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Inland Salinity Management Options for Punjab

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Abstract: Inland salinity is caused due to practice of surface water irrigation without consideration of ground water status. The gradual rise of ground water levels with time has resulted in water logging and heavy evaporation in semi arid regions lead to salinity problem in command areas. Inland salinity in ground water is prevalent mainly in the arid and semi arid regions of Rajasthan, Haryana, Punjab and Gujarat and to a lesser e xtent in Uttar Pradesh, Delhi, Madhya Pradesh Maharashtra, Karnataka, Bihar and Tamil Nadu. In India, the problem of salinity and alkalinity increases every year as a result of secondary salinisation.

In South West Punjab areas which include districts of Firozepur, Faridkot, Bhatinda, Mansa, Muktsar and Sangrur are affected by water logging due to seepage of water from canal and salinity due to salts on the surface appeared as a white salt encrustation. In the southern part of Bhatinda district Jajjal and Bagi bander are showing a maximum rise in water level around 0.05 to 0.13m/yr. because of negligible withdrawal of ground water and recharge through Bhatinda and Kotla branch canal irrigation water. In some parts of Muktsar district, waters are likely to cause both sodium and salinity hazards. Such sorts of salinity problems in irrigated agriculture prevail in some parts of Firozpur, Faridkot, Mansa and Sangrur districts also.

In order to arrest the rising trend and to save the area becoming water logged, the phreatic aquifer system is to be exploited and used the water in the conjunctive use of ground water and surface water for irrigation purpose. Cropping pattern may be changed. Drip irrigation system may be embodied which will reduces the recharge to ground water. The canal system may be monitored and breaching of canal may be repaired to decrease the ground water recharge from the canal.

Emphasis should be given on construction of multiple well point systems in linear or triangular grid pattern in massive scale to exploit maximum quantity of fresh quality of groundwater with regulated pumping for irrigation purpose, which do not mix floating good quality groundwater with the underlying saline groundwater avoiding up coning of fresh-saline water interface and create more subsurface storage for fresh ground water lenses formed from rainwater, canal seepage and return flow in the salinity affected plains of Punjab state.

An in depth study was carried out during the year 2009 at Sundarbans to investigate coastal salinity. A few of the lessons have been incorporated in this paper to aid the salinity situation in Punjab. Salt tolerant crops have been listed to improve the socio economic conditions of the farmers.

Key words: Punjab, Inland salinity, Coastal salinity, Salt tolerant crops, Sundarbans, UNESCO Heritage site.

INTRODUCTION

In India, inland salinity occurs in Rajasthan, Gujarat (both states are quite arid), Haryana, Maharashtra, Punjab, Delhi, Uttar Pradesh, Bihar, Delhi, Madhya Pradesh and in the interior areas of Karnataka and Tamil Nadu.

Inland Salinity problems become aggravated in the semi-arid region of Punjab state with rising trends in water table and their quality deterioration after the introduction of canal networks. Provision of subsurface drainage systems are needed to avoid salinity damage to plants. But several socio-economic, administrative and organizational constraints are hindering the drainage installations on a large scale. Thus vast areas of saline soils continue to remain barren. Some of the special management practices like proper selection of tree species, planting techniques, post-planting irrigation to control salt fluxes.

As the name suggests, inland salinity is not caused by the ingress of saline sea water. It is in fact mainly caused by man's actions. Inland salinity is caused by a number of factors. One of the most common is when forests or other deep root plants are cleared to make way for plants with shorter roots, typically crops. The short rooted plants use up less water, and more water percolates downward. This causes the water table to rise and so ironically causes the water to go saline due to contact with sources of salts, such as rock, saline soil etc as well as due to a much greater rate of evaporation near the surface. A similar situation arises when surface water is used inappropriately .Water logging of fields causes a similar effect, especially in arid or semi-arid areas where the rate of evaporation is quite high. Inland salinity can also be caused by the leaching of certain fertilizers and industrial effluents. This has an adverse effect on the socioeconomic status of the farmers as they are not well conversant with salt tolerant crops or irrigation management using saline water.

