USE OF REMOTELY SENSED DATA AND GIS TECHNIQUES FOR ASSESSMENT OF WATERLOGGED AND SALT-AFFECTED AREA TEHSILWISE IN MUKTSAR DISTRICT OF PUNJAB

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ABSTRACT

The introduction of canals made the state of Punjab surplus in food grains but at the same time same time this also led to the development of waterlogging and subsequent salinization, rendering large chunks of land unproductive. Remote Sensing and GIS (Geographical Information System) techniques can be extremely useful in accurate mapping and quantification of waterlogged area and salt-affected soils. Thus helping in preparing a sound database required for taking up various reclamative and preventive measures. In this study visual interpretation of satellite data, IRS 1D LISS III + PAN merged data of 11th March 2001 and IRS 1D LISS III data of 2nd September 2001, authenticated by ground truth was carried out for delineation of pre monsoon and post monsoon waterlogged areas and pre monsoon salt-affected soils in Muktsar district. The area affected by waterlogging is found to be 1116.13 ha (0.42%) and 1802.42ha (0.68%) respectively during pre and post monsoon season. The land affected by salinity during pre monsoon is 1320.91ha (0.50%).The waterlogging follows a north-east to south-west direction and is predominant along the western side of twin canals (Sirhind and Rajasthan Feeder). Gidderbaha tehsil with 387.15ha (0.58%) during pre monsoon and Muktsar tehsil with 695.18ha (0.77%) during post monsoon is most affected by waterlogging, while Muktsar tehsil with 774.01ha (0.86%) is most affected by salinity during pre monsoon season. Improper alignment of canals, canal seepage, drainage congestion, brackish groundwater, faulty irrigation practices and cultivation of high water requirement crops are some of the factors contributing to the problem. These problems are further compounded by natural factors such as existence of topographic depressions, buried palaeochannels, absence of natural drainage and incessant rains.

INTRODUCTION

There has been a spectacular increase in food grain production in Punjab, especially after the initiation of green revolution. The cultivated irrigated area increased from 54 percent to 95 percent, while cropping intensity increased from 126 percent to 187 percent between 1960-61 and 1995-96 (Sharma, 2003). The introduction of extensive and enhanced system of canal irrigation system throughout the state could be attributed to as one of the major factors contributing to this phenomenal increase. However, due to lack of proper investigations taken up at the planning stage itself of canal introduction, without keeping in view of the regional/local topography, groundwater table, geomorphology, soil resources and cropping pattern of the area has resulted in

large scale land degradation of land and soil resources due to waterlogging and subsequent salinization. In addition to this natural factors such as topographic depressions, absence of natural drainage and incessant rains have further compounded the waterlogging and salinity problems. Spate of newspaper articles in Punjab, on the waterlogging and salinity problem especially in south-western districts, have been highlighting the problem from time to time.

Due to the incessant rains during August 1997, waterlogging became an acute problem in the entire cotton producing belt (i.e. south-western districts) of the state. The menace of waterlogging assumed alarming proportion especially in and around Muktsar district. (Dhillon, 1997).The cotton fields were converted into big lakes due to incessant rains (Walia, 1997). In Muktsar district 12.29% of the total geographical area was estimated to be affected by surface and sub-surface waterlogging during the year 1997 (Chopra et.al. 1998).During the year 1998 only Muktsar district suffered a loss of rupees two-hundred crores cotton crop due to waterlogging according to Department of Agriculture (Bhamrah, 1998).

Every year special girdawari (revenue) surveys are carried out by the district administration for the assessment of damaged crops and villages affected by waterlogging. Due to waterlogging and subsequent salinization, the fertile productive land is gradually becoming unproductive. And the owners of these lands are now being forced to work for petty amounts and low profile jobs (Chana, 2003). Keeping in view the above situation, an attempt has been made to delineate, map and quantify the spatial distribution of waterlogged area and salt-affected soils during 2001, using remotely sensed data and GIS techniques. And to find out the possible causes responsible for the problem and remedial measures to be taken.

STUDY AREA

The study area lies between latitudes 29° 54’ 15.95” and 30° 40’ 9.57” N and longitudes 74° 14’ 56.00” and 74° 49’ 22.34” E, having an aerial extent of 263121ha. It is located in south-western part of Punjab. It is bounded by the state boundaries of Rajasthan and Haryana in the south whereas; it is bordered by the district boundaries of Faridkot in the north, Ferozpur in the west and by Bathinda in the east (Figure1). There are 234 villages constituting three tehsils (Muktsar, Malout and Gidderbaha) and four blocks (Muktsar, Malout, Lambi and Kot Bhai at Gidderbaha).

Physigraphically, the area is nearly level with a very gentle slope in NE-SW direction. Lithologically, the area is a part of the vast Indo-Gangetic alluvial plain, comprising of alternate bands of sands, silt and clay with pebbles. Sandy plains, sand dunes and topographic depressions are the common landforms. The general relief of the area varies between 185m to 219m above sea level (msl). Climatically, the western Himalayas in the north and the Thar Desert in the south and south-west mainly influence the climatic conditions.

The area is intensively cultivated (except for high dunes) and mostly irrigated. Wheat and cotton are the main crops in rabi and kharif season.

However, the area under paddy is increasing replacing cotton crop. The area is mainly irrigated through the Sirhind and the Rajasthan Feeder canals and its distributaries.

