujarat have come down significantly during the last three decades of the twentieth century. There exists a high income inequality along with rural urban divide. As per the 2001 Census, the population of Gujarat is 5.06 crores accounting for about 5 per cent of the total population of the country. Nearly 65 per cent of the population lives in rural areas depending on agriculture, animal husbandry and related activities. The main occupations of the coastal population include agriculture, and allied activities like fishing and animal husbandry. Some studies show that in certain pockets of the state and also among certain communities like tribal and fishing, poverty continues to persist, or grow (Krishna, Kapila, Porwal, and Singh, 2003;Sathyapalan and Iyengar, 2009). The high performance of the state also puts immense pressure on natural resources especially water. For example, intensification of dairying has been accompanied by an intensive use of water for growing feed and fodder crops. This study observes that dairying-based rural livelihoods systems are now threatening the sustainability of the limited water resources in arid and semi-arid areas, whose future, in turn, is threatened by the depletion of these resources (Singh, Sharma, Singh, and Shah, 2004). In this context, we have tried to identify the factors that lead to the degradation or depletion of natural resources like land and water in the coastal areas of Gujarat State. Hence, in the first section of the chapter, we present trends in the use of ground water resources, while in the second section we discuss various factors that exert pressures on ground water resources.

Trends in Rainfall and Ground water resource Use

A number of factors have contributed to the expansion of groundwater irrigation in Gujarat. Among the various factors widely acknowledged in literature include improvements in technology in terms of drilling and lifting water, availability of liberal loans for drilling wells, subsidised electricity pricing etc. The productivity per unit of water tapped is considered to be much higher in the case of groundwater as compared to surface irrigation, because groundwater irrigation involves relatively much less waste by way of conveyance and application losses and also farmers enjoy much greater flexibility in terms of adjusting timing and quantum of water application required for the crop needs (Vaidyanathan, 2006). However, excessive withdrawal of water has not only led to problems of availability, which is inherently related to quantity of water used but also to qualitative problems. Depending upon the geological formations, the quality problem varies from place to place. While the hard rock areas are mostly confronted with fluoride linked problems, in coastal areas, it is the problem of salinity ingress that is most pertinent. In Gujarat about 1448 sq.kms of land have already been classified as salinity affected wastelands (NRSA, 2005). These figures do not include salinity affected degraded lands still under cultivation.

The annual rainfall received has implications for the annual withdrawal as well as recharge of groundwater. The average rainfall figures of the Gujarat coastal districts are presented in Figure 7. It indicates Gujarat eastern region as the highest rainfall receiving area of the state where the average rain fall per year works out 1593 (mm). Across districts, Kutch receives the lowest amount of rainfall (382mm), while Navsari district experiences the highest at 2201 mm. Only three coastal districts of Gujarat eastern region receives an annual normal rainfall above 1000 mm. But the recent data presented in a study reports above-average rainfall in some places of Sourashtra and Kutch regions (Shah, Gulati, P, Shreedhar, and Jain, 2009). The study notes that during 2002 when almost all of India experienced a shortfall in rainfall precipitation, Gujarat too faced an overall shortfall; however, drought conditions hit only the central and southern parts, covered by canal irrigation. All the drought-prone regions had above or near-normal rainfall (Shah, Gulati, P, Shreedhar, and Jain, 2009). The past data on ground water tables presented in Table 6 shows that the water tables in low rain fall areas (Dry region and Sourashtra regions) dropped more than 150 percent from 1980 to 1997. This indicates high pressures on ground water resources during this period. In the dry region, water tables went down by

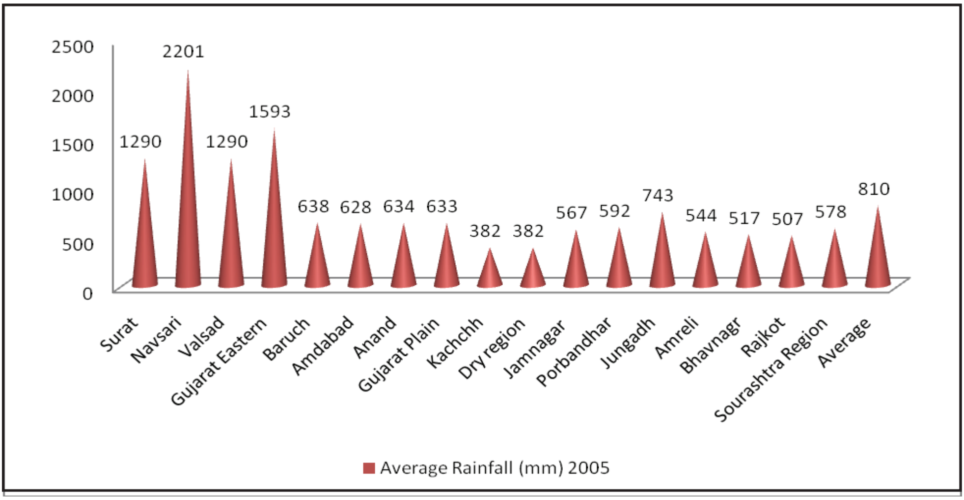
162 per cent between 1980 and 1997. The decline in groundwater tables is also very high in Sourashtra region. Although the recent data on ground water shows an improvement in ground water tables between 2000 and 2008 (Shah, Gulati, Shreedhar, and Jain, 2009), it is difficult to make out whether it has helped reduce saline ingress in coastal areas. A study conducted on drinking water quality of two blocks of Surat district in 2004, also found high salinity ingress and chemical contamination in the ground water source (Sathyapalan and Joshy, 2004; Sathyapalan and Iyengar, 2005).

Table 6 Variations in Environmental Indicators related to forest, ground water, grasslands and mangroves in different regions of Gujarat

NSS regions of Gujarat	Percentage change in the dense forest cover between 1960 and 1997	Ground water table drop at levels between 1980 and 1997 (%)	Grass land reduction in percentage between 1990 and 1996	Loss of mangroves
Dry region	No estimate available	162	20	72.5 percent during 1960 to 1993 in the Gulf of Kachchh area
Eastern region	-40.78	Not available	Not available	Not applicable
Plain Southern region	-68.88	Not available	50	96 percent during 1960 to 1993 in the Gulf of Khambhat area
Plain Northern region	-64.49	104	Not available	Not available
Sourashtra region	-34.98	132	Not available	Not available
Gujarat	-52.68	132.66	13	84

Note: own estimates based on data provided by the Gujarat Ecological Commission (undated

Figure 7 Average rain fall across coastal districts and regions



Factors driving Resource degradation

The theoretical relationship between population, poverty and natural resource base in developing countries has been well established (Dasgupta, 1996). It has been argued that when the communities' natural resources are degraded or depleted, more hands are needed for gathering fuel and water for daily use. As a result, more children are produced, further damaging the local resource base which in turn provides the households with an opportunity for expanding further. When this happens, poverty, fertility and environmental degradation reinforce one another in terms of a vicious circle. The basic reasoning underlying the poverty induced environmental degradation is that poverty causes desperation, which, in turn, induces over-extraction of resources, and together eventually leads to degradation and poverty (Jodha, 1998). The basis for the vicious circle perception is that in developing countries, the poor depend directly on the natural resource environment for their livelihood needs. A positive relationship observed between fertility and the need for workers (Mäler K. G., 1997) has clear implications for the relationship between poverty and environment. If environmental degradation worsens the demand for workers, and fertility will increase. For example, if land gets overgrazed, cattle may have move around long distances in search of grazing lands requiring more workers in the process to tend them; if local water resources are polluted or depleted, more people will be needed to fetch water; and if deforestation reduces the local supply of firewood, more workers will be required to collect the same amount of wood as before. Similar examples all over the globe show that the poor in large numbers are problems leading to environmental degradation. Such a perspective may treat population growth as the main driver of all environmental ills and it can divert the attention from other matters that call for urgent actions, such as concentration of land resources in the hands of a few people, industrialisation without environmental concerns, ill specified property rights with regard to common pool natural resources, introduction of modern technologies in agriculture and consequent land use changes etc. It is in the above context that we need to understand the factors that cause depletion of ground water resource and salinity ingress in the coastal areas of Gujarat.

Population Pressure and Poverty

The census totals for Gujarat State in 2001, shows that the State ranks 10th among Indian States with respect to population. It is a thinly populated State (258 persons per sq km in 2001) as compared to the national average density of population, i.e., about 324 persons per square kilometre in 2001. The State is ranked 21st in India in terms of population density. The change in the density of population in 2001 as compared to 1991 works out to around 22.27 per cent. The decadal growth rate of population for the period 1991-2001 has increased in comparison to 1981-1991 from 21.19 to 22.45. The sex ratio and female literacy are also found low during 2001 as compared to many other Indian states. The fertility rate in many parts of Gujarat is closer to the national average.

We have estimated that the area of 13 coastal districts of Gujarat (again divided into 46 sub districts) coming within approximately 20 km from the shoreline comes to 30022.25 km2 (15.3 per cent of the total area of the state) with a total population of 10,331,258 in 2001. As per the census classification, the total rural population in this area stands at 6,573,663. The coastal districts included in the "Gujarat eastern region" are Surat, Navsari, and Valsad. The total number of sub-districts in the coastal area of eastern region comes to 10, with a population of 2,872,365 out of which 1,910,053 live in rural areas (Table 7). While the state has recorded a decadal growth of 21.44 per cent, the Gujarat Eastern region has recorded a growth of nearly 30 per cent. Although this region has attained a literacy level of 75 percent, it shows a low sex ratio of 897. An important reason for this low sex ratio in the Gujarat eastern region is the immigration of male population from other parts of the Indian states and Gujarat for industrial activities (Sathyapalan and Joshy, Socio Economic Study of Suvali Area, 2004). Female literacy level (61.09 per cent) and total fertility level (2.70) are also found relatively high in this region.

Gujarat plain southern region has a substantial tribal population with degraded forest resource base. Bharuch is the only district in the Gujarat plain region having a coastal line. The average literacy level of this region is 73.72 per cent while the female literacy is 50.19. The Gujarat Plain Northern region, Ahmedabad and Anand share a small coastal area with a total population of 686,360 spread over 4 sub districts. The literacy rate of this area is as low as 68 per cent. High total fertility level (3.10) is another important

Table 7 Demographic characteristics of coastal talukas (with coastal line) in Gujarat State

Districts	Sub-districts	Total Population	Rural Population	Literacy	Sex ratio
Surat	Olpad	185844	172997	73.6	898
	Chorasi	585733	199195	81.5	723
	Palsana	118887	91294	67.0	794
Navasari	Jalalpore	220003	140124	82.1	927
	Gandevi	240291	153016	83.2	959
	Chikli	293014	286065	71.9	970
	Bansada	201288	201288	61.3	991
Valsad	Valsad	385156	222608	83.2	945
	Pardi	405902	232644	80.7	826
	Umbergaon	236247	210822	69.1	942
Baruch	Jambusar	176557	137781	72.5	926
	Amod	92921	92921	70.6	931
	Baruch	383746	196113	82.6	937
	Vagra	82647	82647	72.8	913
	Hansot	14830	68782	70.1	897
Amdabad	Dholka	214836	153267	68.0	910
	Dhandhaka	134662	105090	66.0	917
Anand	Khambhat	261012	167818	72.0	923
	Tharapur	75850	75850	67.0	923
Kachchh	Abdasa	97508	97508	57.5	943
	Mandvi	170573	128218	70.0	937
	Mundra	83010	70079	63.6	930
	Ghandhidham	201569	35181	69.5	888
	Bachau	147891	122502	47.2	923
	Rapar	198000	174943	83.0	918
Jamnagar	Okhamandal	144269	46422	60.7	944
	Kalyanpur	160538	160538	55.1	969
	Jodiya	89578	89578	66.0	941
	Lalpur	101637	101637	62.0	952
	Jamnagar	761365	177185	73.0	914
	Khambhalia	208739	145385	57.0	954
Porbandhar	Porbandar	350322	152940	71.3	957
Jungadh	Veraval	280485	122453	66.2	959
	Sutrapada	122405	122406	59.0	961
	Kodinar	198181	165571	65.9	974
	Una	330809	279548	55.5	977
	Mangrol	189053	132733	65.0	950
	Maliya	144975	123735	64.7	943
Amreli	Rajula	145628	113233	57.7	990
	Jafrabad	90732	65646	46.0	969
Bhavnagr	Bhavnagar	662680	135267	77.1	924
	Talaja	269986	225407	57.2	896
	Mhuva	375809	288039	52.2	976
	Ghogha	85624	74776	61.0	947
Rajkot	Maliya	83471	83471	58.0	945
	Morvi	326995	148940	76.0	921
Total		10,331,258	6,573,663	67.23	929

Source: (GoI, 2001)

characteristic of the region. Both regions have higher populations in rural areas that do not own land, the basic production asset. The sex ratio of the Gujarat plain southern coastal region is 920 which is better than the eastern region. Low total fertility level and high female literacy make the region better off as compared to Dry region and Sourashtra.

The Sourashtra region of Gujarat state is bound by sea on three sides. This Sourashtra region compromises 5 census districts. The total number of sub-districts in the coastal area is 21, with a population of 5,123,281, out of which 2954910 people live in rural areas. This region has attained a literacy level of 60 percent, and shows a sex ratio of 955. The Kutch district encompasses the dry region (arid) of Gujarat State, with an area of 45.652 km sq. The district shares its north and northwest boarders with Pakistan with the Arabian Sea lying in the west and south west. On the southern side, the district is bound by the Gulf of Kutch. This area has a total population of 898,551 of which 628431 people live in rural areas. The average sex ratio is 919 while literacy rate constitutes 66 per cent. Highest fertility rate (3.47) and lowest female literacy rate are other two characteristics of this region. But the important question is to what extent population growth and poverty per say exert pressures on natural resources like land and water. The answer lies in the livelihood strategies they adopt for making a living from these resources.

Table 8 Percentage shares in Population, workers to total population and workers in agriculture sector in Gujarat State

Regions	Percentage share in Population	Percentage of workers to total population	Percentage share of workers in Agricultural sector
Eastern region	15.46	45.97	57.18
Plain Southern	18.15	46.37	69.63
Plain Northern	29.54	42.22	47.48
Saurashtra	23.56	39.98	52.55
Dry Area	13.29	43.81	65.08
Gujarat	100	43.67	58.38

Source: (GoI, 2001)

The main livelihood of the people is based on agriculture and allied activities like livestock and fishing which require a considerably high amount of water use. A majority of the working population are engaged in primary sector (agriculture and allied activities) constituting around 57 per cent. The work participation and involvement in the agriculture sector are found to be quite high in the Eastern and Plain Southern regions of Gujarat State. The percentage share of workers in the agriculture sector in Eastern and Plain Southern region comes to 57.18 and 69.63 respectively. Therefore, with increasing population, it is natural that they put more pressure on land and water to secure their livelihoods. The fact that 63 per cent of the total coastal population lives in rural areas, where low literacy and high fertility levels along with high decadal growth rate of population prevail, indicates vulnerability of the coastal districts in terms of high population pressure on natural resources like land and water.

Table 9 Region wise variations in Poverty, Population and fertility in Gujarat

Regions	Poverty (Headcount ratio 43d 50th and 61th rounds of NSS			Population			
	Rural Poverty 1987-88	Rural Poverty 1993-94	Rural Poverty 2004-05	Decadal Growth of Population (1991-2001)	Total Fertility Rate (TFR) (2001)*	Sex Ratio 2001*	Female Literacy 2001*
Gujarat Eastern	25.79	19.78	11.00	29.88	2.70	924	61.09
Plain Southern	18.08	19.19	17.10	20.45	3.10	942	50.19
Plain Northern	20.27	19.76	26.40	17.85	2.52	918	62.18
Saurashtra	14.55	8.97	4.00	18.09	2.48	949	58.75
Dry area	40.47	20.72	20.00	22.04	3.47	926	43.21
Gujarat	23.83	17.68	15.70	21.44	2.85	919	55.08

Source: Compiled from (Jha and Sharma, 2003); (Chaudhuri and Gupta, 2009)

As far as poverty is concerned, the data from the national sample survey (NSS) shows a declining trend over the last few? (Chaudhuri and Gupta, 2009). The recent poverty estimates (NSS round 61) across districts are provided in Table 9. The head count ratio of the Gujarat eastern region shows a declining trend from 25.79 in 1987 to 11.34 in 2004-05. In Gujarat plain southern region, the head count ratio is found declining from 18.08 in 1987 to 17.10 in 2004-05. The NSS estimates also show a drastic decline in poverty ratio of Kutch region from 40.47 to 20.02 during the same period. One of the reasons for the decline in poverty ratio might be the performance of agriculture sector during the last few decades. It is reported that the semi arid Gujarat has clocked an exceptionally high and relatively steady rate of growth of 9.6 per cent per year in its agricultural state domestic product for the period 2001 to 2007 due to a boom in massive cotton production, livestock and fruits and vegetables and wheat production. Although several factors are responsible for this growth, the most prominent ones are an above normal rainfall in drought prone areas and improvement in ground water management (Shah, Gulati, P, Shreedhar, and Jain, 2009). In general, recent studies show that Gujarat economy has witnessed a positive trend in poverty reduction, improvement in ground water management and agriculture production (Jha and Sharma, 2003); (Shah, Gulati, P, Shreedhar, and Jain, 2009); (Dixit, 2009).

Land Use and Cropping Pattern

Historically it is known that land use and cropping pattern changes are also an important driving force in terms of ground water use, e.g., changes from agriculture to non agriculture use, low water intensive crop cultivation to high water intensive crop cultivation etc. Hence, the land use pattern and the changes there after between 1971 to 2003 for Gujarat State have been reviewed. Table 11 shows that total cropped area as a percentage to the total reported area increased from 53.5 per cent in 1971 to 58 per cent in 2003. But the proportion of net sown area increased marginally from 49.6 per cent to 50 per cent. We have computed the present land use pattern of the coastal areas in Table 12; it shows that 22.55 per cent of the land is not available for cultivation in coastal areas. Increasing trends in the proportion/extent of land not available for cultivation represent a land use change in favour of non agriculture purposes. It could be due to the degradation of agricultural lands. This in turn creates pressures on productive land and water due to increasing population and poverty. The cultivable waste amounts for 9.87 per cent. Most of the cultivable land has remained un-irrigated that means a majority of farmers depend on rains for cultivation. However, due to increasing population, the per capita net sown area has declined in the region.

