Engineering Problems in Sodic Soils and its Feasible Measures – A Pilot Study in Sultanpur District, Uttar Pradesh

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***Abstract* – Sultanpur district of Uttar Pradesh is highly affected by sodic soils. Sodicity refers to the excess of sodium salts loosely held in soil which adversely affects the productivity and engineering properties of soils. Sodic soils in the study area have problems of low porosity, low nutrient content and inefficient drainage resulting in water logging conditions. The study area is adversely affected by sodicity and water logging conditions making the area less suitable/ unsuitable for agricultural and engineering use. This paper deals with the various chemical and geotechnical analysis to confirm the presence of sodic soil and to assess its effect on the engineering properties of soil. The suitability of soil for any civil engineering project was also analyzed and the feasible measures to deal with the problems of sodicity are suggested.**

Keywords: Sodic soils, Sultanpur, feasible measure, engineering problems

1. INTRODUCTION

About 7.3 million hectares of India's land area is afflicted with the twin problems of alkalinity and salinity coupled with water logging, which seriously reduce agricultural productivity and has grave implications for our food security system. Not only agriculture it has also resulted in many problems related to construction of roads and other civil engineering structures. The problem of salt affected soils is pronounced in the Indo-Gangetic plains. Singh and Bajaj (1988) stated that about 16% of the country's total area is found in Uttar Pradesh alone. Only a negligible portion of soils in UP is saline, the bulk is suffering from alkalinity, associated with excess of available sodium, poor porosity, low nutrient content, indifferent drainage and high water table. The problem of alkaline soils is known to be closely related to conditions of poor drainage and impervious sub-soils in arid and semiarid regions.

Sharma et. al. (2008) found that maximum sodic soil is found in the older alluvial plain, moderate in recent alluvial plain and less in the active alluvial plain of Etah district, Uttar Pradesh. Excessively high values of pH, ESP, high precipitation of lime, development of a natric horizon and platy soil structure testified the complete saturation of exchange complex with Na in sodic soils of the old alluvial plains. The information on differential sodification stages in geomorphic surfaces appear to be useful in planning strategies for the reclamation of sodic soils in Uttar Pradesh.

Geotechnical properties of soil form the primary requirement of construction of any structure or roads. Biggs et. al. (2004) have stated that soil physico-chemical properties may prove to be hazards to engineering and their risks need to be assessed. He added that soil chemical properties such as sodicity may corrode steel, concrete structures and roads. Sodic soils tend to decrease the permeability and create water logging conditions. More the water in soil lesser is its strength. Also in such case, the water interacts with the foundation and walls, seeps into the structure causing dampness and corrosion thereby inversely affecting the strength of structure. When water gets evaporated the salts result in crustation of surface. Moreover proper drainage is one of the most important criteria for road construction and sodic soils do not provide proper drainage condition which results in loss of strength and disintegration of road material.

1.1 Location of the study area

The study area (figure 1) selected is the sodic land around Kitiyawan village of Shahgarh Block; district Sultanpur (now Amethi). The physical location map of the study area is given in the figure 1. The study area lies between 26º13'21.3'' N to 26º22'25'' N latitude and 81º38'15'' E to 81º51'30'' E longitude, with average altitude of 107m above mean sea level. The area is mostly affected by sodicity.

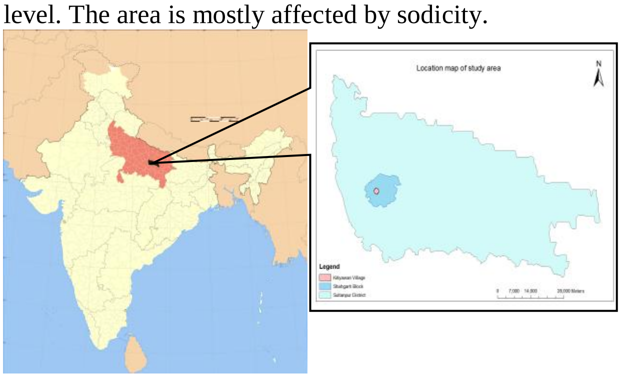


Figure 1: Physiological map of the study area

The average annual rainfall is 1005.1 mm. The climate is sub-humid and it is characterized by a hot summer and a pleasant cold season, about 89% of rainfall takes place from June to September. The mean monthly maximum relative humidity is 65% and mean monthly minimum relative humidity is 51%. Winds are generally light to moderate with some strengthening during later part of summer and monsoon season. As per CGWB district profile report, geologically the area comprises of quaternary alluvium. Alluvial formation consists of clay, kankar and granular material comprising of medium to coarse sand and gravel which by and large form the principal aquifer. The river Gomti divides the district into two unequal tracts, the larger lying in south & smaller in the north.