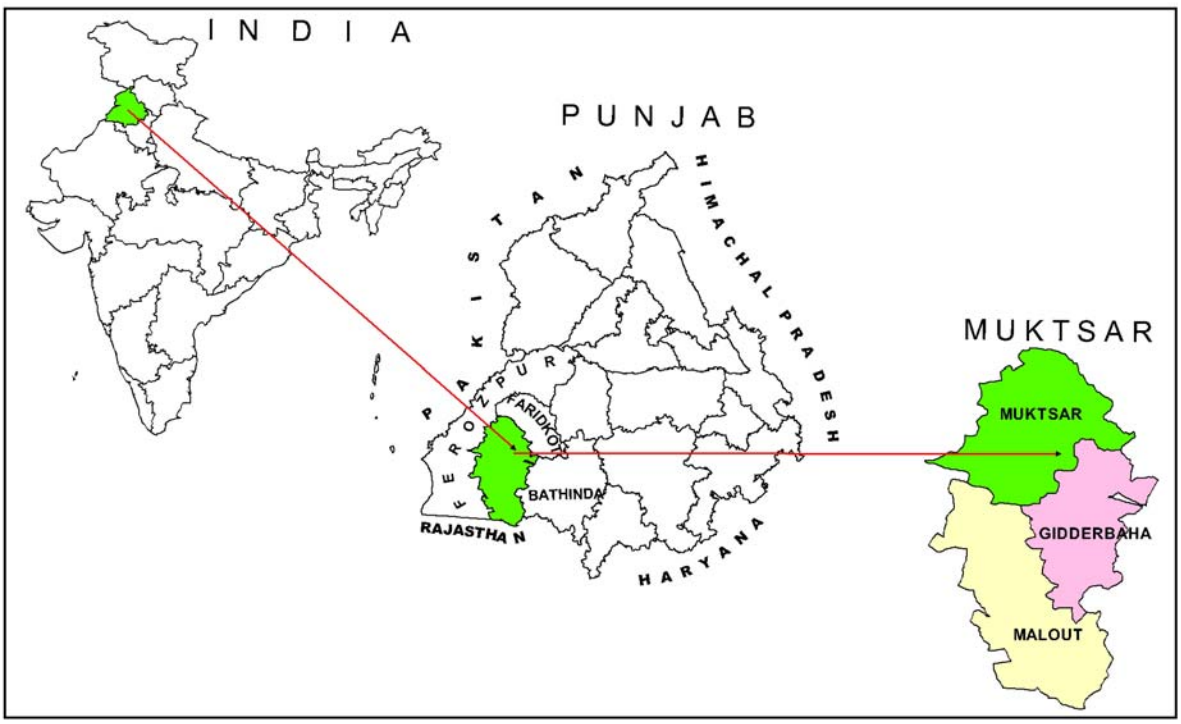

Figure 1. Location of the study area.

METHODOLOGY

A systematic visual interpretation of the IRS-ID, PAN and LISS-III (11, March) merged satellite data and IRS-ID, LISS-III (2, September) satellite data (Figure2a&b) for the year 2001 on 1:50,000 scale, by overlaying the base map and other ancillary information, was carried out for delineation of the pre and post monsoon waterlogged area and pre monsoon salt affected soils. Based on the differential manifestations in the form of tone, texture, pattern, shape, size and association the waterlogged area and salt affected soils were characterized and classified under different categories.

The waterlogged area (Figure3&4) was classified under two categories one where there was clear surface ponding as “waterlogged area” and other where there was high moisture content as “area sensitive to water logging”. The waterlogged area was very clear in dark blue to bluish black tone during pre monsoon and in bluish black to light bluish tone during post monsoon, whereas the area sensitive to waterlogging appeared in light gray to dark grayish tone during pre monsoon and light to dark brownish gray tone during post monsoon season.

The area under salinity (Figure5) was also classified under two categories one where the salt efflorescence was clearly visible on the image as “salt affected” land and the other where there was saline land having a little crop cover as “saline soils with patchy crop”. The salt affected area appeared in

white to yellowish white tones whereas the saline soils with patchy crop appeared in dull white to grayish red tone with red mottling. The merged data used for pre monsoon due to high spatial and a better spectral resolution allowed mapping of scattered small patches of waterlogged and salt affected areas and also in a better delineation of sensitive areas of waterlogging.

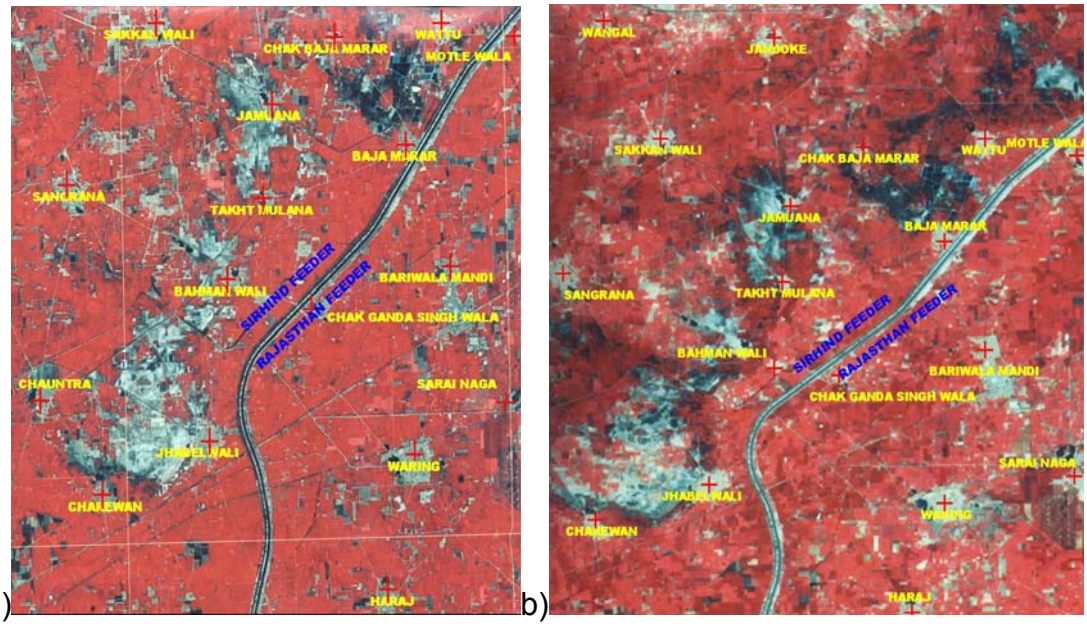

Figure2.Waterlogged and salt-affected areas in parts of Muktsar block. (a) IRS ID PAN+LISS III, March 2001 (pre monsoon) (b) IRS ID LISS III, September 2001 (post monsoon).

