Evaluation and Management of Waterlogging Problems in the Command Area of Kadana Dam, Kheda District Using GIS

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Abstract— Water logging problem occurring in the command area of Mahi Right Bank Canal (MRBC) of Kadana dam has been evaluated using remote sensing and Geographical Information Systems (GIS). Various thematic maps have been prepared such as topography, geohydrology, soil, land use, Digital Elevation Model (DEM) and synthesised with the ground water and surface water and collated with irrigation data in GIS environment Major part of MRBC command area is occupied by Alluvium of Sabarmati and Mahi River and most part of the area is flat. Appreciable rise in the sub-soil water level has been observed since 1980 that is after starting irrigation through canal network of MRBC. Now major part of the Kheda district is either affected by water logging and salinization or presently under critical condition requiring immediate remedial measures and suitable management plan. Three talukas of Kheda district namely Matar, Mahudha and Kapadvanj are almost water logged and remaining under critical stage except part of Balasinor and Mehmedabad where water table is still in safe zone. Flat topography (0 to 1° slope), inadequate surface and sub-surface drainage, poor maintenance of existing drainage system, over irrigation and cultivation of more water intensive crops after the operation of canal network are some of major causes of water logging in the area.

Key words: Waterlogging, GIS, DEM, Topography, MRBC, Management

I. INTRODUCTION

Waterlogging is a major problem in the Mahi-Right Bank Canal (MRBC) command area adversely affecting the soil condition and agricultural productivity. The Kadana Dam is one of the major irrigation projects of Gujarat State, constructed on Mahi River in the year 1978 with the main objective of augmenting the supply of water in the command area through two main canal systems namely Mahi-Right Bank Canal and Left Bank Canal. Mahi Right Bank Canal (MRBC) covers parts of Thasra, Nadiad, Cambay, Matar, Borsad, Anand and Petlad talukas of Kheda districts and Mahi Left Bank Canal (MLBC) covers two talukas of the Panchmahal district, namely Lunawada and Santrampur. Appreciable rise in the water table was observed in the command area of MRBC since the start of canal irrigation. Problems of rise of water table and increase in the salinity in the area continued with time. Sub-soil water level in some part of the Kheda district has reached within 2m and even up to ground level creating water logging problem in the area. This problem has accentuated within last twenty years, especially in the area west of Vadodara-Ahmedabad railway line, namely Khambhat, Matar, Tarapur, Limbasi talukas. Hence, detailed study of the area affected by water logging has been carried out in the Kheda district using Remote Sensing and GIS to suggest preventive measures to arrest further degradation of land and to improve the soil condition and thus agriculture productivity.

II. STUDY AREA

The MRBC area falls between latitude N 22°26'-N 22°55' and longitude E 72°19'-E 73°23' The study has been done in the areas of seven talukas of Kheda district lying within command areas of MRBC (Fig. 1). Major part of the study area lies between Mahi and Sabarmati Rivers in alluvium (Fig. 2). Watrak and Shedhi rivers also flow across the area. The command area is irrigated by main canal and distributary canal system. Aggregate length of canal system network is 5600 km length. The cultural command area (CCA) is 212694 hectares. The climate is dry and semiarid except during the monsoon period.