IRRIGATION MANAGEMENT IN AGRICULTURE WITH SALINE WATER

An improvement in the quality of saline water is considered essential in areas, where farmers are compelled to use saline water for irrigation. Plant growth is affected by saline water because of higher osmotic tension of soil solutions. As there is a limit to salinity beyond which the water cannot be successfully used for crop production, there is a necessity to undertake measures to improve the quality of saline water. The quality of saline irrigation water may be improved considering the following measures (Majumder, 2009):

- Use of powered gypsum in water containing a high amount of sodium (Na) and relatively low amount of total salts. Gypsum dissolves in water on agitation and reduces the Sodium Adsorption ratio (SAR) of the soil solution.
- Mixing fresh water with saline water to reduce the salt concentration below the level that may cause plat injuries. To overcome inadequacy of fresh water, it may become available from harvested rain water during monsoon season.
- Leaching process may be adopted for removing soluble salts from surface soils. It is the process of dissolving the soluble salts and removing the same from surface soils by downward movement of water. To leach out the excess salts, water is applied in a more quantity more than the normal requirement of the crop to avoid accumulation of salts in top soil. Leaching of soil occurs by ponding irrigation water on the soil surface by borders and allowing a downward movement of water through the soil column. Rectangular checks and level borders are used when the land is level and contour checks are used when land slope is more. Intermittent ponding of water may be adopted for effective leaching. Irrigation water requirement considering with leaching may be estimated as:

  $D_{iw} = D_c + D_d = EC_d/(EC_d - EC_{iw}) * D_c$
  [Leaching Ratio (LR)=$D_d/D_{iw}=EC_{iw}/EC_d$]

  where, D_c- Depth of irrigation water (cm)
  D_d- Depth of drainage water (cm)
  EC_d- Electrical conductivity of drainage water (mmhos/cm)
  EC_{iw}-Electrical conductivity of irrigation water (mmhos/cm)
- There are a few desalination technologies like distillation under low pressure, electrolysis with canvas membrane, reverse osmotic process, solar humidification, freezing and ion exchange, which are costly and are not techno-economically viable for treatment of saline irrigation water.

Salt tolerant crops are usually grown where saline water is used for irrigation. Cereals are more salt tolerant than legumes. Some improved verities of wheat, barley and bajra are more suitable than others. In designing a cropping system in such areas with low leaching requirement, low consumptive use and more salt tolerance are preferred.

Predicting and preventing the advance of salinity

The knowledge gained from the new monitoring techniques, along with that generated by decades of painstaking field research, is offering many insights to the causes of salinisation.

Mapping Salinity

Testing remote-sensing techniques

Scientists may peer at satellite images or process them using high-powered computers, but the only way to assess their accuracy is to go out into the field and measure the salinity at ground level.

A recent study by scientists at CSIRO Mathematical and Information Sciences tested a remote sensing technique in three study areas in Western Australia. They analysed a series of Landsat images, which they combined with information on contours, the location of roads and farm boundaries, and farm management histories. They then compared the results of these analyses with the locations of known salt-affected and changing sites, as supplied by farmers, field officers from Agriculture Western Australia and from previous salinity mapping exercises.

Results were very encouraging. At one study site, salt-affected land was mapped remotely at an accuracy of almost 100 per cent. Accuracy was lower at other sites, but refinement of the techniques will continue to improve results.

Predicting where salinisation will occur next

Scientists have shown that a number of factors determine the vulnerability of sites to salinisation. These include:

- The position of a site within a landscape – generally the lower it is, the more likely it is that the water table will reach the surface and cause salinisation;
- soil type;
- management – such as the extent of clearing;
- rainfall.

Combining information on these and other factors could allow the prediction of sites vulnerable to the saline menace. Scientists can use data on rainfall, topography, soil type – indeed, any spatial information that is available electronically – to first determine the combinations most susceptible to salinisation, and then to predict similar regions that may be at risk.

Lessons from a case study of coastal salinity of Sundarbans, West Bengal:

Coastal salinity, as the name suggests is predominant mainly in the coastal regions of the country. It is caused due to the ingress of sea water into ground water reservoirs. It is predominantly a natural phenomenon, very common in areas where estuaries are present and where sea and surface water mix. In high tide, some sea water moves upstream and this water gets contaminated. If some of this water percolates down to groundwater reservoirs, contamination can occur. However, over-extraction of groundwater can exacerbate this problem as more sea water collects in the aquifers with their boundaries close to or in contact with sea water and concentration of salt goes up with the loss of fresh water. Also, depending on the region, in Chennai for instance, aquifers with freshwater and seawater are found on different levels. When freshwater is overexploited, it disturbs the delicate balance and can cause mixing of the two. Coastal salinity is predominant in Minjur in Tamil Nadu, due to overexploitation (especially considering its proximity to Chennai).Coastal salinity is also prevalent along the Saurashtra coast, in the region around Subarnrekha, Salandi and Brahamani in Orissa and in Pondicherry.