Table 10 Land use classification in Gujarat from 1970-71 to 2003

Year	Total cropped Area	Net Area Sown	Forest Area	Permanent Pastures and grazing lands	Cultiva-ble Waste	Land under miscell-aneous tree crops	Permanent Fallow	Area under non agricul-ture use	Barren land	Total Reported Area
1970-71	104919	97130	15731	9485	19664	137	4014	7710	30765	195984
1980-81	107459	95765	19655	8483	19856	41	3322	10670	25034	196024
1990-91	106348	93502	18307	8457	19700	40	521	11221	26092	196024
1991-92	105577	92471	18289	8481	19828	41	353	11208	26085	196024
1992-93	110582	96379	18314	8479	19825	40	327	11227	26069	196024
1993-94	107289	94470	18298	8485	19813	40	327	11253	26063	196024
1994-95	112451	96653	18306	8485	19769	40	275	11271	26050	196024
1995-96	109400	96116	18628	8484	19711	40	275	11371	26008	196024
1996-97	110008	95995	18612	8490	19737	40	241	11384	26040	196024
1997-98	111567	96741	18590	8490	19802	40	255	11401	26043	196024
1998-99	111438	96674	18647	8489	19727	40	244	11408	26034	196024
1999-00	106449	94429	18648	8491	19818	40	131	11414	26038	196024
2000-01	104400	94433	18653	8507	19849	40	131	11419	25997	196024
2001-02	107336	96217	18655	8503	19875	40	113	11439	25951	196024
2002-03	106307	94251	18535	8502	19848	40	112	11446	26084	196024
2003-04	113627	97952	18536	8503	19767	40	112	11453	26074	196024

Source: Government of Gujarat, Agriculture Statistics, Various issues.

Table 11 Land use classification in Gujarat from 1970-71 to 2003 in percentages to the total reported area

Year	Total cropped Area	Net Area Sown	Forest Area	Permanent Pastures and grazing lands	Cultiv-able Waste	Land under miscell-aneous tree crops	Permanent Fallow	Area under non agricult-ure use	Barren land
1970-71	53.5	49.6	8.0	4.8	10.5	0.07	2.05	3.9	15.7
1980-81	54.8	48.9	10.0	4.3	10.5	0.02	1.69	5.4	12.8
1990-91	54.3	47.7	9.3	4.3	10.5	0.02	0.27	5.7	13.3
1991-92	53.9	47.2	9.3	4.3	10.5	0.02	0.18	5.7	13.3
1992-93	56.4	49.2	9.3	4.3	10.5	0.02	0.17	5.7	13.3
1993-94	54.7	48.2	9.3	4.3	10.5	0.02	0.17	5.7	13.3
1994-95	57.4	49.3	9.3	4.3	10.5	0.02	0.14	5.7	13.3
1995-96	55.8	49.0	9.5	4.3	10.5	0.02	0.14	5.8	13.3
1996-97	56.1	49.0	9.5	4.3	10.5	0.02	0.12	5.8	13.3
1997-98	56.9	49.4	9.5	4.3	10.5	0.02	0.13	5.8	13.3
1998-99	56.8	49.3	9.5	4.3	10.5	0.02	0.12	5.8	13.3
1999-00	54.3	48.2	9.5	4.3	10.5	0.02	0.07	5.8	13.3
2000-01	53.3	48.2	9.5	4.3	10.6	0.02	0.07	5.8	13.3
2001-02	54.8	49.1	9.5	4.3	10.6	0.02	0.06	5.8	13.2

Source: Government of Gujarat, Agriculture Statistics, Various issues.

Increased cropping intensity and declining per capita net sown area indicate the pressure on land resources in the region (Figure 8) in terms of agriculture production. An earlier study on crop diversification (from 1961 to 1996-97) found that farmers had shifted their cropping pattern from subsistence crops to commercial crops (Shyani and Pandya, 1998). The trend in cropping pattern change is still continuing in Gujarat agriculture. A recent study (Shah, Gulati, P, Shreedhar, and Jain, 2009), while explaining the agricultural growth in Gujarat reports that Bt Cotton has become one of the preferred crops of farmers. The area and production of sugar cane are also increasing (Table 13) (Table 14) at a very high rate of 12.6 and 13.4 percent respectively per annum. This also reveals that market forces (high price and profitability) are an important driving force behind Gujarat agriculture land use.

In this context, it is important to remember that during the recent decades, most parts of Saurashtra and Kachchh, have sustained their agriculture production by depleting their aquifers. Around 2008, over 800,000 electric tube wells pumped out some nine BCM of groundwater for irrigation, mostly in Saurashtra and Kachchh, and North Gujarat. (Shah, Gulati, P, Shreedhar, and Jain, 2009).

Figure 8 Trends in per-capita net area sown and cropping Intensity

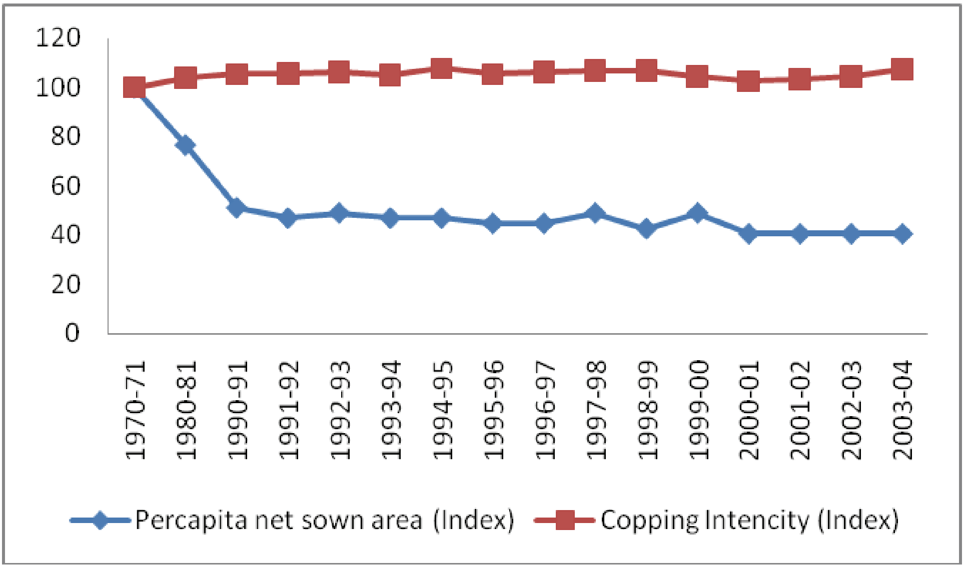


Table 12 Land use pattern and average rainfall in 20 km shoreline of Gujarat coast by different regions

Regions	Forests	Irrigated land	Un-irrigated land	Cultivable waste land	Land not available for cultivation	Total	Rainfall (mm)
Gujarat Eastern	65.82 (1.76)	749.18 (20.06)	1216.45 (32.58)	265.88 (7.12)	700.64 (18.76)	3733.97 (100)	1593
Gujarat Plain Southern	61.56 (1.71)	627.94 (17.42)	1635.51 (45.38)	133.12 (3.69)	833.69 (23.13)	3604.36 (100)	638
Gujarat Plain Northern	8.69 (0.22)	514.43 (12.81)	1563.07 (38.94)	352.63 (8.78)	930.37 (23.18)	4014.38 (100)	628
Dry Region	606.96 (8.63)	286.23 (4.07)	2925.9 (41.58)	880.76 (12.52)	2049.92 (29.13)	7036 (100)	382
Saurashtra Region	346.62 (2.21)	1838.36 (11.73)	6833.14 (43.61)	1729.43 (11.04)	3166.81 (20.21)	15668.27 (100)	578
Total	1089.65 (3.20)	4016.14 (11.79)	14174.07 (41.62)	3361.82 (9.87)	7681.43 (22.55)	34056.98 (100)	810

Source: Census of India 1991 (District handbooks)

Table 13 Area Under Major Crop Groups Gujarat (1960-61 to 2000-01, '000 hectares)

Year	Rice + Wheat	Coarse Grain	Cereals	Pulses	Foodgrains	Groundnut	Oil Seeds	Sugar Cane
1960-61	0911	2973	4121	512	4632	1982	2206	26
1970-71	1158	3691	5087	496	5583	1778	1966	39
1980-81	1192	2906	4324	794	5118	2179	2660	98
1985-86	1092	2949	4213	870	5083	1868	2492	123
1989-90	1196	2502	3830	941	4770	2038	2873	106
1990-91	1232	2457	3800	949	4749	1826	2818	115
1991-92	1182	2454	3632	883	4515	1976	2865	113
1992-93	1310	2512	3925	962	4887	1880	2919	127
1993-94	1220	2395	3711	880	4591	2035	3028	128
1994-95	1514	2320	3926	932	4858	1914	2981	222
1995-96	1318	2234	3634	877	4511	1871	2912	251
1996-97	1384	2182	3642	915	4557	1803	2850	232
1997-98	1454	2099	3620	905	4525	1839	2885	225
1998-99	1363	2014	3446	884	4330	1881	2927	243
1999-00	1238	1904	3207	792	3999	1849	2864	255
2000-01	1047	1865	2975	743	3718	1822	2861	257

Source: Government of Gujarat, Agriculture Statistics, Various issues.

Table 14 Production of Major Crop Groups Gujarat (1960-61 to 2000-01, '000 tonnes)

Year	Rice + Wheat	Coarse Grain	Cereals	Pulses	Foodgrains	Groundnut	Oil Seeds	Sugar Cane
1960-61	0564	0973	1719	0169	1888	1214	1260	130
1970-71	1605	2844	4643	0201	4844	1869	1943	228
1980-81	1957	2314	4438	0520	4958	1616	2005	790
1985-86	1437	1243	2762	0385	3147	473	964	715
1989-90	1923	2430	4438	0572	5010	1670	2580	916
1990-91	2285	1993	4359	0624	4983	983	2044	1035
1991-92	1922	1440	3420	0419	3839	711	1650	974
1992-93	2373	2837	5285	0656	5941	2200	3332	1087
1993-94	1994	1533	3602	0549	4151	596	1550	1023
1994-95	3165	1988	5215	0546	5760	2305	3684	1687
1995-96	2325	1904	4287	0486	4774	1032	2212	2060
1996-97	2760	2597	5425	0664	6089	2368	3802	1665
1997-98	2799	2637	5469	0618	6113	2494	3866	1467
1998-99	2879	2465	5399	0640	6038	2465	3881	1734
1999-00	2120	1812	3992	0446	4438	733	1826	1867
2000-01	1403	1485	2936	0249	3185	740	1738	1818

Source: Government of Gujarat, Agriculture Statistics, Various issues.

Conclusion

The purpose of this chapter was to explore the driving forces of ground water depletion in the coastal areas of Gujarat state. Due to data constraints, this exercise was limited to exploring the role of population growth and land use change in the depletion of ground water across coastal regions of Gujarat. We found both the variables as significant driving forces in the depletion of ground water resources of the state. These driving forces were found exerting considerable created pressures on the ecosystem resulting in the intensive agri production. The important indicators of agriculture intensification were declining per capita net sown area and increasing crop intensity. Gujarat agriculture also has been witnessing a shift towards cash crops like Bt cotton and sugarcane of late due to better incentives prevalent in the market (profitability and prices). The cropping pattern shift in favour of cash crops especially water intensive crops has implications for ground water use. Excessive drafting of ground water has already led to the spread of salinity in many parts of the coastal areas. More importantly, the ground water depletion varies across regions and is getting depleted much faster in Sourashtra and Dry (Kutch) region.

Chapter 3

Socio Economic Characteristics and Distribution of Salinity Affected Households

Introduction

Water is n extremely scarce resource in dry land areas, especially in saline affected areas. Accessibility to good quality water for agriculture and domestic purposes varies across regions and communities depending up on their socio economic characteristics. Moreover, a certain level of private investment is required to access ground water which is not affordable for many households. Therefore, in this chapter, we focus on household accessibility to ground water across different socio economic groups. Data from both primary census and sample survey of 24 sample villages are used for this analysis. In the first part of the chapter, we discuss the socio demographic characteristics, productive assets and main occupation of the households. Part two of the chapter explains salinity affected households located in different regions and also across different socio economic groups followed by summary and conclusion.

Socio-demographic characteristics of the households

A brief overview of the demographic characteristics of the study area is presented in Table 15. As noted earlier, we selected 1129 sample households with a population of 6231. The sex ratio (number of females per 1000' males) estimated for the entire study area stands at 934. It is significant to note that in all the regions except Gujarat eastern, the sex ratio is not in favour of female population. The household size in the study area is estimated to be around 5.5. The average size of the households ranges from 4.7 in Gujarat eastern region to 5.9 in Sourashtra region. The literacy rate of the study area is about 60.1 per cent. In the Gujarat Eastern region, the literacy rate is 82.8 percent and is much higher than in Kutch and Saurashtra regions as is evident from Table 15. The villages of Saurashtra and Kutch are on the lower side of literacy rate that is 60.8 and 68.1 per cent respectively.

Table 15 Demographic details of sample households in the study area

Regions	Male	Female	Total Population	Sex Ratio	Literacy level	House hold size
Gujarat Eastern	515	536	1051	1041	82.8	4.7
Saurashtra	2228	2038	4266	915	60.8	5.9
Dry Region	479	435	914	908	68.0	5.0
Gujarat (Total)	3222	3009	6231	934	60.1	5.5

Source: Primary survey

Another important socio-demographic characteristic to be noted is the prevalence of joint family system in the study area. The survey reveals that nearly 41 per cent of the total households follow joint family system. Nevertheless, these are not very large families since the estimated household size is only about 5.1. The major religion followed in the study area is Hindu accounting for 90.0 per cent of the total population. The remaining 10 per cent of the population belongs to other religions such as Muslim, Parsi, Christian, Sikh etc. Thus in terms of religion, the population under study is a homogeneous group. Nearly 25 caste groups were identified in the primary survey. They include Koli Patel, Rajputs, Gohil, Kardika Rajputs, Muslim, Rabari, Ahir, Rathod, Kumbhar, Mahyavanse, Halpati, Anvil, Brahmin, Parsi, Dubla, Mesurya, Darbar, Darji, Mehta, Valand, Kanthariya, Prajapati, Modi, Machi, Bavaji and Sikha, Kaduva Patel etc. Each of these caste groups has its own traditional occupation.

Table 16 Distribution of households by social categories

Regions	Scheduled Caste	Scheduled tribe	Other Backward Communities	Others	Total
Gujarat Eastern	6 (2.68)	43 (19.20)	165 (73.66)	10 (4.46)	224 (100)
Saurashtra	63 (8.74)	18 (2.50)	606 (84.05)	34 (4.72)	721 (100)
Kutch	35 (19.02)	2 (1.09)	62 (33.70)	85 (46.20)	184 (100)
Total	104 (9.21)	63 (5.58)	833 (73.78)	129 (11.43)	1129 (100)

Source: Primary survey

Although there is a diversified caste structure observed in the villages, the Other Backward Caste (OBC) constitutes the majority group/community in the coastal area of Gujarat. It is reported that 73.8 per cent of the total households belong to OBC category. The scheduled caste and scheduled tribes form approximately 9.21 and 5.58 per cent respectively. The remaining 11.36 per cent of the households belongs to general category. The household distribution based on social groups is provided in Table 16. Only in Kutch, households belonging to other communities outnumber the OBCs. The size of the labour force and its distribution in various economic activities provide an understanding of the resource base, the system of social organisation and the nature of the economy prevailing in the region. The survey data shows that nearly 67 per cent of the total population is in labour force, while dependants constitute about 33 per cent[6].

Productive assets and occupational structure

Land is the major productive asset in the study area. Data collected through a census enumeration in the sample villages shows that 52.9 per cent of the households are landless. The sample survey data also shows that more than half of the total numbers of households in the study area are landless (Table 17). As per the sample survey data, 55 per cent are landless in the entire study area [7] .

Table 17 Distribution of the sample households across different land classes

Land class in acres	Total number of Sample households	Total number of households
Landless	625 (55.35)	6586 (52.70)
0.01 to 2.5	276 (24.40)	2765 (22.10)
2.51 to 5.0	109 (9.70)	1177 (9.40)
5.01 to 10.0	69 (6.10)	1167 (9.30)
10.01 and above	50 (4.40)	806 (6.40)
Total	1129 (100.0)	12501 (100)

Source:: Based on primary Survey

The number of landless households is lowest in Sourashtra region (48.5 per cent), whereas it is as high as 70 per cent in Kutch (Table 18). Again, the distribution of land holdings shows that most farmers in this region are either small or marginal. Only, in Kutch, the distribution of land holdings is found more skewed towards medium or large farmers.

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[6] Dependents are those who are below 15 years and above 55 years of age group.

[7] The percentage difference in the estimation (52.9 and 55 percent) of land less using census and sample data may be due to errors committed during data collection.