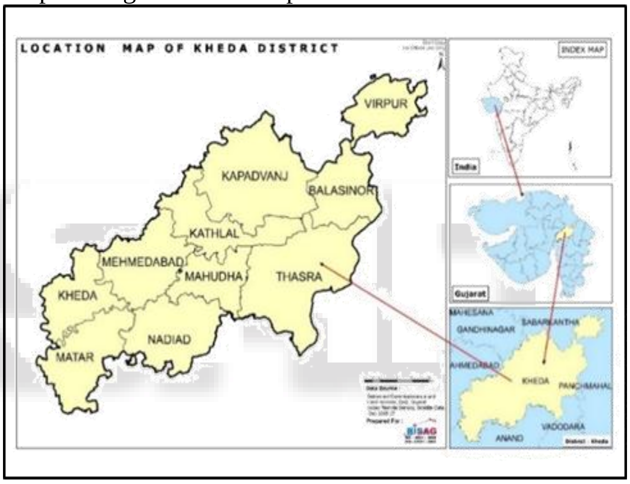

Fig. 1: Location Map of Kheda District

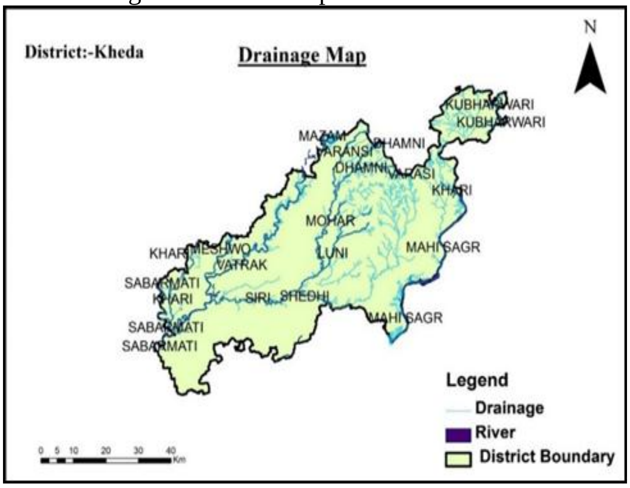

Fig. 2: Drainage Map of the Study Area

The average rainfall of the District is 744.36 mm for the years 2010 to 2014, whereas rainfall in different parts of the District varies from 436 mm to 1230 mm with average number of 45 to 50 rainy days (Fig. 3.).

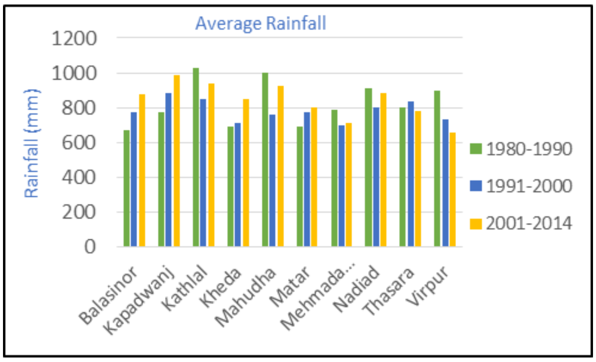

Fig. 3: Annual average Rainfall since Year 1980 to 2014

A. Topography:

The MRBC is characterized by a generally flat topography. There are some isolated local high spots and ridges in the north-eastern and central regions. There are no distinct valleys in the command area to facilitate easy natural drainage. The land slopes from northeast to southwest with an average gradient of 1 to 1600. The southwest region comprises a relatively flat land locally known as 'Bhal' area.

B. Soil:

The soils of MRBC command area are deep alluvial deposits formed within Mahi and Sabarmati river basins. The soils in the area are derived from phyllites, schist and quartzite and hence differ from place to place. The phyllites and schist give rise to medium to heavy soils. Varying from sandy loam to clay, whereas the quartzite form the coarse material in flood-plains, giving rise to loamy sand to sandy loam soils. Soils of hilly plains and interfluves occur in the northern part. A small part of the marshy waste land is located in the southern part of the district.

