POLICY BRIEF 41

Is Indian Agriculture Becoming Resilient to Droughts? Evidence from Rice Production

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Introduction

Extreme climatic events, such as droughts, always pose a significant threat to sustainable development of agriculture; and thereby to the agriculture-based livelihoods. The threat is more pronounced in developing countries like India where agriculture still engages about half of the workforce. A widespread severe drought may cause a significant decline in food production, aggravate food insecurity, exacerbate rural poverty and lead to depletion of productive assets (Pandey et al. 2007).

More than two-third of India's geographical area is prone to droughts; and almost every third year is a drought year (GoI 2009). In the past four decades, India experienced 13 major droughts, of which four occurred between 2000 and 2012. Nonetheless, India's capacity to cope with droughts has also improved due to a paradigm shift in drought management strategy, from crisis management to risk management. The new strategy emphasises prevention and mitigation of climate risks using innovations in water management and technological advances in crop breeding besides a focus on developing infrastructure and institutions for delivery of advisory services, information and inputs (Rathore et al. 2014). This strategy seems to have worked, as is reflected by a small decline (2.5%) in rice production in 2009-10 over its previous level, despite a rainfall deficit of more than 20%. In this brief, focusing on rice, a water-intensive crop, we provide an evidence that Indian agriculture is becoming resilient to droughts.

Frequency and Severity of Droughts

Often, a drought is defined in terms of rainfall-deficit[1] or alternatively degree of dryness. Scientific evidence, however, suggests that dry and hot weather, rather just the dryness, is more damaging to crops (O'Brien et al. 1996). Therefore, a drought can be conceptualized as an outcome of rainfall being below normal and temperature being above normal. Following Yu and Babcock (2010) we construct a drought index using mean monthly temperature and cumulative rainfall during the *kharif* season (June to September) for the period 1969/70 to 2005/06. This index is the 'product of the standardized deviations of temperature being above normal and the standardized deviations of rainfall being below normal[2]. The index ranges from zero to eight (Figure 1); zero implying rainfall being above normal and temperature being below normal. Abnormally low values of the index can be considered representative of the normal weather. The index is skewed toward left, indicating most drought events during this period were not severe. The incidence of severe droughts, say of drought index of 3 or more, was rare.

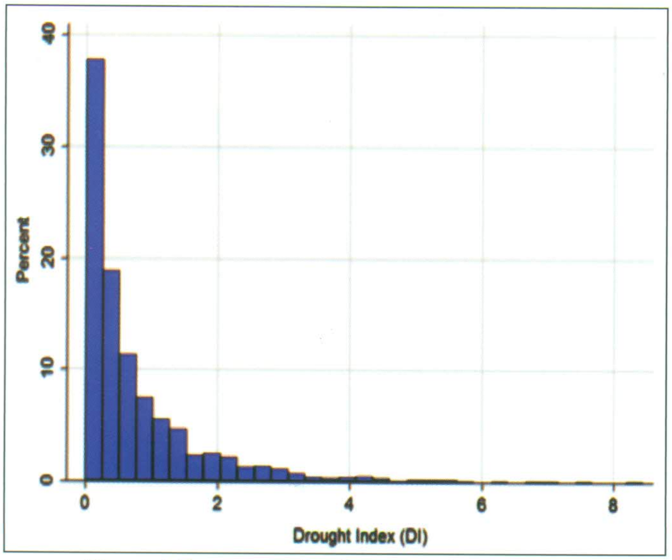

Figure 1: Frequency distribution of drought index

Based on the value of drought index we classify a drought into low, moderate and severe. A drought is of low intensity if the drought index is one standard deviation less than its own mean; moderate if it falls within ± 1 standard deviation around the mean; and severe if it is equal to or more than one standard deviation above the mean. During 1969-2005 about 83% of the droughts were of moderate intensity; and only 15% were of severe intensity (Table 1). However, the frequency and intensity of droughts have changed over time. The mean value of drought index fell from 0.97 during 1969-1987 to 0.57 during 1988-2005 primarily due to decline in severe drought events; from 21% to 9%. Frequency of moderate droughts rather increased, from 77% to 88%.

