GEO-ENVIRONMENTAL STUDIES OF MAHI COMMAND AREA CENTRAL GUJARAT, WITH SPECIAL REFERENCE TO IMPACT OF IRRIGATION ON SOIL AND WATER REGIME IN MATAR BRANCH

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Introduction

Mankind depends heavily on the development and exploitation of natural resources for satisfying the escalating societal demands. Consequently nature can not be preserved in an unaltered condition. Thus development of resources and environmental changes goes together. Developing countries, like India, facing population explosion, still it yearns for economic and social progress to catch up with the developed countries

Gujarat, a predominantly agricultural based state. Owing to highly erratic and unevenly distributed monsoon, the exploitation of states' total water resources for irrigation, industries and domestic utilities had grossly overutilized.

An increased pace in irrigation potential has brought up the stability in agricultural based production by reducing the effect of weather based fluctuation. This uncontrolled utilization of water and land has caused imbalance in natural environment, causing an irreparable damage to states' precious land and water resources.

This presented study represents a case of one of such irrigation project i.e. Matar Branch of the Mahi Right Bank Canal (MRBC) command in the Central Gujarat.

Study Area

The study area "Matar Branch" is situated in the western periphery of the

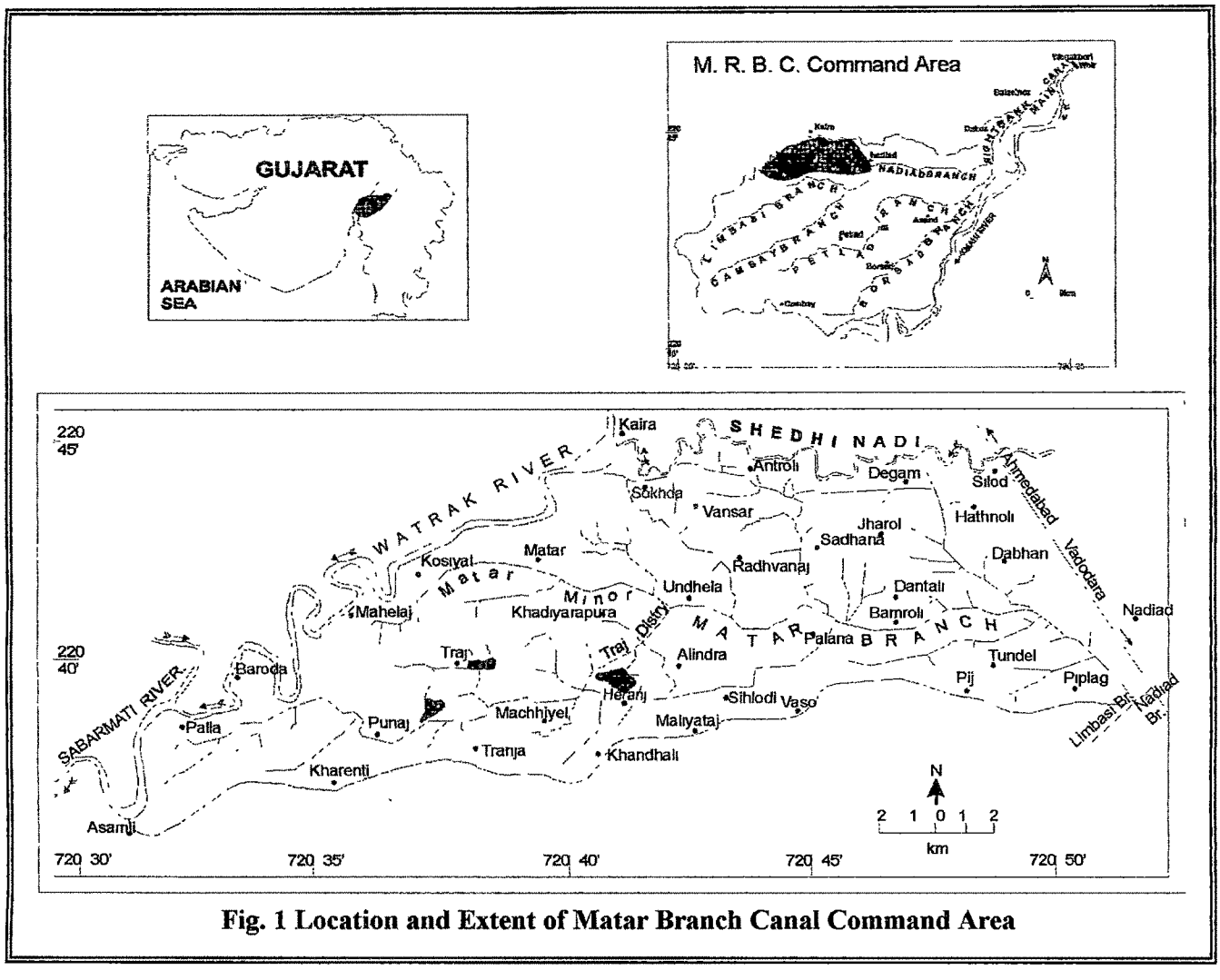

Fig. 1 Location and Extent of Matar Branch Canal Command Area

Kaira district and lies between 72^0 30' to 72^0 50' E longitude and 22^0 18' to 22^0 51' N latitude. It constitutes a small irrigation command (22640 hectares) of the vast area of Mahi Right Bank Canal (MRBC) Command area.

Aims and Objectives

Presented study aims at evaluating the consequences of canal irrigation and its impact on soil and water regimes; corroborating secular and the vector changes in water table, water chemistry and the salt balance in soil and sub-soil horizons. The information thus generated to be utilized for conceptualizing three-dimensional modeling and suggesting appropriate management strategies, to mitigate the adverse effects.

The main thrust of the investigation pertains to a critical evaluation of the following parameters:

- ✓ Surface and subsurface geological conditions, sediment nature and extent,
- ✓ Basic terrain characteristics, landuse pattern and long term changes,
- ✓ Water table behaviour pattern – secular and vector changes and its causes,