The report claimed a three tier aquifer system on the basis of hydro-geological information viz. first Aquifer Group (between the depth range of 25.00 & 130.00 mbgl). The aquifer material is fine to medium sand, kankar variably occurs with clay formations. Second Aquifer Group (depth range of 80 & 240 mbgl) and Deep Aquifer Group (Depth limit of this potential aquifer system from land surface is 180 m to 410 mbgl).

1.2 Type of soils in study area

As per CGWB report, Gautam identified that in Sultanpur district chief variations of soil are Dumat or loam which is a mixture of sand and clay in various proportions, Matiyar or clay and Bhur or sand. Pre-dominant soil of the district is loam or Dumat occurring in central level land. Matiyar occurs in low lying areas while Bhur is found along the river Gomti. The low-lying land consists of paddy land with patches of "Usar" swamps and marshes. Table 1 gives the soil types and their characteristics.

Table 1: Types of Soil and their Characteristics

Sl. No.	Soil Type	Characteristics	Area (in ha)
1	Sandy loam	Plain, productive, major area under irrigation. Major crops are rice, wheat, jwar, pigeon pea, chick pea, field pea, lentil, urd, vegetable crop, sugarcane and live stock production	68798.00
2	Loam	Plain, productive, some of the area under water log major area are irrigated . Major crops are rice wheat, chick pea , field pea, sugarcane, vegetables etc.	193742
3	Clay	Compact in nature major area under temporary water log. Major crops are rice wheat followed by vegetables and live stock production	68798
4	Sandy	Loose textured , partially irrigated, railfed condition, ravenous area eroded with perennial wild grasses , majore crops are wheat, pigeon pea, urd, moog, vegetables and live stock production.	193742
			525080

Source: ATMA, SREP Agriculture Department, Sultanpur

1.3 Problem

For soil to be used as an engineering material it is essential to remove the biological properties, alteration of chemical properties and physical properties for more suitability. Some physico-chemical properties hinder the engineering properties of soil thereby adversely affecting its strength. Also in case of water logging, water is in direct contact with the structure, thereby causing dampness and deterioration of reinforcement. This further results in loss of strength and durability of the structure. Also for structures like roads, pavements and railway tracks drainage is very essential condition for construction and maintenance. Sodic soils reduce the permeability of soil thereby hold back the water and damage the materials. Figure 2 shows the adverse effect of capillary rise on the walls of houses made in the village.

Figure 2: Capillary Rise in Water-logged Area, growing unhygienic living conditions (Sultanpur District)

2. METHODOLOGY

The soil analysis was carried out in two different phases – chemical analysis for validating that soil was sodic in nature and geotechnical investigation for determining the strength and suitability of soil as construction material. Two sites A and B had been selected for study. The sampling was done using a post hole auger. The soil samples were collected at every 30 cm of depth. The samples were taken for 30, 60, 90, 120 and 150 cm of depth below ground level. The chemical and geotechnical analysis of soil samples were carried out in the Environmental and Geotechnical Lab of Shri Ramswaroop Memorial University.

2.1 Chemical Analysis:

As per studies carried out at Colorado State University by Waskom et al. (2012) the visual symptoms can be used to identify the problem of soil sodicity, but ultimately a soil test is the best way for an accurate diagnosis. Therefore field photos were taken for visual inspection. But for accurate analysis the soil samples collected were tested for pH and electrical conductivity. The pH and conductivity were determined by pH meter (Toshniwal Model No. CL 46) and electrical conductivity was measured by EC meter (Toshniwal Model No. TCM 15).

2.2 Geotechnical investigation of soil:

Various geotechnical tests were then performed in the laboratory on these samples viz. grain size analysis, Atterberg's limit, specific gravity of soil and permeability of soil in order to confirm presence of sodicity, to determine the effect of sodic soil on geotechnical properties of the soil and thereby ensure it suitability as engineering material.