Field survey was undertaken to check the interpreted units and find out the causes for the land degradation by waterlogging and salinity. The local farmers were interviewed about water table depths, salinity problems, villages under water logging, cropping pattern, crop productivity, canal seepage and other possible reasons for water logging and salinity in the area.

Tehsil boundary maps were overlaid over the waterlogging and salinity maps for the area estimation tehsilwise in GIS (ARC GIS software Version 8.2) environment. Based on the satellite interpretation, field survey and area statistics major causes responsible for the problem and remedial measures to be taken up to alleviate the problem were suggested.

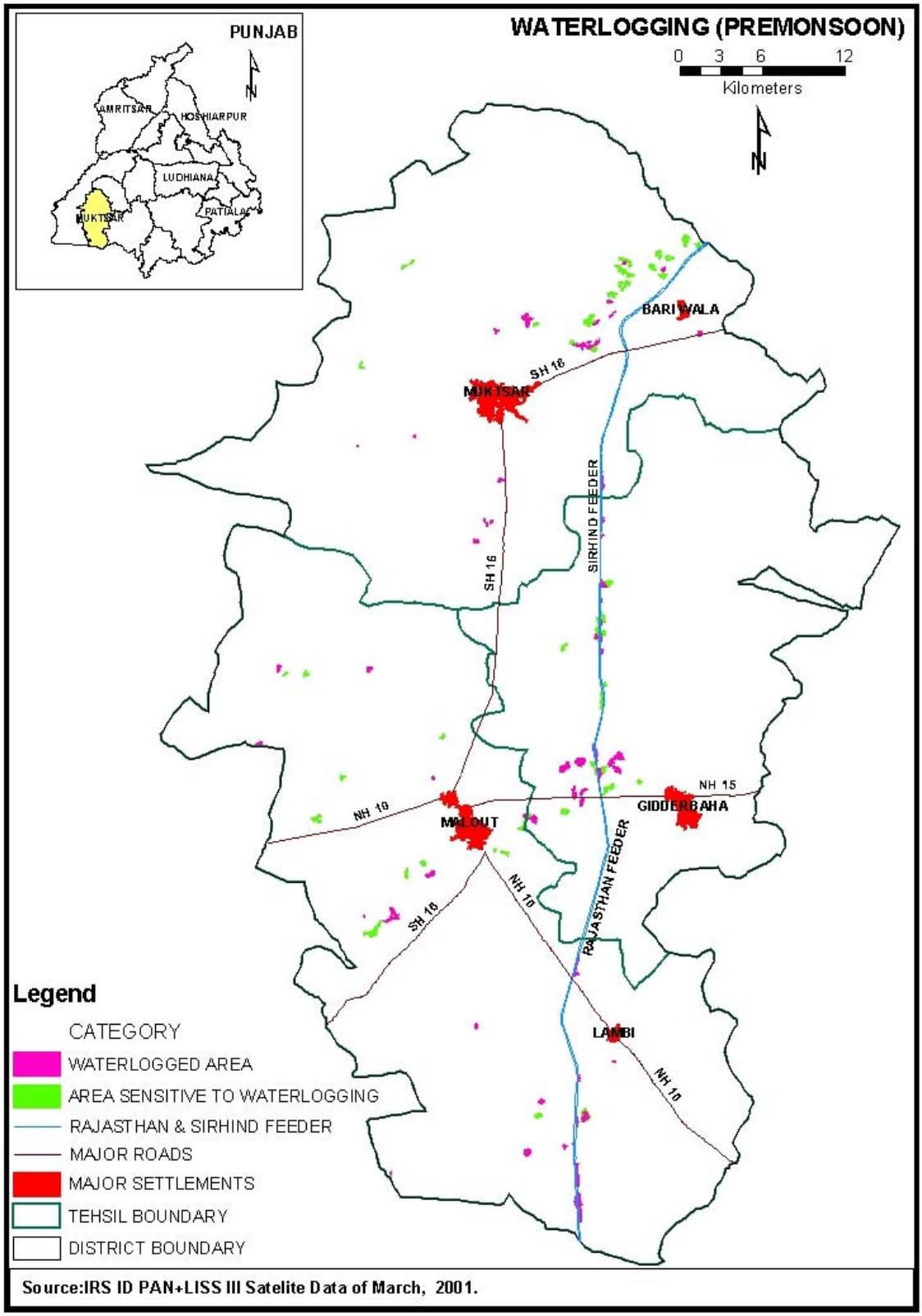

Figure 3. Map showing waterlogged and sensitive areas to waterlogging during pre monsoon season.