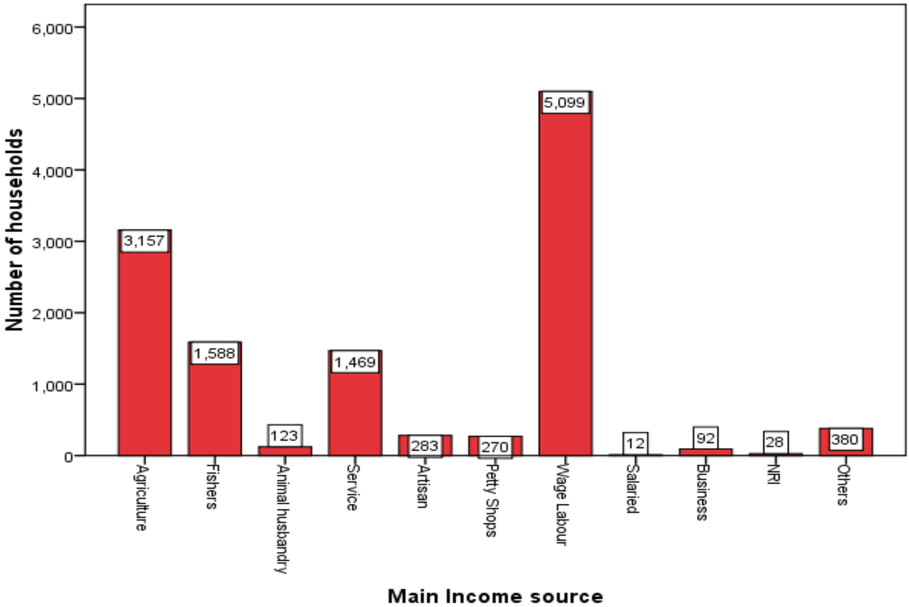
Table 18 Distribution of sample household by landholding class (in acres) across different regions of coastal Gujarat

	Landless	.01 to 2.5	2.51 to 5	5.01 to 10	10.01 and above	Total
Gujarat Eastern	147 (65.6)	63 (28.1)	5 (2.2)	3 (1.3)	6 (2.7)	224 (100)
Saurashtra	350 (48.5)	200 (27.1)	92 (12.8)	43 (6.0)	36 (5.0)	721 (100)
Kutch	128 (69.6)	13 (7.1)	12 (6.5)	23 (12.5)	8 (4.3)	184 (100)
Total	625 (55.4)	276 (24.4)	109 (9.7)	69 (6.1)	50 (4.4)	1129 (100)

Source: Primary Survey

Based on the definitions of the census of India on occupational categories, we find 62.7 percent of the total sampled population gainfully employed. Table 19 shows the percentage share of each occupational category to the total gainfully employed population in these regions based on the sample data. Approximately 17.10 percent of the total gainfully employed population are cultivators while 23.69 percent of the total employed population are agricultural labours. This means that for over 40 per cent of the gainfully employed are in the agricultural sector in the region. Only in Kutch, this proportion is slightly less. In the study region as a whole, nearly 5.10 percent of the total employed population are working in fisheries sector (See Figure 9). The number of people engaged in animal husbandry and artisan works is low (around 0.69 percent each). Others working as wage earners in industrial and service sectors constitute a larger percentage of 52.66. Landless people work mostly as agricultural labourers even though a considerable number of people are also into various other small activities. In the Gujarat Eastern region, agricultural labourers are mostly from the landless category, where as in the case of Saurashtra and Kutch, small and medium farmers also work as agricultural labourers. A classification of the occupational categories based on land holding size shows that in each land size category a substantial number of people are employed in non-agricultural sectors.

Figure 9 Distribution of households by main source of Income



Source: Based on primary census enumeration conducted across all sample villages.

As far as the main source of household income is concerened, large number of people reported that their main source was wage labour accounting for, they around 40.7 percent (5099) of the total number of households. The second main source is agriculture constituting around 25.3 per cent (3157) of the total number of househlds. The number of households depending on marine fisheries workout to around 12.7 per cent (1588). Other important livelihood source include livestock rearing, petty trade and other services sector jobs.

Source: Based on data collected through census enemeration in all sample villages.

Table 19 Distribution of gainfully employed population by occupational category, region and land holdings size

Regions	Land class (in acres)	Agriculture	Agriculture labor	Fisherman and fishing labours	Animal husbandry	Artisan	Other category	Total gainfully employed population
Gujarat Eastern	Landless	1 (0.2)	153 (37.2)	79 (19.2)	2 (0.5)	0 (0.0)	176 (42.8)	411 (100)
	.01 to 2.5	56 (26.3)	18 (8.5)	0 (0.0)	15 (7.0)	1 (0.5)	123 (57.7)	213 (100)
	2.51 to 5	5 (31.3)	1 (6.3)	0 (0.0)	0 (0.0)	0 (0.0)	10 (62.5)	16 (100)
	5.01to10	4 (30.8)	0 (0.0)	0 (0.0)	2 (15.4)	0 (0.0)	7 (53.8)	13 (100)
	10.01 and above	9 (32.1)	0 (0.0)	0 (0.0)	2 (7.1)	0 (0.0)	17 (60.7)	28 (100)
	Total	**75 (11.0)**	**171 (24.2)**	**79 (11.6)**	**21 (3.1)**	**1 (0.1)**	**332 (52.4)**	**681 (100)**
Saura-shtra	Landless	18 (1.5)	382 (31.8)	114 (9.5	1 (0.1)	21 (1.7)	665 (55.4)	1201 (100)
	.01 to 2.5	175 (24.3)	200 (27.8)	13 (1.8)	1 (0.1)	0 (0.0)	330 (45.9	719 (100)
	2.51 to 5	174 (44.8)	48 (12.4)	0 (0.0)	2 (0.5)	0 (0.0)	164 (42.3)	388 (100)
	5.01 to 10	97 (46.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	114 (53.0)	211 (100)
	10.01 and above	81 (46.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	95 (54.0)	176 (100)
	Total	**545 (20.2)**	**630 (24.7)**	**127 (4.7)**	**4 (0.1)**	**21 (0.8)**	**1368 (49.4)**	**2695 (100)**
Dry Region (Kutch)	Landless	0 (0.0)	125 (31.0)	0 (0.0)	2 (0.5	5 (1.2)	271 (67.2)	403 (100)
	01 to 2.5	11 (17.2)	22 (34.4	0 (0.0)	0 (0.0	1 (1.6)	30 (46.9)	64 (100)
	2.51 to 5	11 (21.2	8 (15.4)	0 (0.0)	1 (1.9)	0 (0.0)	32 (61.5)	52 (100)
	5.01 to 10	30 (29.7	0 (0.0)	0 (0.0)	0 (0.0	0 (0.0)	71 (70.3)	101 (100)
	10.01 and above	18 (46.2	0 (5.1)	0 (0.0)	0 (0.0	0 (0.0)	21 (53.8)	39 (100)
	Total	**70 (10.6)**	**155 (11.3)**	**0 (0.0)**	**3 (0.5)**	**6 (0.9)**	**425 (77.7)**	**659 (100.0**
Total		**690 (17.10)**	**956 (23.69)**	**206 (5.10)**	**28 (0.69)**	**28 (0.69)**	**2125 (52.66)**	**4035 (100)**

Source: Primary survey

Note: Figures in parentheses are percentages to the row total; Other category includes people working as government employees, general labourers; drivers; priests; factory labourers; contractors; petty traders; brokers; businessmen construction workers etc

This is seen in all the regions. In the Gujarat Eastern region, nearly 11.6 per cent are also found engaged in fisheries sector. Koli-Patel, Ahir, Rabari, Kumbhar are the dominant caste groups of Gujarat eastern region engaged in agriculture and animal husbandry.

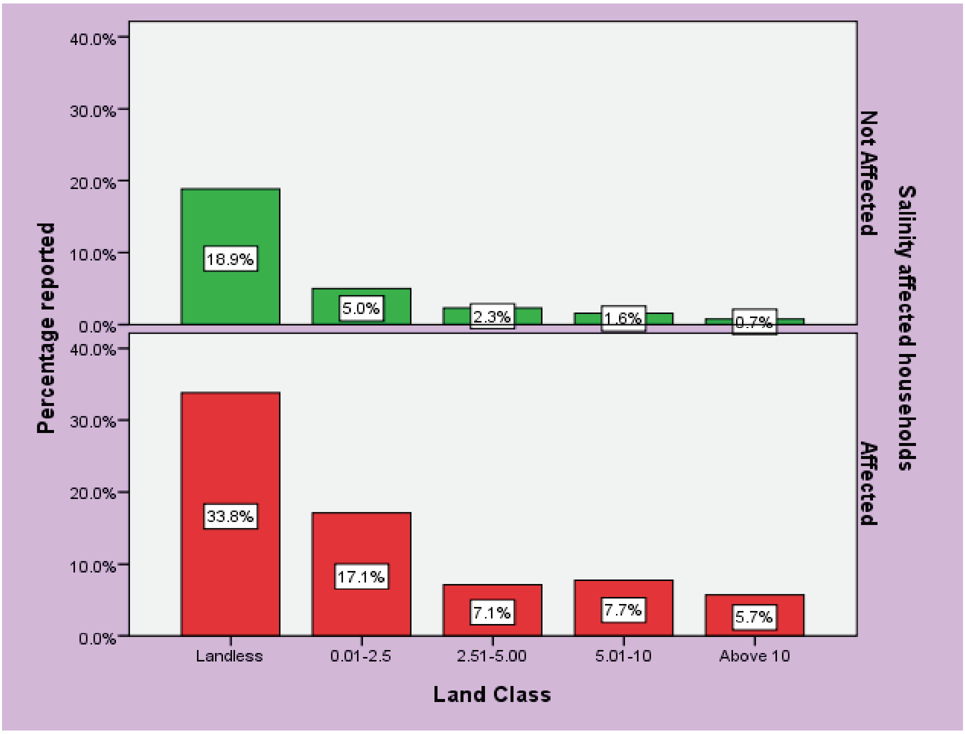
Other caste groups like Halpati Rathod, Mahyavanse and Harijan are mostly daily wage employees in this region working either as general labourers or agricultural labourers. It is also observed that Halpati and Harijans are occupied in fishing activities also. In Saurashtra, the Kardika Rajput is one of the dominant caste groups engaged as cultivators. Karvas, Machiyaras, and Ahirs are engaged in fishing activity.

Distribution of Salinity affected Households

We have already mentioned in chapter 1 that 71.5 (8940) per cent of the households are salinity affected of which 41.4 per cent fall in the low land, 22.3 per cent in the middle land and 7.8 per cent in the upper land. The remaining 28.5 per cent (3561) are not salinity affected. That means, only 28.5 per cent of the total households have accessibility to fresh water source for agriculture or for domestic purposes. Approximately 53.8 per cent of the total households own agricultural lands of which 38.2 (4777 households) per cent reported that their lands were affected by salinity. Landless households also reported that salinity affected water they were using for domestic and drinking purposes. Figure 10 explains/shows the distribution of salinity affected households across different land size classes. The distribution shows that a large number of farmers come under small holding group (22.1 per cent), out of which 17.1 percent reported that salinity had affected their lands. The percentage share of farmers across medium and large holdings is also found high. Interestingly, we found that villages lying in the low land area and also close to the sea shore had been severely affected by salinity ingress. Approximately 51 per cent of households are located in these areas (Figures 11 and 12)[8] , out of which 34.5 percent are salinity affected. Some villages located approximately 48 km away from the sea shore also reported high salinity presence in ground water (Villages based on distance from the seashore are given in Appendix of this chapter, Figure 13).

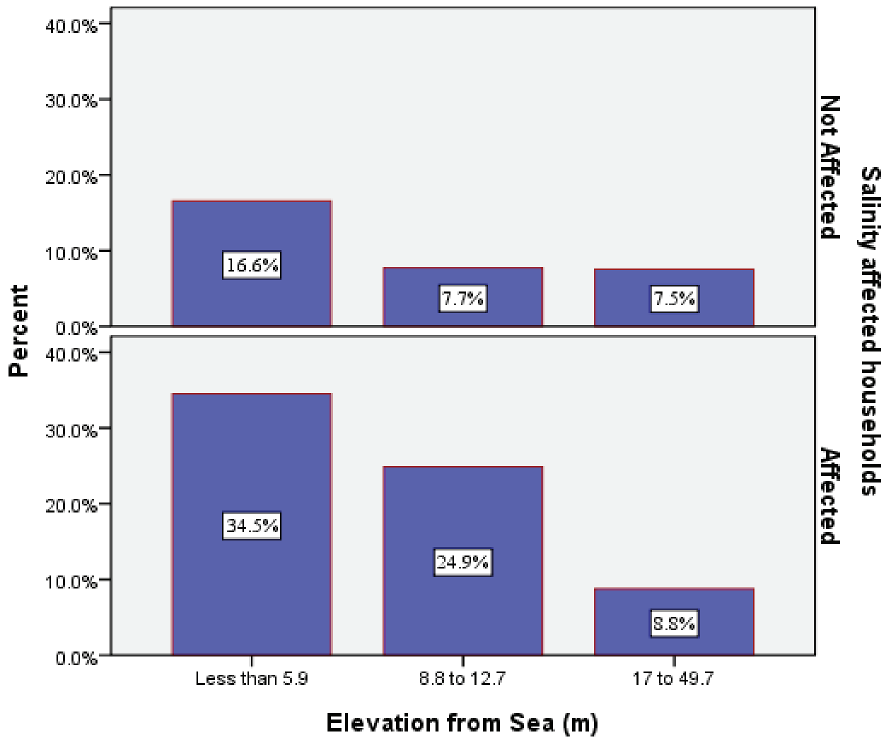
[8] Location of each village is presented in Appendix of this chapter. Elevation and distance from the seashore are calculated using GPS.

Figure 10 Distribution of salinity affected households by land holding sizes



The relative share of salinity affected households with in a stratum is higher across all the land classes. Since a large number of households belongs to small and medium farmers, they are the worst affected category. Source Chart is based on the census enumeration conducted in sample villages

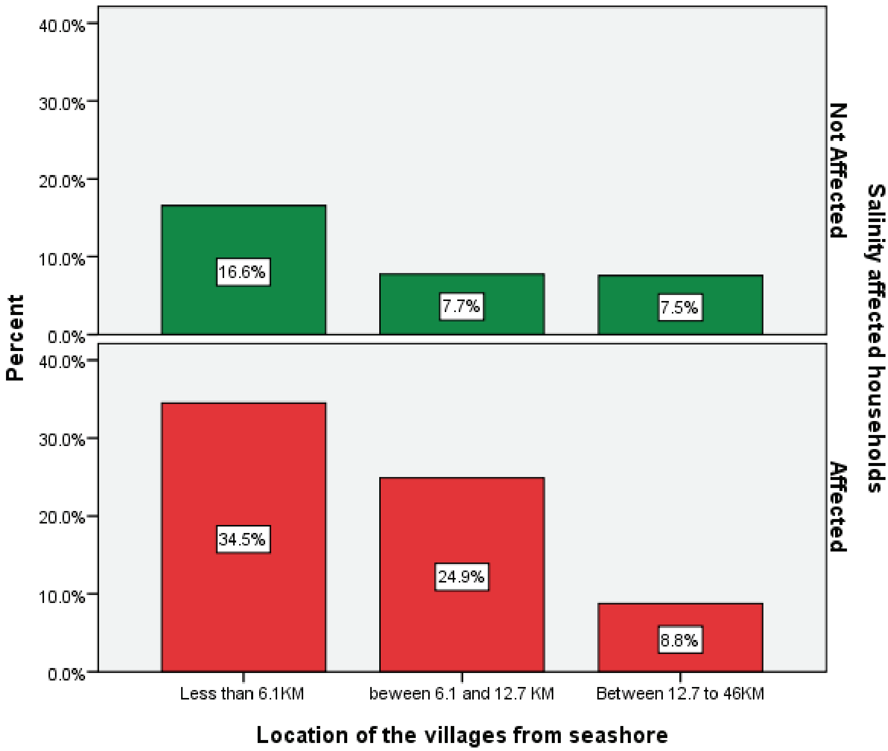
Figure 11 Distribution of salinity affected households by elevation



This chart shows the relative share of salinity affected and not affected households across different elevations from the mean sea level. Not surprisingly, a high proportion of salinity affected households live in low land area. The chart also indicates salinity reach in villages located at a higher elevation. Elevations are calculated using GPS equipment,

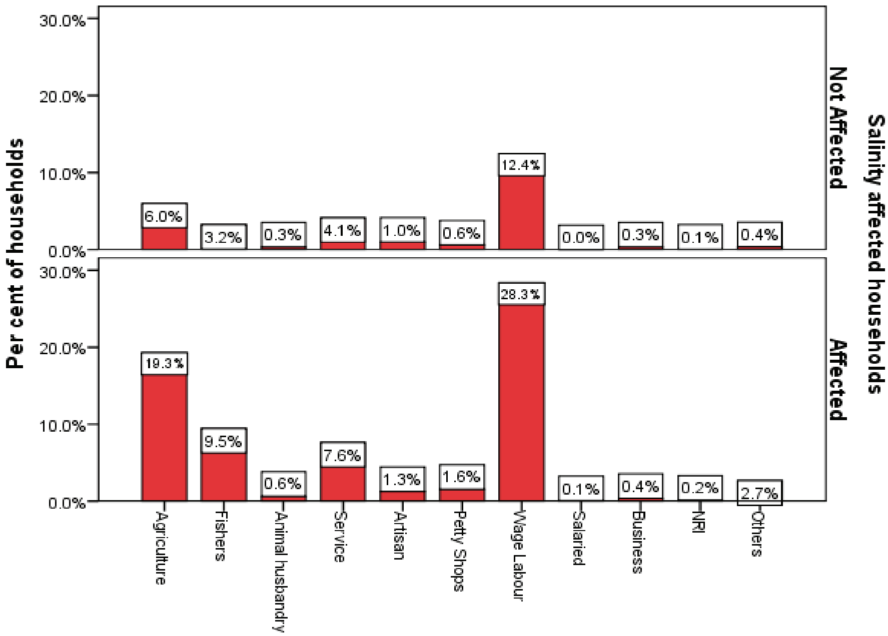
Source: Chart is based on the census enumeration conducted in sample villages

Figure 12 Distribution of Salinity Affected Villages from the seashore (distance in Km)



This chart shows the relative share of salinity affected and not affected households over different distances from the seashore. Not surprisingly, a high proportion of salinity affected households live close to the seashore. The chart also indicates salinity reach in villages located over longer distances. Source: Chart is based on the census enumeration conducted in sample villages

Figure 13 Sources of Income of the Salinity Affected Households



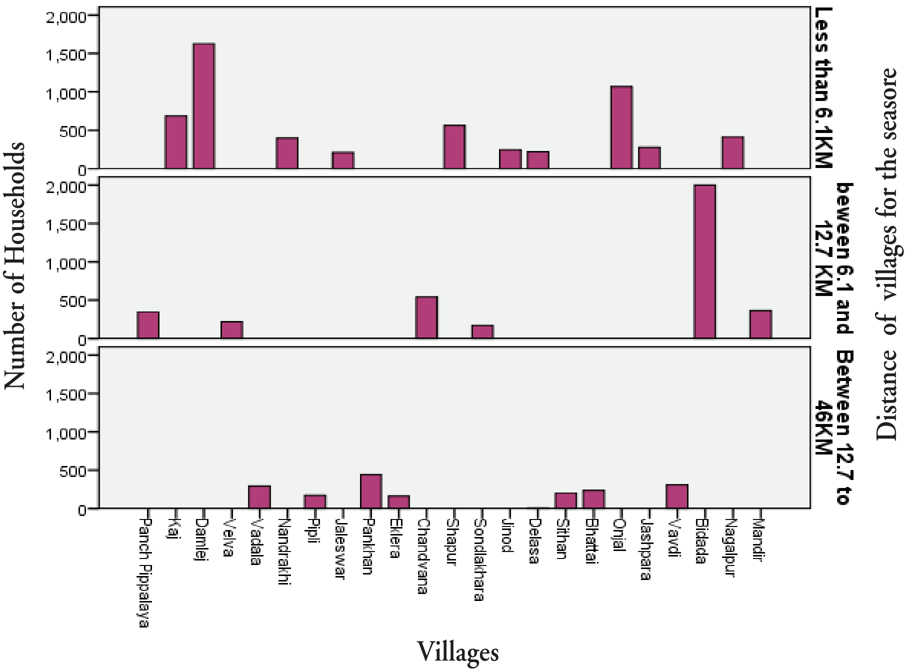
Main Sources of Household Income

Conclusion

In this chapter, we have tried to understand the magnitude of salinity concentrates across different soico economic groups. We find wage labours, and the households depending on marine fisheries also affected a part from with small and marginal farmers. Another important observation is that the relative share of salinity affected population is higher among small and medium farmers who are the worst affected category. It is also important to note that a large number of salinity affected households live in low land area.