Table 1: Distribution of drought events, their severity and rice area affected

Period	Severity	Mean drought index	% of total events	% rice area affected
	Low	0.05 (0.07)	2.7	1.1
1969-2005	Moderate	0.47 (0.45)	82.7	25.7
	Severe	2.59 (1.26)	14.6	4.6
	Average	0.77 (0.99)	100.0	31.4
	Low	0.04 (0.04)	2.3	0.7
1969-1987	Moderate	0.49 (0.47)	76.8	24.5
	Severe	2.84 (2.55)	20.9	6.5
	Average	0.97 (1.21)	100.0	31.8
	Low	0.06 (0.08)	3.1	1.5
1988-2005	Moderate	0.45 (0.42)	88.4	26.8
	Severe	2.00 (0.78)	8.5	2.7
	Average	0.57 (0.64)	100.0	31

Figures in parentheses are standard deviations.

About one-third of the total 39 million hectares of the kharif rice area suffers from droughts. But, only 15% of this experiences severe droughts (Table 1). Nonetheless, there has been a significant decline in the area affected by severe droughts. Figure 2 shows year-wise kharif rice area affected by droughts. Three important observations stand out. One, the country experiences a drought almost every year in one or another part. Two, the droughts of 1972, 1974, 1979, 1982, 1987, 1995, 1998, and 2002 were widespread and affected more than half of the rice area. Three, the incidence of severe droughts has come down, while that of moderate droughts has increased.

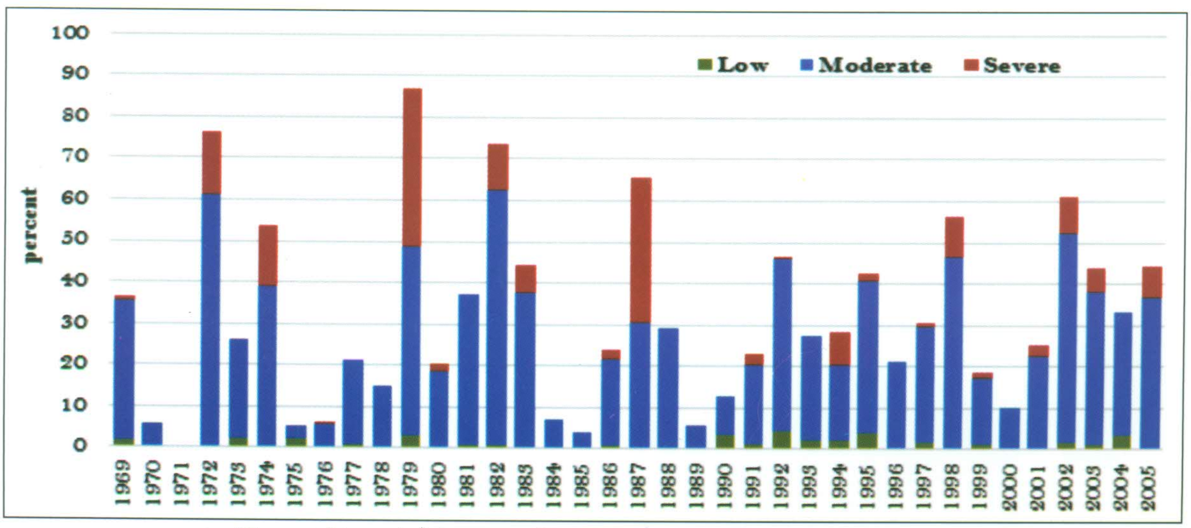

Figure 2: Year-wise rice area affected by droughts of different intensities

Impact of Droughts on Rice Yield

We contemplate impact of drought as 'negative deviation in crop yield from its trend'.[3] Table 2 shows loss in rice yield so estimated. As expected, yield loss is more under severe drought conditions, but it has declined considerably, from 16.8% during 1969-1987 to 8.1% during 1988-2005. Yield loss also declined under moderate drought conditions. This gives us an indication of the rice production in India becoming resilient to droughts.

