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Droughts, Distress, and Policies for Drought Proofing Agriculture in Bihar, India

Avinash Kishore

Pramond Kumar Joshi

Divya Pandey

New Delhi Office

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AUTHORS

Avinash Kishore (a.kishore@cgiar.org**)** is an associate research fellow in the New Delhi Office of the International Food Policy Research Institute (IFPRI), New Delhi.
Corresponding author

Pramond Kumar Joshi (p.joshi@cgiar.org) is the director of the South Asia Office of IFPRI, New Delhi.

Divya Pandey (d.pandey@cgiar.org**)** is a senior research assistant in the New Delhi Office of IFPRI, New Delhi.

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ABSTRACT

Climate change-related weather shocks are becoming more frequent in India, and poor, agrarian populations are the most vulnerable to these effects. This study was undertaken to assess if various drought-proofing and drought-relief programs are effective in mitigating the impact of droughts on crop production and household consumption in rural Bihar, India. This study is relevant as Bihar has experienced four drought years since 2009. The drought in 2009 led to an increase in the number of poor people in the state from 2004–2005 to 2009–2010, in spite of rapid growth of gross domestic product in this period. The government of Bihar runs a number of drought-proofing and drought-relief programs to mitigate the impact of drought, but with little effect. The two largest social safety net programs—the Targeted Public Distribution System (TPDS) and the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS)—provide little relief to drought-affected families in rural Bihar. Additional subsidy on diesel to irrigate Kharif crops in drought-affected areas does not reach many farmers. Delays, uncertainties, and high transaction costs in its disbursal to farmers further reduce the subsidy's effectiveness. Public tubewells and subsidy on private wells and pump-sets fail to provide wide-scale relief for the drought-stricken area. The results of our year-long study of 160 farmers with access to cheap irrigation from solar powered pump-sets in Bihar showed that these farmers grew paddy in all their land in Kharif in 2013, in spite of low rainfall. The farmers reaped nearly 20 percent higher yields compared to their neighbors. These results indicate that affordable groundwater irrigation is essential for effective drought proofing in Bihar. A well-designed program to promote solar pumps can help to promote drought proofing and make agriculture more resilient to climate change.

Keywords: drought, social safety nets, TPDS, MGNREGS, public tubewells, solar pumps

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ABBREVIATIONS AND ACRONYMS

Ag GDP	agricultural gross domestic product
BIGWIS	Bihar Groundwater Implementation Scheme
GSDP	gross state domestic product
HCR	head count ratio
ICRISAT	International Crops Research Institute for the Semi-Arid-Tropics
MGNREGS	Mahatma Gandhi National Rural Employment Guarantee Scheme
MPCE URP	monthly per capita expenditure (uniform reference period)
MSTP	Million Shallow Tubewell Program
NABARD	National Bank of Agriculture and Rural Development
NSSO	National Sample Survey Organisation
PDS	public distribution system
PTWs	public tubewells
STWs	shallow tubewells
TPDS	Targeted Public Distribution System

1. INTRODUCTION

Do drought proofing and drought social safety programs meant to provide drought relief help sustain agricultural output and household consumption in adverse years? In this paper, we explore this policy question, which has become even more relevant as climate change–related extreme weather events (droughts and floods) have become more frequent, using a recent spell of consecutive droughts in Bihar—a large state in India with high levels of endemic poverty.

Agriculture in India has always been vulnerable to the vagaries of monsoon (Kumar et al. 2004). The rainfall-related volatility in agricultural production is a big concern for food security, economic development, and household welfare in India and other tropical countries (Rosenzweig and Hillel 2008, World Bank 2007a). These concerns have grown in recent years as altered rainfall patterns associated with climate change have become more frequent, increasing the likelihood of short-run crop failures and long-run production declines. Smallholders and agricultural laborers, who are poor and have few assets and limited access to credit and insurance, are the worst affected. It is crucial for them and for the agriculture sector that farmers be able to adjust their farming practices to adapt to the changing climate. Besides adaptations in agriculture, we also need effective social safety net programs to mitigate the impact of negative weather shocks on poor families.

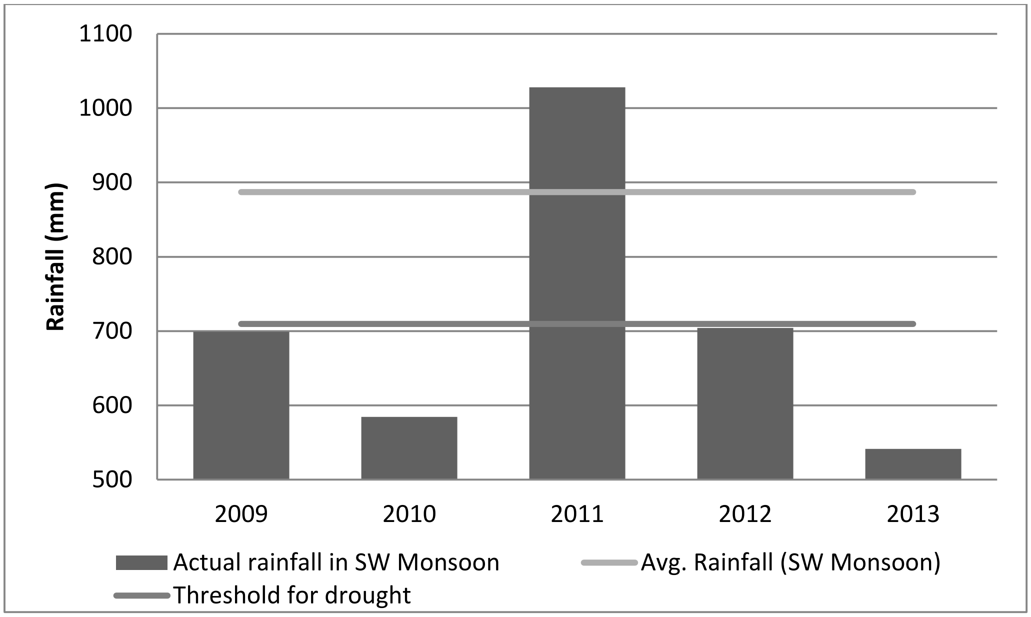
Large areas in Bihar, the poorest state of India and one of the poorest regions of the world, have suffered moderate to severe droughts in four out of five years from 2009 to 2013 (Table 1.1 and Figure 1.1), with terrible consequences for the state's agricultural economy and its more than 110 million people (Office of the Registrar General and Census Commissioner 2011). The period from 2009 to 2013 has been the driest continuous five-year period in more than a hundred years for which we have weather records in Bihar. Five of the 38 districts in the state (Khagaria, Pashchim Champararn, Saharsa, Siwan, and Seohar) have experienced droughts in all five years from 2009 to 2013, 14 districts experienced droughts in four out of these five years, another 14 saw three years of drought, and the remaining five saw two years of drought. We believe that looking at the impact of this dry spell on agricultural production and household welfare and the performance of government programs for drought relief and drought proofing can provide useful lessons not only for Bihar, but also for other parts of the developing world where agriculture is important to people's livelihoods and is vulnerable to climate change and weather shocks.

Table 1.1 Number of districts affected by drought in Bihar, 2009–2013

Year	Number of drought-affected districts
2009	26
2010	38
2012	25
2013	33
Total districts in Bihar	**38**

Source: Bihar, DoA (2014a).

Figure 1.1 Rainfall in Bihar during Southwest Monsoon from 2009–2013



Source: India Water Portal (2012).
Note: mm = milimeter; SW = Southwest.