The Sundarbans, an UNESCO Heritage site has a high rural population with dependent on natural resources for their sustenance The present paper deals with the management of the salt water intrusion condition of the Piyali River a tributary of the Matla River which empties into the Bay of Bengal. The study also delves into the population affected by the effects of the perennially saline river and their dependence on it for their livelihood. A look into the soil texture, seasonal variation in chloride content of soil along with pH and EC levels of water taken both seasonally and spatially is analyzed in order to improve management options. With Electrical Conductivity (EC) values of 17,000 mS and pH 8.94 , the area is quite challenging in terms of sustainability of its inhabitants.

Under the threat of climate change, increased levels of salinity arising from sea level rise and coastal flooding will pose a serious problem to the rural inhabitants of the Sundarbans. The predicted negative impacts of climate change are likely to bring new challenges in addition to magnifying existing problems, particularly in the Sundarbans community that already has limited capacity to adapt to these changes.

STUDY AREA

Salinity is common problem in the South 24 Parganas, West Bengal (Fig 1). Sea water contains chlorides with other salts that can be detrimental to agricultural crops and which exceed drinking water standards. During the summer period when the saltwater intrusion becomes more severe due to extensive over pumping in the absence of the development of supplemental water supplies to the area. The livelihood of rural population mainly depends on the sustainable development and management of groundwater resources. The selected River basin is Piyali River basin (Fig 2) which is a perennially saline river. The otherwise sweet water river is affected by salt water intrusion from the Bay of Bengal through the Matla River. The Basin of the Piyali River, an estuarine river with regular tidal influx, during flash floods the entire catchments of the Piyali River overflows.

PROBLEM IDENTIFICATION

At present, the main source of traditional water supply is by drawing water from wells and also from bore wells. But as salinity was fastly setting in the wells, around the coastal villages and towns of the peninsula, the need for pure drinking water has become the most priority issue. The existing tube wells, being very deep, have already become saline, and some way has to be found as

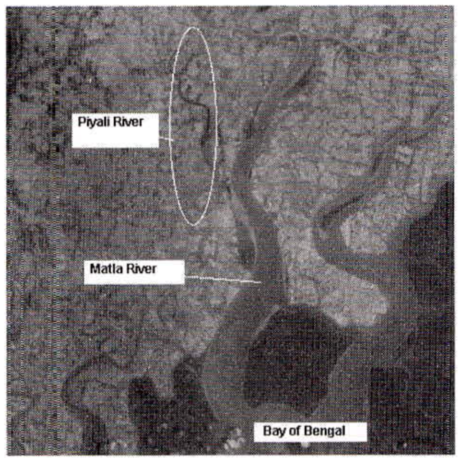

Fig. 1: Satellite imagery of the Piyali River a tributary of the Matla River flowing towards the Bay of Bengal

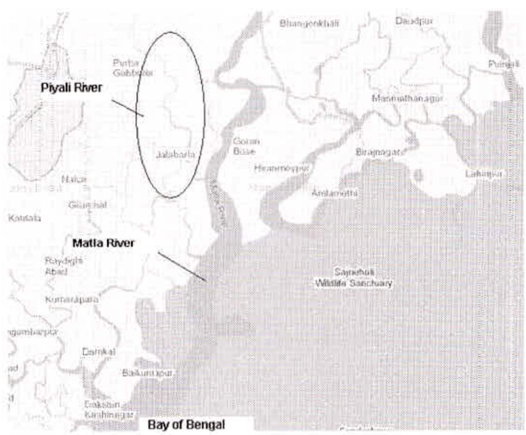

Fig. 2: Map of the Piyali River a tributary of the Matla River flowing towards the Bay of Bengal