Appendix

Figure 14 Location of Villages from seashore (distance in Km)



Chapter 4
Impact of Salinity on Drinking and Domestic Water Use

4.1 Introduction

We have already mentioned that an important factor contributing to the welfare loss of the household's in terms of health related problems such as knee pain, kidney stone, tooth decay etc concerns the presence of salinity in water. In order to avoid the risk of such diseases, households either buy fresh water from the market or walk long distances for collecting fresh water. This means that the impact of salinity ingress on the household welfare could be reflected either in the form of additional spending or extra time allocation for fetching better quality water at the cost of other productive activities or leisure. In this chapter, we are trying to find out the defensive spending of the households to avoid the risk of consuming saline affected water at the household level. First, defensive expenditure occurs when the households spend money on buying fresh water for drinking and cooking purposes from the market. Secondly, households tend to spend additional time for collecting water from far off places at the cost of other gainful employments or leisure. We find that some households even employ hired labour or school going children for collecting water. The estimation of the defensive expenditures helps understand the magnitude of welfare loss and also identify groups incurring a relatively high expenditure due to salinity related problems. The chapter is organised into three sub sections: The first section deals with the source and quality of water used for domestic and drinking purposes[9] ; in the second section, we have tried to develop a model for estimating welfare implications of defensive spending followed by results and discussions in the third section.

Source and Quality of water used for drinking and domestic purposes

The important sources of water for drinking are open wells, hand pumps, and public taps. In addition to this, some households purchase water from the market. We have tried to classify these sources in terms of major and minor sources[10] . From Table 20, it

[9] Domestic purpose means all types of water use within a household other than drinking.

[10] By major source we mean that source which provides more than 50 per cent of the drinking water requirements of the households. Minor source means the source that supplements the major source.

is seen that more than 60 per cent of the households are connected with tap water for drinking as a major source. Approximately 22 per cent of household depend upon open wells for drinking water. That means the second most important source of water is wells especially open wells. If we look at these region wise figures, it seems that tap water is the major source for drinking water in Kutch region followed by Gujarat Eastern and Sourashtra. The coverage of tap water is relatively less in the Sourashtra region. Although only about 3 per cent of the households solely depend upon purchased water, a large number of households (28.66 per cent of the reported households) purchase water as a way of supplementing water from the major source. A higher percentage of water purchased either as a major source or as a minor source has been observed in the Saurashtra region of the state. Households in the Gujarat Eastern region using tap water are not found to have reported any saline taste in water, whereas, the percentage of households reporting salinity in tap water tends to be more in Saurashtra and Kutch. In Saurashtra nearly 25 per cent of the households report salinity presence in drinking water. In this context, it needs to be pointed out that the presence of salinity is just the perception of the households. It also needs to be borne in mind that the households have been used to the saline taste of water for a long period of time and as such might not be able to differentiate the taste. Even if salinity is present within a mild and moderate range, they still consider it as sweet water. Salinity problem is reported by the households only if it is beyond a tolerable limit i.e., when they find it difficult to adjust with the quality of water.

As far as domestic water use is concerned, households depend upon public taps and wells to a greater extent. The trend is very different in the Sourashtra region, where nearly half of the total numbers of households rely on open wells for their domestic uses (Table 21). In the case of water for domestic uses, it is important to note that a majority of the households report salinity presence. We also tried to examine if there had been any changes in the relative importance of various water sources at present as compared to the scenario existing/prevailing some 10 years ago. The important water sources considered for this purpose included own open wells, public wells, own hand pumps, public hand pumps, rainwater and purchased water. The results of the multiple response analysis are presented in Table 22. From the table it is seen that public wells were then the most important source of water in the coastal areas of Gujarat, whereas now it was the tap water. If we look at the relative importance of various sources region wise, it is seen that in Kutch region, there is not much difference observed in the importance of tap as a major source of though also it is has gained in more importance now. In Gujarat Eastern and Saurashtra regions, public taps were not a very important source of water some 10 years ago according to the households; but now it has turned out to be a very important source of water. In these regions, public wells were an important source of water, in the past and still continue to be the second most important source of water at present.

Table 20 Distribution of households by Major and minor sources of drinking water and their perceptions towards quality of water in different zones of Gujarat

Zones	Gujarat Eastern		Saurashtra		Kutch		Total	
Quality of water	Major	Minor	Major	Minor	Major	Minor	Major	Minor
Wells (Saline)	2 (3.70)	1 (1.35)	40 (25.48)	13 (54.16)	4 (57.14)	0 (0.00)	46 (21.11)	14 (14.00)
Wells (Sweet)	52 (96.29)	73 (98.64)	117 (74.52)	11 (45.83)	3 (42.85)	2 (100.00)	172 (78.89)	86 (86.00)
Total (wells)	**54 (100) [30.16]**	**74 (100) [83.15]**	**157 (100) [26.17]**	**24 (100) [10.04]**	**7 (100) [3.85]**	**2 (100) [28.57]**	**218 (100) [22.18]**	**100 (100) [29.85]**
Hand pump (Saline)	1 (7.14)	0 (0.00)	28 (38.89)	10 (58.82)	15 (65.22)	0 (0.00)	44 (40.37)	10 (40.00)
Hand pump (Sweet)	13 (92.86)	8 (100.00)	44 (61.11)	7 (41.18)	8 (34.78)	0 (0.00)	65 (59.63)	15 (60.00)
Total (Hand pump)	**14 (100.00) [7.82]**	**8 (100.00) [8.99]**	**72 (100.00) [12.00]**	**17 (100.00) [7.11]**	**23 (100.00) [12.64]**	**0 (0.00) [0.00**	**109 (100.00) [11.34]**	**25 (100.00) [7.46]**
Tap (Saline)	0 (0)	0	24 (7.00)	14 (13.46)	3 (1.97)	2 (66.67)	27 (4.47)	16 (14.04)
Tap (Sweet)	109 (100.00)	7 (100.00)	319 (93.00)	90 (86.54)	149 (98.03)	1 (33.33)	577 (95.53)	98 (85.96)
Total (Tap)	**109 (100.00) [60.89]**	**7 (100.00) [7.87]**	**343 (100.00) [57.17]**	**104 (100.00) [43.51]**	**152 (100.00) [83.52]**	**3 (100.00) [42.86]**	**604 (100.00) [62.85]**	**114 (100.00) [34.03]**
Purchase (Saline)	0	0	2 (7.14)	2 (2.13)	0	1 (50.00)	2 (6.67)	3 (3.13)
Purchase (Sweet)	2 (100.00)	0	26 (92.86)	92 (97.87)	0	1 (50.00)	28 (93.33)	93 (96.88)
Total (Purchase)	**2 (100.00) [1.12]**	**0**	**28 (100.00) [4.67]**	**94 (100.00) [39.33]**	**0**	**2 (100.00) [28.57]**	**30 (100.00) [3.12]**	**96 (100.00) [28.66]**
Total households	179	89	600	239	182	7	961	335

Notes: Major source is that source which provides for more than 50 per cent of water requirement of the household; Minor source means sources that meet less than 50 percent of water requirements of the households; Households totals will not tally to total. Respondents categorize water as saline if they feel hardness, bad taste or salt taste; Figures in parentheses are percentages to the subtotals of each category; figures in square brackets are percentages of sub totals to grand totals.

Source: Primary Survey

Having understood the perceptions of the people, we have tried to understand the qualitative aspects of drinking water scientifically by carrying out water quality tests to assess total dissolved solid (TDS) in all the villages.

Table 21 Distribution of households by Major and minor sources of water for domestic use and their perception towards quality of water in different zones of Gujarat

Zones	Gujarat Eastern		Saurashtra		Kutch		Total	
Quality of water	Major	Minor	Major	Minor	Major	Minor	Major	Minor
Wells (Saline)	24 (70.59)	19 (73.08)	272 (76.62)	63 (90.00)	4 (57.14)	0	300 (75.76)	82 (85.42)
Wells (Sweet water)	10 (29.41)	7 (26.92)	83 (23.38)	7 (10.00)	3 (42.86)	0	96 (24.24)	14 (14.58)
Sub-Total (wells)	**34 (100.00) [14.29]**	**26 (100.00) [24.30]**	**355 (100.00) [50.00]**	**70 (100.00) [51.85]**	**7 (100.00) [3.83]**	**0**	**396 (100.00) [35.71]**	**6 (100.00) [39.67]**
Hand pump (Saline)	2 (9.09)	2 (22.22)	165 (79.71)	38 (95.00)	18 (78.26)	0	185 (73.41)	40 (81.63)
Hand pump (Sweet water)	20 (90.91)	7 (77.78)	42 (20.29)	2 (5.00)	5 (21.74)	0	67 (26.59)	9 (18.37)
Sub-Total (Hand pump)	**22 (100.00) [9.24]**	**9 (100.00) [8.41]**	**207 (100.00) [29.15]**	**40 (100.00) [29.43]**	**23 (100.00) [12.57]**	**0**	**252 (100.00) [22.28]**	**9 (100.00) [20.25]**
Tap (Saline)	52 (29.55)	48 (70.59)	60 (42.25)	9 (45.00)	7 (4.58)	0	11 9(25.27)	57 (64.77)
Tap (Sweet water)	124 (70.45)	20 (29.41)	82 (57.75)	11 (55.00)	146 (95.42)	0	352 (74.73)	31 (35.23)
Sub-Total (Tap)	**176 (100.00) [73.95]**	**68 (100.00) [63.55]**	**142 (100.00) [20.00]**	**20 (100.00) [14.81]**	**153 (100.00) [83.61]**	**0**	**471 (100.00) [41.64]**	**8 (100.00) [36.36]**
Purchase (Saline)	1 (16.67)	1 (25.00)	1 (16.67)	1 (20.00)	0	0	2 (16.67)	2 (22.22)
Purchase (Sweet water)	5 (83.33)	3 (75.00)	5 (83.33)	4 4(80.00)	0	0	10 (16.67)	7 (77.78)
Sub-Total (Purchase)	**6 (100.00) [2.52]**	**4 (100.00) [3.74]**	**6 (100.00) [0.85]**	**5 (100.00) [3.70]**	**0**	**0**	**12 (100.00) [1.05]**	**9 (100.00) [3.72]**
Total households	**238**	**107**	**710**	**135**	**183**	**0**	**1131**	**242**

Notes: Major source is that source which provides for more than 50 per cent of the domestic water requirements of households; Minor source means sources that meet less than 50 percent of domestic water requirement (other than drinking)of the households; Household totals do not tally with the total sample households since many households have more than one source providing equal amount of water(50:50); Respondents categorize water as saline depending up on hardness, bad taste or salt taste of water ; Figures in parentheses are percentages to the subtotals of each category; figures in square brackets are percentages of sub totals to grand totals.

Source: Primary Survey

Table 22 Distribution of households based on their perceptions on the importance of water sources at present and 10 years back and beyond in different regions of Gujarat

Sources	South Gujarat		Saurashtra		Kutch		Gujarat	
	Today	10 years back	Today	10 years back	Today	10 years back	Today	10 years back
Own well	7 (3.2)	0	90 (12.5)	107 (14.9)	8 (4.4)	14 (7.9)	105 (9.4)	121 (10.8)
Public well	91 (41.6)	179 (81.7)	115 (16.0)	389 (54.0)	3 (1.6)	52 (29.2)	209 (18.7)	620 (55.5)
Own hand pump	1 (0.5)	0	67 (9.3)	26 (3.6)	8 (4.4)	6 (3.4)	76 (6.8)	32 (2.9)
Public hand pump	16 (7.3)	34 (15.5)	40 (5.6)	44 (6.1)	2 (1.1)	3 (1.7)	58 (5.2)	81 (7.3)
Public tap	158 (72.1)	29 (13.2)	432 (60.2)	129 (17.9)	84 (46.2)	75 (42.1)	674 (60.2)	233 (20.9)
Rain water	0	0	14 (1.9)	9 (1.3)	3 (1.6)	1 (0.6)	17 (1.5)	10 (0.9)
Purchase	2 (0.9)	2 (0.9)	117 (16)	45 (6.3)	2 (1.1)	1 (0.6)	121 (10.8)	48 (4.3)
Tanker supply	0	0	41 (5.7)	40 (5.6)	0	3 (1.7)	41 (3.7)	43 (3.8)
Total number of households responding	219	219	718	720	182	178	1119	1117

Note Percentages do not add up to 100 as the table contains multiple responses.

Water quality based on scientific water tests

We conducted basic water quality tests in all sample villages of Gujarat coast. In the Gujarat eastern region, we conducted some rigorous physical, chemical and micro biological tests of water samples, covering Colour, Turbidity, Conductivity, Alkalinity, Total Hardness, Total dissolved solids, Salinity, Calcium, Magnesium, Chloride, pH, Nitrate, and Fluoride contents of water. We also examined the coli form of few samples from the most frequently used wells. From the Gujarat Eastern region, water samples were collected from 10 open wells with depths ranging from 15 to 40 feet and distances ranging from 1 to 7 kms from the seashore. The age of these wells also ranged from 10 to about 100 years. The important methods adopted for testing these parameters are given in Table 24

Table 23 Characteristics of open wells examined in the Gujarat eastern region

Well No	Depth of the well (feet)	Distance from sea (in km)	Quality as per villagers' opinion	Availability of irrigation water nearer to the well	Age of wells in years
1	30	6	Drinking	Available	100
2	40	6	Domestic Use	Not available	100
3	22	1	Domestic Use	Not available	54
4	20	2	Domestic Use	Not available	100
5	30	6	Domestic Use	Not available	50
6	25	7	Abandoned	Not available	15
7	25	3	Domestic Use	Not available	50
8	40	7	Drinking	Not available	100
9	15	4	Drinking	Available	10
10	35	4	Domestic Use	Available	50

Note: Micro biological tests also were conducted for water samples from well number 1, Domestic use includes all uses of water other than drinking i.e., water for cattle, irrigation, washing cloths etc

Source: Primary data

Table 24 Methodologies adopted for physical, chemical and micro biological analysis of water

1	Parameter (Units)	Methodology Adopted
2	Colour (colour units)	Visual Comparison Method
3	Turbidity (NTU)*	Nephelometric Method
4	Conductivity ms/m	Conductivity Metre
5	Alkalinity mg Ca CO3 L at pH 4.5	Titration Method
6	Total Hardness mg/I	EDTA Titrimetric
7	Total dissolved solids mg/L	Dried at 1800 C
8	Salinity 0/00	Argentometric Method
9	Calcium mg/I	EDTA Titrimetric
10	Magnesium mg/I	Calculation method
11	Chloride mg/I	Argentometric Method
12	pH	pH metre
13	Nitrate mg/L	Colorimetric Method
14	Nitrate mg/L	Cadmium Reduction
15	Fluoride mg/L	SPADNS method
16	Total coli form MPN Index/100ML	Multiple tube fermentation technique.

Notes: *NTU (Nephelometric turbidity units; ** 0/00 parts per thousand; MPN means most probable number

Table 25 provides physical properties of water collected from these sample wells. It is clear from Table 25 that certain properties of drinking water exceeded the permissible limits as per the Indian and WHO standards of drinking water. We found high levels TDS in water samples drawn from all the wells used for drinking water purpose even though other parameters wer found in the upper limits of Indian standards. The dissolved solids for the 3 drinking water wells were in the range of 560-1800 Mg/L which was in excess of permissible limits. The high TDS presence was inferior in palatability with a possibility of inducing physiological reaction in the transient consumer. The total hardness was also an important parameter observed in the quality of water. Depending on the interaction of other factors such as pH and alkalinity, water with hardness above 200 may cause scale deposition in the distribution system and may result in excessive soap consumption and subsequent scum formation.

Table 25 Physical properties of water samples collected from Gujarat Eastern Region

Well No	Conduct-ivity Ms/m	Color Units	Turbidity NTU	Alkalinity mg Ca CO3/L at pH 4	Hard-ness mg Ca CO3/L	TDS Mg/L	Salinity
1	1.788	10.00	2	105	370	1400	0.41
2	1.748	15.00	2.5	108	182	1800	0.33
3	16.216	75.00	2.5	165	2470	11600	8.77
4	6.170	40.00	22	170	568	3900	2.59
5	1.320	10.00	10	146	330	1220	0.16
6	5.320	5.00	2	140	850	3200	2.34
7	9.790	<5	<1	76	3100	7600	4.72
8	1.110	10.00	<1	98	3000	600	0.14
9	0.930	10.00	2	76	280	560	0.11
10	2.350	25.00	3	118	1000	1860	0.75
INDIAN STD	6			150	200	500	
WHO STD	6			150	150	500	

Note STD (standard) : Source: Primary data

Hardness of drinking water wells in the study area ranged from 280 to 3100 mg Ca CO3/L. Across these drinking water sources, calcium and magnesium were found within the permissible limits that is, 75 and 50 Mg/L respectively. Chlorides, Nitrates and fluorides were also found within the permissible limits (Table 26). It is important to mention here that all these parameters were controlled within the permissible limits just because of their proximity to the sweet water canal.