We look at the impact of drought on agriculture and poverty in Bihar, and assess the effectiveness of big social safety net programs and irrigation and drought-proofing schemes in providing relief from droughts and in sustaining crop production in years of low rainfall, respectively. We find that droughts significantly reduce the agricultural output of Bihar and retard its growth. *Kharif* paddy, the crop with the highest fraction of gross sown area in the state, is affected the most. We also show that in spite of the physical abundance of groundwater and higher fraction of sown area under irrigation, crop output is more vulnerable to droughts in Bihar than in other states of India where farmers have access to cheaper irrigation. Bihar is the most rural state of India and has the highest share of its main working population engaged in agriculture. This high level of dependence on agriculture in Bihar means that drought-induced recession in the agrarian economy affects households' consumption and poverty levels.

We also show that large social safety net programs like the Targeted Public Distribution System (TPDS) and the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) are not very helpful to poor households in providing additional income or consumption smoothing. The scale of these programs is too small and their penetration too limited in Bihar to make a real difference on a significant scale. The government of Bihar also runs several schemes to make agriculture less vulnerable to the vagaries of monsoon by making access to groundwater more affordable. We look at three such schemes, (1) capital subsidy for shallow tubewells (STWs) and diesel pump-sets, (2) revival of old public tubewells (PTWs) and construction of new ones, and (3) subsidy on diesel for irrigation in drought-affected areas. We show that all three schemes have very limited effect on achieving drought proofing because they fail to make groundwater irrigation more affordable to farmers. We believe that making irrigation cheaper is essential for drought-proofing agriculture in Bihar. In the final section, we recommend promoting solar pumps using smart subsidy and innovative financing to achieve this goal.

2. METHODS AND DATA

In this paper, we use data from various secondary sources and a series of 3 primary surveys we conducted in 16 villages of Nalanda district in Bihar. We use simple comparison of means, and occasionally multivariate regressions to understand the impact of droughts and drought relief or drought-proofing schemes. Because the incidence of drought in a district is an exogenous event these comparisons and regressions show causal effect on the outcome being measured.

Data on district-level rainfall and droughts are from the Indian Meteorological Department (GIZ 2013). We classify a district as drought affected in a year if deficit in the monsoon rainfall is 20 percent or more from the long-term mean monsoon rainfall of that district. We use crop output data from the web page of the Ministry of Agriculture in Bihar, and the value (in rupees or USD) of agricultural output is taken from the Central Statistics Office (India, CSO 2013). We estimate household consumption expenditure and incidence of poverty using data from the 61st, 66th, and 68th rounds of consumption surveys conducted by the National Sample Survey Organisation (NSSO) in the years 2004–2005, 2009–2010, and 2011–2012, respectively, to assess the impact of drought in 2009–2010. Consumption surveys also provide us data for measuring the household penetration of the public distribution system (PDS) in drought-affected districts. The discussion on PTWs is based on data and information from the Minor Irrigation Department of Bihar, which is the nodal department for their construction and management. We use data from a primary survey of 240 farmers in Nalanda district in 2013–2014 to understand the workings of the diesel subsidy scheme in Bihar. We supplement the data from the primary survey of farmers with information gleaned from focus group discussions with farmers and informal interviews with managers of gas stations and village- and subdistrict-level government officials responsible for implementing the scheme. The discussion on solar pumps is based on three rounds of surveys of farmers who were using solar-powered PTWs in Nalanda district in Bihar and their neighbors who did not have access to these pumps.

3. RESULTS

Impact of Droughts on Agricultural Output in Bihar

The ongoing streak of droughts in Bihar started in 2009, when the average rainfall in the state was only 79 percent of its long-term mean (India Water Portal 2012). The state government declared drought in 26 of 38 districts (Minisitry of Agriculture 2014). Total production of paddy, the principal *Kharif* crop of Bihar,[1] declined from 5.8 million tons in 2008–2009 to 3.6 million tons (38 percent decline) in 2009–2010 (Department of Agriculture 2014a) and its value of output declined from Rs 46 billion to Rs 29 billion at 2004–2005 constant prices (India, CSO 2013). The state experienced a second consecutive drought in 2010. This time, drought was declared in all 38 districts. The production and the value of paddy declined to nearly half (53–54 percent) of what they were two years ago in 2008–2009, the most recent year of normal rainfall. Paddy was not the only crop affected by drought; the total value output of agriculture (excluding allied activities like livestock and fisheries) in Bihar shrank by more than 10 percent between 2008–2009 and 2009–2010, and it remained at around the same low level in 2010–2011 (India, CSO 2013). In 2011, when the state received normal rainfall after two consecutive years of drought, agriculture boomed and production of paddy breached all previous state records to exceed 8 million tons (Bihar, DoA 2014a).

A simple comparison of area under *Kharif* paddy and its yields across districts where rainfall was 20 percent or more below normal (drought) and 60 percent or more below normal (severe drought) with districts of normal rainfall shows large and statistically significant negative impacts of drought on both area and yield (Table 3.1). It is possible that districts more prone to droughts may have smaller cultivable area and lower yields even in normal years. We address this issue by regressing area under paddy and average paddy yield (columns 1 and 2 in Table 3.2) on incidence of drought (*if drought*) while including district fixed effects in our model to control for time-invariant characteristics of the districts. Again, we find that the incidence of drought led to reduction in area sown with paddy and the paddy yields in comparison to years of normal rainfall.

Table 3.1 Average yield (kg/ha) and area (ha) under *Kharif* paddy in districts affected by drought in Bihar, 2001–2010

If there was a drought	Number of districts	Average paddy yield (kg/ha)	Average paddy area per district (ha)
Normal	215	1,411.44	94,969
Drought (≥20% below normal rainfall)	143	1,009.81	86,916.31
Severe drought (≥60% below normal rainfall)	16	854.31	51,639.30

Source: Bihar, DoA (2014a) and India, DES (2014).

Note: We did a t-test and the results are highly significant. We did the same for wheat—a winter crop—and did not find a statistically significant effect of drought on area or yield of wheat.

[1] Paddy accounts for more than 40 percent of the gross cropped area in Bihar.

Table 3.2 Impact of drought on district average yield (kg/ha) and area (ha) of paddy in Bihar

Variables	(1) Paddy yield	(2) Paddy area
If drought	-318.8***	-7,751***
	(71.73)	(2,840)
Year	-8.414	-1,173***
	(7.773)	(357.7)
Constant	18,004	2.477e+06***
	(15,580)	(717,440)
Observations	374	374
R-squared	0.568	0.904
District dummies	Yes	Yes

Source: Bihar, DoA (2014a) and India, DES (2014).

Note: Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Bihar was not the only state affected by drought in 2009. It was one of the worst droughts India had seen in more than a 100 years. Nationally, rainfall in monsoon was 23 percent below the long-term average and 246 of the 640 districts were declared drought hit (Preethi, Revadekar and Kripalani 2011). For example, on September 2009, rainfall was 28 percent below the normal in Bihar. The deficit in rainfall was comparable with Jharkhand (23 percent), Assam (30 percent), and Coastal Andhra (25 percent), and was much worse in Punjab (34 percent), Telangana (35 percent), eastern Uttar Pradesh (38 percent), western Uttar Pradesh (43 percent), and Haryana (35 percent). Jharkhand, a state with only 8 percent of its net sown area under irrigation, recorded the maximum (percentage) production loss of *Kharif* paddy in 2009–2010 compared to the average production in the preceding triennium (2006–2008). Bihar, despite having 64 percent of its net sown area under irrigation, suffered production loss of 28 percent in *Kharif* paddy—a significantly higher loss than the other states with comparable rainfall deficit in 2009. Paddy production increased in Assam, Haryana, and Punjab in spite of the drought, while it declined by 10 percent in Uttar Pradesh, by 20 percent in Andhra Pradesh, and by 8 percent in India as a whole (Table 3.3).