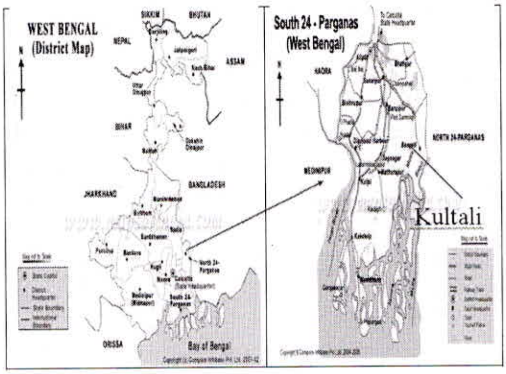

Fig. 3: Location map of Kultali block in South 24 Parganas, West Bengal,India

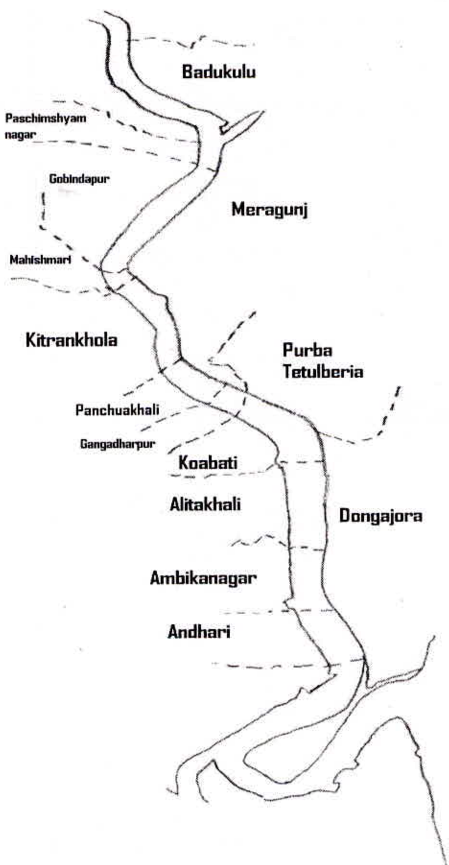

Fig. 4: Village map of the Kultali block in the South 24 Parganas, West Bengal (scale 1:50,000)

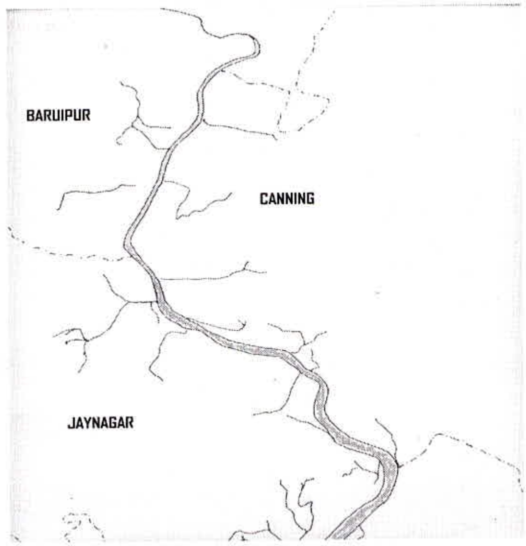

Fig. 5: Upper Basin of the Piyali River spanning Baruipur, Jaynagar and Canning blocks of South 24 Parganas district of West Bengal state (scale 1:50,000)

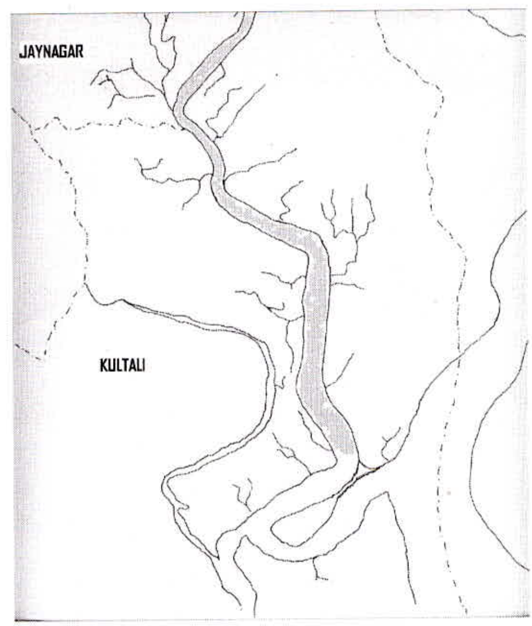

Fig. 6: Lower Basin of the Piyali River through Jaynagar and Kultali blocks of South 24 Parganas district of West Bengal state (scale 1:50,000)

quickly as possible to stop sea water seeping into these bottomless wells.

The saline water has affected the villages situated along the river. Due to non availability of drinking water health of the villagers is also affected. Lack of potable water source leads to disease, adverse effects on health which in turn affects the country's GDP. Also lack of education, malnutrition further lowers the economic condition of the people of this region. The agriculture is being a main occupation; the socio economic condition is also poor. Brief description of the water problems/challenges in the locations (Table 2):

Table 1 : Locations within Kultali block

Name of village, Tehsil, District, State/UT and River basin	Population of village	Remarks
Kaikhali, Kultali block, South 24 Parganas, West Bengal. Piyali River Basin	5180	BPL families with low awareness levels
Ambikanagar, Kultali block, South 24 Parganas, West Bengal. Piyali River Basin	451	
Alitakhali, Kultali block, South 24 Parganas, West Bengal. Piyali River Basin	2155	Poor education and high dependence on agriculture
Koabati, Kultali block, South 24 Parganas, West Bengal. Piyali River Basin	2175	
Gangadharpur, Kultali block, South 24 Parganas, West Bengal. Piyali River Basin	825	High dependence on pissiculture and lack of alternate job opportunities
Panchua Khali, Kultali block, South 24 Parganas, West Bengal. Piyali River Basin	654	
Kirtankhola, Kultali block, South 24 Parganas South, West Bengal. Piyali River Basin	4083	
Meraganj, Kultali block, South 24 Parganas, West Bengal. Piyali River Basin	6926	Lack of arable land holding due to disintegration of joint family system
Dongajora, Kultali block, South 24 Parganas, West Bengal. Piyali River Basin	9071	

