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Evaluation of water resources management practices in the salt-affected areas of Pratapgrah district, Uttar Pradesh - a GIS and remote sensing perspective

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Abstract

The entire stretch of Indo-Gangetic alluvial plains has large water-resource potential with respect to surface as well as groundwater. However, the unscientific and non-balance utilization of these water resources has given rise to several problems in certain areas. Satellite data reveals that these salt-affected lands are closely associated with canal irrigated areas and critical/semi-critical water-logging conditions. Temporal analysis of satellite data during last twenty years shows that there is substantial decrease in the intensity of salt-affected areas due to reclamation efforts where ground water level is deeper than 5 mbgl during post-monsoon period, but in other areas where shallow water table exists, reclamation efforts are less effective and perhaps non- sustainable.

In this study a spatial analysis is performed for establishing a correlation between the water resources management practices with the intensity and reclamation of salt-affected areas wtilising Geographic Information System (GIS) capabilities. Several coverage of the study area (data layers) with different relevant themes are prepared. Several of these coverage were converted into polygon topology and were categorised theme-wise. By superposition of these individual themes, the entire study area is categorised into different zones. A correlation is established between the water resource management practices prevelant in sodic land reclamation areas and the district as a whole. Finally, best suitable water resources management practices are suggested.

INTRODUCTION

The key aspect of water resources management consist of conjunctive use of surface and groundwater potential in a planned and effective manner with an objective of achieving maximum benefits. This aspect of conjunctive use becomes more significant in those areas where both surface and ground water resources are present in immense quantity but their distribution as well as utilisation is uneven. It has been observed that excessive rechrage from canal irrigation and poor pumpage of groundwater cause rise in water level resulting in water-logging, land-degradation, low agricultural productivity and loss of horticultural lands. Whereas, extensive pumpage of groundwater results into water scarcity problem.

The area selected for this study consists of entire expanse of Pratapgarh district (Uttar Pradesh, India) covering an area of 3,71,700 ha and is situated in the eastern part of Uttar Pradesh. The district falls within the *Sarada Sahayak canal* command area consisting of high canal density. Excessive water-logging and wide distribution of salt-affected areas are prominent feature of the district resulting in low agricultural production and reduced

cropping intensity. From water resources point of view, the district can be divided into three types of problematic areas :

The areas, which are extensively irrigated by canal irrigation with very little groundwater irrigation and water level is very shallow.

Those areas where ground water level is very deep and both surface as well as ground water utilization is very low.

Those areas where ground water level is shallow or in safe zone and still groundwater as well as surface water irrigation is not optimum.

In this study, an integrated approach is adopted in order to perform a spatial analysis utilizing ARC/INFO Geographical Information System (GIS) for establishing a correlation between the water resources management practices in the above mentioned problematic areas and the distribution of salt-affected areas. For this purpose, an inventory of data layers consisting of several relevant themes is prepared in GIS including drainage, canals, ground water levels, ground water quality, rainfall, etc. along with salt-affected areas as mapped from satellite imageries. Subsequently, contour maps of pre-post ground water level, utilizing ARC/INFO capabilities are prepared for the entire study area. Several polygon coverage's were also prepared and categorized into different zones including rainfall, ground water draft, fluctuation of water tables, seepage buffers showing water logging zones etc. Then, all these themes (data layers) are superimposed to facilitate the zonation of entire study areas into different problematic area and best suited measures for water resources management (type of irrigation required) are recommended for each zones (Rai, D et.al, 1999). This regional level study is also linked with the water resource management scenario in the sodicland reclamation areas of the district where a intense monitoring of ground water and surface water is being done since 1995 under *U.P. Sodic Land Reclamation Project*. An assessment is made regarding the applicability of water resources management practices suggested for reclamation areas to the district as a whole.

STUDY AREA

The study area covers the entire Pratapgarh district of Uttar Pradesh, lying between latitudes 25° 34' to 26° 11'N and longitudes 81° 19' to 82° 27'E. The district consists of three tehsils and fifteen development blocks. The annual rain fall of the district is 977.2 mm, the annual normal evapotranspiration is 1538 mm (Choudhary, N..K.,et. al, 1997).