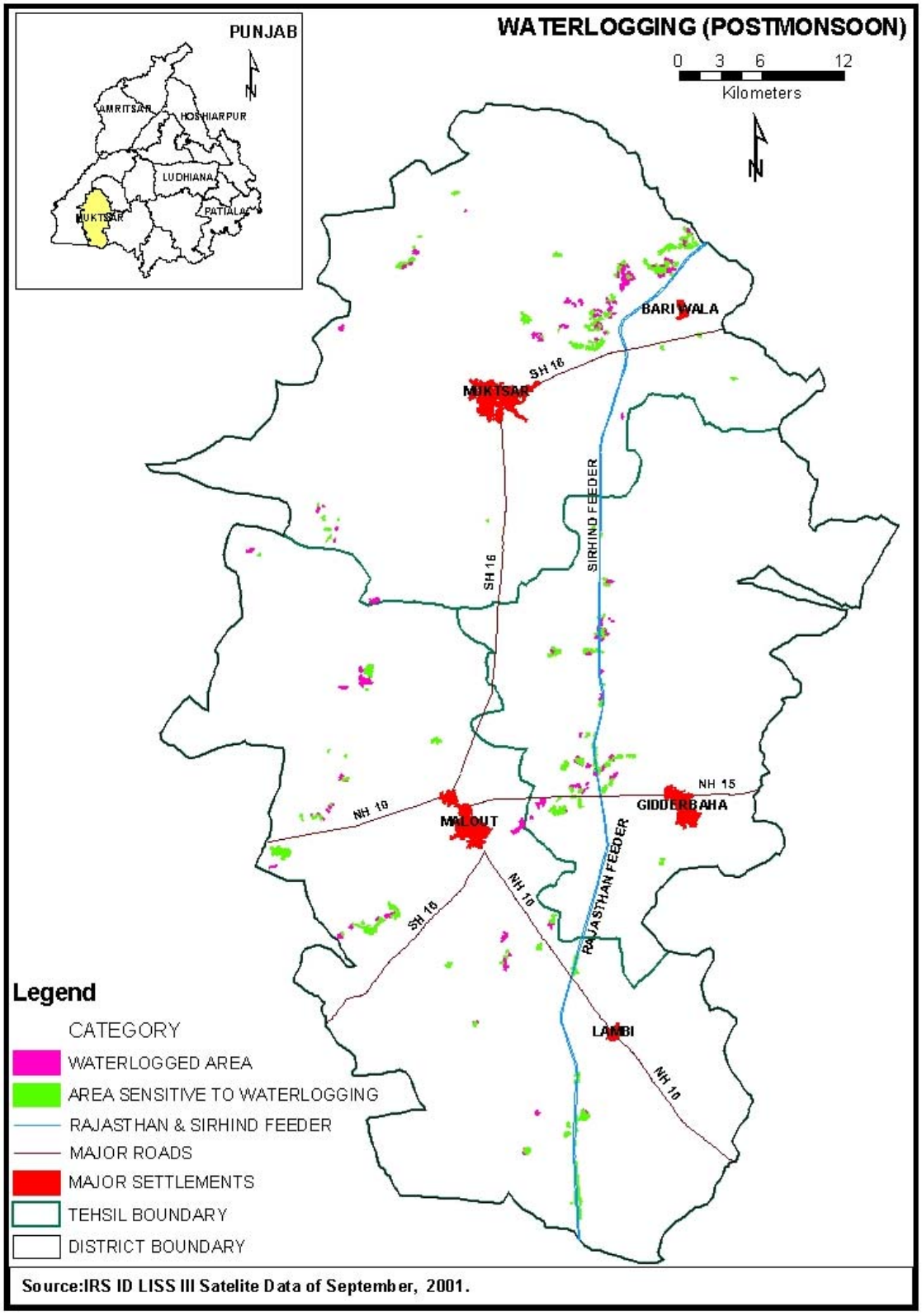

Figure 4. Map showing waterlogged and sensitive areas to waterlogging during post monsoon season.