Table 2: Location wise problems caused by water challenges in the Sundarbans,West Bengal

Sr no.	Location	Problem
1.	Ambikanagar	High salinity levels in water leading to lack of potable water causing risk of disease and no recharge to ground water facility leading to low level of water table causing dry spells and an acute safe drinking water shortage.
2.	Alitakhali and Dongajora	Absence of RWH structures and tube wells for drinking water supply leading to low availability of water causing adverse health issues
3.	Koabati Panchuakhali and Gangadharpur	Reduced flow of sweet water, inundation/flooding of low lying land near Piyali River and inadequate drainage and lack of canopy plantation to help enable increased evapotranspiration to improve water cycle
4.	Kirtankhola and Meraganj	Lack of sweet water ponds and canals and shortage of sweet water due to absence of irrigation canals

Solute transport is of concern in many hydro geological problems. Historically, first interest in solute transport in aquifers arose because of the problem of seawater intrusion. This was and still is a very practical and acute problem in coastal areas where one needs to keep production wells fresh. It is now realized that groundwater is not an inexhaustible natural resource. Groundwater is very vulnerable to contamination as a result of agricultural, industrial and urban activities. Society has to deal with both historical and ongoing unavoidable contamination of the environment.

Freshwater aquifers are bounded at their seaward margins by salt-water. Under natural conditions, the seaward flow of freshwater prevents saltwater from encroaching coastal aquifers. Ground-water withdrawals, however, lower coastal water levels and can cause saltwater to be drawn landward and upward toward the points of withdrawal, a process called saltwater intrusion. Saltwater intrusion reduces ground-water storage and can lead to the abandonment of supply wells when concentrations of dissolved ions, such as chloride, in water withdrawn at the wells exceed drinking-water standards. The degree of saltwater intrusion along the coast varies widely, how-ever, and is affected by the hydro geologic setting, history of ground-water development, and sources of saline water within a particular area.

The rate at which freshwater is being exploited from the aquifers greatly control the intrusion of saline water into the coastal aquifers. The phenomenon is common in the extensive coastal sedimentary deposits and delta of major rivers of the east coast of West Bengal. Seawater intrusion can be halted or prevented by maintenance of groundwater levels well above the sea level.

METHODOLOGY

The long term data included collection of climatological data (precipitation, temperature, evaporation, water level fluctuations, etc.) over the period of approximately three years, which will be correlated with other area full time climatological data stations. The focused surveys will include establishing topographic and water level elevation reference controls, geophysical surveys (electrical resistivity, electro-magnetics and possibly ground penetrating radar). The first stage of the project was initiated by collection of secondary data and literature survey coupled with a reconnaissance survey to identify the sampling points for collection of relevant primary data pertaining to study area. This was be followed by collection of socio-economic data with the help of questionnaires in order to conduct an extensive survey of the local residents and stakeholders of the Kultali block.

The next stage was to define the mechanisms of ground-water flow and movement of saltwater in the Piyali River aquifer and delineation of the paths and rates of ground-water flow and intrusion of saltwater into the Piyali River aquifer and simulate a variety of water-management scenarios to alleviate rates of saltwater contamination and to provide inhabitants with options to move away from over dependence on single source to multiple sources through conjunctive use of groundwater, surface water and rainwater harvesting.

Further, evaluation of present practices of pure water supply sources and further assessment of alternative sources of water supply from seepage ponds connected to the Piyali River aquifer based on issues of potability, reliability, sustainability, convenience and equity. Assessment of long-term ground-water levels and quality is equally important and the development and maintenance of a comprehensive groundwater data base in order to aid ensuring drinking water security through measures to improved/augmented existing drinking water sources and conjunctive use of groundwater, surface-water and rain water harvesting are also considered.

Table 3 illustrates the location of the sampling points and their respective coordinates within the Kultali block.

The instruments procured by the financial order of this project are provided in Table 4 which are been used for precision in salinity results.

