WPP
WATER PARTNERSHIP PROGRAM

97156

WPP Briefing Note 7 / May 2015

BRIEFING NOTE:

# Mapping Results from Space:

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

Anju Gaur (Senior Water Resources Specialist & Project Team Co-Leader, Water Global Practice, World Bank Group), Winston Yu (Senior Water Resources Specialist & Project Team Co-Leader, Water Global Practice, World Bank Group), Danielle A García-Ramírez (Program Analyst, Water Global Practice, World Bank Group)

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).

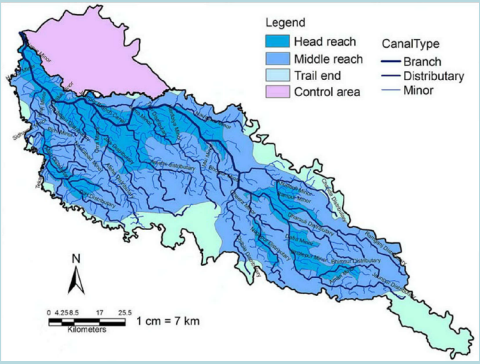
The pilot activity catalyzed demand for RS technologies to monitor agricultural performance under a new US$500 million Phase II UPWSRP project. It also resulted in pairing up the Remote Sensing Agency Center in Lucknow with local irrigation authorities in Uttar Pradesh (UP) to help develop a systematic, 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.

1. US Census Bureau, 2013.
2. Planning Commission Government of India/Academic Foundation, 2007. Agriculture data for 2001-02.

## A REMOTE SENSING PILOT STUDY IN UTTAR PRADESH




JBS command area

A pilot study based on RS data over the period 2000–10 was conducted for the Jaunpur Branch System (JBS). Its objective was to analyze the impact of improved irrigation on agricultural intensification—through modernized infrastructure, use of more efficient technologies, and higher-quality seeds, among other mechanisms.

The study serves as a benchmark for a geospatial evaluation tool for current agricultural and water projects supported by the World Bank in India.

Study results over the same period reveal that income levels increased by 78 percent,* and overall income distribution improved in the areas where reforms were piloted. Moreover, water productivity increased substantially, as did crop yields.

* Adjusted at 2011 prices.

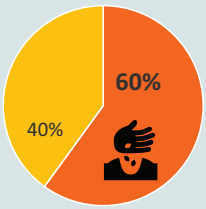
WATER PARTNERSHIP PROGRAM

The Water Partnership Program (WPP) is a longstanding partnership among the World Bank and the governments of the Netherlands, the United Kingdom, Denmark, and Austria. As an integral part of the World Bank's Water Global Practice, the WPP supports the institution's poverty reduction efforts by mainstreaming climate-resilient growth and pragmatic approaches in Water Resources Management and Water Supply and Sanitation in World Bank projects and analytical work.

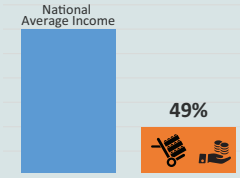
WORLD BANK GROUP

### 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

UP ranks:

- **2nd** in **rice** production; and
- **2nd** in **pulse** production nationwide

Source: Planning Commission Government of India. 2014. Per capita net state domestic product at current prices. Data for 2010-11; and Planning Commission Government of India/Academic Foundation, 2007.

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 agriculture to foster inclusive growth in low-income states like UP.

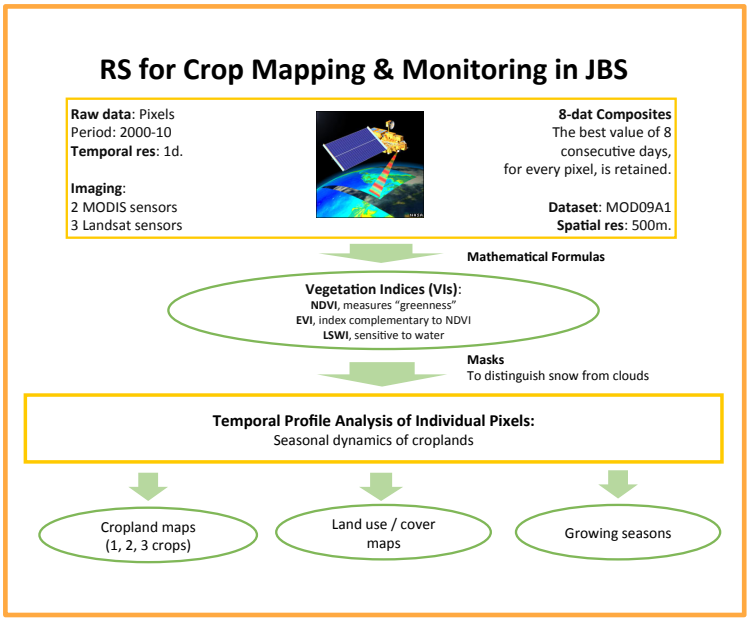
The first phase of the UPWSRP has been a key part of this strategy. The project invested in the rehabilitation and modernization of the irrigation and drainage systems across 300,000 ha of land and piloted new management approaches, including targeted training to system operations and the introduction 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.