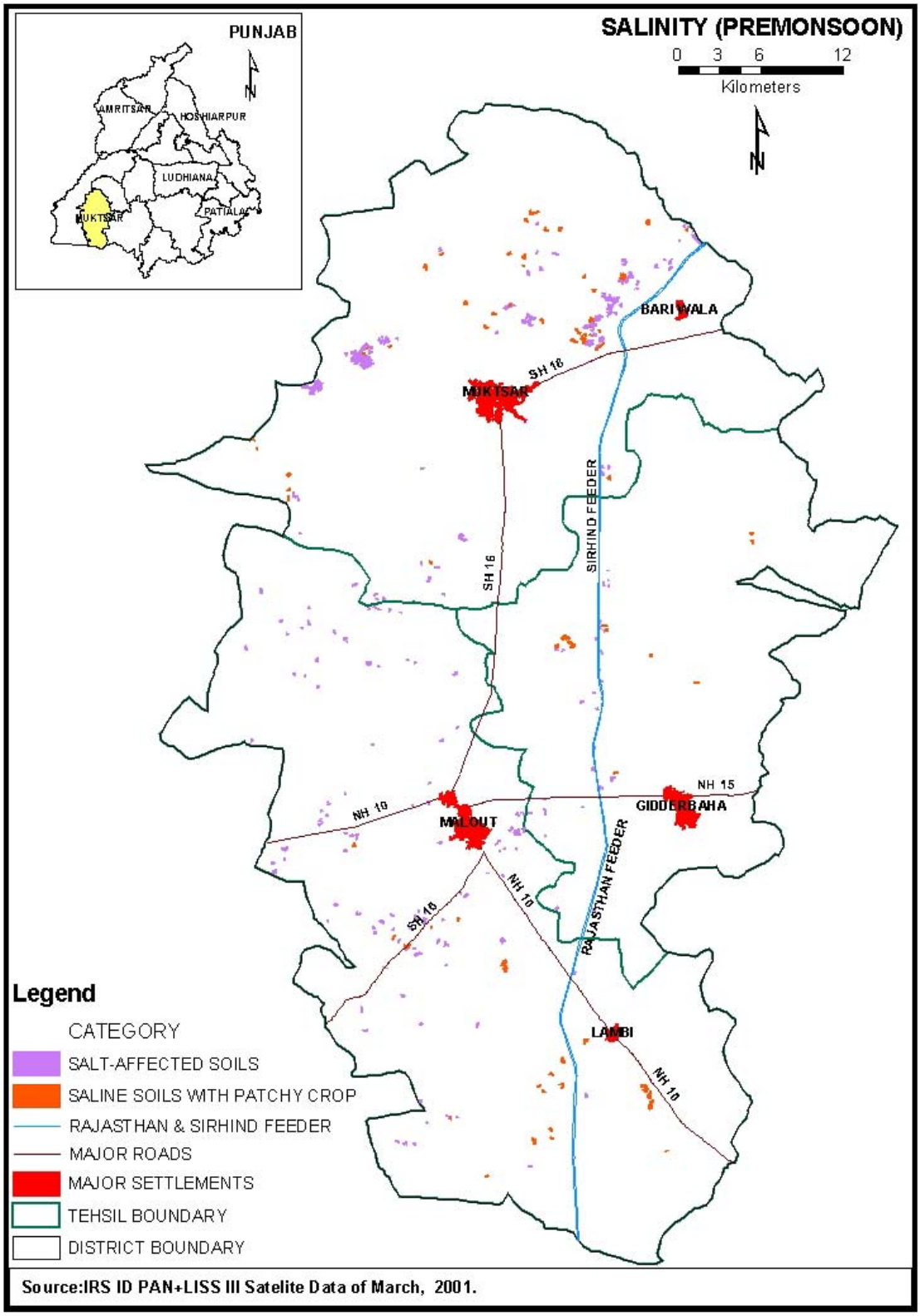

Figure 5. Map showing salt-affected and saline soils with patchy crop cover during pre monsoon season.

RESULTS AND DISCIUSSIONS

The waterlogging was found to be predominant along the western side of the twin canals (Sirhind and Rajasthan Feeder), following a particular pattern i.e. occurring in a north-east to south-west direction.

The area statistics generated through spatial database created in GIS (Geographical Information System) environment reveals that out of the total geographical area (263121 ha) of Muktsar district 0.42% or 1116.13 ha of land during pre monsoon, 0.68% or 1802.42 ha of land during post monsoon is affected by waterlogging and 0.50% or 1320.91 ha of land during pre monsoon is affected by salinity (Table1). Of the total land affected by waterlogging, 0.22% or 584.58 ha area is waterlogged and 0.20% or 531.55 ha area is sensitive to waterlogging during pre monsoon and 0.44% or 1154.69 ha area is waterlogged, 0.24% or 647.73 ha area is sensitive to waterlogging during post monsoon. And of the total land affected by salinity, 0.36% or 937.72 ha of area has salt affected soils and 0.14% or 383.19 ha of area has saline soils with patchy crop cover during pre monsoon (Table1).

Table 1: Pre monsoon and post monsoon waterlogged and salt affected soils area statistics for Muktsar district.

District Area (ha)	Category	Pre Monsoon ha (%)	Total Area ha (%)	Post Monsoon ha (%)	Total Area ha (%)
Muktsar 263121	Waterlogged Area	584.58 (0.22)	1116.13 (0.42)	1154.69 (0.44)	1802.42 (0.68)
	Area Sensitive to Waterlogging	531.55 (0.20)		647.73 (0.24)	
	Salt Affected Soils	937.72 (0.36)	1320.91 (0.50)	Not Assessed	Not Assessed
	Saline Soils with Patchy Crop	383.19 (0.14)			

Note: Figures in parenthesis are percentage of the total geographical area of the district.

During pre monsoon Gidderbaha tehsil (0.58% or 387.15 ha) and during post monsoon Muktsar tehsil (0.77% or 695.18 ha) has maximum area affected by waterlogging (Table2). During pre monsoon Muktsar tehsil (0.86% or 774.01 ha) has maximum area affected by salinity (Table3). Of the 234 villages in the district 56 villages (22 in Muktsar, 23 in Malout and 11 in Gidderbaha tehsil respectively) during pre monsoon and 62 during post monsoon (26 in Muktsar, 24 in Malout and 12 in Gidderbaha tehsil respectively) are affected by waterlogging. Total 110 villages (41 in Muktsar, 53 in Malout and 16 in Gidderbaha tehsil respectively) are affected by salinity during post monsoon season.

Total 0.17% or 447.80 ha land (of total district area) remains affected by waterlogging throughout the year, affecting 44 villages (16 in Muktsar tehsil, 17 in Malout tehsil and 11 in Gidderbaha tehsil).Total 47 villages (19 in Muktsar tehsil, 18 in Malout tehsil and 10 in Gidderbaha tehsil) remain affected by waterlogging and salinity problem during pre monsoon season.

Table 2: Pre monsoon and post monsoon waterlogged area statistics tehsil wise.

Season	Tehsil	Tehsil Area ha	Category		Area Tehsil wise ha (%)	Villages Affected
			Waterlogged Area ha (%)	Area Sensitive to Waterlogging ha (%)		
Pre Monsoon	Muktsar	90275	132.10 (0.15)	230.62 (0.25)	362.72 (0.40)	22
	Malout	106379	224.30 (0.21)	141.96 (0.13)	366.26 (0.34)	23
	Gidderbaha	66467	228.18 (0.34)	158.97 (0.24)	387.15 (0.58)	11
Total	Distt. Area	263121				56
Post Monsoon	Muktsar	90275	430.43 (0.48)	264.75 (0.29)	695.18 (0.77)	26
	Malout	106379	431.04 (0.40)	225.94 (0.22)	656.98 (0.62)	24
	Gidderbaha	66467	293.22 (0.44)	157.04 (0.24)	450.26 (0.68)	12
Total	Distt. Area	263121				62

Note: Figures in parenthesis are percentage of the total geographical area of the tehsil.

Table 3: Pre monsoon salt affected area tehsil wise.

Season	Tehsil	Tehsil Area ha	Category		Area Tehsil wise ha (%)	Villages Affected
			Salt Affected Soils ha (%)	Saline Soils with Patchy Crop ha (%)		
Pre Monsoon	Muktsar	90275	582.38 (0.65)	191.63 (0.21)	774.01 (0.86)	41
	Malout	106379	290.08 (0.27)	141.04 (0.13)	431.12 (0.40)	53
	Gidderbaha	66467	65.26 (0.10)	50.52 (0.07)	115.78 (0.17)	16
Total	Distt. Area	263121				110

Note: Figures in parenthesis are percentage of the total geographical area of the tehsil.