Particle size Analysis

Particle size analysis was done to classify the soil. It was carried out by sieve analysis (for particle size greater than 0.075 mm) and by hydrometer analysis (for particle size smaller than 0.075 mm) conforming to IS2720: Part 4. For dry sieving, the soil samples were dried up in the oven at 100ºC using 2, 1, 0.6, 0.425, 0.3, 0.1 and 0.075 mm sieves. The weight retained on each sieve was determined. For hydrometer analysis, 50g of oven dried sample (passing 0.075mm sieve) was added to 100ml of dispersion solution and then water was added to make it 1 litre. The hydrometer was inserted in the solution and the readings of hydrometer were taken at different time intervals. The particle diameter and the respective percentage passing were then plotted on semi-log paper.

Specific gravity

The specific gravity of soil was determined as per IS2720: part 3 using pycnometer. The specific gravity was calculated by the given formula

$G = (W_2-W_1)/ [(W_2-W_1)-(W_3-W_4)]$

Where; W_1- Weight of empty pycnometer

W_2 - Weight of pycnometer +soil

W_3 - Weight of the pycnometer +soil +water

W_2 - Weight of the pycnometer +water

Liquid limit

The liquid limit of soil was determined as per IS: 2720 (Part 5) – 1985. The liquid limit of fine-grained soil is the water content at which soil behaves practically like a liquid, but has small shear strength. 120g of oven dried sample passing 425micron was taken and water was mixed at certain percentage. The paste thus formed was placed in casagrande's apparatus and the groove using casagrande's tool was made. The number of blows was recorded for the particular water content. The water content was varied and the corresponding number of blows was plotted on semi-log to obtain the flow curve. The liquid limit was water content corresponding to 25 number of blows.

Permeability test

The permeability of the soil samples was determined by variable head permeability method conforming to IS2720: part 17. The soil specimen was connected through the top inlet to selected stand-pipe. The reading of initial and final height of water in piezometer was recorded for given time intervals. Alternatively, after selecting the suitable initial and final heads, h_1, and h_2, respectively, time intervals can be noted for the head to fall from h_1 to h_2. Permeability was calculated by the given formula –

$$k = 2.303\ (aL/At) \log(h_1/h_2)$$

3. RESULT & DISCUSSION

3.1 Chemical Analysis:

The field images as shown in figure 3. It was found that soil samples taken from site A as well as from B are of poor condition and can be classified under sodic soil as the white powdery layer of salt deposited could be clearly seen. Also soil at site A was more affected i.e. more sodic than soil at site B.

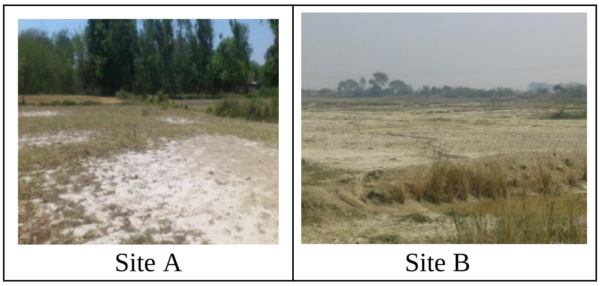


Figure 3: Sodic soils as visible near Kitiyawan village (study area).

3.1.1 pH - The variation of pH value with depth for both sites A and B is shown in figure 4. The pH of soil samples at site A show increase in pH with depth indicating presence of calcium nodules (kanker) at 150 cm depth. In the samples at site A kanker were found at this depth and samples could not be taken through auger beyond this depth. pH value ranges between 8.9 (at 30 cm depth) to 9.9 (at 60 cm depth), with a trend indicating that pH may increase with the capillary rise of the water table in the root zone. Whereas at site B the trend was opposite and maximum pH of 9.85 was found at 30cm depth while 9.2 was the value of sample at 150 cm depth.

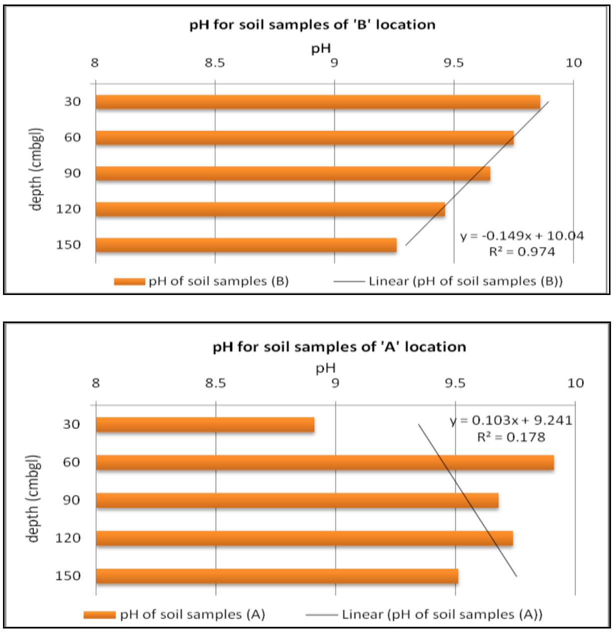


Figure 4: Variation in pH of soil samples at site "A" and "B"