3 *Plant phenology* is the study of periodic plant cycle events (leafing, flowering, maturation of plants, etc.) and how they are influenced by seasonal and inter-annual variations in climate, as well as habitat factors.
4 *Spatial resolution* refers to the discernible detail in the image expressed in units of distance at the Earth surface. *Temporal* resolution refers to the time difference between images covering the same geographical area. Generally there is a trade-off between these two kinds of resolution.

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[3] (see box on the previous page). The geospatial data gathered were broken down at the head-reach, middle-reach, and tail-end of the JBS command area in order to understand the irrigation water distribution pattern and its impact on productivity.

Data for this pilot study were acquired through three sensors on Landsat satellites and through MODIS (Moderate Resolution Imaging Spectroradiometer)—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,[4] 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.

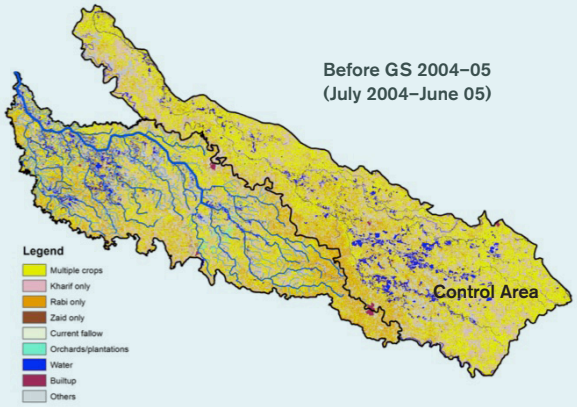
**Women farmers in the JBS command area. In the background, *rabi* and *kharif* crops in previously waterlogged areas.** Photo: Winston Yu / World Bank

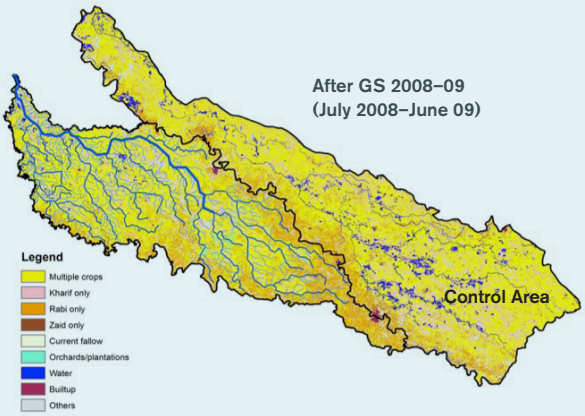
## Findings: Quantifying Impacts and Benefits

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.

### LAND USE MAPS OF THE JBS COMMAND AREA AND SULTHANPUR CONTROL AREA (BEFORE AND AFTER UPWSRP PHASE I INTERVENTIONS)



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[5] 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 UPWSRP Phase I operation. As a result, periodic monitoring of crop performance in project areas using RS imagery was made a key subcomponent of UPWSRP 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 UPWSRP 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.

### ACKNOWLEDGEMENTS

This activity was made possible by the World Bank project team: Anju Gaur (Sr. Water Resources Specialist) and Winston Yu (Sr. Water Resources Specialist). Consultants included Chandrashekhar Biradar (University of Oklahoma, Norman, OK, USA) and Pradeep Srivastava (SWaRA, Luknow, India). Production of the briefing note was supported by Danielle A. García Ramírez and Ingrid Pakulski Van de Kamp.

### REFERENCES

— Biradar, C, Gaur, A., Yu, W., Srivastava, P. (2012). Quantifying Changes in Agricultural Intensification and Expansion in India. Washington, D.C.: World Bank. Unpublished.
— Planning Commission Government of India/Academic Foundation. (2007). Uttar Pradesh Development Report (State Development Report), Volume I and II. Chapter 1. Uttar Pradesh Economy; Trend and Status. New Delhi. pp. 91-122.
— Planning Commission Government of India. (2014). Per Capita Net State Domestic Product at Current Prices (as on 31-10-2014). http://planningcommission.nic.in/data/datatable/data_2312/DatabookDec2014%20160.pdf. Retrieved 2014-12-14.
— Riggs, G., & Hall, D. (2002). Reduction of Cloud Obscuration in the MODIS Snow Data Product. 59th Eastern Snow Conference. Vermont, USA.
— US Census Bureau. (2013). "United States Census Bureau - International Data Base (IDB)". Census.gov. Retrieved 2015-01-05.

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.

The Water Partnership Program (WPP) supports technical assistance and analytical work, and bolsters project preparation and implementation across all water sub-sectors and water-related sectors in all World Bank Borrowing Member Countries. WPP activities are coordinated within the World Bank's Water Global Practice through nine Windows: six Regional Windows, the Expert Support Team, the Programmatic, and the Global Programs Windows.

The WPP is coordinated by a Program Management Team based in the Water Global Practice of the World Bank.

WATER PARTNERSHIP PROGRAM