Table 3.3 Impact of low rainfall on production of *Kharif* paddy in different states of India, 2009–2010

State	Deviation (%) from normal (June–August) rainfall[1]	Change (%) in production from triennium (2006–08) average[1]	Net irrigated area as % of net sown area, 2009–10[2]
Andhra Pradesh	-35 (Telangana); -25 (Coastal A.P.)	-19.82	42
Assam	-30.00	26.92	7
Bihar	-28.00	-28.02	64
Haryana	-35.00	5.81	86
Jharkhand	-23.00	-52.57	8
Punjab	-34.00	6.57	98
Uttar Pradesh	-38 (Eastern U.P.); -43 (Western U.P.)	-9.93	81
India	-22.00	-7.59	45

Source: [1]India Metereogical Department (2014); [2]India, DES (2014).

Note: (Old) Andhra Pradesh and Uttar Pradesh consist of two meteorological subdivisions each: Coastal Andhra and Telangana, and Eastern and Western Uttar Pradesh, respectively. Figures in the table show change in paddy production for both subdivisions in these states.

One of the main reasons that droughts lead to such a drastic decline in paddy production in Bihar, and not in many other parts of India, we claim, is lack of access to affordable irrigation in the state. In Punjab, farmers coped with rainfall shock by resorting to groundwater irrigation, made affordable by free electricity for farming. In Bihar, farmers could not afford to transplant paddy using groundwater irrigation, simply because it is so costly. A farmer in Bihar might be paying 30–40 times for a cubic meter of water as his counterpart in Punjab and Haryana (Shah et al. 2009), even though groundwater is more abundant in Bihar. Groundwater, considered the best bet against drought among all sources of irrigation (Dhawan 1985), is physically abundant in Bihar, but is economically scarce, because of the near complete dependence on expensive diesel as motive power for pump-sets.[2]

Droughts and Ill Fare in Bihar

Bihar is the poorest state of India. It is also the most rural and the most agriculture-dependent state in the country. Nearly 90 percent of the state's population lives in rural areas and depends directly or indirectly on agriculture for its livelihood (Office of the Registrar General 2011). In the census of 2011, 70 percent of all main workers in Bihar (78 percent in rural Bihar) reported cultivation or agricultural labor as their principal occupation—the highest of all states in India. Further, most cultivators in Bihar have very small landholdings. According to the Agricultural Census Division (2010), there were more than 16.2 million agricultural landholdings in Bihar in 2010, with an average size of just 0.39 hectare (ha). More than 90 percent (14.74 million) of these holdings were smaller than 1 ha, with an average size of only 0.25 ha. A vast majority of these sub-marginal (defined as less than one acre of land) farmers grow rice and wheat,[3] harvest relatively low yields, and barely make enough to secure subsistence for themselves. They are desperately poor and highly vulnerable to weather shocks like floods and droughts. Poor access to credit and insurance and weak performance of social safety net programs, such as TPDS and MGNREGS, limit their ability to smooth consumption when faced with natural calamities like droughts. High dependence on agriculture, dominated overwhelmingly by very small and poor subsistence farmers, who have poor access to credit and insurance and little support from social safety net programs, leads to huge welfare losses from droughts in Bihar. This becomes clear when we see the impact of drought in 2009 on poverty in the state.

At the time of the 61st round of consumption survey by the NSSO in 2004–2005, 55.7 percent of Bihar's rural population lived below the poverty line. Between 2004–2005 and 2009–2010, when the 66th round of consumption survey was carried out, Bihar's per capita gross state domestic product (GSDP) had increased at a rate of 5.95 percent per year in real terms, from Rs 8,773 to Rs 11,815 (at 2004–2005 constant prices). Bihar experienced unprecedented rates of economic growth in this interval. Still, the 66th round of consumption survey showed that the head count ratio (HCR) barely declined to 55.3 percent. Between 2004–2005 and 2009–2010, the total number of people below the poverty line increased from 45.1 million to 49.87 million in rural areas, and from 49.38 million to 54.35 million in rural and urban areas (Dutta et al. 2014). This rise in the number of poor people and the negligible decline in the HCR, in spite of rapid economic growth, puzzled social scientists and embarrassed the state government. It is our conjecture that the drought in 2009–2010 and the resultant recession in the agrarian economy—the main source of livelihood for more than 70 percent of the state's working population—was one of the big reasons why we saw no change in the HCR between 2004–2005 and 2009–2010, in spite of rapid growth in per capita GSDP and a sharp increase in public expenditure on social sectors and roads.[4] While per capita GSDP increased by 35 percent from Rs 8,773 to Rs 11,815 between 2004–2005 and 2009–2010, per capita agricultural gross domestic product (AgGDP) declined from Rs 2,608 to Rs 2,501.

The NSSO carried out another round of the consumption survey just two years later, in 2011–2012. Bihar received normal rainfall in 2011 (see Figure 1.1) and it turned out to be an excellent year for

[2] Ninety-seven percent of all irrigation pump-sets in the state run on diesel or kerosene.

[3] Paddy, wheat, and pulses together account for more than 90 percent of the gross cropped area (GCA) of Bihar.

[4] The developmental expenditure on social and economic services increased from about Rs 112.5 billion in 2006–07 to about Rs 276 billion in 2009–10 (Bihar, FD 2011).

agriculture, with record production of paddy and wheat. The per capita AgGDP jumped to Rs 3,175 and the rural HCR came down to 33.74 percent—a more than 20 percent decline in just two years—an unprecedented change in the state's history. The number of people living below the poverty line came down to 32 million in rural areas and 35.81 million in urban and rural areas in 2011–2012 (Duttaet al. 2014).

It is a well-known fact that the poverty rate in India responds more sharply to growth in agriculture than to growth in other sectors of the economy (Ravallion and Datt 1996, 2002). Ligon and Sadoulet (2008) estimate that each percentage point of agricultural GDP growth in India increases consumption of the lowest three deciles by 4 to 6 percent. Growth in agriculture is even more important in Bihar, because a greater fraction of the state's population lives in rural areas and depends directly on agriculture for its livelihood. From 2004–2005 to 2009–2010, the per capita AgGDP of Bihar declined by about 4 percent. This drought-led recession in the agricultural economy in 2009–2010 was one of the reasons why the poverty rate remained stubbornly high in the state in spite of rapid growth in overall GDP (7.5 percent per year) over the preceding five years. The effect of recession in agriculture was evident on the average monthly per capita expenditure (MPCE), which grew by a miniscule 1.75 percent per year between the 61st and 66th rounds of the NSSO, for the entire rural population (Table 3.4), and by less than 0.5 percent per year for those in the bottom quintile of MPCE. Even the aggregate poverty gap and the poverty gap ratio increased between 2004–2005 and 2009–2010, suggesting that the non-reduction in HCR was not due to the high intensity of poverty in 2004–2005. It was not so that the consumption of the poorest of the poor had not increased between 2004–2005 and 2009–2010, but it was not by a big enough amount to push them above the poverty line. Table 3.4 shows that there was very little increase in MPCE in this period across the board. As agriculture revived in 2011–2012, rural MPCE increased sharply for all consumption quintiles (Table 3.5).