The area is more or less a flat terrain with very low topographical gradient towards south-east. The average elevation of the load is between 100 to 115 m above MSL. The district is drained by river Sai and its tributaries which passes almost from the center of the district and flows towards south-east. River Ganga forms the south-western boundary of the district. (Mukherjee, 1989).

The soil of the study area is typically alluvial in nature, consisting mainly of : Clay dominated type, loamy type or sandy type. Alkali soils have higher clay percentage than

normal soils. The sodium content reaches up to 470 meq/lt in soil profile (Bhargava, 1989).

The study area forms a part of the Central Ganga plain and exhibits fluvial features typical of the flood plains. The entire stretch of Pratapgarh districts is underlain by thick pile of quaternary alluvial sediments of about 5000 m thickness, consisting of alternatively clay, sand and occasional beds of gravel, kankar etc. The sand zones present at various depths form aquifers (Mukherjee, 1989).

These are two reclamation areas identified in Pratapgarh district one in Rampur block around Lalganj area and the other one in Patti block. In these areas intense reclamation activities are followed since 1993 under U.P. sodicland reclamation project. These areas show high concentration of salt-affected lands. In this paper an attempt has also been made to relate the regional level analysis performed for water resources management with the scenario prevailing in these sodic land reclamation areas.

METHODOLOGY

This study involves preparation of several thematic coverage or data layers relevant to water resources management specially, in salt-affected areas. For this purpose, capabilities of ARC/INFO Geographical Information System (GIS) are utilized in creation of several data layers generated from variety of sources which are stored as coverages for subsequent spatial analysis. Since, many of this coverages are generated from different sources hence for effective superposition at later stages, all of these are transformed into the same co-ordinate system. Following steps were followed in this study :

Thematic Coverage Generation

Several arc and point coverages are prepared for different themes including ; drainage, canal network, observation well distribution, tubewell intensity etc. The polygon covergaes prepared include: rainfall distribution, groundwater draft, salt-affected areas etc.

Drainage coverage is prepared utilizing the mapping done from satellite imageries (Landsat TM, 1975) covering entire district area (Mukherjee, 1989). All the major drains have a south-eastern flow including Sai and Ganga. The northern tributaries of river Sai flows from north to south, but those on the right bank are more wandering and generally have an eastward tendency. The total length of drains in the study area is about 2131 km. With average drainage density of about 5.85 m/ha. The study area consist of numerous ox-bow lakes and palaeo-channels in the flood plain of river Ganga. Canal network coverage is prepared from S.O.I. toposheet No. 63G, 63F, 63J and 63K on 1:25,000 scale. The coverage shows a high canal density in the south-western portion of the district covering Rampur, Laxmanpur, Bihar, Kalakankar, Babuganj and Kunda blocks and also in north-eastern parts in Patti, Mangraura & Deosara Blocks. The northern and central parts of district has low canal density (Fig. 1).

A seepage risk zone map (Fig 1) is prepared from this canal coverage by creating a buffer-zone of about 5 km width approximately, adjoining major distributaries and minors, which are most prone to canal seepage. The drainage coverage prepared earlier is

superimposed on this seepage risk zone map to assess the capability of existing drainage network in handling seepage and water logging problems.

A point coverage consisting of groundwater level monitoring wells (Chaudhary, et. al, 1997) is prepared. The attribute attached with each well point includes pre/post ground water level, water-table elevation from MSL and annual water-table fluctuations.