The relationship between pre and post monsoon waterlogged area (Figure6) shows that increase in waterlogged area for Muktsar tehsil (increase of 0.37%) is maximum and for Gidderbaha tehsil (increase of 0.10%) it's the minimum. The relationship between waterlogging and salinity for pre monsoon season (Figure7) shows that for all tehsils area under salinity is more except for Gidderbaha tehsil, where area under waterlogging is more.

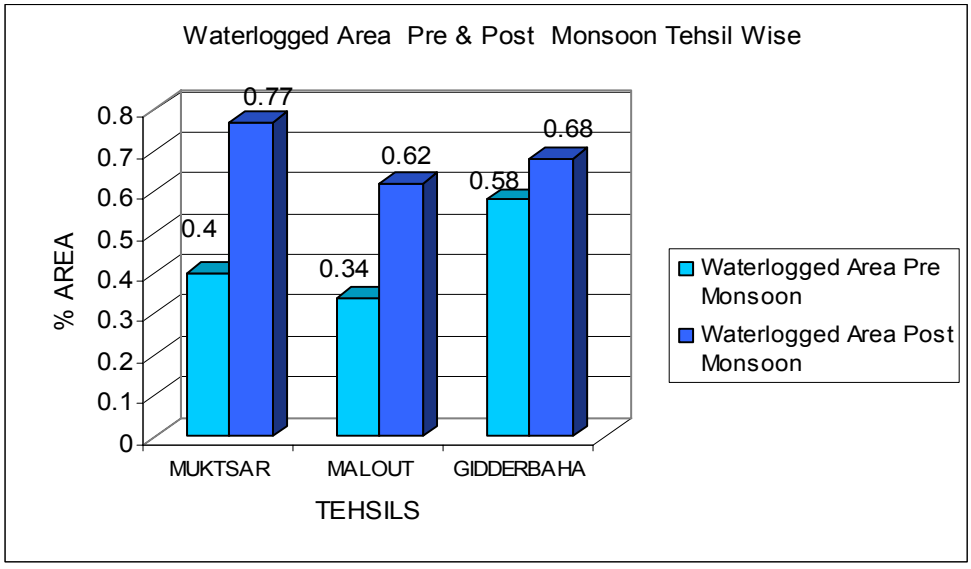

Figure 6. Relationship between waterlogged area during pre and post monsoon tehsil wise.

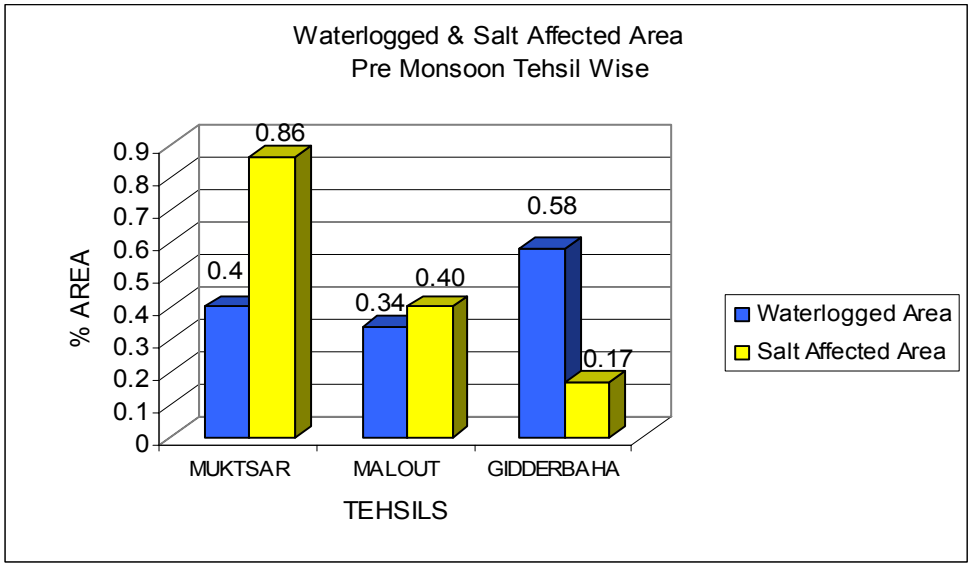

Figure 7. Relationship between waterlogged and salt affected area during pre monsoon tehsil wise.

The satellite data interpretation and field survey clearly reveal that waterlogging and salinity problem in Muktsar tehsil is mainly due to the presence of numerous natural topographic depressions and buried palaeochannels. These channels especially during post monsoon get activated bringing down excess rain and irrigation water from topographically higher regions i.e. central part of Punjab. This is the reason for the increase in area under waterlogging in Muktsar tehsil during post monsoon season. Whereas, in Gidderbaha tehsil the waterlogging problem is mainly the result of canal seepage, occurring from the damaged canal lining portions. Therefore, areas near canal banks are found to be permanently waterlogged in this tehsil. This is the reason for a greater area under waterlogging as compared to salinity during pre monsoon season in Gidderbaha tehsil.

Causes of Waterlogging and Salinity

The satellite data interpretation and physical verification of the waterlogged and salt affected land reveal the following main causes responsible for the waterlogging and salinity problem in Muktsar district.

1) **Canal seepage:** The seepage from the unlined and damaged portions of lined canal beds and distributaries contribute significantly to the waterlogging and subsequent salinization problem. The borrow pits excavated near the canal in filling are continuously submerged by the seeping water from the canals and also from irrigation and rain water as well. Canal seepage can be clearly seen along Sirhind and Rajasthan feeder in Gidderbaha tehsil in the satellite imagery as well as during the field survey.