Table 3.4 Per capita GSDP, per capita AgGDP, MPCE, and HCR in rural Bihar, over three rounds of consumption surveys

Year	GSDP/ capita (Rs)*	AgGDP/ capita (Rs)*	Average rural MPCE (Rs)*	Rural HCR (%)
2004–2005	8,773	2,608	438	55.7
2009–2010	11,815	2,501	478	55.3
2011–2012	14,634	3,175	624	33.74

Source: Created by authors using Consumption Survey data from NSSO 61st (2004–2005), 66th (2009–2010), and 68th (2011–2012).

Note: GSDP = gross state domestic product; agricultural GDP = AgGDP; MPCE = monthly per capita expenditure; HCR = head count ratio. Rs = Indian rupee. * At 2004–2005 constant prices.

Table 3.5 MPCE in rural Bihar, 2004–2005, 2009–2010, and 2011–2012 (at 2004–2005 constant prices)

Rural MPCE quintiles	NSSO survey year		
	2004–2005	2009–2010	2011–2012
1	264	271	361
2	349	374	492
3	427	461	605
4	525	581	775
5	808	929	1260

Source: Created by authors using Consumption Survey data from NSSO 61st (2004–2005), 66th (2009–2010), and 68th (2011–2012) rounds.

Note: MPCE = Monthly per capita expenditure; NSSO = National Sample Survey Organisation.

The imperceptibly slow growth in rural MPCE in a year of recession in agriculture and a sharp increase in a year of bumper agricultural production (as seen in Table 3.4) suggests strong linkages between performance of agrarian economy and poverty reduction in Bihar. The performance of agrarian economy itself depends on drought, as shown in the earlier section. Therefore, it appears that the drought in 2009–2010 wiped out the positive effects of rapid growth in overall GDP and the increase in development expenditure in the state, and pushed millions of people into transitory poverty and deprivation.

Social Safety Net Programs Do Not Mitigate the Impact of Drought in Bihar

The government of India runs some of the world's largest social safety net programs to help the poor and spends nearly 3 percent of the country's annual budget on such programs. TPDS and MGNREGS are two large social safety net programs implemented across all districts of India. TPDS provides a fixed quota of highly subsidized rice and wheat to poor and extremely poor households every month, while MGNREGS guarantees 100 days of employment to every willing adult in rural India in his or her own village, at the official minimum wage. Both of these programs are meant to help poor households and could be especially important for them in a drought year, when they face scarcity of both affordable food and gainful employment opportunities. One would expect that these programs would respond to natural calamities and provide more relief in affected areas. We examine the performance of both schemes in drought-affected districts of Bihar, to see whether this is indeed the case.

MGNREGS and Droughts

MGNREGS was launched in 2006 as the world's largest employment guarantee program. It entitles 100 days of wage employment every year to all rural households, whose adult members volunteer to do unskilled manual work. One would expect a higher demand for wage employment from a rural workfare program like MGNREGS in a drought year, when there is less opportunity for work in the agricultural sector—the main employer in rural Bihar. We test whether this was indeed the case in drought-affected districts of Bihar.

We created a district-level panel with data on percentage deviation in monsoon rainfall from long-term mean (1901–2002), total employment demanded from MGNREGS, total employment provided, and total wages disbursed under the program, each year from 2006 to 2013. A district was classified as drought affected in a year when monsoon rainfall was more than 20 percent below the long-term mean. A simple comparison of means of total employment demanded, total employment provided, and total wage disbursed between district-years affected by drought with normal district-years (Table 3.6) shows that there was significantly greater demand for employment under MGNREGS (18–19 percent), more employment was provided (18–9 percent), and more wage money disbursed (44 percent) when droughts occurred. Regressing these three dependent variables of interest on incidence of drought in a district-year (*if drought*) also shows similar results with positive and statistically significant coefficients for the *if drought* variable in all three cases, even after we control for district fixed effects and a linear time trend (Table 3.7). Thus, the regression shows that there is a greater demand for employment in public works in drought-affected districts and MGNREGS does respond to this demand by providing more work and wage income in affected districts.

Table 3.6 Performance of MGNREGS across districts in Bihar, 2006–2013

Drought situation in districts	Number of districts	Employment demanded (persons)	Employment provided (persons)	Wage disbursed (million Rs)
Normal	156	78,734	77,726	215.54
Drought affected	148	93,013	92,898	312.11
t-value		-2.03**	-2.17**	-2.95***

Source: MGNREGA Public Data Portal (2014).

Note: MGNREGA = Mahatma Gandhi National Rural Employment Guarantee Scheme; Rs = Indian rupee.

Table 3.7 Impact of drought on demand and provision of employment and wage distribution under MGNREGS in Bihar

Variables	(1) Employment demand	(2) Employment provided	(3) Labor expense
Drought	16,917**	17,494**	886.7**
	(6,902)	(6,855)	(361.3)
Year	-1,355	-1,207	49.01
	(1,438)	(1,428)	(75.25)
Constant	72340.37***	71067.73***	218.0488**
	(19182.44)	(19051.17)	(100.4058)
Observations	304	304	304
R-squared	0.404	0.407	0.265
District dummies	Yes	Yes	Yes

Source: MGNREGA Public Data Portal (2014).

Note: MGNREGA = Mahatma Gandhi National Rural Employment Guarantee Scheme. Standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

However, the extra benefit it provides is still too little and helps too few households in Bihar to be called an effective drought-relief program. Data from the 66th round of employment and unemployment survey of the NSSO in 2009–2010 show that only 44 percent of rural households in Bihar sought work under MGNREGS in that year. Of the households whose member(s) sought work, only 1in 5 (21.5 percent) got any work, and that was for an average of 25 days per household. Thus, member(s) of fewer than 10 percent of all rural households in Bihar got any MGNREGS work in 2009–2010. The modest demand for MGNREGS work does not reflect lack of need for wage employment. Instead, the demand seems to have adjusted to the limited availability of work (Dutta et al. 2014).

TPDS and Droughts

TPDS is the longest running of the social safety net programs in India, and it provides a fixed amount of subsidized rice, wheat, sugar, and kerosene oil every month for household consumption. Households designated as "below poverty line," or BPL, and *antyodaya* (poorest of the poor) get rice and wheat cheaper than other households.

Unfortunately, Bihar has the dubious distinction of having the worst PDS in India (Khera 2011), with the lowest household penetration rates and the highest leakage of subsidized grains to the open market. Only 11 percent of all households in Bihar obtained any rice or wheat from PDS shops in 2009–2010, and the average uptake of rice and wheat for these lucky few households was less than 2 kg/household/month—a very small fraction of their allotted quota and monthly consumption needs.

We find that the poorly performing TPDS in Bihar did not show much improvement in drought-affected districts either. Using data from the 66th round of NSSO consumption survey conducted in 2009–2010, we estimate a probit regression with "*if the household received any rice or wheat from PDS shop*" as the dependent variable and incidence of drought (*if drought*) as the main independent variable, with various household characteristics as controls. The probit model shows that in 2009–2010, households in drought-affected districts of Bihar were not significantly more likely to benefit from TPDS than households in other districts with normal rainfall. The coefficient for the dummy variable indicating a household's location in a drought-affected district does have a positive coefficient, but it is statistically not significant (Table 3.8).

Even for households that did buy some subsidized rice or wheat from PDS shops, the average uptake quantity was too small (2 kg/household/month) to be of much help in dealing with hardships caused by the drought.