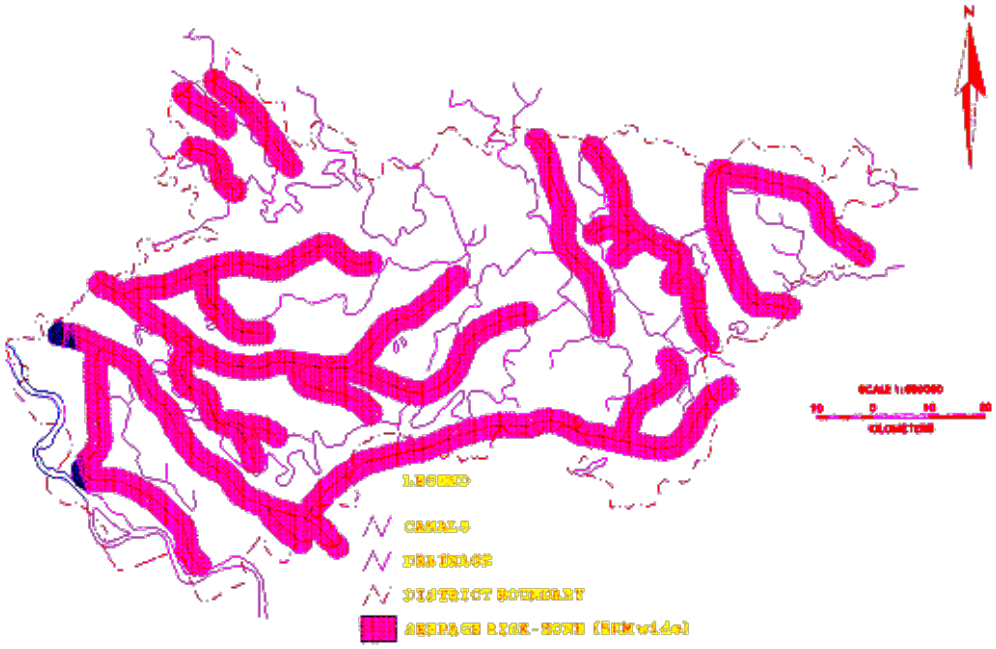

Figure 1. Map showing seepage prone areas in the visinity of canals and their relationship with drainage.

Polygon Coverages

The major polygon coverages prepared are : rainfall distribution, groundwater level trend and ground water discharge. The entire district is divided into 15 polygons representing individual blocks, which serve as single entity for data entry. For each block, data regarding rain-fall (monsoon period) ground water level and discharge is given. Rainfall data utilized is taken from rain gauge stations of IMD and state meteorological department.

Ground water level trend is determined by estimating the net decline or rise in ground water level between post-monsoon period of the years 1986-1997 at individual monitoring well and this value is extrapolated for entire block. Ground water discharge is estimated on the basis of intensity of shallow tube wells per unit block area (Chaudhary, N.K. et. al, 1987).

Categorization of polygon coverage

Utilizing the capabilities of ARC/INFO package, each of these polygon coverages are categorized by merging of polygons under specified logical expressions, defining the range of individual categories.

The rain-fall coverage is categorised into following three zones : Monsoon period rainfall < 500 mm covering about 14,5540 ha area; between 500 -800mm rainfall covering 19,7150 ha area and > 800mm rainfall covering about 11,9010 ha area.

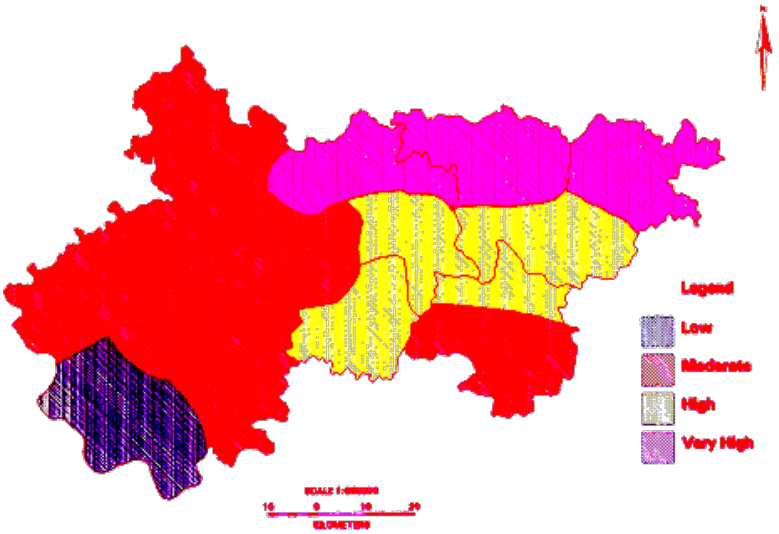

Figure 2. Map showing areas of varying groundwater discharge.