III. METHODOLOGY

The methodology adopted for the present study includes (Fig. 4):

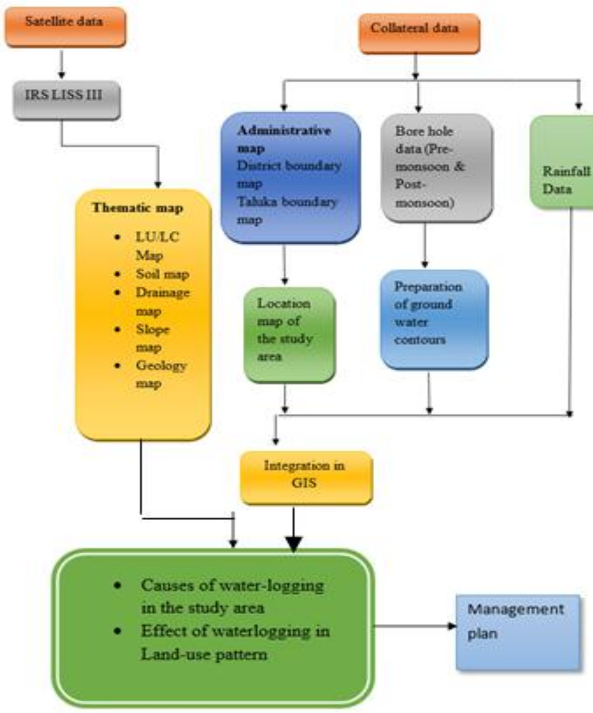

Fig. 4: Flowchart of methodology

1) Creation of thematic Maps (Land use, Contours, Slopes, geology, Soils, etc.) with the help of LISS-III images and Arc GIS software.
2) Collection and integration of collateral Data such as District Boundary, Taluka Boundary, Meteorological Data and Hydrological Data with the thematic layers.
3) Integration of various thematic layers and data using GIS to identify water-logged area. Analysis of thematic layers and data to develop suitable management plan.

A. Land Use/Land Cover Map:

Land use map has been developed with the objective to identify and demarcate the areas of Agriculture, Built up, Forest, Water Bodies and Waste Land for assessing especially the impact of irrigation on agriculture land. In the study area agriculture, built up, forest, water bodies and waste lands have been identified and delineated. It has been observed that around 90% command area is covered by agriculture land (Fig. 5). This area of agriculture land has been especially studied to know the adverse effect of waterlogging and thus for proper groundwater management.

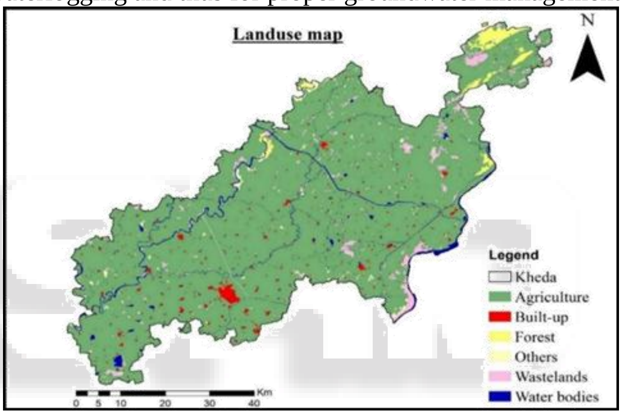

Fig. 5: Landuse map of study area

B. Soil Map:

Major part of the commnd area is occupied by alluviam comprising of sandy and loamy soil (Fig. 6). Loamy soil is considered good for agriculture. Infiltration rate in sandy and lomy soil is highy due to inherent porosity and permeability.

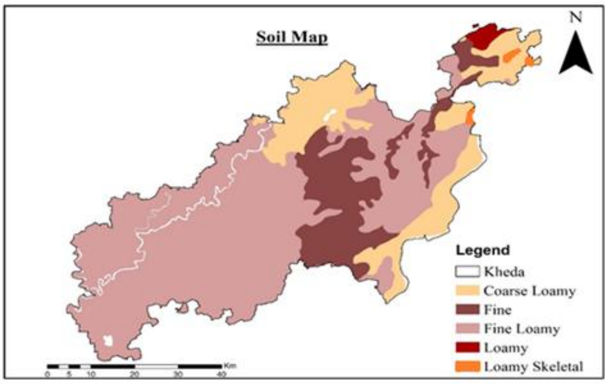

Fig. 6: Soil map of study area

These types of soils help in vetrtical movement of water down ward as well as upward resulting in the rise of sub-soil water level. Rise in water table creates faourable condition for water logging. Presence of clay lenses/ calayey layers at shallow depth create the perched water condition and aggrevate the situation by restricting the flow of water downwards. Rise in water through capillary action in subsoil and evaporation of water from surface causes concentration of salt in the soil and thus helps in further deteriorating soil condition.