Table 3.8 Probit model showing likelihood of getting rice or wheat from PDS shops in Bihar, 2009–2010

Variables	(1) If rice or wheat PDS
If drought	0.179
	(0.137)
Land owned	372.4
	(240.2)
Salary	0.574***
	(0.180)
MPCE URP	-0.000376**
	(0.000162)
If firewood	-0.330***
	(0.111)
If electricity	0.209*
	(0.111)
Household type (agricultural labor)	0.301***
	(0.116)
Household type (non-agricultural labor)	0.402***
	(0.119)
Household type (cultivator)	-0.758***
	(0.134)
1. social group (Scheduled tribes)	0.296
	(0.330)
2. social group (Scheduled castes)	0.413***
	(0.121)
3. social group (Other backward classes)	0.191*
	(0.108)
Constant	-3.280***
	(0.499)
Observations	3,292

Source: Created by authors using Consumption Survey data from NSSO 66th (2009–2010) round.

Note: PDS = public distribution system; MPCE URP = Monthly per capita expenditure uniform reference period. Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Standard errors clustered by first sampling units.

Government Programs for Drought Proofing or Mitigating the Impact of Drought on Agriculture in Bihar

In the previous section, we saw that both the food-based safety net program (TPDS) and the workfare program (MGNREGS) have been of limited help to drought-affected households in Bihar. In this section, we shift our focus from drought-relief programs to drought-proofing schemes meant to make agriculture less vulnerable to the vagaries of monsoon. We will discuss three such schemes initiated by government of Bihar, (1) Bihar Groundwater Implementation Scheme (BIGWIS), which provides subsidy on purchase of diesel pump-sets and construction of STWs; (2) State Tubewell Project, which revives old PTWs and installs new PTWs funded by loans from the National Bank of Agriculture and Rural Development (NABARD); and (3) cash subsidy on diesel for irrigation of paddy and other crops in drought-affected blocks of the state. All three schemes seek to make groundwater irrigation more accessible and affordable for farmers.

Subsidy on STWs and Diesel Pump Sets

According to the Minor Irrigation Census (2001), there were nearly 0.65 million pump-sets in Bihar. This number, in all probability, has gone up significantly since 2007. Primary surveys across the state, however, show that most of the sub-marginal and marginal farmers, who constitute an overwhelming majority of landowners in Bihar, do not own pump-sets even now. Pump ownership is much more common among larger landowners. For example, in a census of all households in three villages of Vaishali district in 2012, the International Water Management Institute found that only 5 percent of farmers with 0.4 ha (equal to one acre) or less land owned a pump-set, while the ownership rate was 19 percent for farmers with 0.4–1 ha of land, 38 percent for small farmers (1–2 ha), and 74 percent for medium and large farmers (greater than 2 ha). Similarly, in the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) panel of 160 households from four villages in Darbhanga and Patna districts of Bihar, only one of the 40 sub-marginal farmers had a diesel pump-set, while 73 percent of farmers with more than 1 ha of land owned pump-sets (ICRISAT 2012).

Smallholders in Bihar rely mainly on water markets to irrigate their land. In a survey by the World Bank in 1997–1998 that covered a random sample of 1,035 households in the state, more than 70 percent of farmers reported buying irrigation water from water markets (LSMS 1997–1998). This was corroborated by the NSSO’s survey on cultivation practices in India in its 54th round (1999), which shows that 68.6 percent of farmers in Bihar report hiring in irrigation services from others—the highest among all states in India (Mukherji 2008). A higher fraction of farmers depends on rented pump-sets (or water markets) for irrigation in Bihar than in any other state of India. Further, 85 percent of pump-sets in Bihar run on diesel or kerosene (India, MWRD 2001), and 97 percent of irrigators irrigate their lands from diesel pumps (NSSO estimate, cited in World Bank 2007b) because the rural power supply is extremely poor and unreliable in the state. When diesel price goes up, the cost of irrigation increases for all farmers in Bihar, but the increase is much higher for water buyers (Shah 1993, 2007), as they have to obtain water from monopolistic or oligopolistic water markets.[5]

The government of Bihar, with funding from the government of India, launched the Million Shallow Tubewell Program (MSTP) in 2001–2002, to promote wider ownership of STWs and pump-sets and to increase irrigated area in the state. Since then, 0.41 million new STWs were built under the scheme until 2006–2007, with a subsidy outlay of Rs 3.13 billion (Bihar, DoA 2014b). MSTP helped double the number of STWs in Bihar, between the two minor irrigation censuses of 2000–2001 and 2006–2007. In 2009, MSTP was repackaged and launched as BIGWIS with the aim of distributing 0.464 million pump-sets at 45 percent subsidy to create additional irrigation potential in 0.9 million hectares (Mha) of land

[5] A historical record of diesel-pump irrigation prices in selected locations in eastern Uttar Pradesh shows that water prices increased every time diesel prices increased, and the former increased substantially more than would be enough to cover the increase in diesel price (see Figure1 in Shah 2007). Water buyers are under greater pressure to economize on water use than pump owners, and this differential pressure increases with every increase in diesel price.

(NABARD 2014). Between 2008–2009 and 2012–2013, 0.133 million pump-sets were distributed to farmers under the scheme at subsidized rates.

Access to irrigation was widespread across all landholding groups in Bihar even before the implementation of BIGWIS. The Minor irrigation census in 2006–2007 shows that 74 percent of all villages in Bihar have groundwater levels within 10 meters' depth. The alluvial soil in the top layer and shallow groundwater levels make digging of tubewells (relatively) easy and economical, and farmers in Bihar have invested heavily into pump-sets and bores in recent years. In the World Bank's Living Standards Measurement Survey (1997–1998), 78 percent of marginal, 70 percent of small, 57 percent of semi-medium, 54 percent of medium, and 59 percent of large farmers report all (100 percent) of their land as irrigated, at least once in the year. Public data also show that 61 percent of the net sown area in Bihar is irrigated, compared to the national average of 40 percent (India, DES 2014). More recent primary surveys after LSMS (such as NSSO 1999, Thorpe et al. 2007, Shah 2012, and ICRISAT 2012) also show that almost all farmers in Bihar—small and large—have access to irrigation. The state policy in Bihar needs to promote intensification of irrigation and not so much the extension of it, to increase crop yields and cropping intensity and to protect crops from moisture stress (Kishore et al. 2014).

Farmers in Bihar practice deficit irrigation because irrigating with diesel pumps is costly, even more so for water buyers. The ICRISAT data from four villages in Bihar show that sub-marginal farmers who depend almost entirely on water markets provided only one survival irrigation to 73 percent of their total land under paddy in 2012—a drought year—because they face a steep cost of Rs 2000/ha per watering. On the other hand, small and medium farmers, 73 percent of whom own a pump-set and a tubewell, provided three or more waterings to nearly 70 percent of their land (Table 3.9).

Table 3.9 Share (%) of total area under paddy that received different number of irrigations by landholding size class in Bihar, 2012

Landholding size class	Number of irrigations				
	1	2	3	4	≥5
Sub-marginal (<0.4 ha)	26.9	48.4	15.9	2.1	6.7
Marginal (0.4–1 ha)	27.5	28.0	11.6	2.8	30.1
Small-medium (>1 ha)	13.7	16.3	6.7	6.9	56.4
Total	18.0	21.7	8.6	5.5	46.2

Source: ICRISAT (2012).

Farmers are likely to apply adequate irrigation only if the variable cost of irrigation becomes more affordable. Holding other things constant, as number of pump-sets increases in an area, one would expect water markets to become more competitive and water prices to come down. However, even with increasing pump density, water prices in Bihar have stayed high and have been steadily rising, more than proportionately, with the rising price of diesel.

Curiously, farmers continue to buy new pump-sets even as the existing ones are seriously underutilized, but we do not see pump owners reducing rental rates to increase capacity utilization. Two questions come to mind. First, why do some pump owners, especially owners with very little land of their own, not increase rented hours by reducing the rental rates? Second, why do farmers in Bihar continue to buy new pump-sets even when the existing ones are so underutilized?