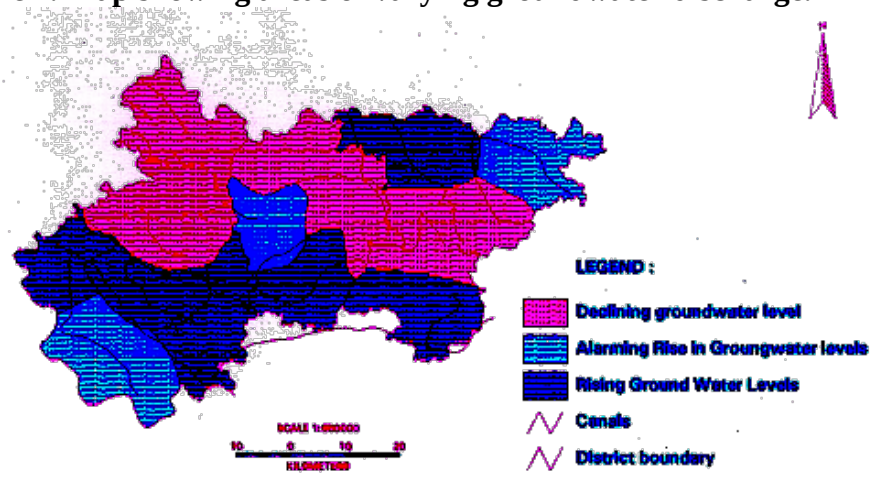

Figure 3. Areas showing different trends of ground water levels and its correlation with canal intensity.

Ground water discharge coverage is categorised into four main zones (Fig.2): low draft area consists of shallow tubewell intensity less than <2%, Moderate draft area having S.T.W. intensity between 2-4%, High draft area having S.T.W. intensity between 4-6% and very high draft showing S.T.W. intensity >6%. Ground water trend coverage is categorised in to three main zones(fig.3). deciling trend areas :showing alarming rising trend consist of those parts where g.w. table rise is more than 2-5 m.during last ten years and, areas showing significent rising trend consist of those parts where g.w. table rise is within 2.5 m during last ten years.

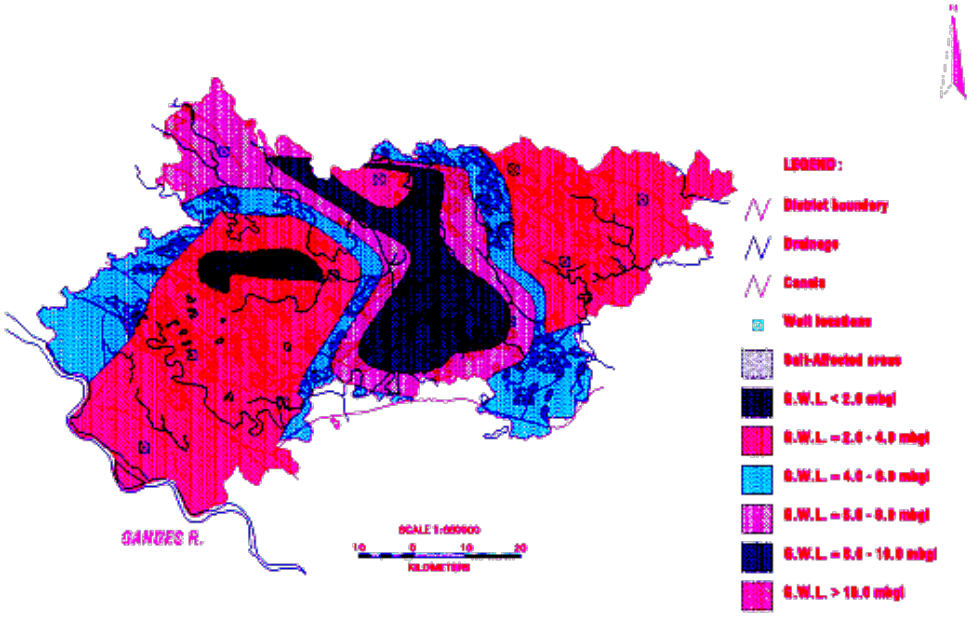

Figure 4. Map showing correlation of salt affected areas with sub-surface water-logging and canal intensity.