Table 26 Inorganic non-metallic constituents of water samples from the Gujarat eastern Region

Well No	pH	Calcium Mg/I	Magnesium Mg/L	Chloride Mg/I	Nitrate Mg/L	Phosphate Mg/I	Flouride Mg/L
1	7.9	53.7	57.35	211.90	0.670	0.050	0.15
2	8.5	36.07	22.35	167.90	0.300	0.070	0.15
3	8.4	561.12	260	4838.40	0.700	0.175	ND
4	8	120.24	65.12	1419.50	0.250	0.240	.20
5	7.8	84.17	29.16	71.97	0.200	0.095	.15
6	8.2	64.13	167.67	1279.60	1.100	0.130	ND
7	7.7	480.96	461.7	2599.10	0.950	0.040	ND
8	8	68.14	31.59	59.98	0.900	0.040	ND
9	8.2	40.08	43.74	43.98	0.950	0.070	.16
10	7.8	112.22	174.96	399.80	1.000	0.090	.13
INDIAN STD	7.50 -8.50	75	50	250	50		1.5
WHO STD	7.50	75	50	250	50		1.5

Note: STD (standard), ND (not detectable) Source: Primary survey

However, the micro biological test conducted for a water sample of the most frequently used well for drinking water showed an MPN index of 130 (most probable number) which was quite high. It suggests that water was not of high-quality for drinking.

As far as the quality of water in Saurashtra and Kutch is concerned, it has been already proved through various studies that the water is hard and saline in the coastal areas (GoG, 1978). The total dissolved solids of water samples collected from Saurashtra and Kutch are given in Table 27. The TDS estimates of these regions were found much higher than the permissible limits. However, a majority of the households in this region were found unable to make out the water quality as they had been used to its taste since long (Table 20). Nearly 74.58 per cent of the households reported that they were getting sweet water from these wells. In Sourashtra, among the households who reported taps as their main source of water, only 7 per cent reported that the tap water was saline. In Kutch region, 42.85 per cent reported their wells providing sweet water. In the Gujarat Eastern Region, 96.29 per cent of the households said the water quality was good and sweet.

Table 27 Water quality of Kutch and Saurashtra Region

Name of the source	Depth of the well	pH	TDS	Electrical Conduc tivity
Kutch, Mandvi taluka, Nagalpur Village	220	6.5	1710	5.96
Kutch, Mandvi taluka, Bidada Village	800	8	1180	3.32
Kutch, Mandvi taluka, Bidada Village	450	7	1190	3.76
Kutch, Mandvi taluka, Bidada Village	520	7	490	1.56
Kutch, Mandvi taluka, Bidada Village	600	7.5	2560	5.86
Saurashtra, Bhavnagar, Vavdi village	700	7	992	2.43
Saurashtra, Bhavnagar, pipali village (hand pump)	-	7	1840	3.66
Saurashtra, Bhavnagar, Jashpara village	40	6.5	1980	5.55
Saurashtra, Bhavnagar, Jashpara village	788	6.5	628	1.25
Permissible limit		7.5	500	

Source: Primary water tests

Time and Money Allocation for water collection

As observed in an earlier chapter, scarcity of water has implications for the budgeting of households and also for labour allocation decisions. There are households who collect water with their own family members and those who hire labour for collecting water. Out of the total number of households surveyed nearly 863 (76.44 per cent) reported collection of water by family members and another 38 (3.37 per cent) households reported hiring of labour for collecting water from their premises or from far off places (Table 28).

Across regions, Saurashtra reported a maximum percentage (84 per cent) of households collecting water by family members. In Gujarat Eastern and Saurashtra regions, where the coverage by tap water was comparatively less, households on an average, spent about 2 hours for collecting water from wells; further on an average, they spent about 25 minutes for each trip for collecting at least two pots of water, travelling a distance of 1.15 kms (Table 29). The distance covered by households per each trip was found comparatively less in Kutch region, followed by Saurashtra. It was generally observed that in places where there were acute shortage of water, better tap connection was available.

There is also a gender dimension involved in the collection of water for domestic use. It is seen that provision of water for domestic uses is mainly the responsibility of women members in the family. We estimated the total number of members engaged in water collection per thousand population. The estimates show that 2077 persons were engaged

Table 28 Details of water collection by Family members, hired labour and school going children

Regions	Total No. of sample households	No. of households reporting collection of water by family members	Estimated No. of households reporting collection of water by family members per 1000 households	No. of households reporting collection of water by hired labour	Estimated No.of households reporting collection of water by hired labour per 1000 households	Estimated No. households reporting collection of water by school going children per 1000 households
Gujarat South (Eastern)	224	144	643	8	36	272
Saurashtra	721	605	839	29	40	218
Kachchh	184	114	620	1	5	179
Gujarat (Total)	1129	863	764	38	34	222

Source: Primary survey

Table 29 Details of time allocation for water collection by Family members

District and Regions	Average time a household spent for collecting water in a day (minutes)	Average time household members spent for one trip (minutes)	Average number of trips per day	Average distance covered per trip (kilometers)	Average number of pots used per trip
Gujarat South (Eastern)	126	26	5	1.15	2.06
Saurashtra	116	26	5	0.74	2.12
Kachchh	67	12	6	0.24	1.76
Gujarat (Total)	111	24	5	0.74	2.06

Source: Primary survey

in water collection (Table 30) that works out to 333 persons per thousand population. Out of 2077 persons engaged in water collection, 2045 were women which means 985 out of 1000 water collectors were women. This ranged from 997 in Saurashtra to 948 in the Gujarat Eastern region. No inter regional differences were observed in this case. Even gainfully employed women were also engaged in water collection. Almost 260 per 1000 women water collectors are gainfully employed. This was an additional burden for women. The proportion of women gainfully employed engaged in water collection per 1000 women water collectors was found highest in the Gujarat Eastern region and lowest in Saurashtra. Similarly, as seen in an earlier table out of 1000 households engaged in water collection as many as 222 reported school going children in water collection. Given the fact that majority of water collectors happened to be women, it become clear that they were basically school going girl children. The involvement of school going children was much higher in Gujarat Eastern and Saurashtra regions.

Table 30 Distribution of population engaged in water collection by gender

Regions	Total no. of members engaged in water collection	Estimated No. of members engaged in water collection per 000 population	Total no. No. of female members engaged in water collection	Estimated no. of female females engaged in water collection per 000 water collectors	Total No. of gainfully employed women collecting water	Estimated no. of gainfully employed women engaged in water collection per 000 water collectors
Gujarat Eastern	409	389	388	949	130	335
Saurashtra	1363	320	1358	997	324	238
Kachchh	305	334	298	977	78	261
Gujarat (Total)	2077	333	2045	985	532	260

Source: Primary survey

As pointed out in the previous sections, the households were incurring expenditure in various ways for water collection. This was mainly due to the shortage of water for some households, and for some households, it was for obtaining better quality of water to avoid health risks. We have estimated the cost of defensive expenditure using a defensive expenditure model ((Bartik, 1988).

Defensive Expenditure function

In this section, we analyse the expenditure incurred by the households for obtaining water for drinking and other domestic purposes using a simple household utility maximisation model (Bartik, 1988). A household maximizes utility (U) with respect to X (the numerarie commodity) and Z (the quality of personal environment).

U=U (X,Z)

With respect to X+D (Z,P)=Y

D ( ) is the defensive expenditure function and Y = income

An example of Z is the quality of drinking water in a household, where P is salinity level and D ( ) is the act of mitigating the effects of marginal quality water (saline water). The first order condition reduces to:

$$\frac{U_Z}{U_X} = D_Z$$

The household chooses X and Z to equate marginal value of environmental quality to the marginal cost of maintaining that level of personal quality. The benefit from a reduction in salinity is equal to the income required to keep the household at the original level of utility, given the change in salinity. The indirect utility function "V" expresses utility as a function of income and pollution, the two exogenous variables in the model.

V=v (Y,P) =U(U*,Z*)+v(Y - X* - D (Z,P))

Where X* and Z* are optimum quantities of X and Z given salinity level P and income Y.

$\frac{\partial Y}{\partial P} = D_p$ The benefit of a change in P while V, Z and X remains fixed is:

The benefit from a small reduction in salinity level Dp, saving in defensive expenditure needed to maintain the original level of personal environmental quality Z*. It is argued that estimating Dp is not straightforward, since the data requirement for estimating the households demand for personal environmental quality are forbidding (Bartik 1988). The observed change in defensive expenditure given an actual change in environmental quality is not equivalent to Dp. Actual change in defensive expenditure can be expressed as

D(Z0, P0) - D (Z1- P1).

A lower bound of estimate of Dp requires information only on defensive expenditure function. So, the change in utility can be represented by the observable variable, that is, defensive expenditure. If the defensive expenditure is positive, the utility gain will be observed and vice versa. Considering this theoretical fact, the present study provides a lower bound estimate of rural households' willingness to pay for saline and pollution free water for drinking and domestic purposes.

Modelling Willingness to Pay for non-saline drinking water

In order to estimate a defensive expenditure function, we have used a logit model. Here the dependent variable is a dummy variable which represents whether the households are incurring any defensive expenditure for the purchase of water or for hiring labour to fetch water. The logit model is adopted since it is capable of capturing even small changes in the independent variable on the probability of adopting a defensive expenditure. The decision of a household towards adoption of defensive expenditure can be considered as a binary choice variable representing indirect utilities with or without such expenditure. The specification of the model is given below. The logit model can be written as:

$$\Pr\{Yes\} = \left(1 + e^{-\Delta v}\right)^{-1}$$

$$F\eta(\Delta V) = a_0 + \sum b_j X_g$$

ΔV is the change in the indirect utility function or the decision to adopt defensive expenditure. A multivariate extension is feasible to j explanatory variables. Maximum likelihood estimation fits a curve to the observed responses, which trace the probability of adopting defensive expenditure. The variables are included based on field experiences and theoretical possibilities (Table 31).

The variable '***Education***' defines the educational level of the households which is defined as the number of literates in the households. Here it is assumed that households having more number of literates they would be in a better position to judge the potential consequences of salinity related problems and, therefore, would be more desirous of getting better quality water for household purposes.

During the survey, it was observed that households had reported several diseases like knee pain, malaria, cholera, typhoid, fever, dysentery, tooth decay, kidney stone etc. These diseases were classified into two categories: water borne diseases and those perceived to be salinity related. Therefore, the variable ***SB_diseases,*** represent households reporting diseases perceived to be due to salinity, and ***WB-disease*** represents the households reporting water borne diseases. The coefficients of both these variables were expected to be positive.

Sourashtra and Kutch are the most saline areas as compared to the eastern coastal region of Gujarat. The variable representing Sourashtra and Kutch is '***Sou_Kutch***' which is a dummy variable representing 1 if the households belong to this region, otherwise 0. We expected a positive sign for the coefficient since both these areas have been facing salinity problems for a long time.

The ability to purchase water or hire labour for fetching water is of course related to the households' current income levels. Therefore, it is assumed that those with higher levels

Table 31 Definition of variables used in the logit regression

House size	Expected sign	
Education	+	Schooling in number of years of the highest educated member in the household (treated as educational level of the household)
SB_disease	+	Dummy variable representing the presence of diseases due to water salinity =1 (example kidney stone), otherwise 0
WB_disease	+	Dummy variable representing the presence of diseases due to water contamination =1 (example malaria, cholera, typhoid, fever, dysentery), otherwise 0
Sou_Kutch	+	Dummy variable representing Sourashtra and Kutch =1 otherwise zero
Cons_Exp	+	Monthly Consumption expenditure of the household in rupees
Landless	-	Dummy variable Landless =1 otherwise zero
Small_holdings	+	Dummy variable small holding (0.1 to 2.5 acres)=1 otherwise 0
Marginal_holdins,	+	Dummy variable marginal holding (2.51 to 5 acres)= 1 otherwise 0
NS_land	-	Dummy variable representing ownership of nonsaline land =1 otherwise 0
SB_fishers	+	Dummy variable representing people setttled on beach (all are fishermen) =1 otherwise zero
Constant,		

of current income are more likely to incur these expenditures. Since we experienced some difficulty in getting information on household income, we have considered the average monthly expenditure of the household as a proxy for current income in the logit model. The average consumption expenditure is represented by ***'cons-exp'*** variable. Another aspect is the position of households in terms of landholdings represented by proxy dummy variables. We have used dummy variables for categories such as landless, small, marginal, treated medium and large holdings as a single category for the convenience of estimation. Since the total number of landholding category are 4, we have selected three dummy variables for landholdings categories such as ***landless, smallholding,*** and ***marginal holding***. We expected a positive sign for the landless since the absence of land represents difficulty in terms of accessing potable drinking water. As access to non saline land is an important determinant of accessing potable drinking water, we have assumed a negative relation of willingness to pay and ownership of such land. The variable ***NS_land*** denotes ownership of such non saline lands. Finally people living on the beach are more vulnerable as far as drinking water is concerned. We have used the variable ***SB_fishers*** for representing this category. As fisherman do not own any land and live on beaches, they are bound to buy or collect water from far off places. Therefore we have hypothesised a positive relationship between fishers settled on beaches and willingness to pay for potable drinking water.

Results and discussion

The important variables found to be significant and positively related to the decision of the households in terms of bringing potable drinking water by different means, such as spending money, employing labour, travelling by hired vehicles etc., include *WB-disease, Sou_Kutch, landless, small_holding, marginal_holding, and SB_fishers*. These results indicate that poor people were more inclined to buy potable water at a higher cost. The coefficients of all these variables were found to be positive and statistically significant. In a developing country context, these results assume greater significance to observe. In this context, it is important to know that those who really face water related problems are more likely to purchase water in the open market or employ hired labour. For example, of the diseases reported, water borne diseases were more of immediate concern and problematic for the households rather than those diseases which exhibited slow progression (e.g. kidney stone). As the poor households are more worried about their present and immediate future, they incur expenses to mitigate or avoid those effects with priority.

The regions of Sourashtra and Kutch are represented by a single variable (Sou_Kutch) since both the areas are more affected by salinity ingress as compared to Gujarat eastern region. The results indicate that those households living in Saurashtra and Kutch regions were more likely to purchase water or hire labour for collecting water, because the variable *Sou_Kutch* was found statistically significant with a positive sign. It should be remembered that Kutch region was found having a better access to tap water when compared to Saurashtra regions. Therefore, people from Sourashtra had a relatively higher probability to pay for drinking water.

As far as wealth indicators (consumption expenditure and land holding) are concerned, we found the coefficient of consumption expenditure variable (cons_exp) negative and not statistically significant. In the case of landholding variable, logit model shows landless, small and marginal holdings positively related to willingness to pay. This indicates that relatively poor households bought water at the cost of other household needs. This means that it did not matter much whether the household were rich or not; if they faced

Table 32 Maximum likelihood estimates of the logit regression

Variables	Coefficient	Std. Err	t-static	P>|t|	[95% Conf.nterval]	
Education	0.0029823	0.0393525	0.08	0.940	-0.0741472	0.0801119
SB_disease	-0.5167392	0.1936944	-2.67	0.008	-0.8963733	0.1371051
WB_disease	0.2955403	0.1743507	1.70	0.090	-0.0461809	0.6372615
Sou_Kutch	2.765548	0.3597299	7.69	0.000	2.06049	3.470606
Cons_Exp	-0.0000337	0.0000708	-0.48	0.634	-0.0001725	0.0001051
Landless	1.041145	0.3365887	3.09	0.002	0.381443	1.700846
Small_holdings	1.487276	0.3456429	4.30	0.000	0.8098282	2.164723
Marginal_holdins,	1.079893	0.390119	2.77	0.006	0.3152734	1.844512
NS_ land	-1.559502	0.332939	-4.68	0.000	-2.21205	0.9069533
SB_fishers	0.7703225	0.3131747	2.46	0.014	0.1565114	1.384134
Constant	-4.286919	0.5104631	-8.40	0.000	-5.287408	3.286429

Number of obs = 1129
LR chi2(10) = 194.77
Prob > chi2 = 0.0000
Log likelihood = -573.829
Pseudo R2 = 0.145
Mean willingness to pay Rs 8.40 per day
Average quantity of water collected per day 34 lit

problems due to poor water quality, they would incur additional expenses for procuring better quality water. Alternatively, this also means that the burden of poor quality water did not fall proportionately on rich people. Moreover, those having access to non saline lands (NS_land) were found to be negative and statistically significant(Table 32). The people living in the beach (fishers) were found procuring water with additional expenditures. The coefficient of the variable SB_fishers was found statistically significant at one percent level with a positive sign. The coefficient of constant was negative and statistically significant, but this does not have any physical meaning. The LR Chi2(7) of 194.77 was found statistically significant. We estimated the average willingness to pay for water at Rs 8.40 per month. An important conclusion that we drew from this analysis is irrespective of wealth, people procured potable drinking water by incurring additional expenditure. For example, landless communities and fishers also were found incurring additional expenditure for procuring water. The very acute scarcity of water made them incur a cost irrespective of their ability to pay. In this context, it is important to think of some public action in terms of building infrastructure with a view providing water to the poor households living in the coastal areas that might add to their welfare. It is also important to mention here that no scope for imposing water use fee or tax simply because the people procuring water with additional expenditure are very poor.

Estimating Welfare gain from Salinity Removal

The annual welfare gain from removal of salinity from drinking water was estimated by proportionately scaling up econometric estimates of willingness to pay for a marginal change in the quality of water (high saline water (TDS more than 900) considering the standard quality of drinking water of public taps (TDS 900) in this region. We estimated mean willingness to pay at Rs 8.40 per household per month using a defensive expenditure model (Table 32). A proportionate extrapolation of the mean WTP to the entire sample villages showed a welfare gain of Rs 12.60 million rupees per year. The important categories of people gaining from the availability of potable drinking water were found to be poor and landless (like daily wage workers, fishers, small and marginal farmers). The WTP that we estimated shows only the lower bound of welfare gain since it is not accounted for by other benefits of improved water quality e.g. reduced health expenditure, more time for productive work and leisure.