C. Geomorphology Map:

Geomorphologically area is mainly occupied by structural hills in the north east, alluvial plain and pediplain in the main central part (covering about 90% area) and coastal plain in south eastern part (Fig.7). The study area of MRBC is almost flat except a few isolated spots of ridges, hills and depressions and. There are no distinct valleys in the command area to facilitate easy natural drainage.

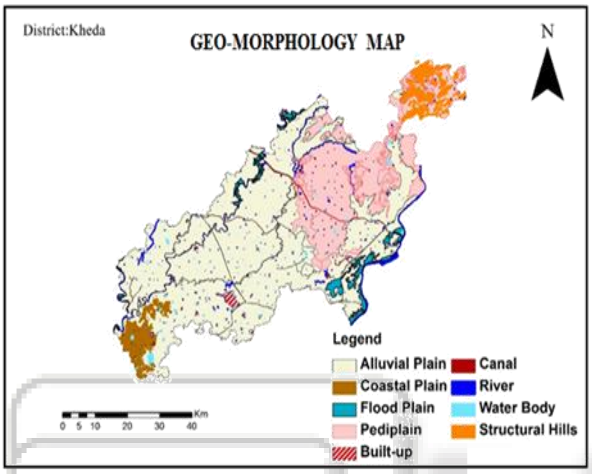

Fig. 7: Geomorphology Map of the study area

D. Slope Map:

Slope map was generated from Digital Elevation Model (DEM) of the area (Fig. 8 & 9). Major part of the command area is nearly flat (0-1%) creating ideal condition for low run off and thus high infiltration resulting in water logging problem in poorly drained area (Table 1).

Slope	Slope type	Area (Sq. Km.)
0 - 1 %	Nearly level	3968.3899
1-3 %	Very Gentle Slope	15.509
3-5%	Gentle Slope	0.6148
5-10%	Moderate Slope	1.909

