Mapping Results from Space:

SATELLITE DATA SHOW IMPACT OF INVESTMENTS ON AGRICULTURAL AND WATER USE EFFICIENCY IN UTTAR PRADESH, INDIA


India is home to one-sixth of the world’s total population and its population is expected to grow by 34 per cent in the period 2005–30.1 Uttar Pradesh, located in northern India, is one of the country’s poorest and most populous states, with over 200 million residents. To be able to meet future demand for food, either more land must be brought into production or existing cultivated land should produce more. Either way, optimization of water use in agriculture will be required.

The World Bank has been supporting its clients to deliver efficient irrigation services through projects like the Uttar Pradesh Water Sector Restructuring Project (UPWSRP) to increase agriculture and water use efficiency. With the support of the Water Partnership Program (WPP), UPWSRP used remote sensing (RS) and state-of-the-art modeling to provide evidence of the impact of the Bank’s investment on agricultural productivity.

The pilot study in UPWSRP Phase I used multi-temporal free satellite imagery to track the agricultural productivity in the project area before and after the project interventions and compared with adjacent non project areas. Through the study, it was possible to map beneficiaries with land use diversification, as well as agricultural intensification and enhanced crop productivity due to improved irrigation and drainage services (see box on the right).

The pilot activity catalyzed demand for RS technologies to monitor agricultural performance under a new US$500 million Phase II UPWSRP project. It also resulted in pairing up the Remote Sensing Agency Center in Lucknow with local irrigation authorities in Uttar Pradesh (UP) to help develop a systematic, RS-based monitoring and evaluation (M&E) tool to strengthen the future design and replication of effective programs. These efforts are already boosting agricultural productivity in UP as well as in other World Bank project areas in India.

Background

Uttar Pradesh is an agricultural powerhouse in India (see box on the next page). The state’s arable land and available water resources, however, are limited. Almost 51 percent of the land in Uttar Pradesh is used for cultivation and 74 per cent of the cultivated land is irrigated.2 Due to the current spatial constraints, agricultural land expansion is practically impossible. Boosting agricultural productivity in UP thus requires improved irrigation and drainage infrastructure, coupled with multiple-cropping agriculture.

The World Bank and the government of India have partnered to implement a comprehensive, state-focus assistance strategy to unlock the potential of India’s rural areas and translate it into improved living standards for the poor. The partnership includes long-term program of fiscal and governance reforms as well as investments in water and agricultural activities to foster inclusive growth in low-income states like UP.

The first phase of the UPWSRP has been a key part of this strategy. The project invested in the rehabilitation and modernization of the irrigation and drainage systems across 300,000 ha of land and piloted new management approaches, including targeted training to system operations and the introduction of a Participatory Irrigation Management (PIM) legal framework of the canal irrigation system through 396 Water Users’ Associations (WUAs). The investments aimed to increase agricultural intensification and diversification. The outcomes of these interventions had to be monitored against the project’s objectives to determine the best performing sites and practices and to be able to replicate these conditions and practices in other project areas.

A Remote Sensing Approach for Monitoring Changes in Agriculture

Assessing the impact of project interventions in irrigation is not an easy task. If the project area is large and involves a tapestry of croplands, it is even more challenging. Crop changes and trends over time are difficult to track, especially when these are influenced by seasonal patterns of precipitation and temperature, such as monsoonal climatic changes, other variations in water uses by irrigation systems, and different crop types.

For instance, India’s agricultural calendar runs from July to June. It consists of three distinct growing seasons, two of which depend on the monsoons: (1) the Kharif (“rainy”) season, from July to October, and (2) the Rabi (“winter”) season, from October to March. The third growing season, known as the Zaid (“summer”) season, requires irrigation and lasts from March to June. Many crops, however, are cultivated in both the Kharif and the Rabi seasons.

Remote sensing, also known as earth observation, is a tool to obtain information about objects or areas from a distance, typically from aircrafts or satellites. If used with adequate hydrophysical modeling and properties as well as with sufficient on-ground validation, RS can accurately capture data on cropping and water use patterns across large areas and over different time periods. This is particularly useful to track localized interventions and evaluate the overall performance of irrigation and drainage systems.