- ✓ Canal water input and its contribution to groundwater regimes as return irrigation seepage,
- ✓ Soil-water chemistry vis-a-vis secular and vector changes,
- ✓ Surface and sub-surface outflow and the factors governing the outflow.
- ✓ Crop-water demand scenario and existing management practices.

Approach and Methodology

A multi-disciplinary approach was adopted to achieve the above-cited objectives. The methodology thus followed:

- Collection of existing geohydrological data pertaining to the study area, to be used for working out long term and spatial changes in the command area in general and Matar Branch specific.
- A detailed fieldwork carried out to delineate the effect of irrigation on soil and water regime, change in land use pattern using satellite data and the field checks.
- Inventory of groundwater table changes for different seasons on identified observation wells and groundwater sampling.
- Collection of soil samples from surface and sub-soil horizons.
- Determination of physical and chemical characteristics of the water and soil samples.
- Data evaluation – graphical and statistical treatments for establishing geohydrological regime, groundwater flow maps and spatial distribution of soil-water chemical content.
- Synthesizing predictory model for groundwater, soil, landuse changes, using computer added software modules.
- Working out an appropriate management strategy to minimize the geo-environmental hazards.

Terrain Characteristics:

The MRBC command area comprises part of an alluvial plain laid by Mahi and Sabarmati River. The eastern part of the area is rocky where Trappean rocks

are exposed which on moving westward overlained by thick alluvial deposits. The altitudinal heights varies between 64.06 to 8.0 m.

The area is characterized by a steep slope in eastern part, gentle in the central part and in the western part the slope is flat. The rocky ridges in the eastern part are forming undulating topography.

The overall drainage, which is governed by the river Mahi, Sabarmati, Watrak and Shedhi rivers, constitutes southwesterly flowing drainage system. There are smaller tributaries and rivulets, which follow the general trend of topographic slope.

The Matar branch command area comprises mainly alluvial deposits. The altitude of the command area varies between 36 and 17 m above mean sea level and characterized by almost flat topography. The overall slope of the command area is southwesterly and gradient is very gentle (< 1%). The river Shedhi, Watrak and Sabarmati are forming the command area boundary in the north. These rivers act as main drains of the command area.