2) **Brackish quality of groundwater:** Due to the brackish nature exploitation of groundwater is less then 60% of its annual utilization. Nearly 61% (Figure8) area of the district has poor quality groundwater out of which 37% area has saline to highly saline, 19% has saline-sodic and 5% area has sodic waters (Sharma et.al.,2003).The erratic rainfall and water allocation to farmers meet only about 50% of the demand, hence the farmers are forced to make use of

brackish ground water in order to compensate for the shortfall which ultimately adds to salt accumulation in the soil and affects the crop yield adversely (Figure9). Secondary salinity appears to be linked to the use of poor quality water drawn from the water table with a higher salinity than water drawn from the irrigation canals.

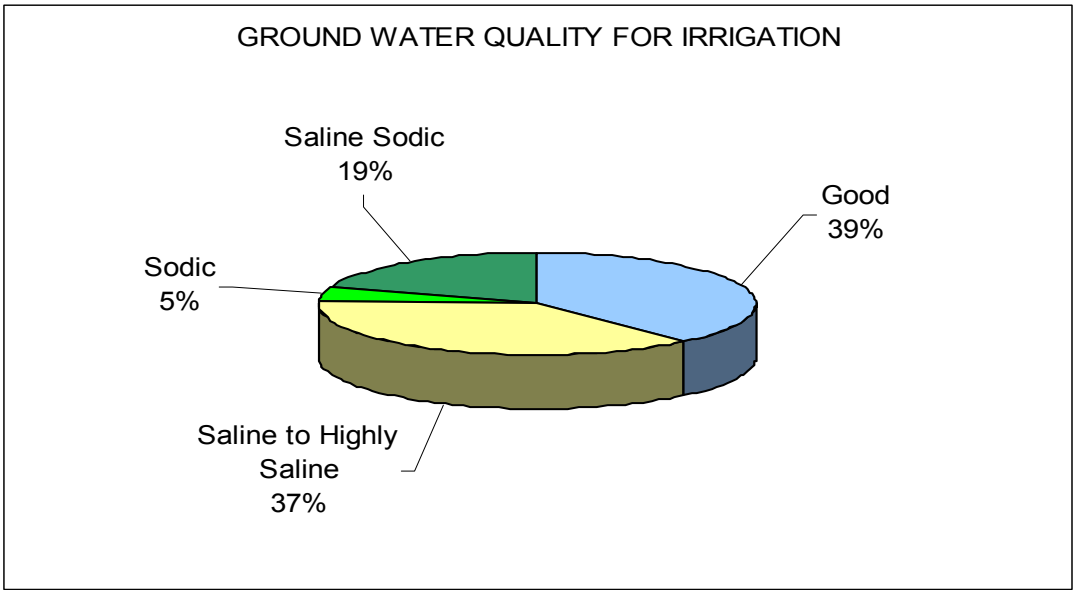

Figure 8. Area under different ground water quality zones in Muktsar district.

Figure 9. Soil surface covered with white salt crust. Village: Baja Marar, Tehsil: Muktsar.

3) **Improper alignment of canals:** The Rajasthan and Sirhind Feeder canals (twin canals) originating at Harike cut across the natural gradient this in turn disturbs the hydrological equilibrium of the area. This cutting across of the natural drainage by the twin canals leads to the pounding of monsoon runoff on the upstream side of the structures thus increasing the water table and aggravating the water logging problem.

4) **Buried palaeochannels and topographic depressions:** There exists a well defined channel network of the buried palaeochannels left by once flowing Sutlej River through the region. These channels especially during monsoon season get activated and bring down excess rainfall and irrigation water applied to the paddy fields from the central part of Punjab, which is at a topographically higher elevation then the south-western part. The area having a low lying topography has numerous topographic depressions (especially in Muktsar tehsil), which are poorly drained topographically and remain waterlogged throughout the year (Figure10). Thus allowing a greater detention of water on the land causing more percolation and an increase in the ground water table, contributing towards waterlogging and subsequently salinity. These depressions have fine grained soils where by the primary salinity appears to be linked.

Figure 10. Surface ponding in natural topographic depressions. Village: Sarai Naga, Tehsil: Muktsar.

5) **Inadequate Drainage:** Although formulation of the irrigation projects and the drainage both should go hand in hand, however drainage being an essential component has not been given the attention that it deserved. Muktsar area because of having low lying topography and being devoid of any natural streams, rain water falling over the land and the excess irrigation water in absence of proper drainage constantly percolates down raising the water table. The sand ridges covering the entire district have been flattened for cultivation, these ridges provided quick removal of excess rain water due its natural slope.

6) **Drainage Congestion:** The field survey has shown that most of the drains constructed for dewater logging the areas have been choked by debris and weed growth (Figure11). Thus having reduced there carrying capacity and loosing the main objective but contributing to the rising of water table. Due to which there is no proper disposal of excess water during post monsoon season which leads to subsequent rising of the water table and hence contributing to waterlogging problem.