Conclusion

In this chapter, we have tried to find out defensive spending by the households to avoid the risk of consuming salinity affected water at the household level. We have found that defensive expenditure occurs when households spend additional money for buying fresh water from the market for drinking and cooking purposes. The households also spend additional time to collect water from long distances at the cost of other gainful employment or leisure. It has been observed that some households employ hired labour or school going children for collecting water. The household behaviour in averting the risk of marginal quality water consumption through defensive expenditure as mentioned above indicates the extent of welfare loss due to salinity ingress. In other words it shows the utility gain of the households if we controlled the present salinity ingress.

The estimation of defensive expenditure shows that Saurashtra and Gujarat eastern region are more vulnerable to water quality in that they incur defensive expenditure. It is important to note that the variable representing water borne diseases like malaria, dysentery, cholera etc is significant. On the other hand, a dummy variable representing ailments like kidney stone, knee pain, tooth decay caused by chemical content of water is not significant. This indicates, in the context of developing countries that those facing immediate water related problems are more likely to purchase water or employ hired labour rather than suffering from various diseases with slow progression. As the poor households are more worried about their present and immediate future they willingly spend money on mitigating or avoiding adverse effects on a priority basis. Our personal observations show that most of these households are located very close to sea, e.g. villages of Saurashtra and Gujarat eastern region.

Chapter 5:

Impact of Salinity Ingress on Agricultural Production

Introduction

As noted in previous chapters, salinity ingress in the Coastal Gujarat, which in fact is an outcome of over-use of groundwater resources over the years, has implications for agricultural production as well. This is due to the fact that with the depletion of fresh water, farmers resort to the use of salinity affected ground water for protective irrigation. Continuous use of saline water affects the biotic structure of soil and salt balance of the soil. Some of the useful bacteria, and plants essential for the stability of soil system, are known to perish as a result (GoG, 1978). Salinity ingress due to which soils get degraded, is essentially a problem of land degradation, which can affect agricultural production and productivity. It has been noted that the impact of salinity on agriculture can be both direct and indirect. The direct impacts of salinity ingress are reflected in terms of a reduction in quantity and quality of agricultural outputs, changes in biodiversity etc. Some of the indirect effects include changes in vegetation cover, which can reduce supply of fodder for livestock population leading to a decline in livestock population etc. Prolonged use of saline water for irrigation can not only lead to a decline in agricultural productivity and decreased soil fertility but also can render the land unsuitable for future cultivation. This means that the impact on agriculture can differ depending upon the extent and intensity of salinity ingress. In other words assessing the impact of salinity on agriculture is an onerous task.

Beside on the literature, it can be said that one of the ways to assess the impact of salinity ingress on agriculture would be to observe the changes in production and productivity of agricultural output on saline and non-saline lands. This approach is generally a production function approach or change in productivity approach. In this case, salinity ingress may affect the output, costs and profitability of producers through its impact on their environment. If there is a market for goods and services, the effects of environmental impact can be represented by the value of the change in output. Effects on production have also been used to trace the impact of environmental changes such as soil erosion, deforestation, wetland, etc on agriculture, forestry, fisheries, power, public services and other sectors. Since prolonged use of saline water for cultivation can render the land unfit for cultivation, assessing the cost and returns from the cultivation of different crops would be another way of looking at the problem. It has been found that low salinity water can be used in irrigation for growing most crops on most soils with little likelihood of developing salinity problem (Elango, Ramachandran, and Choudari, 1992). Excellent irrigation water is found with TDS less than 200 mg/L. The permissible limit of TDS in irrigation water ranges from 500 to 500 mg/L (Elango, Ramachandran, and Choudari, 1992). In the present context, it is reported that water gets saline during rabi and summer seasons. Many farmers find it difficult to carry out cultivation during this period and is more so in the case of small farmers grew crops on unirrigated lands.

While the production function method would give more accurate and scientifically sound results regarding the impact on output and thereby on profitability of the producers, it requires an enormous amount of both natural and social sciences based data to establish the linkages scientifically. For example, although it is known that salinity ingress can have impact on crops grown and productivity, the linkages in the study context are not known with quantitative precision. Establishing the impact of varying degrees of salinity ingress on different soils and different crops needs a more detailed scientific enquiry from a natural science point of view. The second method of assessment is equally important as it provides a more realistic picture of the current scenario and pinpoints where things are heading to and what needs to be done. Employing this method, a detailed investigation of costs and returns on various crops cultivated on lands affected by salinity ingress and those not affected by salinity ingress have been carried out and compared. This assessment is essentially made from the producers' point of view. Although we have attempted to follow effects on production approach for estimating the impact of salinity ingress, we feel constrained by the lack of some vital scientific data. Therefore, we have mainly relied on data collected from farmers based on their experiences and perceptions.

Agricultural scenario in the study area

As a backdrop for assessing the impact of salinity ingress on agriculture, first and foremost, it is important to take a look at the agricultural scenario in the study region. It is seen that out of the 1129 sample households, nearly 644 or 57 per cent did not own any cultivable land. This included a few landless and land owning households who, due to some reasons were not found cultivating their lands. The rest of the 485 households were engaged in cultivation. The percentage of households without cultivation was more in Kutch (70 per cent) and less in Saurashtra (50 per cent). The households engaged in cultivation were classified into three types (Table 33).

(1) households engaged in cultivation of land with water affected by salinity;

(2) Households with salinity affected cultivable lands

(3) Households engaged in cultivation on both salinity affected and non-salinity affected lands and water.

Table 33 Distribution of households by salinity affected cultivation in different regions of Gujarat Coast

Regions	No. of household not engageds in	No. of households engaged in cultivation using salinity affected land and water	No of households engaged in cultivation using land and water not affected by salinity	Number of households engaged in cultivation using both salinity affected and not affected land and water	Total number of sample households
Gujarat Eastern	153 (68.3)	40 (17.9)	27 (12.1)	4 (1.8)	224 (100)
Saurashtra	363 (50.3)	252 (35.0)	101 (14.0)	5 (0.7)	721 (100)
Kutch	128 (69.6)	45 (24.5)	11 (6.0)	0 (0)	184 (100)
Total	644 (57.0)	337 (29.8)	139 (12.3)	9 (0.8)	1129 (100)

Source: Primary survey
Note: figure in parentheses are percentages to the total of each region

It was observed that a large proportion of the households were engaged in cultivation using land and water affected by salinity. Although 30 per cent of the total households were reported cultivating on saline land using saline water, when seen as a percentage of the total number of households engaged in cultivation it amounted to nearly 70 per cent. As shown in Table 33, the percentage of households cultivating on salinity affected land in Gujarat Eastern was slightly less at 56 per cent, whereas it was found as high as 80 per cent in Kutch and 70 per cent in Saurashtra.

With regard to area under cultivation, it is observed that the total area in the study region reported to be under cultivation constituted about 2360 acres out of which 1859 acres (79 per cent) were found irrigated. Across regions, Kutch and Saurashtra regions were found with more coastal area under cultivation. However, it is to be borne in mind that the total reported area under cultivation across regions could not be considered for comparison, as there were differences in the number of villages covered by each region.

It can be observed from Table 34 that the coverage of area by irrigation was highest in Gujarat Eastern region where more than 90 per cent of the total cultivated area had been brought under irrigation. The area of total irrigated, total un-irrigated and also the total cultivated land per household was reported high in Kutch and Saurashtra regions.

Table 34 Details of area under cultivation across different regions in Gujarat (area in acres)

Region	Total irrigated land			Unirrigated			Total cultivated	
	Area	%	Average area per house hold	Area	%	Average area per house hold	Area	Average area per house-hold
Gujarat Eastern	159.96	93.25	2.58	11.57	6.75	0.89	171.53	2.45
Saurashtra	1427.8	78.36	4.84	394.2	21.64	3.65	1822	5.02
Kutch	269.78	73.85	6.58	95.52	26.15	5.94	365.3	6.64
Total	1858.66	78.75	4.67	501.42	21.25	3.66	2360.08	4.83

Source: Primary survey

Now when we take a closer look at the irrigation scenarios, mainly four categories of households can be identified. They are differentiated in terms of the quality of land and water used for cultivation. Here the important parameter differentiating the quality differences is the presence of salinity based on the perceptions of the households. The households so identified are those with (a) non-saline land with sweet water irrigation; (b) non-saline land with saline water irrigation; (c) Saline land with sweet water irrigation, (d) Saline land with saline water irrigation. In the entire study area, only 126 households or 30 per cent of the households had good quality or non-saline land with sweet water irrigation. The remaining 70 per cent of the cultivators were affected by salinity. It is to be remembered that continuous use of saline water on non-saline land would result in soil salinity thereby causing land degradation. Therefore, for our analytical purpose, we considerd households with non-saline land using sweet water irrigation as one category, and the rest as salinity affected. Across regions, the proportion of households with non-salinity affected land was more in Gujarat Eastern (45 per cent), Saurashtra (31 per cent) and very less in Kutch (12 per cent). It is also important to point out that a major chunk of the un-irrigated land had been affected by salinity. Many farmers opined that since it was uneconomical to irrigate that land, they had not brought it under irrigation. However, these did not include those lands, totally unfit for cultivation. It is important to remember the fact that Kutch and Saurashtra come under arid and semi arid zones of

Gujarat with low rainfall, where as the Gujarat eastern region is humidity-prone with high rainfall as a result of which it faces less incidence of salinity as compared to other two regions. Moreover, farmers in the Gujarat eastern region can access canal irrigation which is not the case with Saurashtra and Kutch. The main sources of irrigation in Saurashtra and Kutch regions are open wells and bore wells. During rabi season irrigation through check dams is also common in Saurashtra and Kutch regions. A more detailed analysis of the sources of irrigation is presented in the following sections.

As mentioned in an earlier chapter, we had conducted a Census survey of the households in the coastal villages of Gujarat in which details of the number of wells in each village were recorded. Across fifteen villages included in the Saurashtra region, a total of 2984 wells were reported, while the number of wells reported have been 1920 in six villages in Gujarat Eastern region, and three villages in Kutch region, 833 wells were reported.

Table 35 Average area under irrigated and non irrigated agriculture in different regions of Gujarat Coast (Area in acres/ha)

Region	Sweet water irrigated non-saline land	Saline water irrigated non-saline land	Sweet water irrigated saline land	Saline water irrigated saline land	Total irrigated Land	Saline land without irriga-tion	Average Non-saline land without irriga-tion	Average land without irriga-tion	Average area under cultivat-ion
Gujarat Eastern	3.52 (28)	2.35 (15)	1.42 (16)	0.55 (6)	2.58 (62)	0.63 (7)	1.03 (7)	0.89 (13)	2.45 (70)
Saurashtra	4.72 (93)	2.87 (43)	4.89 (59)	3.90 (148)	4.84 (295)	3.87 (88)	2.68 (20)	3.65 (108)	5.02 (363)
Kutch	7.36 (5)	5.44 (14)	6.53 (5)	7.31 (17)	6.58 (41)	6.24 (13)	4.80 (3)	5.97 (16)	6.64 (55)
Total	4.56 (126)	3.26 (72)	4.30 (80)	4.12 (171)	4.67 (398)	3.95 (108)	2.50 (30)	3.66 (137)	4.83 (488)

Source: Primary survey
Note: figures in parentheses are percentages to the total of each region

Table 36 Number of open wells and bore wells reported as a sources of irrigation in the Gujarat Coast.

Village	Number of open wells	Number of bore wells	Total no. of wells	Area under cultivation	Number of wells per 100 acres of cultivated area
Panch Pippalaya	190	6	196	1768	11
Kaj	367	0	367	2361	16
Velan	103	0	103	1345	8
Damlej	309	159	468	1792	26
Velva	48	0	48	841	6
Vadala	122	65	187	929	20
Nandrakhi	169	1	170	595	29
Pipli	16	63	79	1010	8
Jaleswar	1	0	1	0	
Pankhan	207	94	301	2261	13
Eklera	72	32	104	531	20
Chandvana	501	10	511	2178	23
Shapur	196	4	200	575	35
Jashpara	140	32	172	1287	13
Vavdi	54	23	77	1086	7
Saurashtra	**2495**	**489**	2984	**18560**	16
Sondlakhara	0	0	0	434	0
Jinod	0	1	1	597	0
Delasa	0	0	0	211	0
Sithan	2	44	46	524	9
Bhattai	0	0	0	12	0
Onjal	0	3	3	141	2
Gujarat Eastern	**2**	**48**	50	**1920**	3
Bidada	131	599	730	7386	10
Nagalpur	0	79	79	1314	6
Mandir	3	21	24	155	15
Kutch	**134**	**699**	833	**8855**	9
Total	**2631**	**1286**	3917	29335	13

Source: Primary census survey

The total area reported under cultivation at the time of survey stood at 29 thousand acres. Based on this we estimated the number of wells per hundred acres of area under cultivation (Table 35). It was observed that Saurashtra region followed by Kutch region had accounted for the maximum number of wells per 100 acres of cultivated area; while Saurashtra and Kutch regions shared 16 and 13 wells respectively per hundred acres of cultivated area, just three wells in the Gujarat region were reported. This indicates the dependence of Saurashtra and Kutch on groundwater resources for irrigation purposes. However, these figures do not capture the magnitude of the failure of wells in the region.

Table 37 Important agricultural crops grown in the non-saline and saline areas of Gujarat coast

Crops	Non Saline Area Cultivation		Saline Area Cultivation	
	Number of cultivators	Percentage	Number of Cultivators	Percentage to total farmers
Wheat	87	64.0	94	31.6
Bajra	69	50.7	143	48.1
Jowar	12	8.8	61	20.5
Maze	12	8.8	3	1.0
Groundnut	74	54.4	139	46.8
Cotton	44	32.4	87	29.3
Sugarcane	25	18.4	13	4.4
Rice	1	.7	2	.7
Tuver	1	.7	4	1.3
Chana	1	.7	0	
Mag	4	2.9	19	6.4
Adad	1	.7	3	1.0
Tal	3	2.2	7	2.4
Sarasau	6	4.4	1	.3
Cocout	1	.7	1	.3
Potato	2	1.4	0	
Kandola	1	.7	0	
Chikku	3	2.2	7	2.4
Guver			2	.7
Caster oil			3	1.0
Alsi			1	.3
Vegetables	50	36.8	58	19.5
Total	397		649	

Source: Primary Survey

A number of crops were reported to have been cultivated in the study area. Altogether more than 25 crops were reported in the study region. However, the most important crops grown included wheat, bajra, jowar, maize, groundnut and cotton. Marked differences in the cropping pattern have been observed in the case of saline and non-saline lands. In the case of saline land, the average cropped area per household worked out to about 10.9 acres of which nearly 30 per cent each had been under pulses and oil seeds. The proportion of area under cereals constituted nearly 22 per cent, where as under cash crops it was just over 2 per cent.

If we consider important crops separately across regions, it becomes clear that the area under cereals per household was very less in the Kutch region when compared to Saurashtra and Gujarat eastern regions. In the case of pulses, it was more in Kutch, where the average area per farming household worked out to about 3.7 acres as shown in Table 38. Oilseed cultivation was not reported in the saline areas of Gujarat Eastern region, where as it was very high in Saurashtra. In terms of the area under different crops, in Saurashtra region, it was more under oilseeds and it was pulses in Kutch. No significant differences in the average area under different crops in the saline region were observed. It was also equally important to have observed a large proportion of current fallow land across Gujarat Eastern and Kutch regions.

Table 38 Cropping Pattern in the reported saline Area (average area per farming household in acres under different crops)

Regions	Cereals	Pulses	Oil seeds	Cash crops	Other plants and current fallow	Average Gross cropped area
Gujarat Eastern	0.9 (27.3)	0.7 (22.0)	-	0.2 (6.4)	1.5 (44.4)	3.4 (100)
Saurashtra	2.3 (29.9)	0.4 (5.6)	3.0 (39.3)	0.3 (3.7)	1.7 (21.6)	7.7 (100)
Kutch	3.7 (15.7)	3.7 (15.8)	3.3 (14.3)	0.4 (1.6)	12.2 (52.5)	23.3 (100)
Total	2.4 (22.1)	3.2 (28.9)	3.0 (27.8)	0.3 (2.6)	2.0 (18.6)	10.9 (100)

Note: Figures in parentheses are percentages to the total cropped area
Source: Primary Survey

Now, when we compare the cropping pattern of the salinity affected lands with that of non-saline lands, the differences become very obvious. The average area coverd under cultivation of each crop shows that it was more under oil seeds (32.6 per cent), followed by cereals (30 per cent), and cash crops (20.6 per cent). Regional differences in terms of the cropping pattern on non-saline lands were also noted. Almost 50 per cent of the total cropped area in the Gujarat region was under cash crop cultivation. When compared to other regions, in Gujarat Eastern region the average cropped area per household was only 5.4 acres where as, it was as high as 15 acres in Saurashtra and 13 acres in Kutch (Table 39). No single crop was found dominant in Saurashtra and Kutch regions. if cereals and oil seeds were the major crops in Saurashtra region, it was cereals and cash crops in Kutch region. Another important aspect to note is that, in terms of average size of land holding per households, in Saurashtra and Kutch the farmers possessed large holdings whereas in Gujarat Eastern, they were mostly in possession of small and medium size holdings.