General Geology

Present study area forms a part of the intracratonic Cambay basin belonging to the Mainland Gujarat. Cambay basin falls between the latitude 21^0 to 24^0 N and longitude 71^0 30' to 73^0 30' E respectively.

The rocks of the mainland shows an age from Proterozoic to Recent, but the most striking feature of the stratigraphy of the mainland is total absence of entire Paleozoic sequence and the development of only upper most Mesozoic rocks.

The present study area falls under the Tarapur-Cambay block, and exhibit following lithostratigraphy (after Pandey et. al. 1993).

Period	Formation	Thickness in m	Lithology
Recent to Pleistocene	Gujarat Alluvium	50-100	Yellow Grey Sandy Clay
	Jambusar	300	Yellow Grey Clays, Coarse Sand, Gravel and Kanker
Pliocene	Broach	300	Chocolate Brown and Red Brown Clay Stone, Sandy Claystone and Sandstone
Up. Miocene to Mid. Miocene	Jhagadia	200	White and Gray Calcretes and Micaceous Sandstone, Gray Shaly Sandstone and Sand
Mid. Miocene to Lower Miocene	Babaguru	300	Ferruginous Sandstone, Conglomerate and Gray Clays and Claystone
Lower Miocene	Tarkeshwar	150	Variegated and mottled claystone and Sandstone, Carbonaceous, Sideritic Shale and Sandstone.
Oligocene to Up. Eocene	Tarapur Shale	200-300	Greenish Grey to Dark Grey Shale, Silty and Sandy Shale, Argillaceous Sandstone
Up. Eocene to Mid. Eocene	Vaso	200-300	Sandstone Calcareous, Silty Shale,
Lower Eocene	Upper Cambay Shale	500-750	Dark grey to grey Shale moderately hard, massive sand, Sandstone, Carbonaceous, dark grey Shale and Coal
Paleocene	Lower Cambay Shale	500-750	Dark Grey to Black fissile shales, hard and rich in organic matter
Upper Cretaceous	Deccan Trap	300-3000	Basalt, Andesite, Trachyte, Picrite and Syenite etc.
Proterozoic	Granite		

Water Resources

The area has plenty of surface water resources in the form of major rivers, namely Mahi, Watrak, Sabarmati, and Shedhi, and number of tanks and ponds. Though area receives an annual rainfall of 800-mm which spread over 35 days is comparatively less than the critical dry spell.

The MRBC command area owing to its vast alluvial thickness offers highly potential hydrogeological conditions. The study of bore hole lithologs and plotted hydrogeological sub-surface profiles corroborates that the area displays a thick pile of alluvial materials representing intercalated sequences of sands and clays. The thickness of these layers varies from 30 to 60 m. based on their deposition patterns, in all two tiered aquifers are inferred i) top between 20 to 50 m and ii) bottom between 65 and 150 m. These aquifers are unconfined to semi-confined in nature.

Subsurface sections of the Matar branch command area have also shown the alternate layers of the clay and sand with varying thickness. In the command area the aquifers mainly of the medium to fine sands of varying thickness and are of confined nature. The thickness of the aquifer mainly varies between 30 to 50 m below ground level. The aquifer at the top is confined by a clay layer and at places by a clayey kanker layer.

The cross section of both the MRBC and Matar branch clearly revealed the aquifers in the command are with local swelling, pinching and bifurcation. The aquifers are generally overlained by a thick clay bed on top and it gradually pinches out as one moves in the eastern direction.

Water level fluctuation

Water level fluctuation studies have been carried out by collection long-term vector data from government agencies as well as candidate's own observations. Secular variation (1979-1999) has been studied to note the water table fluctuation. The ground water contour maps of the region both, MRBC and Matar Branch, command area indicate the flow of the ground water is from NE to SW direction with a varying hydraulic gradient. There is a general seasonal fluctuation in the water table to the order of 1 to 2 m on an average.