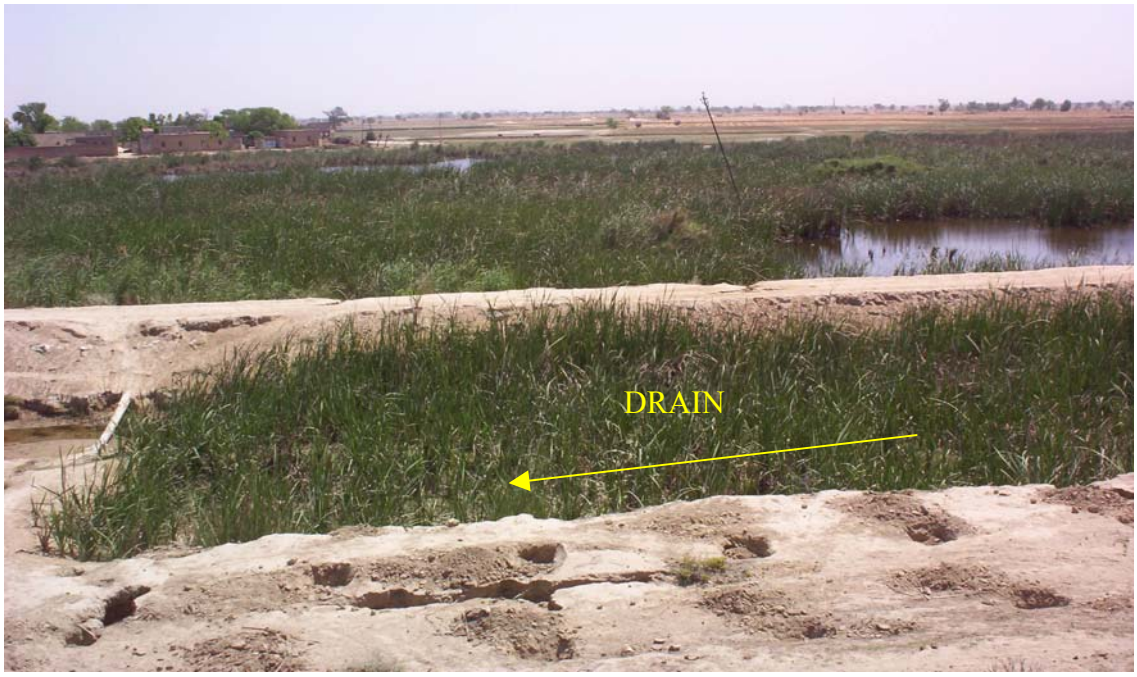

Figure 11. Drainage congestion due to wild grass growth. Village: Theri, Tehsil: Gidderbaha.

7) **Incessant rains:** The heavy showers during monsoon season at times are also responsible for waterlogging. The area being low lying and devoid of any natural streams soon turns up into a ponded zone. In the years of above normal rainfall, the run off water accumulates in low lying areas resulting in flooding and subsequent water logging.

8) **Faulty irrigation practices:** Farmers of the district mostly practice flood irrigation and still have to be accustomed to scientific practices of irrigation. The water percolating through the soil profile contains majority of the salts left behind by evaporation and transpiration phenomenon. As the water moves through the soil profile, it may pick up additional salts by dissolution. In addition, some salts may be precipitated in the soil; while there will be an exchange between some salt ions in the water applied to the land. Thus over irrigation also results in degradation of ground water quality.

Remedial Measures

The steps that area needed to be taken up immediately and in long term for the management of waterlogged and salt affected area:

1) **Prevention of canal seepage:** A considerable amount of water is lost from the conveyance structures in the form of seepage losses, which ultimately increase the water level and hence account for waterlogging problems. Therefore, considerable attention is needed for lining of all the damaged portions of canal network system from time to time. Borrow pits dug up while constructing canals need to be filled with sediments so that seepage water does not collect in there. Tree plantation along canal banks especially the borrow pits excavated during canal construction and also in other waterlogged areas can aid evaporation.

2) **Conjunctive use of saline/sodic groundwater:** The brackish/saline groundwater should be used to irrigate the crops by mixing it with canal water to ameliorate the bad effect of such water. This would help in bringing down the high water level and also in coping with shortage of water in the district. Conjunctive/alternative use with good quality water and proper soil water management practices will help in maintaining a favorable salt-water balance and the crop yields would be affected to the minimum.

3) **Adequate surface drainage:** For quick removal of surface runoff, construction of more surface drains following the natural gradient is required. The surface drains need to be properly maintained and reconditioned from time to time, with due attention before the onset of monsoons. The existing drains should be cleared of the weeds and the sediments, which have reduced there carrying capacity and hence there primary objective. Further all the surface drains should be linked to the field drains through link drains for proposal disposal of excess water; else there construction won't solve the purpose.

4) **Efficient farm management practices:** Various farm management practices can aid in controlling or reducing the impact of waterlogging and salinity.

Use of special planting procedure, sloping beds, other special land preparation procedures and tillage methods to provide a low salt environment. Selection of crop varieties that have higher tolerances for salt or sodium. Use of surface mulches which help in leaching and reduction of water evaporation and salt accumulation on soil surface. Good, sound farming practices and careful fertilizer management. Use of the appropriate irrigation method for the root characteristics of the crop. Use of physical amendments such as manure, compost, etc. for improving soil structure and tilth. Conservation tillage to incorporate crop residues will help create drainage. Deep ripping of soil to break up sodic and other hardpans or other impervious layers to provide internal drainage. Adding gypsum to offset the enhanced alkalinity of the soil.

5) **Alternative use of land :** The land that is sensitive to waterlogging or has been affected can be utilized for occupations like dairy, poultry, bee keeping and floriculture which can pay rich dividends to the farmers of the area, provided the government and the district administration ensures marketing of there products. Similarly fisheries can also work wonders in the area as there are species of fishes which can flourish better in saline/brackish water. This will help in bringing the high water level below in the area in due course of time.

6) **Proper investigation for all irrigation projects:** Investigations should be undertaken in future for all irrigation related projects at the planning stage itself to evaluate the likely impact of irrigation on the extent of possible rise of groundwater table and more so in regard of possibility of waterlogging and drainage congestion. Provision of drainage, thus should be an integral part of any project to be taken up at the formulation stage itself.

7) **Implementation of projects:** All the projects recommended earlier due to the acute waterlogging problem in the region and that have been left halfway or not yet started need to be completed immediately at priority basis. Most of the

dewater logging pumps installed (viz. Malout tehsil) to make the area free from waterlogging need immediate operalization, as the water level that had receded is once again rising. The progress of the work to be monitored regularly, keeping in mind the seriousness of the problem to the fertile agricultural land.

8) **Use of remotely sensed data and GIS:** Multi-temporal satellite data should be used for continuous monitoring of the waterlogging dynamics. Integrated analysis of spatial and non spatial data parameters in Geographical Information System (GIS) environment must be made use of for any kind of decision making.

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