Table 39 Cropping Pattern in the reported non saline Area (average area per farming household in acres under different crops)

Regions	Cereals	Pulses	Oil seeds	Cash crops	Other plants and current fallow	Average Gross cropped area
Gujarat Eastern	0.9 (17.2)	0.2 (4.0)	-	2.7 (49.9)	1.5 (28.9)	5.4 (100)
Saurashtra	5.4 (35.8)	0.4 (3.0)	5.0 (33.1)	3.3 (21.7)	1.0 (6.5)	15.0 (100)
Kutch	3.5 (26.8)	2.3 (17.6)	2.0 (15.5)	3.4 (26.7)	1.7 (13.4)	12.9 (100)
Total	4.6 (30.4)	1.2 (7.9)	4.9 (32.6)	3.1 (20.6)	1.3 (8.6)	15.1 (100)

Source: Primary Survey

Impact of salinity on Agricultural production

In this section the impact of salinity on agricultural production has been assessed in terms of select major crops identified in the study area. One important crop from the group of cereals, cash crops and oil seeds such as wheat, sugarcane and groundnut have been examined in detail. A production function analysis has been carried out for each of these crops to understand the economics of these crops under saline and non-saline conditions. This helps understand the extent of forgone agricultural benefits (loss) arising from saline affected lands in relation to non saline lands. In order to estimate the forgone agricultural benefits in the presence of salinity ingress, we have estimated a production function in terms of two scenarios (with and without salinity presence) and compared. The differences in expected yields across two scenarios are interpreted as the cost of salinity ingress. The cultivation cost includes the cost of preparing the plot, of seeds, sowing and of harvesting for each crop. In addition to this, there are fixed costs involved in the form of agricultural implements and irrigation investments. The recurring costs include material cost incurred in terms of applying fertilisers, manure and pesticides, repairs, maintenance and supervision etc. The benefits include total production of crops and crop residuals. The benefits and costs are expressed at constant prices (2004-05) as the base.

Average Cost and Returns

In the study area, as noted earlier, there are different crops grown. Among the various crops, we have restricted ourselves to one crop each from cereals, oilseeds and cash crops for a detailed analysis of costs and returns; they are wheat, groundnut and sugar cane. Wheat is basically a crop cultivated in rabi season mainly in Saurashtra and Kutch, whereas sugarcane is the major crop grown in Gujarat Eastern region. Harvesting of sugarcane generally takes 11 to 14 months. Some farmers cultivate groundnut or bajra after one harvest of sugarcane. A look into the costs and returns on wheat cultivation shows considerable differences. On an average, the farmers incurred about Rs 8625 per acre for the cultivation of wheat on non-saline areas, where as it was Rs 10250 per acre in saline area. Cost incurred for preparing land, including labour cost constituted a major component of costs with regard to both saline and non-saline areas not withstanding saline prone areas reporting a slightly higher cost for preparing land. Next important component is the seed cost involved in both cases. For the preparation of land, salinity affected farmers were found incurring almost Rs 2250 per acre, where as it was Rs 1750 for non-saline category. This accounted for approximately 22 and 20 per cent of the total costs respectively, of saline and non-saline category. However, we can observe that across saline areas, farmers incurred more cost on farmyard manure and chemical fertilizers. For example, farmers engaged in cultivating crops on saline areas spent Rs 1750 per acre on DAP and Rs 1500 per acre on farm yard manure, while it was Rs1250 per acre with regard to saline and non-saline category of farmers.

Table 40 Costs and returns from cultivation of wheat on saline and non-saline lands in the study area (Per acre)

Item	Non-saline land			Saline land		
	Qty	Cost (Rs)	% to total cost	Qty	Cost	% to total cost
Land preparation	-	1750	20.3		2250	22.0
Seed	100kg	1500	17.4	125	1875	18.3
Planting	-	1500	17.4		1500	14.6
Farm yard manure	5 tractor load	1250	14.5	5 tractor load	1500	14.6
DAP	2.5 bags	1250	14.5	3.5 bags	1750	17.1
Pesticide		125	1.4		125	1.2
Weeding		500	5.8		500	4.9
Harvesting		750	8.7		750	7.3
Total Cost		8625	100		10250	100
Average output	2000kg	14000		1625	11375	

Source: Primary Survey

It is also important to point out that farmers with saline lands were required more expenses on seed as the survival rate of seedling was very less because of salinity presence. During the course of the survey, it was also revealed that the farmers had developed their own coping up mechanism in terms of improving the survival rate of plants by applying only fresh water at certain stages of plant growth etc. However, all these depended upon the availability of fresh water within their vicinity and the technology which were possibly within the reach of rich farmers only. All these could be seen as an impact of land degradation due to salinity resulting in the escalation of costs. It may be logical to argue here that farmers continue to incur higher cost in terms of adding inputs to an extent till it becomes economically unviable. In other words, farmers have to incur higher costs to reclaim soil fertility lost due to salinity by applying more inputs. At a stage when it becomes totally unviable to continue cultivating their saline lands, the farmers might leave them fallow. It may be recalled here that, the proportion of fallow lands was found higher in saline areas as compared to non-saline areas. Now coming to the yield from lands, while farmers on non-saline land managed to reap about 20 quintals of wheat per acre, it is only 16.25 quintals on saline lands. In other words, as compared to farmers cultivating non-saline lands, those cultivating salinity-affected land were required to incur higher inputs costs. The productivity of wheat per acre was also less on saline lands when compared to non-saline lands.

Similar observations were made with respect to groundnut and sugar cane. Groundnut is an important oilseed mainly grown in the Saurashtra coast. It is a kharif crop. Farmers in this context, reported several difficulties in continuing with cultivation. In this case also, farmers faced major difficulties during the seed germination stage. As a coping up activity, farmers were found trying to mix saline water with sweet water at the time of germination, and once the seedlings survived they use saline water for irrigation. The general observation is that farmers try different agronomic practices based on local wisdom to cope up with increasing salinity problems. As in the case of wheat, groundnut seed cost also an important component of the total cost of cultivation, and varied considerably across saline and non-saline lands. On non-saline lands, while 1.1 quintal of seeds was required for one acre, it was 1.4 Quintals in saline lands. The corresponding cost figures amounted to Rs 5625 and Rs 6875 respectively per acre (Table 41).

Table 41 Costs and returns of groundnut cultivation on saline and non-saline lands in the study area (Per acre)

Item	Non-saline land			Saline land		
	Qty	Cost (Rs)	% to total cost	Qty	Cost	% to total cost
Land preparation	—	3125	13.7		3750	13.3
Seed	1.1 quintal	5625	24.6	1.4 quintal	6875	24.3
Planting		1500	6.6		1500	5.3
Farm yard manure+ labour		7500	32.8		10500	37.1
DAP	1.25 Bags	583.75	2.6	2.5	1167.5	4.1
Sand	5 tractor load	1500	6.6	5	1500	5.3
Pesticide	62gms	1000	4.4	62.5	1000	3.5
Weeding		1000	4.4		1000	3.5
Harvesting		1000	4.4		1000	3.5
Total Cost		22833.75	100		28292.5	100
Average output	15 Quintals	52500		12.5 Quintals	42500	

Source: Primary survey

Table 42 Cost and returns of sugarcane cultivation on saline and non-saline lands in the study area (Per acre)

Item	Non-saline land			Saline land		
	Quantity	Amount (Rs)	%	Quantity	Amount (Rs)	%
Land preparation	4750	9.7		5750	11.0	
Seed	6.25 Quintal	5000	10.2	7.5	6000	11.5
Planting		1750	3.6		7500	14.4
Farm yard manure		6250	12.8		7500	14.4
DAP	2.5	1200	2.5	3.75	1751.25	3.4
Urea		1275	2.6	6	1530	2.9
Castor cake	5	1200	2.5	7.5	1050	2.0
Pesticide		1250	2.6		1250	2.4
Weeding		1000	2.0		1000	1.9
Labour cost of irrigation		3750	7.7		5000	9.6
Harvesting and transport		21500	43.9		19350	37.1
Total Cost		48925	100.0		52206.25	100.0
Average output	125	87500		112.5	67500	

Source: Primary survey

In the case of groundnut, the application cost of farm yard manure is very high as compared to other costs. Almost 37 per cent of the total cost of cultivation of groundnut on saline lands was accounted for by farm yard manure, where as it was 33 per cent for non-saline lands. As seen in Table 41 the quantity of FYM and DAP applied was much higher in the case of saline lands when compared to non-saline land. Although the quantities of inputs used were comparatively more on saline lands, the yield per acre was considerably less. While, on an average, the yield was15 quintals per acre on non-saline lands, it was only 12.5 on saline lands. The gross value of output worked out to Rs 52500 for non-saline and Rs 42500 for saline lands. On the whole, three important components of the total costs of groundnut were found; they included costs of manure and fertiliser and seeds. A mention may be made here that since groundnut is a kharif crop, intermittent irrigation was provided mainly with water having salinity. As pointed out earlier, the cost of irrigation was not included in the cost estimation.

Cost of cultivation of sugarcane in the study area also presents similar results. Significant differences in the cost of cultivation and output per acre with regard to saline and non-saline lands were observed. The important components of total cost of cultivation were seeds, land preparation and application of farm yard manure and other fertilisers. The quantity of seeds required for saline lands was found more when compared to non-saline lands. While, on an average 7.5 quintals of seed were required for one acre of land on saline lands, it was only 6.25 quintals on non-saline lands. In the case of sugar cane cultivation, we considered the cost of irrigation as a separate cost component. Here the cost of irrigation was expressed in terms of labour cost sugar cane is labour intensive.

However, with sugarcane, the major components of the total cost included the cost of cutting, loading and transporting. Over 40 per cent of the total cost of sugar cane cultivation was incurred on these components. In fact, this cost was reported more in

Table 43 Average productivity, cost and returns of different crops in respect of saline and non-saline areas (lands)

Non-saline land	**Crops**		
Crop	**Wheat**	**Sugarcane**	**Ground nut**
Output per acre In Quintal	20	125	15
Average Returns per acre	14000	87500	52500
Average cost per acre	8625	48925	22833.75
Net returns	5375	38575	29666.25
Average cost per quintal in Rs	431	391	1522
Saline land Output per acre In Quintal	16.25	112.5	12.5
Average Returns per acre	11375	67500	42500
Average cost per acre	10250	52206.25	28292.5
Net returns	1125	15293.75	14207.5
Average cost per quintal in Rs	631	464.06	2263
% Increase in cost for per unit of output as compared to non-saline land	46.26	18.56	48.68

Source: Primary survey

the case of non-saline lands. On the whole, almost Rs 48925 per acre were incurred on the cultivation of sugarcane on non-saline lands and Rs 52206.25 on saline lands. Differences in yield levels were also observed with non-saline lands reporting high yields per acre. The value obtained per unit of output was also more for sugarcane cultivated on non-saline lands. While sugarcane grown on non-saline lands fetched about Rs 700 per quintal, it was only about Rs 600 in the case of saline lands.

After having examined the cost and returns structure of different crops with respect to both saline and non-saline lands, it is of interest to know whether these differences are statistically significant across saline and non saline areas for which a production function has been used. The production function also shows how certain remedial measures like use of gypsum and sand influences agricultural production.

Production Function

A production function shows the relationship between input and output. A general form of agriculture production function, when all land is homogenous, can be written as:

Y= f (a,l,k)

$$= \beta_1 + \sum_{k=1}^{n} \beta_k \, lnX_i + \beta_k X_j + \varepsilon$$

f output, a, l, k are land labour and capital respectively. to accommodate a land quality variable when there is a quality (Heady and Dillion, 1961). This formulation of the production function is as follwows.

Y= f (a,l,k,q)

Where q represents land quality. Here, farmers opinion on their land quality in terms of salinity can be taken to represent q. The choice of the functional form of this equation depends on the nature of relationship between variables. But to represent the diminishing marginal returns of the conventional inputs, a commonly used functional form is log liner (Cobb-Douglas production function).

$$\log Y = \beta_1 + \sum_{k=1}^{n} \beta_k \, lnX_i + \varepsilon$$

Where Xi represent different inputs with i = 1 .....n,. The equation can be modified with a salinity variable (X_j) as follows.

Using the empirical estimation and coefficient of variable salinity, we have derived the cost of salinity ingress and benefits of conservation that restore land. The opportunity costs are defined as the loss of production due to the presence of salinity which are calculated based on the empirical estimation of the production function.

In order to estimate the production function of wheat, groundnut and sugarcane, we have used cross section data collected through a primary survey. The conventional inputs used in the production function are land, labour, farm yard manure, chemical fertiliser and pesticides, and cost of seeds. The presence of salinity is represented by a dummy variable. We have also used a dummy variable to represent farmers' soil conservation practice (use of sand and gypsum) for reducing the effect of soil salinity (Table 44). In the case of sugarcane, the value of farm yard manure, chemical fertilisers and pesticide cost clubbed together is represented by a variable 'logfert'. The clubbing has been done owing to a small sample of farmers in this category. All variables are expressed in nominal terms at 2005-06 prices.

Table 44 Variables used in the Production Function

Logvalue	Value of agricultural output per acre
Logfym	Value of farm yard manure per acre
Logche	Value of chemical fertiliser used per acre
loglab	Value of labour used per acre
logseed tanma	Value of seeds used per acre
salinity	Nonsaline area =1 otherwise 0
Sand	Use of sand or gypsum = 1otherwise 0
Logfert	(Value of farm yard manure, chemical fertilisers and pesticide cost) used in the case of sugarcane

The estimated equation for wheat and groundnut is;

logvalue= f (Logfym,Logche, Loglab,Logseed,salinity,sand)

The estimated equation for sugarcane is;

logvalue= f (logfert,loglab,logseed,salinity,sand)

The estimated Cob-Douglas production function shows a negative influence of salinity on the value of agricultural production i.e., wheat, groundnut and sugarcane. The significant negative coefficients indicate that salinity is associated with a decrease in agricultural output. In each of the model, input variables separately influence the value of output. We found Labour and chemical fertiliser increases output levels in the case of both wheat and groundnut. We have also noted that some farmers use excessive quantities of seeds, with a presumption that it might facilitate better germination. This might be one of the reasons that the variable seed is not found significant in the production function of wheat. However, the variable seed is significant and positive in the case of groundnut which is a kharif crop. We have also noticed that some farmers mix certain amount of sand and gypsum in the soil to make it more conducive to the root system in terms of percolation and less salinity. The variable sand is positive significantly influencing the level of output in the case of both wheat and groundnut (Table 45,Table 46). An important variable found significant in the case of sugarcane is the amount of labour use. The labour requirement during harvesting is considerably high in the case of sugar cane. Second, salinity level also influences the level of sugarcane output. In the saline areas, we find output considerably low as compared to nonsaline areas. The variable salinity is negative and significant in the case of sugarcane(Table 47).

Table 45 Production function estimates of wheat (cereals)

Variables	Coef	Std. Err	T	P>|t|	95% Conf. Interval	
logfym	-.2678683	.1596259	-1.68	0.095	-.5829079	.0471713
logche	.492682	.124631	3.95	0.000	.2467087	.7386552
loglab	.2783235	.0590506	4.71	0.000	.1617804	.3948666
logseed	.0485525	.0712345	0.68	0.496	-.0920367	.1891417
salinity	-.4140672	.055016	-7.53	0.000	-.5226474	-.305487
sand	.1204625	.0302187	3.99	0.000	.0608226	.1801025
constant	5.368997	1.380631	3.89	0.000	2.644167	8.093827
Number of obs = 182 F(6, 175) = 16.65 Prob > F = 0.0000 R-squared = 0.3634 Adj R-squared = 0.3416						

Source: based on Primary survey

Table 46 Production function estimates of groundnut (oilseed)

Variables	Coef	Std. Err	t	P>|t|	95% Conf. Interval	
loglab	.4729902	.0992135	4.77	0.000	.277369	.6686114
logfym	.1275025	.0500141	2.55	0.012	.0288887	.2261163
logche	.3088558	.0327147	9.44	0.000	.2443516	.3733601
logseed	.1729807	.0640953	2.70	0.008	.0466028	.2993586
salinity	-.1729865	.0257261	-6.72	0.000	-.2237111	-.1222619
sand	.0342982	.0141549	2.42	0.016	.0063887	.0622077
_cons	1.835554	.9675168	1.90	0.059	-.0721168	3.743225

Number of obs = 210
F(6, 203) = 65.26
Prob > F = 0.0000
R-squared = 0.6586
Adj R-squared = 0.6485
Expected value of output per acre from non saline area= 14016
Expected value of output per acre from saline area = 12618
Expected value of output per acre (for all sample) = 13294
Opportunity cost of due to salinity =1398

Source: based on Primary survey

The annual welfare gain arising from removal of salinity from the soil and water has been estimated using opportunity cost method. The estimation shows the forgone benefits of wheat and groundnut at Rs. 1398 and Rs 7882 respectively. In the case of sugarcane, we observed a high cost of Rs 14462 per acre. These estimates are used to find out average opportunity cost incurred by an agricultural household using weighted average method. Weights are the proportion of cropped saline area under each crops (Table 38) cultivated by a household in different regions. In the estimation, we have considered only cereals, oilseeds and cash crops in terms of area cultivated. Vegetables and pulses are excluded due to data limitations. So the estimation needs to be treated as a lower bound of the opportunity cost per households. It is found that the pportunity cost per acre of saline land amounts to Rs 6802 and Rs 6653 respectively in Gujarat Eastern and Sourashtra region. We have estimated a high cost of Rs 6939 per acre of land in Kutch region. Depending upon the extend of cultivation on saline area in three different region, the estimates (Rs 23127 per household in a year) show that the incidence of salinity and the welfare loss are found relatively low in Gujarat eastern region as compared to the other two regions.The welfare loss for an agricultural household in Sourashtra works out to Rs 51228 which is more than double of what it is for Gujarat eastern region.

Table 47 Production function estimates of sugarcane (cash crops)

Variables	Coef	Std. Err	t	P>|t|
loglabour	.7206993	.3510988	2.05	0.048
logfert	.3044717	.2460017	1.24	0.225
salinity	-.1516101	.0310923	-4.88	0.000
_cons	.9340258	4.32203	0.22	0.830
Number of obs = 37				
F(3, 33) = 19.42				
Prob > F = 0.0000				
R-squared = 0.6384				
Adj R-squared = 0.6055				
Expected value of output per acre from non saline area= 83647				
Expected value of output per acre from saline area = 69185				
Expected value of output per acre (for all sample) = 78957				
Opportunity cost of due to salinity = 14462				

Source: based on Primary survey

Table 48 Opportunity cost in the presence of salinity across agricultural lands in rupees (2005-06 prices)

Region	Gross cropped area under salinity cultivation (sample agricultural households) (in acres)	Opportunity cost per household per acre of land	Opportunity cost per agricultural household per year
Gujarat Eastern	3.4	6802	23127
Sourashtra	7.7	6653	51228
Kutchchh	23.3	6939	161678
For all regions	11.4	6798	78677

Source: based on primary survey

In the Kutch region a fully dry area, forgone agricultural output due to salinity amounts approximately to Rs 161678 per year per household. Considering the high cost of salinity in Sourashtra and Kutch, more public investment in these areas is desirable not only to save these lands from the present situation but also to improve the overall all welfare of these regions. It is also important to pay attention to the Gujarat eastern region in order to prevent the region from falling into salinity trap. In short, the study shows a welfare gain of Rs 78677 per agriculture household if we could bring the present saline area to the level of soil and water quality prevailing in non saline areas of the same region (Table 48).