3.1.2 Electrical Conductivity - Electrical conductivity for all the samples of site A and B were found to be less than 4 ms/cm, with range of 3.72 to 0.311 ms/cm at site A. At site B it ranged between 1.5 to 0.544 ms/cm. Electrical conductivity at both sites was found decreasing with increase of depth from ground level as shown in figure 5.

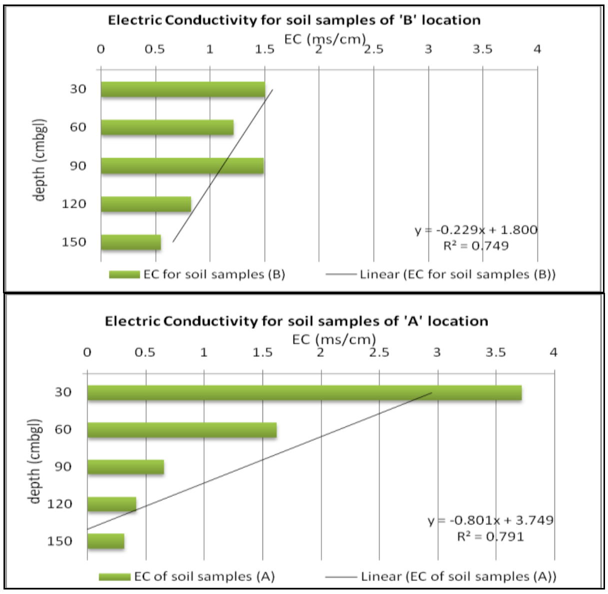


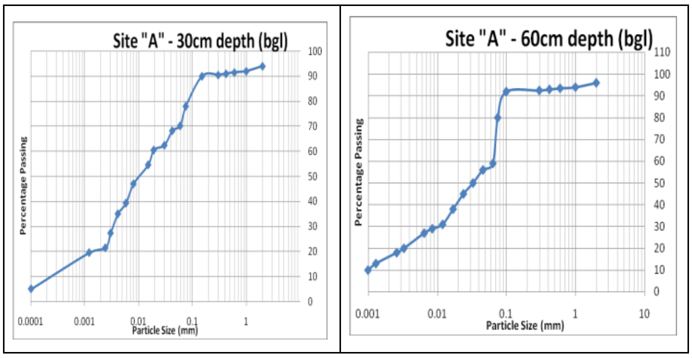
Figure 5: Variation in EC of soil samples at site “A” and “B”

The value of pH of all the samples at both sites is found to be > 8.5 whereas the electrical conductivity was below 4.0 ms/cm. Therefore the Chemical Analysis of the soil samples confirms that the soil of the study area is SODIC in nature.

3.2 Geotechnical Investigation of soil properties:

3.2.1 Particle Size Distribution Curve

Particle size of soil is responsible for their aeration, permeability, water holding capacity (water logging), salinity, sodicity, etc. The soil samples were found to be clayey silt with about 20% clay content, <20% coarse material and >60% silt. However, at 60cm depth the soil had lesser clay content (14%). The gradation curve of soil samples at depth 60cm and 150cm have vertical portion representing uniform fine sand particle (approx. 30% of total weight). Being classified as clayey silt it can be predicted that soil will have low permeability and water logging may occur. The results are summarized in figure 6.