Table 3: Sampling Locations

Sr No	Location ID	Latitude N	Longitude E
1	Sluice Gate	22° 08′ 7.9″	88°35′53″
2	Sluice + 1km	22°08′33.2″	88°36′3.8″
3	Alitakhali	22°09′12.6″	88°36′10.7″
4	Sluice + 3km	22°09′28″	88°36′11″
5	New Bridge	22°09′48″	88°35′32″
6	Jamtala BDO	22°09′26″	88°35′08″
7	Panchuakhali	22°10′3.4″	88°34′59.6″
8	Brick Kiln	22°10′31″	88°34′48.3″
9	New Bridge+4km	22°10′26″	88°34′50″
10	Maheshvari	22°23′11.9″	88°49′56.2″

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Table 4: List of instruments

Sr No	Name of instrument	Manufacturer
1	Orpheuse Mini GW Logger	OTT,Germany
2	e+MCT Soil Probe	Eijelkamp,Netherlands
3	Discrete Interval Water Sampler	Soilinst,Canada
4	TLC Water Meter	Soilinst,Canada
5	Rain Data Logger	Spectrum,USA

Figures 7 and 8 illustrate the soil texture of samples collected at the site spread over locations of the Kultali block along the Piyali River.

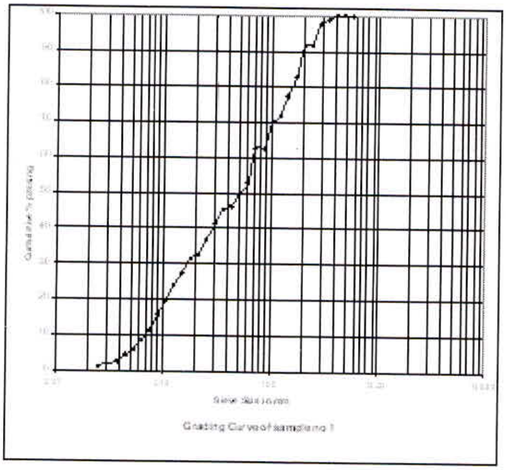

Fig. 7: Soil sieve analysis of sample no. 1

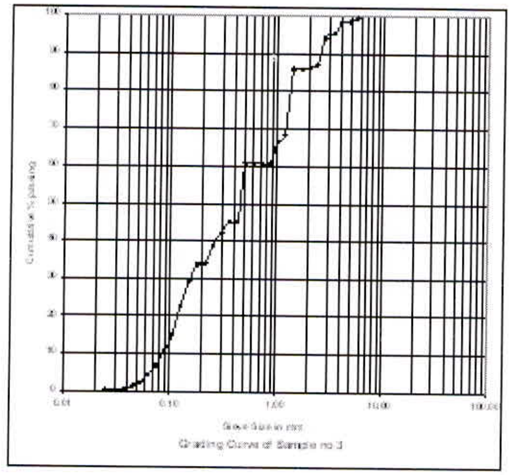

Fig. 8: Soil sieve analysis of sample no. 3

Variation of Chloride in soil

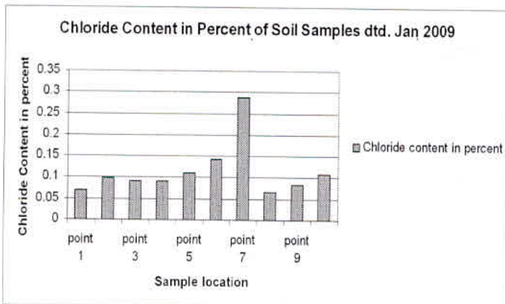

Fig. 9: Chloride content in soil samples taken from site dtd. January 2009

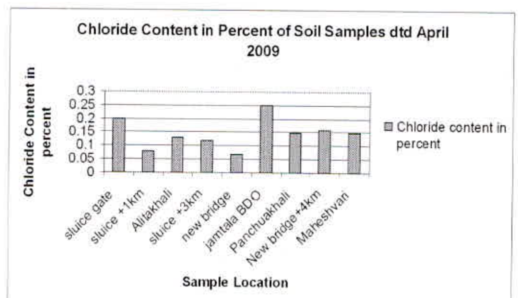

Fig. 10 : Chloride content in soil samples taken from site dtd. April 2009

Figures 9 and 10 explore the chloride content of soil samples taken during the premonsoon month of January and April 2009. As is expected April month has higher salinity as the water content of the soil is less due to lack of rainfall and increased evapotranspiration.

Variation in pH at sluice gate

Another study looked into the variation of pH at the sluice gate of the Piyali River. This is the point where the salinity is maximum as it is the link to the Matla River and hence ultimately the Bay of Bengal. These are illustrated in Figures 11-14.