Conclusion

This chapter focusses on the impact of salinity ingress on agricultural production in the coastal areas of Gujarat. In this chapter, we have analysed the irrigation and cropping pattern in the selected study villages as well as the costs and returns arising from cultivation of various crops. Three important crops in the region have been identified for this purpose; they are wheat, groundnut and sugarcane. The analysis indicates that overall the impact of salinity ingress is felt more in Kutch and Saurashtra regions than in the Gujarat Eastern region. In Kutch region we have observed that more land is going out of cultivation or are left fallow. The proportion of land without the presence of salinity is also very less in Kutch and Saurashtra regions, when compared to the other region. In these regions, more dependence on groundwater resources, open wells or bore wells has been observed. Similarly, considerable differences in production and productivity of all crops included in the study such as wheat, groundnut and sugarcane across salinity affected and lands not affected by salinity have been observed. It is observed that farmers cultivating lands affected by salinity incur more input costs mainly to reclaim the fertility loss due to salinity ingress. A production function analysis shows that there is a differential impact of salinity across crops and regions. The study finds a significant opportunity cost involved across regions in the presence of salinity which can be saved only through public investments on soil and water conservation. It is also important to bring in proper institutional measures to control ground water exploitation in these regions.

Chapter 6:

Summary and Conclusions

Gujarat, one of the leading states in India in terms of industrialization, still has nearly 65 per cent of the population living in rural areas dependent upon agriculture, animal husbandry and related activities for their livelihoods. This state also has the longest coastal line amongst the maritime states of India. The coastal line of Gujarat which is about 1650 km in length constitutes nearly 21 per cent of the total coastal line of India. This is also a water scarce region with groundwater as a major source of irrigation in the state. Apart from the demand for water for irrigation and domestic uses, a fairly high pace of industrialization also exerts pressure on the existing water resources available in the state. As a result, several parts of the state have been witnessing excessive drafting of groundwater resources, well above the recharge rates. Various factors such as improvements in technology in terms of drilling and lifting water, providing of liberal loans for well construction, availability of subsidized electricity etc., have contributed to the excessive withdrawal of groundwater.

The over withdrawal of water has led to the problems of availability as well as quality. In the coastal areas of the state, the excessive withdrawal of ground water has not only resulted in the depletion of water tables but also salinity propagation. It has been noted that the salinity propagation is 0.5 to 1 km distance from the coastline since the groundwater tables are going down by 4 to 5 per cent every year. The state experiences both secular or long term and seasonal depletion of groundwater resources. Qualitative problems are also found reflected in terms of an increase in fluoride content and salinity levels in groundwater in the coastal area. Several studies in the past have shown that the consequences of groundwater overexploitation might differ depending on the geo-hydrological environment. In this study, we have used salinity propagation, salinity ingress and groundwater pollution interchangeably.

The impact of salinity can manifest itself in the form of scarcity of drinking water to the rural households or through the deterioration of soil structure affecting agricultural production. Therefore, the lead objective of the present study was to understand the impact of salinity ingress (due to groundwater depletion) on rural households living in the coastal areas of Gujarat. Within this broader objective, we have examined the characteristic features of the coastal regions of Gujarat in order to understand the relationship, if any, between population, poverty and natural resource base. Besides, we have analyzed the impact of salinity ingress on the rural households in terms of their defensive expenditure on accessing better quality water for drinking and other domestic uses. Salinity being invariably a problem of land degradation has implications for costs and returns arising from agriculture which this study has tried to assess.

In the analytical framework of the study, it was assumed that salinity could lead to the loss of welfare of the households mainly in two ways. One source of welfare loss is the consumption of marginal or poor quality water at the household level which might cause health problems; and this in turn might force the households to spend more on health needs in order to protect themselves from poor quality water, which can be construed as a loss of welfare for the households. The other most important effect of salinity ingress or propagation on rural households is through changes in the production of agricultural commodities and related activities. Here the final outcome of these changes would be in the form of reduced household income levels and loss of livelihood options for the poor people. This is the second source of welfare loss for the households. This study has examined these aspects in detail.

The data required for the study was collected by conducting a primary survey. The households were selected from Talukas which were within 20kms from the coastal areas in Gujarat. We adopted a stratified random sampling for selecting the households. For selecting the sample households, we conducted a census survey listing all the households in these villages. In the first stage of sampling, the villages were classified into three groups based on elevation and distance from the sea as villages near to the sea were more prone to salinity ingress. In the second stage, the households were categorized into salinity affected and not affected households. Samples were drawn proportionately from both the categories of households; and in the third stage, the sample size was determined. Finally, a sample of 1129 households from 24 villages was drawn using random number tables. Data was collected using structured interview schedules. The survey carried out implemented during the period 2005-06

Major Findings

A look into the population, poverty and natural resource base of the coastal region shows interesting results. As per the NSS estimates, although poverty in Gujarat has declined considerably, it still continues to persist in some areas and among some groups.

It is said that there is a higher incidence of poverty in the fragile regions or where natural resources are degraded. The region wise estimates of poverty based on the National Sample Survey indicate that the head count ratio of the Gujarat Eastern region shows a declining trend in poverty from 25.79 in 1987 to 18.34 in 1999-00. However, according to some other studies, this region stands first in terms of rural and urban poverty. Although this region has a low female sex ratio, it has registered a relatively high level of female literacy. As per these estimates, poverty levels in Kutch also show a drastic decline. In Saurashtra region also the head count ratio shows a declining trend. In all the three regions more than 50 per cent of the workers are engaged in agricultural sector.

Across regions, Kutch receives the lowest annual average rainfall. As is known, the rainfall received is an important factor in the recharging of aquifers and, therefore, the availability of groundwater. According to the data provided by the Forest Survey of India, there has been a considerable decline observed in the forest cover between 1960 and 1997. In the Kutch and Sourashtra region, there has been a sharp decline in the groundwater tables. While in the Kutch region, the water tables tend to decline by 162 per cent, the decline observed is as high as 132 per cent in the Sourashtra region. Similarly, a sharp decline in the area of mangroves has been observed in the Kutch region. The decline in groundwater tables has led to the ingress of salinity in several regions of Gujarat and this in turn has led to qualitative problems of drinking water.

In this study we examined the impact of salinity ingress on domestic and drinking water use of the households. We have found that the households have to either incur additional expenses for purchase of better quality water or employ hired labour for water collection. Socio-economic characteristics of the households and the details of the households' access to and availability of water for drinking and for other domestic uses have been analyzed in detail.

The total population in the study area has been estimated to be 6231. The sex ratio is 934 although there are differences across regions. The sex ratio in the Gujarat Eastern region is 1041, where as it is as low as 908 in the Kutch region. The average size of the household works out to 5.5 and it is lowest at 4.7 in the Gujarat Eastern region. The major religion being followed in the study area is Hindu and more than seventy per cent of the population belongs to backward classes. About 67 per cent of the population is found in labour force. Almost 40 per cent of the gainfully employed persons are in the agricultural sector especially in the Gujarat Eastern and Sourashtra regions. More than 55 per cent of the households are landless in the region. The distribution pattern of land holdings reveals that a majority of the farmers belongs to small and marginal categories.

A water quality analysis reveals that both irrigation and drinking water quality is below the prescribed standards. Water samples collected from 10 wells with depths ranging from 15 to 40 feet and distances ranging from 1 to 7 kms from the sea. Show high levels of dissolved solids in water used for drinking purpose. The micro biological analysis of a water sample drawn from the most frequently used well for drinking water shows the most probable number (MPN) index very high indicating that it is not of good quality for drinking.

We have also tired to examine the major sources of drinking water for the households. By major sources we mean those sources which provide for more than 50 per cent of drinking water requirements. In the entire study area more than 60 per cent of the households were have been connected with tap water. However, in the Saurashtra region, the tap water coverage is found relatively less, while just about 3 per cent of the households are dependent on purchased water as a major source and approximately 30 per cent of them depend upon it as a secondary source. The second important sources of water for drinking and for other domestic uses are well. In Saurashtra region nearly half of the total households depend upon open wells for their domestic water use.

It has been reported that nearly 80 per cent of the total households surveyed collect water from different through places either hired labour or through their own family members. We have estimated that for every 1000 households 764 family members are engaged in water. While this figure is found as high as 839 in the Sourashtra region. It is comparatively less in other regions owing to better tap water coverage. For every 1000 households, more than 200 households engage school going children for water collection. The households cover about 0.74 kms for collecting water.

Gender aspects in water collection have also been observed. Water collection is the responsibility mainly of women members in the family. Out of every 1000 water collectors, 985 happen to be women. In Sourashtra this figure is as high as 997.

We also have tried to estimate the defensive expenditure function of the households. For estimating this function, we have used a logit model. The dummy variable in the logit model represents households incurring defensive expenditure for purchase of water or for hiring labour for fetching water. The estimated logit model shows that those households reporting water borne diseases, (living in Sourashtra and Gujarat Eastern regions) are more likely to incur this expenditure. Literacy levels of the households and their monthly expenditures taken as a proxy for income is found statistically insignificant as an explanatory variable. This indicates that irrespective of their economic status, people incur additional expenditure for obtaining better quality of water. Therefore, we argue that, more public action is required in terms of improving the drinking water sector of the coastal area rather than leaving it to the market forces.

It is also known that the continuous use of saline water affects soil structure and salt balance of the soil indicating implications for crop production. The impact on crop production can be either direct or indirect. In this study, only the direct impacts in terms of a reduction in quantity and quality of agricultural products are taken into account. We have assessed the impact of salinity on agri mainly in terms of costs and returns arising from different crops. The scenario of agriculture has been examined before analyzing the cost and returns from agriculture. Out of the 1129 households surveyed, 57 per cent are landless, and among those who possess land are largely small and marginal farmers. Across regions, households without cultivated lands are more in Kutch. However, the area under cultivation is more in Kutch as there are more number of large farmers in the region. Out of the 485 households engaged in cultivation, 337 households are affected by salinity. Only 139 households report that their lands are not affected by salinity. Among the three regions, Gujarat Eastern is the least salinity affected region in terms of the number of households reporting salinity problems. In Kutch only 12 per cent of the households have reported that their lands have not been affected by salinity. Seventy nine per cent of the 2360 acres cultivated in the study area is irrigated. In Gujarat Eastern region, over 90 per cent of the cultivated area is under irrigation.

In Sourashtra and Kutch the main sources of irrigation are open and bore wells, whereas Gujarat Eastern region has enjoys a better coverage in the form of canal irrigation. The number of wells per 100 acres of cultivated area is very high in Sourashtra and Kutch regions. In Sourashtra and Kutch regions there are 16 and 13 wells respectively, whereas it is just 3 wells per 100 acres of cultivated area in which region. A large number of crops are reported to be under cultivation in the study area; these include salinity resistant as well as non-resistant crops. The most important crops grown in the area include wheat, bajra, jowar, maize, ground nut, cotton and sugarcane.

Noticeable differences in the cropping pattern have been observed across saline and non-saline lands in all the regions. If we take region-wise look, it becomes clear that in the saline areas, the area under cereals is less in the Kutch in comparison to the other regions. In Sourashtra region, the cultivation of oil seeds is very high. In the non-saline areas of Gujarat Eastern region, the most important crops cultivated are cash crops, where as it is cereals and oil seeds in the case of Sourashtra and cereals and cash crops in Kutch.

For assessing the impact of salinity, we selected three important crops one each from the group of cash crops, cereals and oil seeds. The crops so selected are wheat, groundnut and sugar cane. We have carried out separate cost and returns analyses for each of these crops in order to understand the economics of cultivation of these crops under both saline and non-saline conditions.

A cost and return calculation of wheat gives important results. It is seen that while the non-saline farmers incur about Rs 8625 per acre for cultivation of wheat, it is Rs 10250 per acre in the saline areas. It is also seen that salinity affected farmers incur more cost for land preparation and farm yard manure, which are basically applied for regaining the fertility of soil. Seed cost for saline farmers is also observed to be very high. In other words, salinity affected farmers, in order to continue cultivation of their saline lands, incur high input costs. Significant yield differences are also observed. While non-saline farmers obtain about 20 quintals per acre, it is just 16.25 for those of saline lands.

Similar observations have been made in the case of groundnut and sugarcane. Groundnut, which is a kharif crop, is mainly cultivated in the Sourashtra region. In this case also, farmers incur higher input costs. As the survival of seedlings is very low, they incur high seed costs. In the case of groundnut, the important costs are incurred for farm yard manure and seeds. Even with higher input use, the productivity per acre is comparatively low on saline lands. The average yield from non-saline lands works out to about 15 quintals. The gross value of output per acre amount to Rs 52500 from non-saline lands and Rs 42500 from saline lands respectively.

An analysis of the costs and returns of sugarcane cultivation also shows very similar results. Here also incurred costs on land preparation, farm yard manure, etc are comparatively more for salinity affected farmers. They spend about Rs 52206 per acre for cultivation of sugarcane. Yield per acre is also less for saline lands. While the yield works out 125 quintals for non-saline lands, it is just 112.5 quintals for saline lands. It is significant to point out that when compared to non-saline land farmers, the saline land farmers spend about 46 and 48 per cent higher cost respectively for producing per unit of output of wheat and groundnut, whereas it is nearly 19 per cent for the cultivation of sugarcane.

Conclusion and Policy Implications

The present study on the impact of salinity ingress on the rural households in the coastal regions of Gujarat throws up some important insights which appear policy relevant. Salinity ingress affects quality of water for drinking and other domestic uses. Because consumption of water, not within the standards prescribed for drinking, cause health problems. This includes salinity related health problems and water borne diseases. Even in those areas where potable water is not adequately available, the tap water coverage is still not enough. It is those households lacking adequate access to and availability of tap water who incur more expenses for water purchase and collection from other sources.

With the defensive expenditure function of the households, it can be noted that a household's decision to purchase water is, to a large extent, dependent upon the potential presence of waterborne diseases in the household rather than salinity related diseases. It is no surprise as most of the salinity related health problems are chronic in nature and the effects tend to last for long, where as waterborne diseases require immediate medical attention. So the households are worried about the present loss of human days.

Although one expects that the higher a household's income, the greater is the probability of buying better quality water, we reject the hypothesis as the coefficient of the proxy variable for this is not found significant. This means that the incidence of salinity and the resultant shortage of potable water do not proportionately fall of the rich. Therefore, in places where there is shortage of drinking water, there exists an immediate need for providing safe drinking water by the government agencies concerned. Therefore, attempts should be made for a better coverage of households with safe drinking water which is tap water here.

The impact of salinity on agricultural production is also substantial. Very clear differences in production, productivity and profitability of all crops across saline and non-saline farmers are also observed. If cultivation under present conditions continues, most crops like wheat, sugarcane and groundnut might soon become unviable. Therefore, there is a need for under taking measures to control salinity propagation as well as for mitigating its effects.

There is a need for controlling indiscriminate extraction of groundwater, by promoting less water intensive crops in the water scare region together with better water harvesting facilities. Since a number of villages fall under rainfall regions, there is a need for adopting better water management practices. As a way to mitigate the effects, there is a need for planning cropping patterns, giving more emphasis on less water intensive and more salt resistant crops. Thus, in order to minimize the effects of salinity intrusion, there is a need to it is important that we carefully plan water use and management, factoring in both demand for and supply of water.

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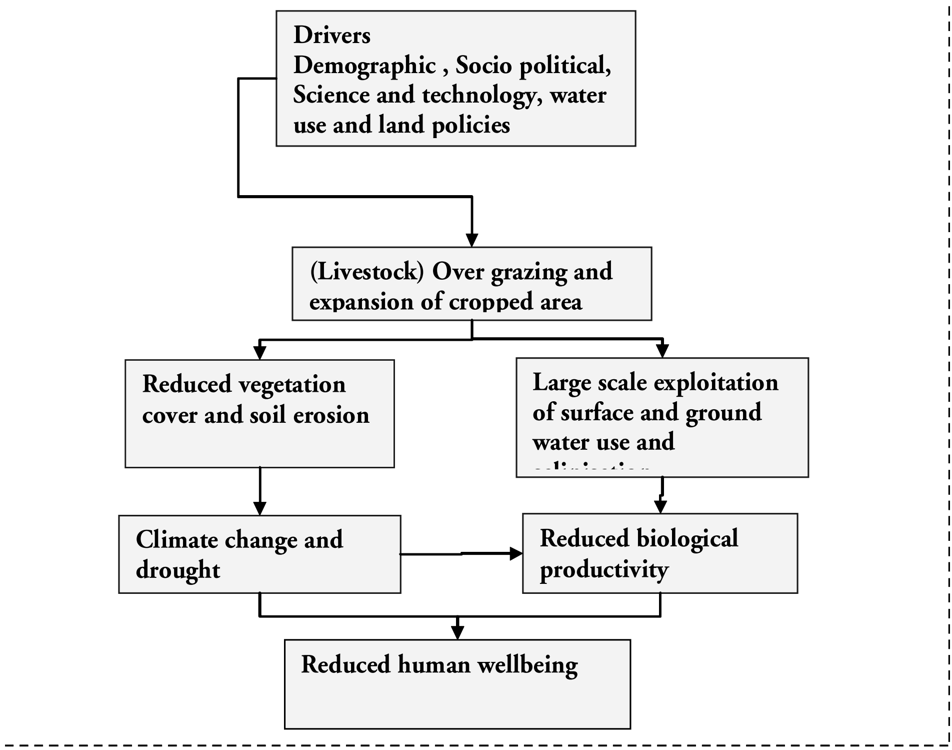
Drivers
Demographic , Socio political, Science and technology, water use and land policies
(Livestock) Over grazing and expansion of cropped area
Reduced vegetation cover and soil erosion
Large scale exploitation of surface and ground water use and
Climate change and drought
Reduced biological productivity
Reduced human wellbeing

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