Table 1: Slope Conditions

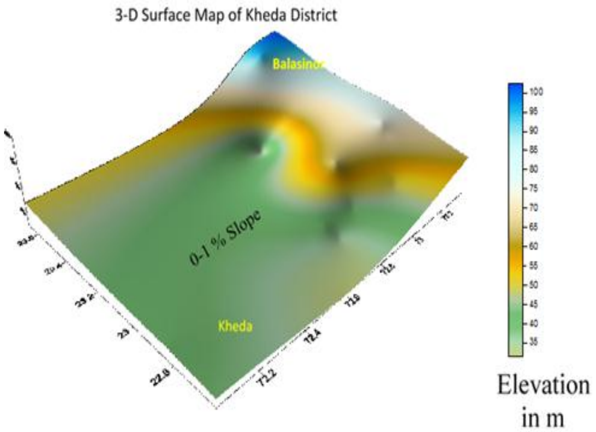

Fig. 8: 3-D Surface Map of Kheda District

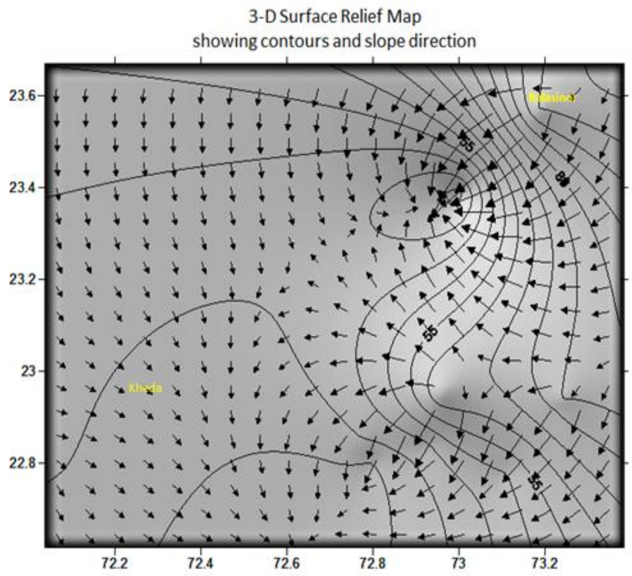

Fig. 9: 3-D Surface Relief Map of Kheda District showing contours (m) and slope direction

E. Water Table Map:

Available sub surface water level data has been synthesised for the period 2006-2014 and water table maps have been created in GIS environment to identify and assess the water logging conditions in the command area of MRBC in Kheda district National Commission on agriculture (1976) has defined an area to be waterlogged when the water table rises to an extent that the soil pores in the root zone of a crop become saturated, resulting in restriction of the normal circulation of air, decline in level of oxygen and increase in the level of carbon dioxide.

The actual depth of water-table when it starts affecting the yield of crop adversely may vary over the range from zero for rice to about 1.5 m for other crops (Table 2 & 3).

Zone	Water level (m)	Classification
Zone I	0-1.5	Waterlogged area
Zone II	1.5-3.0	Critical to get waterlogged
Zone III	>3.0	Safe area

Table 2: Classification of area as per water table depth

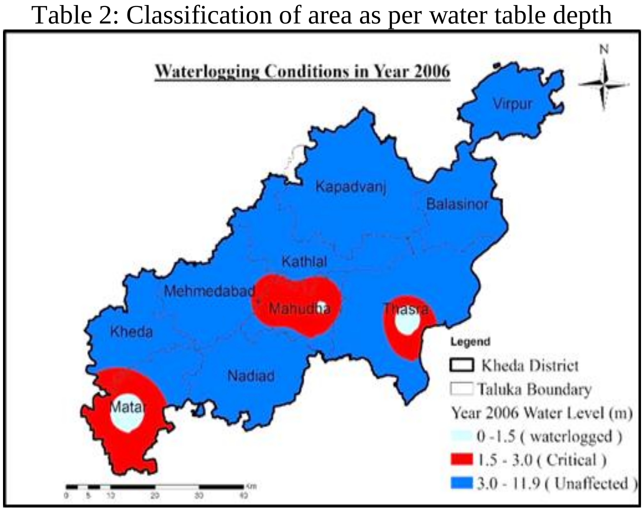

Fig. 10: Waterlogging zones in the Year 2006

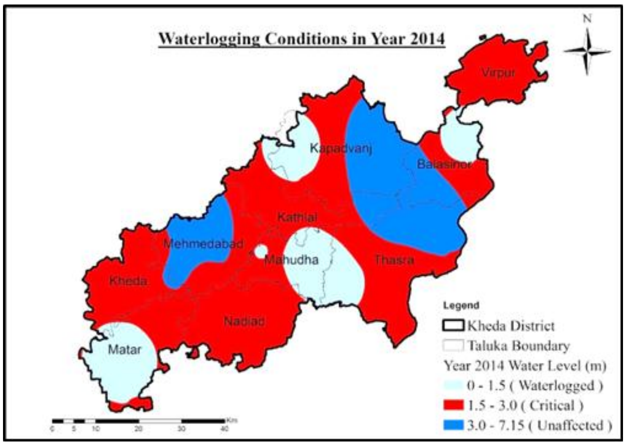

Fig 11: Waterlogging zones in the Year 2014

ZONE	Year 2006	Year 2014
ZoneI (waterlogged)	79.84 km^2	713.94 km^2
Zone II (critical)	543.74 km^2	2408.18 km^2
ZoneIII (unaffected)	3339.34 km^2	840.79 km^2

Table 3: Area statistics of water sub-soil condition in the year 2006 and 2014.

