# Securing the future of India's "Water, energy and food"

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**Discussion Paper 1240** October 2012

**This paper provides an initial, formal analysis for the design of an Indian food procurement system that considers climate driven variations in renewable water supply, the needs for groundwater pumping, varying regional productivity of crops and farm level economics, assuming that the food security goals are to be met while keeping current procurement prices fixed for each crop, and maximizing net aggregate farm income from the procurement system. The results suggest that net farm revenue could be doubled while eliminating the need for irrigation to meet the food requirements.**



Keywords: agricultural income, food security, India, climate, water, groundwater, energy.

India has made tremendous strides towards self-sufficiency in food grains in the last half century. The Green Revolution, marked by higher yielding varieties, chemical fertilizers and pesticides, and irrigation contributed to this growth. The national food security goals led to targeted regions for the government procurement of rice and wheat, with minimum support prices and subsidies. Almost half of the total agricultural land in India is irrigated[1]. Today, the major food grain producing regions face significant challenges with respect to water and energy. The areas targeted for rice-wheat procurement do not match the areas that would be most suitable from the perspective of adequate water availability. Given subsidized electricity, ineffective surface canal systems, and crop water requirements that exceed renewable water supplies, most irrigation is now from pumped groundwater. Nearly 40-60% of electricity use is now due to irrigation pumping in the major states, and groundwater

Suggested Citation: Devineni, N. & S. Perveen 2012, 'Securing the future of India's "Water, energy and food"', GWF Discussion Paper 1240, Global Water Forum, Canberra, Australia. Available online at: http://www.globalwaterforum.org/2012/10/08/securing-the-future-of-indias-water-energy-and-food/ .

levels are dropping at rates between 1 to 3 m/year in key locations[2].

The strategy for procurement from regions that at the time had the best agricultural productivity led to a significant change of the cropping patterns – away from traditional crops that were adapted to the local climate and soils, and to increased demand for irrigation in the targeted procurement regions. Figure 1 shows the spatial distribution of the current cropping pattern in India for 12 major crop varieties currently procured nationally[3]. The crops are grouped into cereals (rice, bajra, maize, jowar and ragi), pulses (tur and other pulses), and oilseeds (groundnuts, sesamum, soybeen, nigerseed and sunflower) in Kharif (June-July-August- September) – the predominant rainfall season. Rice accounts for over 75% of the net cropped area in the arid regions of North Western India (e.g. Punjab and Haryana) and the Indo Gangetic Plains. These are also the regions with the highest rainfall variability.

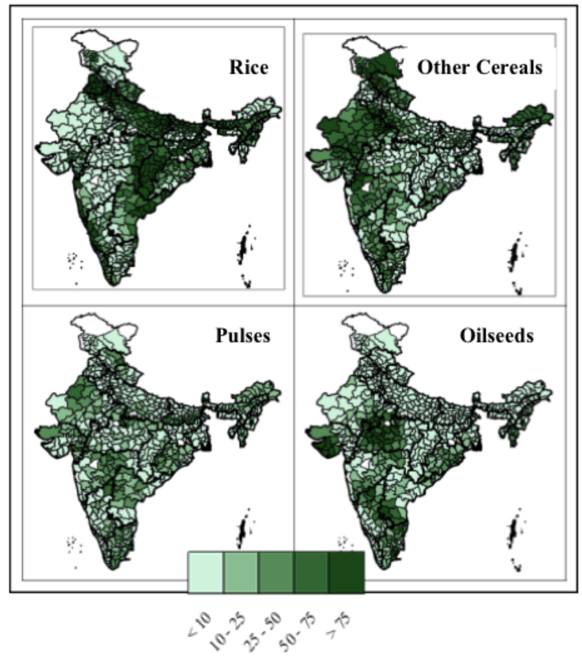


Figure 1. *Current cropping pattern in India as percentage net cropped area in Kharif season.*

The serious water stress in India calls for improvements in aggregate crop yields and water use, since nearly 90% of water consumption is directed at agriculture, of which the rice-wheat system in the current procurement areas leads to the most serious impacts. The 2012 blackout[4] that left over 650 million people without electricity was in large part due to the pumping load on the electrical system from rice irrigation. Consequently, there is interest in targeting new areas (e.g., Eastern India) for intensive food grain production and procurement. Such a shift in cropping and procurement strategies needs to be informed by a thoughtful analysis that considers climatic factors, economics, energy needs and regional productivity.

This paper provides an initial, formal analysis for the design of a national food procurement system that considers climate driven variations in renewable water supply, the needs for groundwater pumping, varying regional productivity of crops and farm level economics, assuming that the food security goals are to be met while keeping current procurement prices fixed for each crop, and maximizing net aggregate farm income from the procurement system. A by-product of the analysis is a reduction in the aggregate use of non-renewable water and the consequent reduction of irrigation water requirements and hence water and energy stress. Thus, the "climate-water-energy-food-livelihood" nexus of issues is addressed conjunctively. A sketch of the model and of the results for the monsoon season assuming a scenario that no irrigation is provided anywhere in the country is presented.

The results illustrate that the average net farm revenue could be doubled while eliminating the need for irrigation to meet the food requirements on average. This is a remarkable result since it suggests that simply shifting where what is grown can meet food security targets while increasing farm income and eliminating water and energy stress.