The negative deviations in yield cannot solely be due to droughts. There could be a number of other factors e.g. insect and diseases that cause yield loss. Hence, we test robustness of the results in table 2 using panel regressions in which yield is regressed on drought index, its quadratic term and their interactions with time trend along with zonal fixed effects to control for spatial differences in adoption of technologies and other agronomic and management practices. The predicted relationship between rice yield and drought index is shown in figure 3. The curve is negatively sloped and convex, suggesting that drought adversely affects yield, but the incremental loss declines with drought severity.

From table 1 we find a fall in the mean intensity of droughts, which probably could have been one of the reasons for a steeper decline in yield loss. Therefore, in figure 4 we simulate loss in yield on the assumption of no change in drought intensity, i.e. we estimate loss at the mean level of drought index (0.77) during 1969-2005, and find a significant decline in yield loss, in absolute as well as relative terms. This provides credence to our findings that rice production in India has become more resilient to droughts. In the following paragraphs we look for the factors contributing to increasing resilience of agriculture to droughts.

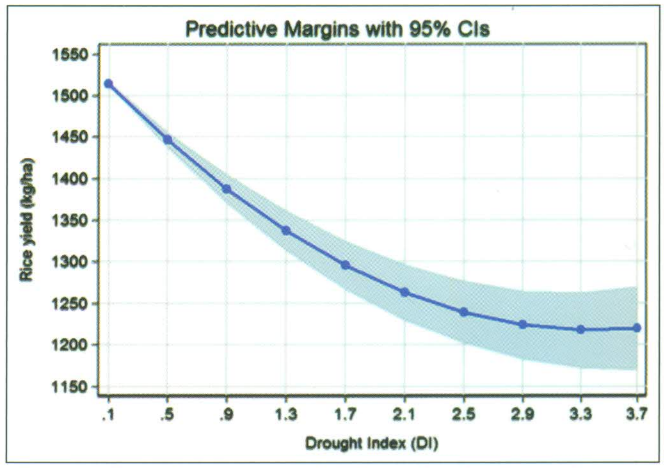

Figure 3: Predicted rice yield at different levels of drought index

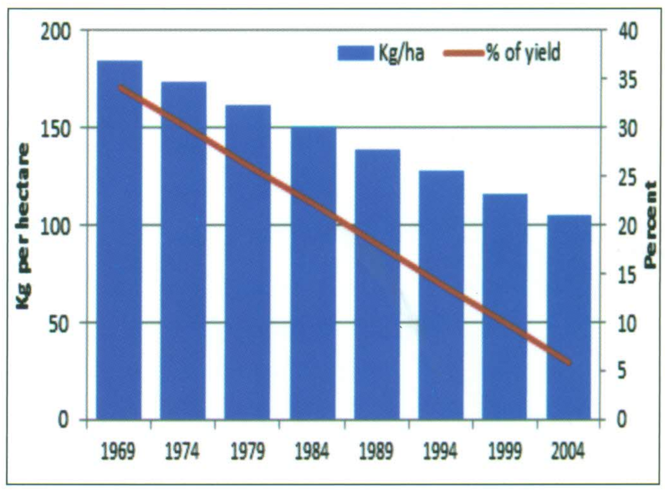

Figure 4: Equation predicted drought-induced yield loss at mean drought index

Table 2: Rice yield loss due to drought

Period	Drought severity	Low	Moderate	Severe	Average
1969-1987	Yield (kg/ha)	1246.2 (127.1)	1259.0 (23.6)	1139.7 (50.8)	1234.1 (21.2)
	Yield loss (kg/ha)	37.4 (26.4)	-45.5 (7.7)	-191.2 (15.1)	-73.7 (7.0)
	Yield loss (%)	3.0 (2.0)	-3.6 (0.7)	-16.8 (1.6)	-6.0 (0.7)
1988-2005	Yield (kg/ha)	1936.9 (145.2)	1900.3 (30.3)	1814.2 (90.4)	1894.6 (28.2)
	Yield loss (%)	4.6 (48.5)	-25.2 (8.1)	-147.0 (38.1)	-34.3 (8.1)
	Yield loss (kg/ha)	0.2 (2.4)	-1.3 (0.5)	-8.1 (2.0)	-1.8 (0.5)

Figures in parentheses are standard errors.