The study of the pre-irrigation (1958) and post-irrigation water table scenario has been carried out with long-term vector data. Prior to irrigation, water table in the entire command area was ranging between 3 to 25 m below ground level. The seasonal rainfall coupled with canal irrigation, where in the incipient return flow recharging the aquifer, cause further rise in water table. Thus the present water table now ranges between the 0.6 to 14 m below ground level. This rise in the water table to the tune of 2.4 - 11m and encompassing almost 2394 ha area of the command, ultimately has rendered waterlogged. The area having water table depth ranging between 1.5 and 3.0 m depict net increase from 2073 ha (pre-irrigation) to 81050 ha (pre-1999) which is said to be prone to waterlogged. This rise in the water table is significant in the eastern part of the area i.e. around Umreth, Kalsar, Lindgda, and in western part i.e. parts of Limbasi, Matar, Nadiad, Petlad and Cambay Talukas.

The Matar branch command area as occupying the western periphery of the MRBC command area, its northern most boundary is marked by the rivers

Sabarmati, Watrak, and Shedhi, the trend of the groundwater flow is locally changed in the near proximity of the river. Prior to canal irrigation only 9% area of the command was having the water table in the range between 1.5 and 3.0 m below ground level. it is interesting to observe that after the introduction of the canal irrigation, the change in water table till 1999 showed significant upward trend; covering almost 3% area of its command ranging between 0 and 1.5 m (i. e. Waterlogged) and 35.10 % of command area between 1.5 and 3.00 m (prone to waterlogged). The area showing high water table is mainly centered around the Matar, Pij, Kharenti, Raghvanaj locality i.e. the western and southeastern parts of Matar Branch command.

Ground water chemistry

The groundwater are characterized by higher concentration of the dissolved constituents than the surface water. This is attributed to greater interaction of groundwater with various materials in sub-strata. The chemical quality for the entire command area of MRBC varies in accordance with the groundwater flow direction i.e. NE-SW. Study of the earlier data i.e. prior to irrigation facilities command area used to possessed good quality of water except in some parts of the Matar, and Cambay. Chemical characteristics of the groundwater quality, monitored at different places during pre-monsoon and post-monsoon periods are observed as under:

1. The Na+K content of the entire command area varies between 231and 3830 mg/lit (1975) where as Cl ranges between 48 and 5520 mg/lit. There is a

considerable rise in both Na+K and Cl, which varies in the range of 345-5081 mg/lit and 391-7234 mg/lit respectively. The area showing higher Na+K and Cl are falling Nadiad, Matar, Limbasi, Petlad and Cambay Talukas.

Incase of the study area both Na+K and Cl shows considerable increase from 500-3000 mg/lit to 505-5081 mg/lit and 48-640 mg/lit to 977-7234 mg/lit respectively. Higher Na+K and Cl are mainly confined to the area around Matar, Kharenti, Dantali, Vaso, and Pij. The increase in the Na+K and Cl may be attributed to basic ion exchange during the down ward movement of the water.

2. The SAR values of the MRBC command area in the year 1975 ranges between 3.34 to 20.4 %, which fall under the good quality of water. But after the introduction of canal water which has resulted in the overall decrease in groundwater utilization; this change in the use of water resources has witnessed increased SAR value to 5.54 to 42.20 and most of the area falls under the category of C_4-S_2, C_4-S_3, and C_4-S_4 of the US salinity chart. However, in the study area pre - 1975 the SAR values were between 4 and 12.5. But the irrigation has resulted in to sharp rise in SAR (8-32) and water now falls under the category of C_4-S_2, C_4-S_3 and C_4-S_4.
3. About 32 % of the MRBC command area has EC > 2000 mmhos/cm which indicate the salinity in groundwater. But the introduction of the irrigation has resulted in to 10% increase in command area now having EC > 2000. However, it is significant to observe that in the Matar branch command area the water salinity has considerably improved thereby reducing the saline area

from 90% to 66% of the total command. This may be due to recharge of the aquifer through good quality of irrigation water in the upper reaches as well as the returned irrigation seepage.