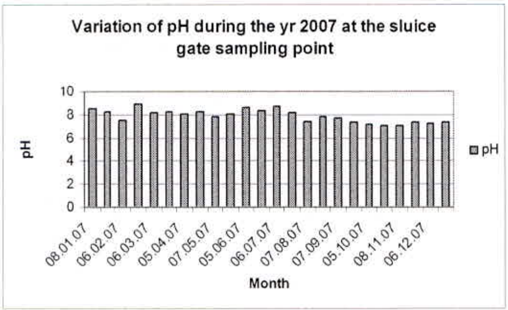

Fig. 11: Variation of pH during the year 2007 at the sluice gate at Kultali block of the Piyali River

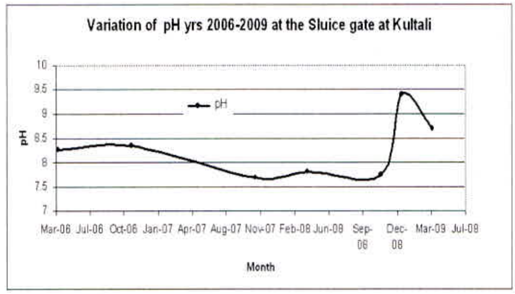

Fig. 14: Variation of pH during the year 2006-2009 at the sluice gate at Kultali block of the Piyali River

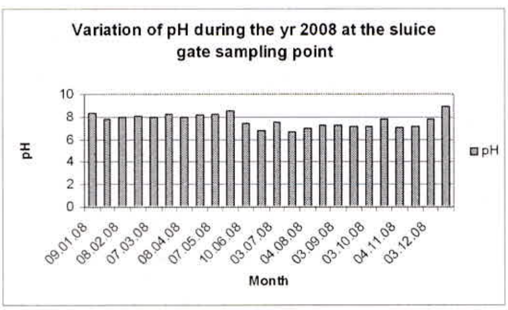

Fig. 12: Variation of pH during the year 2008 at the sluice gate at Kultali block of the Piyali River

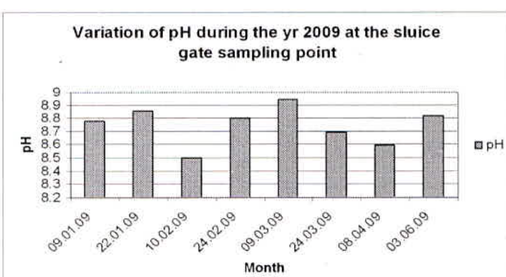

Fig. 13: Variation of pH during the year 2009 at the sluice gate at Kultali block of the Piyali River

Variation of Electrical Conductivity (EC) at the sluice gate

Another study looked into the variation of Electrical Conductivity (EC) at the sluice gate of the Piyali River. This is the point where the salinity is maximum as it is the link to the Matla River and hence ultimately the Bay of Bengal. These are illustrated in Figures 15-17.

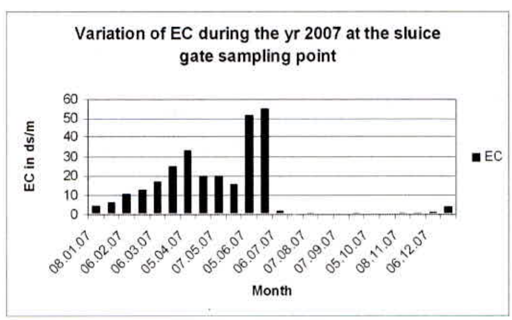

Fig 15: Variation of EC during the year 2007 at the sluice gate at Kultali block of the Piyali River

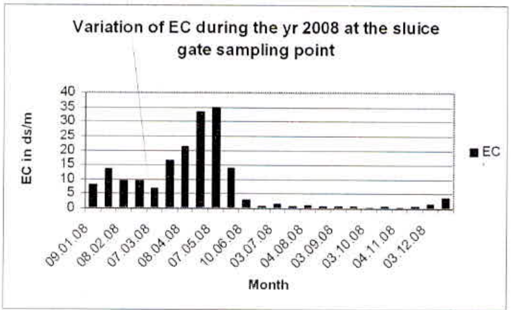

Fig. 16: Variation of EC during the year 2008 at the sluice gate at Kultali block of the Piyali River

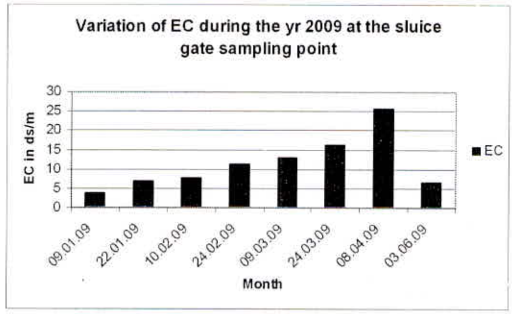

Fig. 17: Variation of EC during the year 2009 at the sluice gate at Kultali block of the Piyali River

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Recommendations for salt tolerant cropping

Tomato is particularly sensitive to salinity in combination with a high temperature during fruit formation. This combination causes blossom end rot, a calcium deficiency, and, consequently, a decrease of the marketable yield. Late-season tomatoes are less sensitive to salinity (UNESCO, 1970). Blossom end rot, however, did not occur during the lysimeter experiment.