Causes of Decline in Yield Loss

Increasing resilience of rice production to droughts can be attributed to the new drought management strategy followed after the drought of 1987. The strategy focused on risk management, in terms of preparedness and prevention or mitigation, using innovations in water management and technological advances in crop breeding, among others.

For a water-intensive crop, such as rice, irrigation is the best option to cope with droughts. There has been a significant expansion of irrigation in India (Figure 5). Rice area irrigated increased from 38% in 1969 to 44% in 1987 and to 59% in 2010, and the increments seems to have come from private investment in groundwater resources. Expanding irrigation infrastructure was complemented by water-saving technologies and agronomic practices, such as direct-seeding, alternate wet and dry irrigation, laser land levelling, lining of field channels, improved tillage, etc.

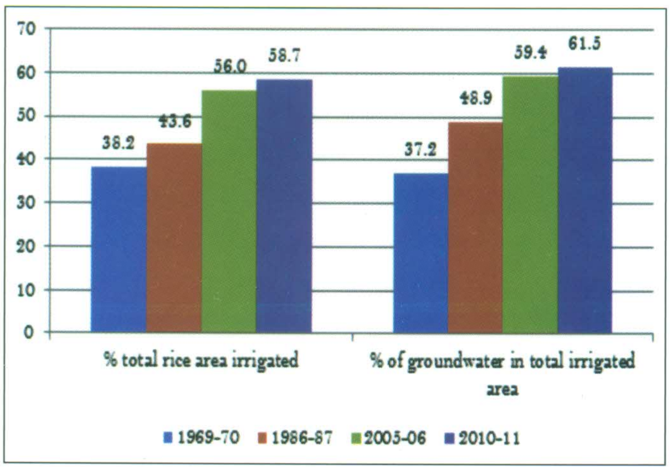

Figure 5: Trend in groundwater irrigation and rice irrigated area in India

Research on crop breeding also played an important role in coping with droughts. Drought-tolerant varieties are of shorter duration; possess yield advantage of 5-10% and save water by 30-40% (Pray et al. 2011). Between 1988 and 2010, there has been a significant increase in the number of rice varieties developed for rainfed environments. On an average, 3.4 rice varieties were released annually for rainfed uplands and 4.4 for rainfed shallow lands, representing an increase of 193% and 141% respectively over those released during 1969-1987 (Table 3). A recently released drought-tolerant variety 'Sahbhagi Dhan' has been reported to yield 15-28% higher with 26-48% less irrigations over other varieties (IRRI 2013).

Table 3: Rice varieties released for different ecosystems (No. per annum)

Ecosystem	1969-1987	1988-2010	% change
Irrigated early	2.7	3.0	8
Irrigated mid-early	1.6	3.2	95
Irrigated medium	1.6	4.4	172
Rainfed upland	1.2	3.4	193
Rainfed shallow land	1.8	4.4	141
Deep and semi-deep water	0.7	1.3	91
Scented	0.5	1.7	214
Others	0.9	3.0	233
Total	11.1	24.3	119

Source: Directorate of Rice Research, Hyderabad

Implications for Research and Extension

Returns on investment in research for drought-tolerance have been estimated quite high, 29-167% (Pray et al. 2011, Mottaleb et al. 2012; Gautam 2009, Kostandini et al. 2009). Until recently, India's agricultural research agenda largely focussed on breeding for higher yields and for favourable environments. However, with growing realization of the limits on irrigation expansion, the focus of research has gradually been shifting towards breeding for drought-tolerance. Modern bio-technology offers scope to develop varieties capable of withstanding severe droughts. The need is to prioritize rice research agenda considering the emerging threat of climate change.

Drought tolerant seeds serve as insurance. These are affordable, easy to multiply and adopt, and provide long-term solution relieving pressure on water resources. The seed policy should, therefore, emphasize evolving sustainable seed systems that can provide farmers crop varieties differentiated by their level of tolerance to droughts of different intensities, and matching with timings of droughts.