The answers to these questions lie in the cost structure of diesel pumps. We carried out a series of discussions with pump owners in five villages of Nalanda to understand the cost structure of diesel pump-sets. More than 90 percent of the operating cost of a diesel pump-set is variable cost (which includes the cost of fuel, lubricating oil, wear and tear of the machine, and operator's time and effort),[6] while the fixed

[6] The cost of fuel includes the price of diesel (Rs 50/liter), the cost of fetching it from the nearest gas station, and the cost of working capital needed to hold a small stock of it. A 5 horsepower (HP) diesel pump consumes 1 liter of diesel per hour. Lubricating oil costs around Rs 400–500 and needs replacement after every 400 hours of operation. Diesel pumps also have

costs are small and relatively unimportant in a farmer's calculus.[7] The variable cost was around Rs 64–90/hour (Rs 50 for kerosene or diesel + Rs 1–1.5 for lubricating oil + Rs 3–4 for repair and maintenance + Rs 10–25 as opportunity cost of operator's time and effort) in 2013, while the fixed cost is a small amount consisting mainly of the depreciation of the value of the pump-set (roughly Rs 3–5/hour). Given small fixed costs, there is little pressure on the pump owner to recover it by increasing capacity utilization. At the same time, reducing rental price of the pump-set to increase demand in the rental market does not contribute much to the bottom line, especially if the operator—often a family member—has alternate employment opportunities or high opportunity cost of leisure. As a result, we do not witness aggressive renting out of pump-sets, even when a number of pump owners have very small landholdings.

It is our surmise that water price in water markets of Bihar will continue to rise with rising fuel costs and rural wage rates, irrespective of the increasing pump density. If anything, the scarce capital invested in the new pump-sets that get purchased with 45 percent subsidy will continue to be severely underutilized. Increasing diesel pump ownership with public subsidy will not make irrigation affordable for water buyers in Bihar and they will continue to economize on water application even in drought years, resulting in loss of production and household income.

Reviving Old PTWs and Building New Ones

PTWs have a long history in Bihar. Construction of PTWs for irrigation started in Bihar in 1937 and 5,311 PTWs were built by 1983. A World Bank staff appraisal report published in 1986 found that 60 percent of these tubewells were already inoperable by 1984 and even the operating ones irrigated only 7.5 percent of their design command area (World Bank 1986). Poor or no power supply and lack of a water distribution system were the main reasons for nonfunctioning or poor functioning of the PTWs. With the World Bank's assistance, the government of Bihar launched the State Tubewell Project (STP) in June 1986 to modernize and rehabilitate existing PTWs and build 500 new ones. However, the World Bank stopped funding the project in 1994 due to its poor implementation. Afterward, the Minor Irrigation department of Bihar revived the project in 1999 with financial support from the government of India, under the Rural Infrastructure Development Fund, and built 5,556 PTWs between 1999 and 2007, at a cost of Rs 5 billion to irrigate 0.33 million ha of land.

A performance audit of these tubewells in 2007 showed that only 5,159 of them were energized (connected to a source of power). More than 400 PTWs were constructed but never connected to any source of power. Of those that were, only 1,860 were working at the time of the audit. Additionally, 594 of the energized PTWs were in disuse because of electrical faults, while another 1,548 had electrical and other faults in them. Even the working ones irrigated only 5–7 percent of their potential command area. Auditors estimated that irrigation from PTWs in Bihar had incurred costs between Rs 28,742 and Rs 41,555/ha, during 2002–2007 (Bihar, AG 2010).

Given the poor power supply situation in rural Bihar and the power utility's reluctance to supply electricity to the PTWs, the Minor Irrigation department of Bihar tried to revive some of these defunct ones by equipping them with diesel generators and transferring their management to water user associations. The performance of the PTWs transferred to water user associations, however, has been no better. Farmers are not willing to buy diesel to run the inefficient generators installed for the PTWs. Instead, they prefer using diesel or kerosene directly to run their own diesel pump-sets. It is more efficient and involves much less hassle compared to managing a PTW and coordinating water distribution among a large number of farmers.

PTWs did not work in the past in Bihar (Shah 2001) or anywhere else in India (Mukherji and Kishore 2003). Ongoing schemes to revive them are not working either. Still, the government of Bihar is

significant wear and tear costs, which increase with increase in hours of operation. These depend on the quality and the vintage of the machine, its care and upkeep, and the quality of fuel and oil used in it.

[7] If we look at the fixed cost of diesel pump-sets, it is quite low—at least as perceived by farmers who own them. Farmers buy a 5 HP pump-set for Rs 15–25,000 and use it for 10 to 15 years, sometimes even longer, with periodic repairs and overhauls. The capital cost of a pump-set is lower for farmers who buy it with the government subsidy.

going ahead with plans to build new PTWs and revive old ones with money borrowed NABARD. Under a NABARD-financed program under way since 2006–2007, around 3,000 new PTWs are being built at the cost of Rs 1.66 billion, and NABARD sanctioned another loan of Rs 1.39 billion in September 2010 to revive 922 old PTWs.[8]

The power supply situation, the big reason for the failure of PTWs, remains grim in rural Bihar, and experience shows that running electric tubewells with diesel generators is not a viable option. Therefore, we think that resources being spent on construction of new and revival of old PTWs is an unfruitful expenditure. As in the past, the objective of providing affordable irrigation to farmers with state-owned tubewells will not be met once again, unless these tubewells are equipped with a cheaper and more reliable source of power and their management is improved.

Cash Subsidy on Diesel for Irrigation in Drought-Affected Blocks

In 2008, the government of Bihar started a scheme where it offered a subsidy of Rs 10/liter of diesel to farmers in drought-affected blocks of the state to encourage them to provide one crop-saving irrigation to their *Kharif* paddy. At the time, diesel sold at Rs 44/liter. A farmer could claim subsidy for ten liters of diesel (which amounted to Rs 100/acre) for every acre of his land under paddy. The subsidy amount was quickly increased to Rs 15/liter (or Rs 150/acre/irrigation) and then to Rs 20/liter in view of the rising price of diesel. Today, diesel sells at Rs 63/liter in Bihar, so the subsidy has been raised to Rs 25/liter (or Rs 250/acre/irrigation). Also, now the government provides subsidy for more than one irrigation, if a drought condition persists. A farmer can get the subsidy on the purchase of ten liters of diesel per acre up to five times during a crop season, including two times during the sowing of paddy seeds, and thrice after transplantation of the seedlings, so that the standing crops are protected. Farmers can also collect diesel subsidy for three irrigations to their *Kharif* maize crop and two irrigations to vegetables (Bihar, DoA 2014b). A farmer can claim subsidy for as much land as he has under *Kharif* crops; there is no acreage limit on diesel subsidy. With these changes, the total budgetary allocation for diesel subsidy has increased more than tenfold, from Rs 631.6 million in 2008 to Rs 7690.6 million in 2014. Assuming zero leakage, this amount is enough to provide 40 percent subsidy (Rs 25/liter) on the current price of diesel for three irrigations to 4.1 Mha of land, which is nearly three-fourths of the net sown area of Bihar—not just the drought-affected area—and more than the entire area under *Kharif* paddy in a year with normal rainfall.

The diesel subsidy scheme, however, is fraught with problems that compromise its effectiveness in providing relief to farmers and mitigating the impact of drought on cropped area and crop yields in the *Kharif* season.