4. The ground water in the total command area indicates higher degree of variation in mineralization. The command area prior to 1975 shows Total Dissolved Solid (TDS) less than 1000 mg/lit. However, there is a significant increase in the TDS, which is presently ranging between 1500 and 6000 mg/lit.
5. Higher values of the K and Na indicate excessive application of chemical fertilizers.

One of the reasons for ground water quality deterioration may be attributed to retention of inherent salts and poor flushing due to near absence of surface drainage in the lower reaches of command area.

Soil

The extent of soils in both MRBC as general and Matar branch command area in particular is very deep (>90 cm deep). The Soils of the study area vary in their textural characteristics and color. The color of the surface soil varies from 10YR 5/4 yellowish brown to 10YR 3/4 dark yellowish brown; where as that of subsurface varies from 10YR 4/4 dark yellowish brown to 10YR 3/4 dark yellowish brown.

The grain size analysis have shown that surface soil is mainly sandy loam and fine sandy loam where as subsurface soil shown the texture of silty clay loam to sandy clay to clayey in nature.

Available Water Holding Capacity (AWHC) of the soil is computed for that of effective soil depth 90 cm. Accordingly, 36.3 % area has AWHC >12 cm and 34.1% area has that of 9-12 cm. There is general increase in AWHC as one move towards the tail end of the command area.

Infiltration rate of the soil varies from 0.18 to 1.34 cm/hr within the command area.

Soils of the study area show permeability ranging from 0.23 to 2.3 cm/hr and considered to be moderately slow to slow. Permeability of the surface soils varies between 0.5 and 2.3 cm/hr. However it in significant that as depth increases there is an overall decrease in the permeability i.e. 0.23 to 1.1 cm/hr.

Soil chemistry

1. Chemical analysis has revealed that 81.5 % of the surface soil is non-saline (EC < 1.0 mmhos/cm) and 3.63 % area have high salinity (EC > 2.0 mmhos/cm). Spatial data has revealed that there is an increase in the saline area within the study area.
2. Soils of the study area falls under the category of moderately alkaline to alkaline in nature. With the increase in depth there is general decrease in the alkalinity of the soil.

3. Soils of the study area has cation exchange capacity less than 25% and it shows general decrease in the value with increasing depth.
4. Na and K values show spatial increase in their concentration, and decrease depthwise. This may be the effect of applied chemical fertilizer as well as the repetitive cycles of wet and dry period, responsible in upward migration of cation under capillary rise.
5. Exchangeable Sodium Percentage within study area have values varying between 0.16 and 32.5, at some places it is observed more than 15, indicating alkali hazards.
6. The surface and subsurface soils under the command area analyzed for their organic matter content and it ranges between 0.06 and 1.33 %.
7. Calcium carbonate content in the soil varies between 0.5 and 15 % and it increases with depth.
8. The macro-nutrient (N, P and K) level decreases in the entire study area indicating an overall decrease in the fertility of the soils.

Broad Inferences

The study area i.e. the Matar Branch represent s a complex case of land and water resources management. The intricacies of these problems owes their existence to the factors relevant to geologic and anthropogenic attributes.

The study area, which constitutes a part of vast tracts of Central Gujarat alluvium plains gradually merges in to coastal plain. Extremely flat gradient, inadequate surface drainage and relatively porous and permeable soils and sub-

stratum had perceived higher order of groundwater recharge i.e. 18% of the annual rainfall.

Implementation of canal irrigation in the study area wherein all canal system (except major branch) is unlined and over irrigation has resulted into added recharge to the groundwater regime.

Lack of any effective mechanism for conjunctive utilisation of an over all water resources; the study area has witnessed sharp rise in water table, to the extent that a large area has become now waterlogged and near waterlogged. This upward movement of water table had also concentrated the salts in the sub-soil and soil horizons and water salinity.

The environmental implications of these problems are amply discernible in the study area as damage in quality of soil and water resources and significant changes in the landuse pattern, thereby socio-economic impact.

The candidate in his endeavor has attempted 3-D mathematical modelling using latest computer software for quantitative and qualitative assessment and prediction of future scenarios.

Accordingly the management strategies mitigating these hazards are recommended.

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