Irrigation is one of the best options to cope with droughts. However, irrigation water is limited and mismanaged. It is, thus, essential to promote water-saving technologies, such as sprinkler and drip irrigation, and agronomic practices like alternate wet and dry system, direct seeding, laser-land levelling, zero or reduced tillage, trenching, vegetative barriers, and mulching that contribute to improving water-use efficiency.

The scope to develop surface irrigation is limited, and the development of groundwater-based efficient irrigation systems is hindered by fragmented landholdings, and farmers' lack of access to capital. It is, therefore, imperative to develop community-based institutions, e.g. self-help groups and water users' associations, to access institutional credit for sustainable development of groundwater resources.

Farmers need various types of information related to varieties, inputs, water management, conservation practices, credit, insurance, weather, etc. The information needs blow up during a drought, in order to cope with it *ex ante*. The outreach of the public information system, however, is limited. It is, therefore, essential to develop information systems that provide farmers real-time information in a right form and at right time.

Notes

[1] An area is supposed to be affected by drought if rainfall is less by 25% or more from its historical average (see GoI 2009). The drought is considered moderate if rainfall deficit is >25% but ≤50%, and severe if the deficit is >50%. Further, for a drought to be universal the rainfall deficiency at national level must exceed 10% and at least 20% of the geographical area must have been affected by a moderate or severe drought.

[2] Normal temperature and rainfall here refer to their mean values during the period 1969-2005.

[3] The loss in yield has been estimated as negative deviation from the HP-filtered trend yield.

References

Gautam, A. 2009. *Impact Evaluation of Drought Tolerant Rice Technologies through Participatory Approaches in Eastern India*. Masters' dissertation. Rutgers: The State University of New Jersey.

GoI (Government of India). 2009. *Manual for Drought Management*. New Delhi: Department of Agriculture and Cooperation, Ministry of Agriculture.

IRRI (India International Rice Research Institute). 2013. *Cluster Demonstrations of Stress Tolerant Rice Varieties in Stress Prone Parts of India*, Annual Report Submitted to National Food Security Mission, Ministry of Agriculture, Government of India. IRRI, New Delhi Office.

Kostandini, G., Bradford, F.M., Omamo, S.W., Wood, S. 2009. Ex-ante analysis of the benefits of transgenic drought tolerance research on cereal crops in low-income countries. *Agricultural Economics*, 40: 477-492.

Mottaleb, K.A., Rejesus, M.R., Mohanty, S., Murty, M.V.R., Li, Tao. Valera, H.G. and Gumma, M. K. 2012. Ex-ante impact assessment of a drought tolerant rice variety in the presence of climate change. Paper presented at the *Agricultural & Applied Economics Association Annual Meeting* at Seattle, Washington, USA. 12-14 August.

O'Brien, D., Hayenga, M., and Babcock. B. 1996. Deriving forecast probability distributions of harvest-time corn futures prices. *Review of Agricultural Economics*, 18:167–180.

Pandey S., Bhandari H. and Hardy B. (Eds). 2007. *Economic Costs of Drought and Rice Farmers' Coping Mechanisms: A Cross-country Comparative Analysis from Asia*. Los Baños: International Rice Research Institute. 203p.

Pray, C., Nagarajan, L., Li, L., Huang, J., Hu, R., Selvaraj, K.N., Napasintuwong, O. and Chandra B.R. 2011. Potential impact of biotechnology on adaption of agriculture to climate change: The case of drought tolerant rice breeding in Asia, *Sustainability, 3:* 1723-1741.

Rathore, B.M.S., Sud, R., Saxena1, V., Rathore, L.S., Rathore, T.S., Subrahmanyam, V.G., and Roy, M.M. 2014. Drought conditions and management strategies in India. Country report presented at the Regional Workshop for Asia-Pacific on "Capacity Development to Support National Drought Management Policies" organized the UN-Water Initiative, May 6-9 Hanoi, Vietnam.

Yu, T., and Babcock, B.A. 2010. Are U.S. corn and soybeans becoming more drought tolerant? *American Journal of Agricultural Economics, 92 (5):* 1310-1323.

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