Uttar Pradesh’s Agricultural Economy Snapshot

One of India’s most populous states, with over 200 million residents

60% of the state’s labor force is engaged in agricultural activities

Income per capita is nearly ½ the national average; UP economy depends significantly on its agricultural output

UP accounts for:
• 1/3 of India’s wheat production
• 39% of total sugarcane production and ½ of total sugarcane growing area in India
• 34% of national potato production

58% of the state’s families own a piece of land


RS for Crop Mapping & Monitoring in JBS

Assess the impact of project interventions in irrigation.
The WPP-funded pilot study was conducted in the Jaunpur Branch System (JBS), which is a parcel of the UPWSRP. The study used RS data over the period 2000–10 to map multiple crop areas, distill crop calendars, and analyze crop phenology—a scientific instrument with two different satellites aboard. Each platform has certain technical limitations. While Landsat has a higher spatial resolution—30 meters versus MODIS’ 500 meters—it has a lower temporal resolution, 16 days versus one day. In practice, both systems complement each other well.

Baseline data were collected on each specific intervention—including improving irrigation infrastructure, using higher-quality seeds, balancing fertilizer application, introducing line sowing, irrigating crops at their critical stages—during preparation and implementation of UPWSRP Phase I. These data were used to assess the project’s impact by analyzing similar information at specific points in time during the project period and beyond.

Findings: Quantifying Impacts and Benefits

Thanks to a phenological analysis based on seasonal dynamics (see box above), it was possible to monitor changes in land use and vegetation cover. Differences between the datasets from the growing seasons (GS) 2004–05 (before UPWSRP Phase I implementation) and 2008–09 (after UPWSRP Phase I implementation) indicate that the total area of multiple-cropped fields increased over the project implementation, and that its distribution across the JBS basin changed (see box below). Results show that significant sections of single-cropped areas in the GS 2004–05 had been converted to double-cropped areas in GS 2008–09 and large expanses of fallow land had been turned into cultivated land over the same period. Differences in the geospatial datasets of areas with and areas without project intervention (the Sulthanpur control area) provide good indications of the increased agricultural productivity in project areas.
It should be noted that the improvement attained in drainage was larger than that achieved in irrigation. Drainage improvements overseen in the study are responsible for adding new rabi and kharif areas in the Jaunpur Branch. Overall, cropping intensity increased by 14 per cent, while total double- and triple-cropped area rose to 21 percent after project implementation. It was also possible to quantify the increase in farmers' income levels in areas where the reforms had been piloted by calculating the economic benefits of agricultural intensification and drainage improvements. An estimated 401,000 farm households benefited from the pilot activities as their annual income went up by an average of Rs 11,325 (78 percent increase in 2011 prices) per hectare, and about 40,100 farm families were able to move above the poverty line after project implementation.

**Informing M&E Systems for Water and Agriculture Productivity**

The WPP pilot provided a rapid assessment of the performance of the UPWSPR Phase I operation. As a result, periodic monitoring of crop performance in project areas using RS imagery was made a key subcomponent of UPWSPR Phase II. The UP Remote Sensing Applications Center (RSAC)—an autonomous state public RS agency—will facilitate the monitoring work in Phase II. Throughout the life of the project, the RSAC will report on water and agriculture indicators including cropping intensity, the cropping calendar, acreage and productivity, irrigated areas, and land use at the cadastral levels. Some ground truth data will also be collected from the field at key times during the growing seasons.

**RS-Based Techniques Can Enhance Project Monitoring & Evaluation**

The use of geospatial technologies and advanced computational modeling in the WPP pilot study proved a cost-effective M&E tool to monitor temporal and spatial dynamics of agricultural intensification and productivity. The acceptance of this approach by the government of UP led to a broader engagement of the responsible irrigation department within the RSAC. It also fostered collaboration with other governmental bodies, non-governmental organizations, and scientific institutions. The successful results of this approach and analytical methodology spurred further investments under a new, US$500 million operation for the water sector in UP, currently being implemented under UPWSPR Phase II.

The technique applied in this study illustrates how spatial maps of project areas may be tapped to guide decisions on interventions and new investment planning. The WPP-funded pilot will also serve as a benchmark for other output-based agriculture or irrigation projects in UP and the West Bengal areas.

Unlike Phase I, Phase II will also target water consumption savings, among other things, by giving the WUAs the authority to take steps aimed at improving water management (including surface water and groundwater), and involving the private sector.

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**REFERENCES**


5. Cropping intensity, the sum of areas cropped in all growing seasons of one agricultural calendar year, divided by the net (single-, double- or triple-cropped) sown area. The cropping intensity may exceed 100 percent if more than one crop is annually harvested from the same area.