CONTOUR MAPS OF GROUND WATER LEVELS

Pre and post monsoon period water-table contour maps are prepared utiliging well point coverage. The premonsoon contour maps show majority of areas having water-table in the range of 6-8 mbgl. A small portion in northern and central part show depth to water deeper than 12 mgbl. Post monsoon contour maps (fig. 4) show80% of area having ground water table depth of less than 6 mbgl. A small portion in northen part show depth to water level deeper than 10 mbgl during post-monsoon period 1997.

INTEGRATION AND ANALYSIS

By integrating the above prepared set of thematic coverege,servel problematic ares are identified which are in urgent need of better water resourses management practice. This spatial analysis is also linked with the temprol analysis of ground water analysis monitored under U P sodicland reclamation project (estimated by counting no. of monitoring wells) in these reclamation ares (Table 1):

Table 1. Temporal variation in water logged areas in the two sodic land reclamation areas of Pratapgarh.

Category of water logged areas	Percentage of total area in each category (Post monsoon)				
	1995	1996	1997	1998	1999
Critical water logged (0-2 mbgl)	52.70	59.20	52.32	56.96	54.76
Semi critical water logged (2-3 mbgl)	17.40	25.90	23.00	27.80	33.33
Potential water logged (3-5 mbgl)	18.40	15.21	15.80	11.70	11.90

This data shows a gradual increase in critical (< 2.0 mbgl) and semi-critical (2-3 mbgl) water logged areas during the last five years in post monsoon period. This increase in water logged condition is basically due to excessive canal irrigation, catalyzed by poor hydraulic gradient and low permeability (Rai, D., et.al, 1999) . Fig. 5 shows increase in critical and semi-critical water logged areas since 1985 till 1999 during post-monsoon period at Lalganj reclamation area. In this area, there has occur about 20 % of increase from 90 % to 70 % between 1995 to 1999 in areas having water level < 3.0 mbgl during post-monsoon period. Fig 6 depicts one of the hydrograph station in Pratapgarh showing a continuous rise in ground water levels since 1995 to 1999 during post monsoon period, along with annual rainfall.

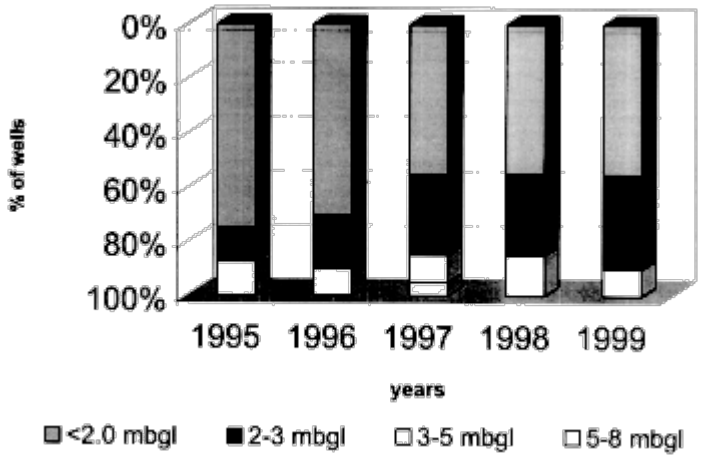

Figure 5. Graph showing percentage of wells falling in different water level zones during post-monsoon period in Lalganj reclamation areas of Pratapgarh district.

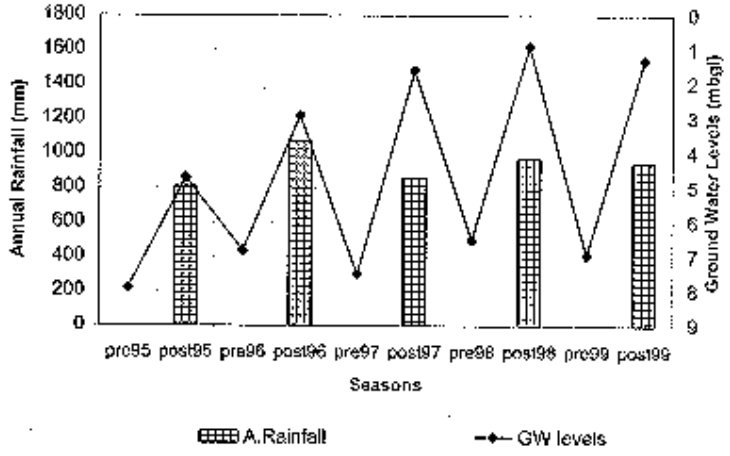

Figure 6. Graph showing a comparison between pre and post monsoonal ground water levels and annual rainfall, village Aspur Deosara, district Pratapgarh.