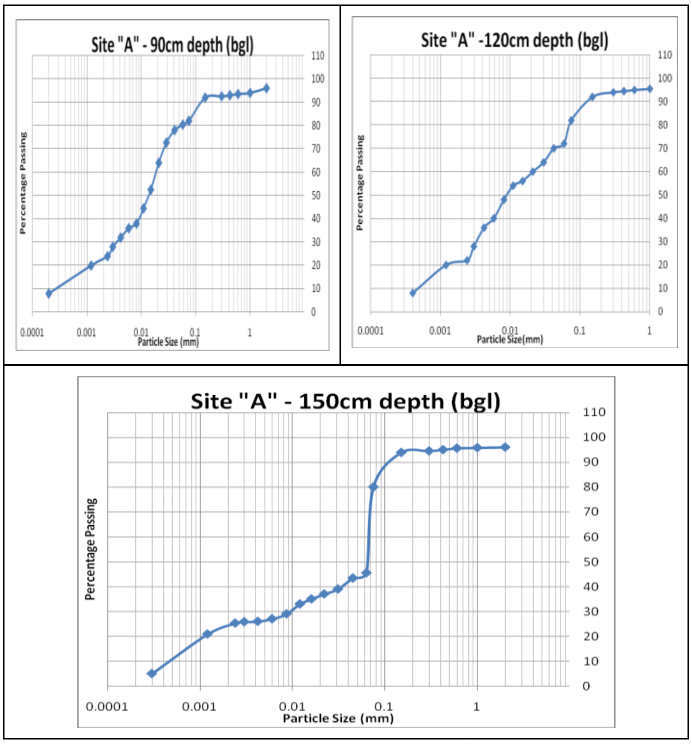


Figure 6: Grain size distribution curve of the soil samples.

3.2.2. Liquid Limit Test

The consistency limits for any soil represent the extreme moisture contents between crumbling (plastic limit) and liquidity (liquid limit). The flow curve was plotted as straight as possible through the various points. It can be clearly inferred from the figure 7 that liquid limit of the site “B” is less than soil at site “A”, indicating that the soil at site “B” is more degraded than that at soil at “A”. This is also confirmed by the presence of kankar on site “A” and more salty patch at site “B”. When compared with normal soil, it is inferred that soil at both the sites, “A” and “B” are under the process of degradation and soils of site “B” is most affected by sodicity.

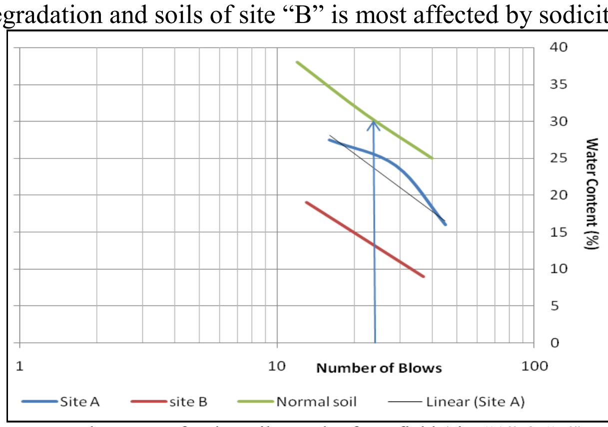


Figure 7: Flow curve for the soil samples from field (site “A” & “B”) and normal soil.

3.2.3 Specific Gravity of Soil

The specific gravity of engineering soils usually varies between 2.6 to 2.8. If it is less than 2.6, it may indicate possible presence of organic matter. As clearly visible from the result summarized in table 2, specific gravity of soil samples at Site “A” and Site “B” are lesser than specific gravity of normal soil (G = 2.6). Also specific gravity at site

"A" is lesser than that of site "B". Site "A" has higher amount of organic content as it is still under process of degradation while soil at site "B" has completely degraded and has negligible amount of organic content.

Depth	30cm	60cm	90cm	120cm	150cm
Site A	1.6129	2.12766	2.08333	2.06186	2.12766
Site B	2.1978	2.24719	2.1978	2.1978	2.150538

3.2.4 Permeability test

The variation in permeability along the depth of soil samples is shown in figure 8. It has been found that permeability of the above samples is very low confirming the clay content and conditions favorable for water logging and sodicity. However, the permeability at depth interval of 90 cm was found to be very low and which is also confirmed by presence of high content of organic matter in the soil.

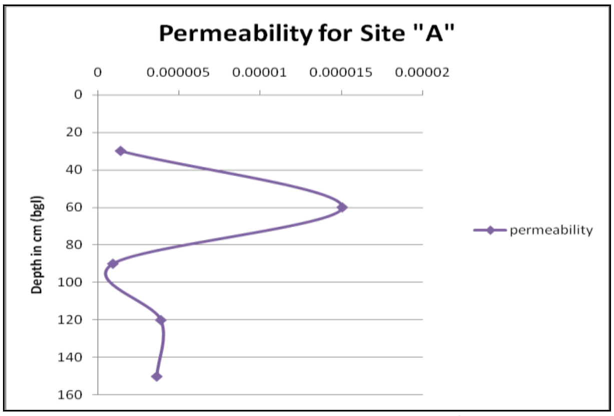


Figure 8: Variation in permeability with depth of soil samples

Geotechnical Investigation confirms sodicity and also the degraded condition of soil to be used as engineering material. Therefore measures are required for its management and improvement.