**Simulation – Optimization Model**

A linear programming model that allocates crop areas at the district level across India for each season was developed. Daily precipitation[4] and temperature were used to assess irrigation needs for each crop per unit area, for each district, and for each year in approximately 100 years of historical data to address climate variations in water supply and demand in space and time. Initial screening to identify the suitability of each crop in each district limited the choices. Potential crop yields are referenced to existing Indian crop yields and decreased to account for water deficits each season.

**Objective**

To maximize the aggregate national agricultural net revenue at current crop prices and using current cost of cultivation data for each crop in each district in the country

**Model Constraints**

(a) Maximum cropped area in each district cannot exceed current area.

(b) Average annual production of each crop has to exceed current total procurement, and also meet the consumption needs of the population

(c) Irrigation water provided in each district is limited by prescribed scenarios linked to either purely rainfed or to locally renewable supply.

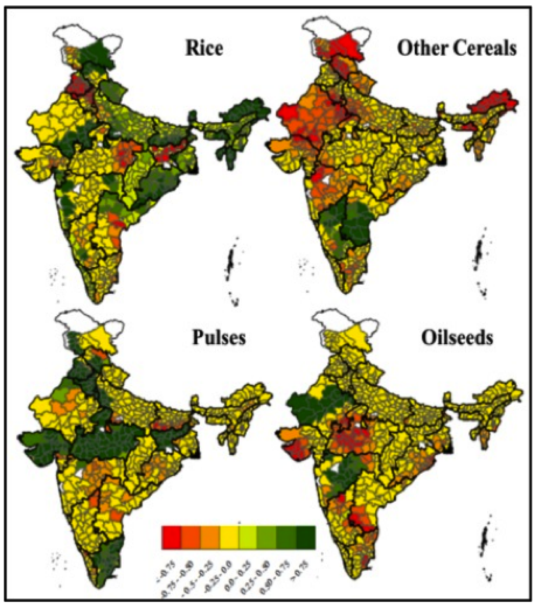


Figure 2. *Optimal cropping pattern as fractional increase/decrease from current cropped area.*

## Results

The spatial distribution of the optimal cropping pattern is shown in Figure 2, as the fractional increase or decrease from the cropped area (Figure 1) in each district. A fractional increase (decrease) for a crop in a district indicates that the model allocates an area that is larger (smaller) than the current cultivated area under that crop in that district. Cultivated area of rice is reduced by over 75% for the districts in Punjab. There is a slight increase in cultivated area of rice over the states in Eastern India (Orissa, West Bengal, Bihar etc). Pulses and oilseeds which are less water intensive emerge in the arid states, consistent with the traditional cropping pattern.

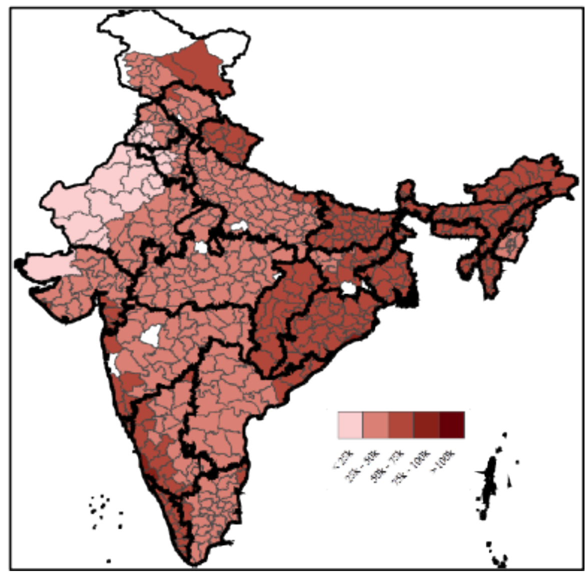

Figure 3. *Spatial distribution of the shadow price for the crop area constraint.*

It is interesting to see where it is economically worth promoting increases in agricultural intensity given the constraints specified. The shadow price (i.e. the incremental change in the net revenue that results from relaxing the constraint by one unit) for the cropped area constraint is shown in Figure 3. The Eastern states, the West coast and some of the Himalayan states are indicated as the most favourable. Many of these have lower population densities and agricultural intensity at present.

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## About the author(s)

Dr. Naresh Devineni is a research scientist at the Earth Institute's Water Center in Columbia University. His areas of research include hydroclimatology, sustainable water resources planning and management; multiscale modeling and forecasting of hydrologic fluxes, systematic climate risk assessment for water systems. At the Columbia Water Center, Dr. Devineni is currently working on climate informed modeling and integrated assessments of the water and energy crises facing India. Dr. Devineni has published his research findings in a variety of scientific journals such as Water Resources Research, Monthly Weather Review, Journal of Climate, Journal of Water Resources Planning and Management, Geophysical Research Letters and Journal of Applied Meteorology and Climatology. The work presented here has resulted from the series of exchanges with the water and agriculture experts, including the decision makers in India as well as the US. Support from the PepsiCo Foundation is gratefully acknowledged. Dr. Devineni can be contacted at nd2339@columbia.edu.

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