Limited Awareness of the Scheme

First, many farmers in Bihar are still not aware of the diesel subsidy scheme, and even among those who are aware of it, a large number do not apply for subsidy even when affected by drought. For example, in 2012, a drought year, the International Water Management Institute surveyed 406 tubewell owners in three villages of Vaishali district. Only one in five farmers in the sample was aware of the diesel subsidy scheme and only 17 of the 406 had actually collected any subsidy. In 2012, we interviewed 240 farmers in 16 villages of Nalanda district for their awareness and use of the diesel subsidy. Nalanda was affected by drought in 2012 and 2013. While most farmers in our sample were aware of the scheme, many among them did not know some of the key provisions of the subsidy. For example, besides paddy, diesel subsidy is now available for *Kharif* maize and vegetables. Most farmers in our sample were unaware of this provision and claimed subsidy only for paddy. Not only farmers but also even some of the block development officers and *kisan salahkaars* (agriculture advisors) were not aware of this change and told us that diesel subsidy was offered only for paddy.

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[8] http://oldsite.nabard.org/hindi/ridf/State-Wise%20List%20Of%20%20Projects%20Sanctioned%20%20Under%20RIDF-XV%20new.pdf.

High Transaction Costs, Delays, and Uncertainties in Subsidy Payments

Even where awareness of the diesel subsidy scheme is high, the uptake or utilization rate is low. In our survey in Nalanda, of the farmers who were aware of the scheme, 40 percent did not apply for it because of high transaction costs involved in collecting the subsidy. Subsidy for paddy is paid in three installments. A typical farmer in our sample lived 7 kilometers away from the block headquarters and the nearest petrol pump and spent, on average, Rs 80 to collect each installment of the subsidy. An overwhelming majority of farmers in Bihar own or operate sub-acre holdings. They are entitled to relatively small amounts in diesel subsidy (less than Rs 250/installment), while the transaction costs are just as high or even higher for them. Smaller landowners and tenants are therefore less likely to apply for the subsidy even if they are aware of it. We see it very clearly in our survey in Nalanda (Table 3.10).

Table 3.10 Application for and receipt of diesel subsidy by sub-marginal and other farmers in Nalanda district (Bihar), 2013

Variables of interest	Farmers with landholding <1 ha (n = 120)	Farmers with landholding >1 ha (n = 97)
Percent of farmers who applied for diesel subsidy in 2013	27	85
Percent of farmers who did not apply for the subsidy in 2013	12.50	3.09
Percent of farmers who were aware of the subsidy scheme but did not apply for it in 2013	61	12
Fraction of area for which the subsidy was received to the area for which it was applied	0.18	0.66
Total subsidy amount received in 2013, until the time of the survey (Rs)	100.9	593.73
Total subsidy amount received in 2013, until the time of the survey (Rs/ha)	494.71	545.68

Source: Primary survey conducted by authors in Nalanda district (2013–2014).

Note: Rs/ha = Indian rupee/hectare.

As mentioned earlier in the paper, almost 90 percent of the farmers in Bihar do not own diesel pumps. They buy water from pump owners. All farmers are required to furnish receipt of purchase of diesel to collect the subsidy. Water buyers often do not buy diesel; the pump owner does. So, water buyers have to make a special trip to the petrol pump and pay money to the manager to get the receipt for diesel they did not buy. Petrol pump managers in rural Nalanda charge farmers a small amount of Rs 10 for each fake receipt. The requirement to furnish the receipt of purchase of diesel makes it harder to collect the subsidy for farmers who do not own pump-sets. Again, we find that non-owners of diesel pump-sets are less likely to apply for and collect diesel subsidy (Table 3.11). We ran a probit regression with primary data from Nalanda to identify household characteristics associated with greater likelihood of a farmer applying for diesel subsidy in the past year. The probit result shows that farmers who belong to the traditionally privileged castes (that is, other than scheduled castes and other backward classes), who have larger landholdings and own diesel pump-sets, are significantly more likely to apply for the diesel subsidy. It is ironic that farmers who incur a higher cost of irrigation (water buyers) are less likely to get the subsidy meant to make irrigation more affordable (Table 3.12).

Table 3.11 Application for and receipt of diesel subsidy by pump owners and non-owners in Nalanda district (Bihar), 2013

Variables of interest	Diesel pump owners (n = 128)	Not owners of diesel pump (n = 88)
Percent of farmers who applied for diesel subsidy in 2013	65	35
Percent of farmers who did not apply for the subsidy in 2013	29	55
Percent of farmers who were aware but did not apply for the subsidy in 2013	6	10

Source: Primary survey conducted by authors in Nalanda district (2013–2014).

Table 3.12 Probit model to identify characteristics associated with a household applying for diesel subsidy in Nalanda district (Bihar), 2013

Variables	(1) If subsidy
Land owned (ha)	1.036**
	(0.406)
If own diesel pump	0.809***
	(0.193)
2. caste farmer	-1.765
	(1.141)
3. caste farmer	-2.250**
	(0.879)
4. caste farmer	9.606***
	(1.329)
5. caste farmer	-0.990
	(0.912)
Constant	1.883**
	(0.775)
Observations	193
Village dummies	Yes

Source: Primary survey conducted by authors in Nalanda district (2013–2014).

Note: Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

There is a large interdistrict variation in uptake of diesel subsidy. The subsidy uptake as a percentage of the total allocation in 2013–2014 varied from 100 percent in Katihar district to 2 percent in Paschim Champaran district. A panel regression using district-level data on uptake of diesel subsidy for 2010–2013 shows that the subsidy uptake per hectare of cultivable land has been rising over the years and is higher in districts with a higher pump density (measured as number of pump-sets per hectare of cultivable land) and more productive agriculture—where productivity is measured by value of agricultural output per unit area of cultivable land (Table 3.13). Interestingly, the subsidy uptake is not significantly higher in districts with a larger negative deviation in rainfall from the long-term mean.

Table 3.13 Determinants of uptake of diesel subsidy (Rs/ha of land) across drought-affected districts of Bihar, 2009–2013

Variables	(1) Uptake per ha
Rainfall deviation[1]	-0.0747
	(0.849)
Year	72.19***
	(13.51)
Tubewells per ha[2]	1,156***
	(217.2)
AgGDP per ha[3]	137.1***
	(33.41)
Avg. landholding (ha)[4]	57.04
	(93.74)
Constant	-145,335***
	(27,179)
Observations	112
R-squared	0.469

Source: [1]Bihar, DoA (2014a), [2]India, MWRD (2001), [3]Bihar, DES (2014), [4]India, ACD (2010).

Note: Standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Sharecropping is common in Bihar, but sharecroppers do not have any legal status. A farmer has to furnish receipt of land revenue (called *malguzari raseed* in local parlance) with his application for diesel subsidy. Sharecroppers cannot furnish this receipt and therefore cannot benefit from the diesel subsidy even when they are the poorest and the most vulnerable farmers. Even if a sharecropper is in a fixed-rent arrangement (called *hunda* in Bihar), where he is the residual claimant and bears all the risk of crop loss, he or she will not be able to collect subsidy money, but the landowner can. This is similar to benefits from a crop insurance scheme where all benefits accrue to landowners irrespective of the risk-sharing arrangement between them and their tenants.

Delays in disbursal of subsidy and uncertainties regarding the payment of subsidy also render it less useful for farmers, especially the poor farmers who are risk averse and often liquidity constrained. Every second farmer in our survey in Nalanda complained about delays in disbursement of subsidy. In *Kharif* 2013–2014, farmers in Nalanda were still waiting for the third and the last installment of subsidy due to them—weeks after the crop had already been harvested. The delay in disbursal of subsidy happens because of the long and cumbersome process followed.