It has been observed that in the year 2006 only small part of the Matar, Mahudha and Thasra talukas were under water logging (Zone I) whereas major part of these talukas were under critical condition (Zone II) (Fig. 10). At that time other talukas were in safe zone (Zone III).

Situation deteriorated by the year 2014, almost entire areas of Matar, Mahudha and Kapadvanj talukas came under zone I. Only part of Balasinor and Mehmedabad remain under safe zone III (Fig. 11).

F. Assessment of Cropping Pattern:

Prior to inception of canal irrigation, only seasonal crops were grown. With the availability of canal water for irrigation cultivators start growing cash as well as two seasonal crops (like tobacco, tuver, cotton etc.) besides perennial crops (like sugarcane & banana) affecting water quality and sub-soil water condition. Formers are now growing three seasons crops i.e. paddy during monsoon, wheat during Rabi and again paddy during summer. Thus, the area remains under irrigation round the year causing waterlogging.

G. Evaluation of Water Logging Problem and Management Plan:

Major part of the MRBC area is occupied by alluvium comprising of sandy and loamy soil. Structure of these types of soils helps in vertical movement of water down ward as well as upward resulting in the rise of sub-soil water level with increase in recharge. In major part of the MRBC command area, it has been observed that pre and post monsoon water remains almost unchanged. This indicate most part of the area has reached saturation stage. Therefore, proper planning of the crop pattern, drainage and regular dewatering of the area is essential.

Topographically, the study area is flat. In flat topography run off is poor and thus infiltration is more which helps in rise in water level in sub-soil. There is also no proper drainage to drain out excess rain water during monsoon resulting in accumulation of surface water in low depression causing subsequent seepage in sub-soil. Adequate planning and maintenance of surface drains are essential. These drains should be linked to the field drains through link drains for disposal of excess water from water logged area.

During monsoon the area on West side of Tarapur Matar road remains under submergence for a longer period. Within last twenty years sub-soil water levels has risen at an alarming rate in the west of Vadodara-Ahmedabad railway line particularly in Khambhat, Matar, Tarapur, Limbasi and along area of Mahi command.

Prior to inception of canal irrigation, only seasonal crops were grown but now formers are now growing three season’s crops and utilizing excessive water for irrigation. Over irrigation and improper crop pattern has deteriorated ground water and soil conditions in the area. It has resulted in the rise of the water table and increase in the salinity in the area. Efficient method of irrigation like Sprinkler and Drip would help in decrease of the use of surface water. Regular dewatering of the area by installing adequate pumps will help in locally lowering the water table. The drained and pumped water can be utilized for other activities such as for drinking, industries and sewage treatment.

Out of 2696 km of length of canal network only 296.60 km is lined while rest of canal is unlined. Seepage is anticipated from unlined canal through soil and rocks and from damaged part of the lined canal with time. To prevent seepage losses regular repairing of the damage lining of the canal network is essential besides concreting of the unlined part of canal. Tree plantation along canal banks helps in the use of sub-soil water and also increase in evaporation.

IV. CONCLUSION

Synthesis and evaluation of available geohydrological data in conjunction with remote sensing and GIS study reveal that flat topography, inadequate surface and sub-surface drainage in sandy and loamy alluvial soil, poor maintenance of existing drainage system, over irrigation and change in crop pattern by growing water intensive crops since the operation of canal network are some of major causes of water logging and thus in deteriorating soil conditions in Kheda district. Adequate planning and maintenance of surface drains, adaptation of agriculture practices requiring less use of surface water, maintaining balance between surface and sub-surface water are some of the water management plan requirement. GIS study with the help of Multi-temporal satellite data would help in continuous monitoring of the waterlogging dynamics and thus proper management of MRBC area.

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