4. FEASIBLE MEASURES AND MANAGEMENT FOR SODIC SOILS

The traditional method for management of sodic soils mainly focus on the proper management of drainage by minimizing the disturbance of natural drainage patterns, and for new construction necessary slab, foundations, and retaining walls all should be designed in such a manner to ensure good drainage and to avoid water logging; cut and fill on sites must be restricted; existing areas of water logging and poor drainage should avoided for new constructions; guttering and down pipes should be properly connected and maintained. Moreover, water infiltration of storm water, leakage from underground water carrying pipes should be checked and surface water features should be lined to minimize any possible seepage. In addition to these checks through proper management of water and drainage; vegetation also plays an important role. The existing areas of established vegetation must be maintained ensuring minimal erosion and disturbances. Moreover, sprinkler method of irrigation must be used.

In addition to above traditional methods involving proper management of water, drainage and vegetation in the sodic soil areas to resolve the issue; some engineering measures should also be considered. These engineering solutions are as follows:

1. The sequence construction activities such as buildings or road construction should be planned in such a way that the soil is not exposed for long periods of time.
2. Care should also to taken for minimal exposure of materials to these corrosive sodic soil by raised slab or pier and beam designs, with consideration of shrink swell hazard.
3. There should be proper installation of damp proofing membrane under the slab. Moreover, measures should be taken to minimize the dampness/moisture and this should be maintained throughout construction, landscaping, and finishing.
4. The materials used in these construction sites should be moisture and salt resistant e.g. salt resistant bricks and rust free iron bars should be used.
5. The disturbed site after construction should be properly stabilized and ground improvement techniques viz. grouting, geogrids, etc. could be used for this purpose

5 CONCLUSION AND RECOMMENDATION

The above study confirms the problem of sodicity and water logging in the concerned study area. It is also concluded that the chemical characteristic of the soil has high pH and EC proving the sodic conditions prevailing in the study area. The geotechnical investigation supported the chemical analysis results. The particle distribution curve infers that the soil samples analyzed are clay and silt dominant, which would ultimately reduce the permeability of the area resulting in the water logging conditions. This finding is further supported by the permeability test of the study area. The experimental result of liquid limit and specific gravity of soil were found to be lesser than the normal soil, confirming the high content of salt in the soil.

It is recommended that for road and construction purposes mitigation measures should be taken at planning stage (mapping of sodic soils and field investigations), designing stage (decisions regarding cross- and longitudinal drainage, structure type, cut and fill slope and vertical and horizontal alignment may all need to be modified), construction stage (improvement and stabilization of soil should be achieved) and maintenance stage (erosion, corrosion and deposition of sediments in structures should be checked).

6. ACKNOWLEDGEMENT

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REFERENCES

[1] Singh S and Bajaj M "Usar (Sodic) Soils in Uttar Pradesh: A case Study of Two Villages in Hardoi District". JSTOR : Economic and political weekly, Vol. 23, No. 52/53 , pp. A 181-A 187, 1988.

[2] Singh A.K. , Singh P.K., Lal B. , Mathur A "Distribution Analysis of Salt Affected Soils under Canal and Non- canal Commanded Area in a part of Etah District , U.P., using Remote Sensing Technique". Journal of Indian Society of Remote Sensing; Vol.36; pp 183-188, 2008.

[3] The World Bank Report - "Uttar Pradesh Sodic Lands Reclamation II Project". (Report No: ICR0000653) March 20, 2008.

[4] Zia M.H. Ghafoor A., Murtaza G., Saifulah, Basara S.M.A. , "Growth Response of Rice and Wheat Crops During Reclamation of Saline-Sodic Soils". Pak. J. Bot., Vol. 38, No. 2: 249-266, 2006.

[5] Gautam J.P. , Report ,Ground Water Brochure of Sultanpur District, U.P (http://www.cgwb.gov.in/ District_Profile /UP/Sultanpur.pdf)