One other reason suggested for this increasing trend is improvement in the porosity and hydraulic conductivity of soil profile due to reclamation efforts resulting in higher percolation rates during post-monsoon period (Jha, C.K. et. al, 2000). However, in the entire study area, there is a rapid increase in the expanse of water logged areas during last twenty years since the inception of Sarada Sahayak Canal project in 1980's. Fig 1 shows seepage risk zone map. This map clearly indicates absence of proper drainage at several high seepage risk zones. The seepage prone zone of 5 km width adjoining canal should have high tube well intensity and no canal irrigation. Table 2 depicts various problematic zones identified on the basis of ground water levels and various thematic coverages prepared and, for each of these zones best suitable water resources management and irrigation practices is suggested.

Table 2. Classification of the Study Area into Different Problematic Areas with respect to Water Resources Management (Irrigation Practices).

Distribution of salt affected Lands	Ground Water Level	Availability of Ground Water	Drainage (Existing)	Ground Water Trend	Lithology (dominant)	Type of Irrigation Suggested
High Intensity Mainly C-Type Sodic lands	GWL- 0.2 m (Critical water-logged)	High	Ineffective	Alarming rise	Generally Clay dominated	100 % T.W irrigation
High Intensity	G.W.L. -2-3M (Semi-Critical water logged)	High	Ineffective	Significant rise	Clay dominated	100-85% T.W.I. 15% Canal Irrigation
Moderate Intensity	G.W.L- 3-5 m (Potential water logged)	High	Moderate to Effective	Rise	Clay	85 -60% T.W.I; 15-40% Canal Irrigation
Moderate to Lower Intensity	G.W.L .5-10m (Safe Water levels)	High to moderate	Effective	Safe	Sandy Clay	60-25% T.W.I.; 75-100% canal Irrigation
Sparce Sodic land Patches	G.W.L. 10 - 12 m (Alarming water levels)	Moderate	Excess run-off & base flow excess	Declining	Sandy Clay	Upto 25% TWI 75% -100 % canal Irrigation
Sparce Sodic land Patches	G.W.L. >12.0m (Unsafe Water levels)	Low (Over Utlization)	Run-off & base flow excess	Significant decline	Sandy Clay	No. T.W. Irrigation; 100% Canal Irrigation

The above analysis reveals that water logging and water resources utilization are closely related. The water logging conditions are exclusively created in those areas where there is poor utilization of ground water and irrigation is excessively through canals. Ineffective drainage is prevalent and ground water level is continuously rising in these areas. On relating the water-logged areas with salt-affected land distribution, it is very well evident that at most of the places, high concentration of sodic land patches occurs in critical and semi-critical water logged areas. Therefore, since water logging - salinity development - groundwater resource utilization are closely related hence for sustainable reclamation of sodic soils, utilization of suitable water resource management practices in reclamation areas of Pratapgarh is essential. Following alternatives are suggested, keep-

ing in view, the present scenario of ground water status and its future impact on the hydrological system and land utilization : (i) extensive ground water irrigation through shallow tube-wells in critical & semi-critical water logged areas, (ii) complete stoppage of canal irrigation in such areas and (iii) Limited use of canal water in those areas where water level is deeper than 10 mbgl.. In such areas, ground water utilization shall be less than 25%.

CONCLUSIONS

On the basis of this study it can be concluded that :

The regional level spatial analysis results are very well correlated with that of the reclamation areas. Therefore, the strategy for water resource management suggested for sodicland reclamation areas are universally applicable for the entire district.

The analysis suggest that Water logging - salinity development - ground water resource utilization are interlinked hence equal emphasis is to be given to all these three aspect in all the identified problematic areas.

On correlating the distribution of salt-affected areas with water table contour map, it is evident that special emphasis is needed to be given for water resources management where ground water level is less than 5mbgl during post-monsoon period for sustainable reclamation process.

Acknowledgement

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