Table 3 : Salt Tolerance of Crops

Crop	Salinity Threshold (A)	Slope (B)	Rating
Alfalfa	2.0	7.3	Moderately sensitive
Barley	8.0	5.0	Tolerant
Beans	1.0	19.0	Sensitive
Corn	1.7	12.0	Moderately sensitive
Corn forage	1.8	7.4	Moderately sensitive
Cowpea (blackeyes)	4.9	12.0	Moderately tolerant
Oats	?	?	Moderately tolerant
Wheat	6.0	7.1	Moderately tolerant

A = threshold value (dS/m)

B = slope of the linear line (or the % reduction in relative yield per increase in soil salinity per dS/m

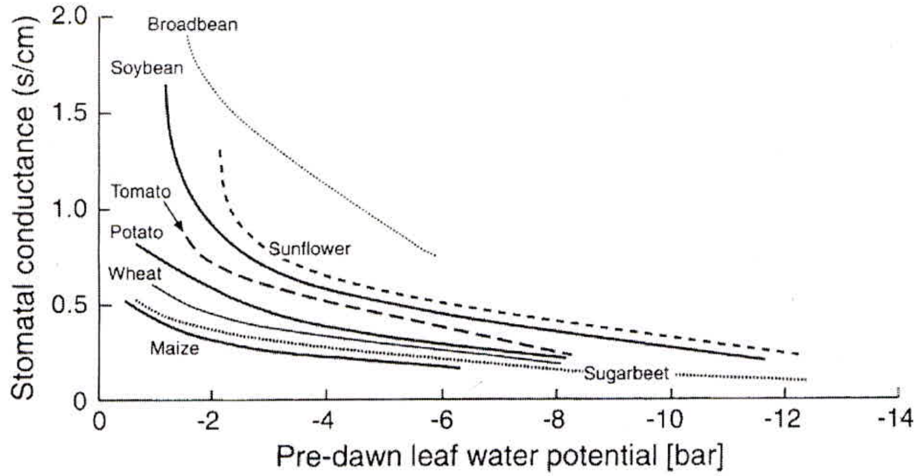

Fig. 18 : Stomatal conductance vs. pre-dawn leaf water potential.

Broadbean, soybean and tomato are all crops of indeterminate flowering. The flowering period lasts longer in comparison with crops having a determinate flowering. Several studies (Salter and Goode, 1967; Mouhouche et al., 1998) indicate a maximum sensitivity during flowering.

CONCLUSIONS

Priorities in Future Water Resources Development in case of salinity

1. To raise the efficiency of overall water use to the maximum limit by raising the pubic awareness about water resource scarcity is the prior. The government plans with policies on water pricing through improving the irrigation system by shifting the modern irrigation facilities or planting new type of crops which require less amount of water both from quality and quantity points of views and even modifying the crop pattern and concentrating on winter crops should be studied. Note that the extraction of water from the wells over the study area should be controlled and measured and to control the extraction, an aquifer utilization law and appropriate obligations have to be installed by both sides.

2. The intrusion of salt water cannot be stopped unless the fresh water table is raised above sea level. Hence, artificial recharge possibilities must be examined in this area to refill the over pumped portions of the aquifer so as to reduce the effect of contamination. In reality it is very difficult and very costly to re-establish the previous natural conditions since backwashing of the aquifer from the salts is not only a time-dependent process but generally is assumed to be irreversible.

3. The existing dams in the area that were constructed for recharge and irrigation purposes have a questionable effect on the aquifer due to siltation. Hence, for the planned ones and for those still under construction, the priorities should be revised. Appropriate locations should be selected for seepage. It is important to harvest the rainfall water and to make full use of torrential streams and flash floods.

4. Construction of several small sewage treatment plants near each village, where the treated water may be used for irrigation of

nearby lands, will be beneficial in the long run. Similarly a desalination plant or plants may be a reasonable alternative as well, especially in overcoming the drinking water needs.

5. To use genetic engineering and tissue culture for the development of salt tolerable crops and even limiting the citrus fruit plantation areas to the present level or even lower by considering the age criteria of the trees will decrease the irrigation water requirements.

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