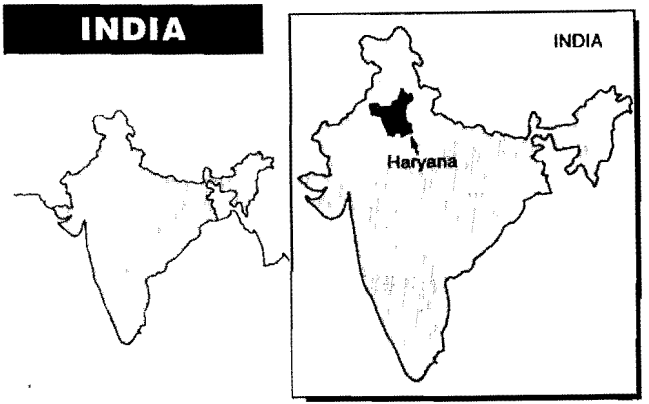
Performance Analysis of a Wheat-Based Irrigation System Using SRS and GIS Techniques: A Case Study from India



INTRODUCTION

The study was undertaken by IIMI in close collaboration with the National Remote Sensing Agency (NRSA) of India and the Irrigation and Water Resources Department (IWRD) of the State of Haryana, India. It aims to inventory the Bhakra canal command area in the State of Haryana.

The main objective of the study is to test the application of a total package of SRS and GIS techniques to evaluate the performance of a wheat-

based system and to demonstrate the utility of these techniques as an operational tool for system improvement. The specific objective of this study are:

- the generation of desagregated statistics on total irrigated areas, area under major crops, and wheat productivity
- the integration of satellite-derived statistics with other relevant ground measured data to identify factors constraining agricultural performance and to develop strategies for improved water distribution and agricultural productivity

THE BHAKRA SYSTEM

The Bhakra system has a cultivable command area (CCA) of 1.2 m ha partitioned into 3 operational systems, 13 divisions, and 41 subdivisions. In this command, area irrigated by groundwater through shallow and deep tube wells is almost equal to that irrigated by canal water. The surface irrigation system is operated according to warabandi principles. The Bhakra canal system has been in operation since 1955-56. Presently, most of the irrigated area is occupied by high yielding varieties of rice, wheat, and cotton.

The average minimum temperature fluctuates around 5 °C and the maximum around 45 °C. The average annual rainfall in the command varies from 750 mm in the northeastern to less than 400 mm in the southwestern parts. During rabi, rainfall varies from 100 mm to less than 50 mm. Evapotranspiration is estimated to vary between 1,250 mm and 1,650 mm per year, being equivalent to an average of 4.5 mm per day.

SATELLITE INVENTORY OF THE BHAKRA CANAL COMMAND AREA

The Bhakra command area is covered by two paths of the IRS IB satellite. Keeping in view the cropping pattern and crop calendar, five dates of satellite overpass (21/22 November 1995; 26/27 January 1996; 17/18 February 1996; 10/11 March 1996; and 01/02 April 1996) were obtained. The above data-supplemented by LANDSAT TM data of December 1995 cover the whole period of the rabi crop season of 1995–96.

Field visits were carried out for collecting information on crop cultivated, crop calendar, crop condition, groundwater quality/utilization, and locational position of crop-cutting experiment (CCE) plots (latitude and longitude) for development of the wheat yield model. The accuracy of crop classification was also validated during this field visit.

Due to staggering in the crop calendar across the command area, satellite data of any one overpass date could not achieve complete classification of crops and hence satellite data of 5 dates during the growing season were analyzed. An innovative classification methodology was developed by combining supervised (maximum likelihood) and unsupervised (clustering) techniques.

The crop classification was validated against sample areas identified during the field visits but not used in classification, as well as randomly selected area observed during the field visit. An overall *kappa accuracy* of 95 percent was obtained.

Ground-harvested wheat yields in 270 plots were obtained from the Agriculture Department of the State of Haryana. The latitude and longitude of CCE plots were measured through a hand-held GPS receiver. The NDVI of 17/18 February 1996, representing the maximum value corresponding to the heading phase of wheat, was used as the independent variable in the regression. The wheat yield model is computed as yield = 3.75 + 0.043 NDVI with coefficient of determination of 0.85 and a standard error of estimate of 0.217 t/ha. The regression coefficient is significant at 99 percent confidence level. Using the linear regression model, the yield in t/ha was estimated for every wheat pixel, to enable aggregation over any desired aerial unit such as distributary/minor command, canal subdivision, division, and water circle.

GEOGRAPHICAL INFORMATION SYSTEM

To enable more comprehensive spatial analysis and to integrate more ground data which are in different

scales and information levels, all relevant data have been organized in a GIS environment using IDRISI. Information integration analysis was attempted through union and intersection techniques.

The GIS application covered two main aspects in this study:

- characterization of command area in regard to agricultural productivity, canal supply, and groundwater regime and their interrelationships to help identify policy issues on the long-term sustainability of the irrigation system
- answer specific queries on location-specific corrective management, such as areas with potential waterlogging problems, areas for reclamation, areas of soil limitations to wheat productivity, etc.

RESULTS OF ANALYSIS

The wheat yield and wheat production across the command area for rabi 1995-96 were obtained. The spatial variability of irrigation intensity (cropped area to cultivable command area), wheat as percent of total cropped area, and oilseed as percent of total cropped area were also obtained. Average wheat yield over the command area is estimated to be 4.09 t/ha. Distributaries/minors having less than 90 percent of divisional mean wheat yield are considered poorly performing distributaries/minors. Based on this criterion the names of distributaries/minors of poor wheat productivity were listed out for taking corrective measurers.

Based on the RS and GIS study, two main observations were made:

1. In canals having fresh groundwater, mean wheat yield is high; percentage of wheat area is also high; and surface water supply is low. Wheat yield, percent wheat area, and canal supply remain constant along the channel length. The groundwater depth is around 10 m and is falling moderately over the years.

2. In canals having marginal and saline water, mean wheat yield and percent wheat area are low; surface water supply is high. Wheat yield and percent wheat area decrease along the canal length while surface water supply remains constant or increases. Groundwater level is fast rising and in many places, the groundwater depth is less than 3 meters.

The above two observations have been used to draw the following conelusions:

CONCLUSIONS

1. This study has demonstrated the utility of SRS and GIS techniques to assess the irrigation system performance of a wheat-based irrigation system.

2. The present practice of allocating and distributing the surface water leads to high productivity of water, but the sustainability of maintaining such high productivity seems to be questionable due to marginal and saline groundwater levels rising fast while the fresh groundwater level is receding. This unsustainable situation can be corrected through proper planning of surface water allocation and distribution.

REFERENCES

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