First, the state government takes time to collect, collate, and process rainfall data and declare a block drought affected.[9] Farmers in a block are entitled to the subsidy only if it is officially declared to be affected by drought, which happens if the rainfall in a given period is less than the long-term mean rainfall in that period by 20 percent or more. Once drought is declared, the subsidy amount is sent to the block development officers from the district headquarters. The block development officers provide the amount to the *mukhiyas* (elected village heads) of the respective *panchayats* (village councils) for disbursement to the farmers, on production of the purchase receipt of diesel and land revenue receipt. The *mukhiya* disburses the subsidy and submits details of utilization of the subsidy amount in his or her *panchayat* to the block development officer, who collates utilization certificates from all *panchayats* in the block and sends it to the district headquarters. There are delays in each step of the process, which slows down the disbursal of subsidy to farmers and release of the next installment of subsidy. These delays discourage farmers from applying for the subsidy and also make the subsidy less effective in

[9] The chief minister of Bihar complained in the State Assembly that district-level bureaucrats were misleading him about the drought situation in the state (http://timesofindia.indiatimes.com/city/patna/Bihar-CM-says-he-is-misled-by-his-own-babus/articleshow/38939890.cms).

achieving its goals of maintaining the crop area and crop production at normal levels in drought-affected regions.

Diesel subsidy in Bihar is designed as a conditional cash transfer program, where a farmer in a drought-affected block gets a cash subsidy (Rs 250/acre/irrigation) if she irrigates her crop. Like all conditional cash transfers, it is meant to encourage the "desirable" behavior—of growing some crops on her land instead of leaving it fallow even in a drought year and irrigating it to realize maximum possible yield. It is not meant to be an ex-gratia payment for victims of a natural calamity. However, at present, it works more like a drought-relief program, where some farmers get some cash from the state in a poor monsoon season, and not like a conditional cash transfer or a drought-proofing program, which would encourage farmers to do something they would not otherwise do—try to maintain their cropped area and crop yields by using more groundwater to make up for the shortfall in rain. Thus, even if the diesel subsidy helps some farmers who receive it, it is not effective in drought proofing agriculture in Bihar, like cheap irrigation from canals and free electricity–powered groundwater do in Punjab and Haryana. The scheme is less effective than it could be because the subsidy is disbursed with a considerable lag and is perceived to be uncertain. The provision of subsidy on diesel does not weigh in on farmers' decisions on how much area to crop in a bad monsoon year and whether to irrigate the crop, because payments come long after the decisions have been made and are not even certain to come.

4. DISCUSSION

Tapping the Sun to Drought Proof Agriculture in Bihar

Widespread access to affordable irrigation can be the best stimulus program for Bihar's agriculture, the best poverty eradication program for the state, and the most effective way of drought proofing agriculture. The government of Bihar has been implementing different schemes to improve access to groundwater irrigation and to make it more affordable. The state government has allocated US$ 0.2 billion to the diesel subsidy scheme over the past five years (Table 4.1), $2.5 billion to BIGWIS to subsidize new diesel pumps and STWs, and a $3.05 billion to revive 922 old PTWs and build 300 new ones over the next few years, after having already spent $5 billion between 2002 and 2007 on PTWs. However, we saw in the last section that these schemes have not succeeded in making irrigation more affordable for farmers of Bihar. PTWs simply do not work. Providing subsidy on diesel for irrigation has not been effective in drought proofing *Kharif* crops either—apparent from the large reduction in area and yield of paddy in drought-affected districts. Increasing the density of STWs and diesel pumps is also unlikely to make irrigation significantly cheaper for pump owners and water buyers. Subsidy on tubewells and pump-sets is encouraging investment of scarce capital in assets that remain severely underutilized in Bihar.

Table 4.1 Declared amount of diesel subsidy for irrigation in drought-affected blocks of Bihar, 2008–2014

Year	Allocation (million Rs)
2008	630.60
2009	3000.00
2010	1796.89
2012	2142.91
2013	2359.486
2014	7690.60
Grand total (2008–2014)	**17,620.49**

Source: Bihar, DoA (2014b).

Note: Rs = Indian rupee.

Improving power supply to rural areas is one way to make irrigation more affordable, as has happened in West Bengal (Mukherji 2007; Mukherji et al. 2012). However, unlike in West Bengal, Bihar has large deficits of power[10] and rural power supply is unlikely to increase and improve to the extent where farmers could rely on electricity for groundwater irrigation in the foreseeable future—it may take years, if not decades.

In the absence of grid power for rural areas, solar photovoltaic water pumping for irrigation is a suitable option to ensure affordable irrigation for farmers, given the ample groundwater at low depths and 280–300 sunny days in a year with annual average solar radiation of 5.04–5.42 kilowatt-hour per meter squared (kWh/m^2) (IMD 2009 cited in GIZ 2013). The economics of solar pumps already look attractive given the high and rising cost of diesel they will replace in Bihar. Several studies in India and other countries of the world show that the life-cycle cost of solar-powered pumps is significantly lower than that of liquid-fuel-based pumping systems (Kolhe et al. 2002, Odeh et al. 2006, GIZ 2013). In India, electricity from solar panels now costs only half as much as that from diesel generators, even when diesel is subsidized. This is mainly because photovoltaic (PV) systems have long lifetimes, need minimal attendance and little maintenance, and have near zero operational cost. PV systems have an additional advantage over fossil fuels: they provide emissions-free power using a renewable source of energy.

[10] Bihar had an energy deficit of 20.2 percent and a peak deficit of 31 percent during 2012–2013 (GIZ 2013). The situation led to wide-scale rationing of power to all categories of consumers, even more so in rural areas.

Solar pumps have a unique cost structure with very high capital investment and near-zero marginal cost of pumping. This makes it very similar to electric pump owners who face high flat tariffs with a rationed power supply at zero marginal cost. A solar-pump-driven groundwater economy will also promote competitive groundwater markets with highly beneficial outcomes for water buyers, who will gain even more with buried pipeline distribution networks such as those found in central Gujarat (Shah 1993).

In 2013–2014, we surveyed 160 farmers in 16 villages of Nalanda who had access to affordable irrigation from solar-powered PTWs and compared them to 80 closely matched farmers in their immediate neighborhood who did not have this facility. We compared cropping patterns, use of inputs, irrigation expenditure, crop yields, and net returns of both groups of farmers using data collected from three rounds of surveys carried out during growing seasons of rice and wheat. We found that farmers with access to cheaper irrigation from solar pumps applied more water to their crops, saved money on irrigation (Rs 5864/ha for rice and Rs 2417/ha for wheat), reaped higher yields of both paddy (3671 kg/ha vs. 3414 kg/ha) and wheat (2974 kg/ha vs. 2625 kg/ha), and were able to plant rice in 90 percent of their land in *Kharif* 2013—a drought year—while other farmers had to leave 25 percent of their land fallow for want of supplementary irrigation.[11]

Given all the positive features, the government should aggressively promote solar irrigation pumps in the state. The agricultural roadmap of the state government proposes to install 285,000 solar pumps of 2 HP (or 1.5 kW) capacity by 2022 in several phases, at an estimated cost of Rs 85.5 billion (US$1.425 billion) (Bihar, ED 2012). The high upfront cost of solar pumps (Rs 0.15 million/HP) is, however, a big barrier to the adoption of this technology. Subsidizing capital costs of solar pumps and evolving innovative financing mechanisms that reduce the initial investment requirement for farmers can be part of a sound promotional strategy.

In the budget for 2014–2015, the government of India has earmarked Rs 4 billion (approximately US$67 million) for a new scheme to promote solar-power-driven agricultural pumps. The government of Bihar has also launched a scheme inviting applications from farmers who have at least 1 acre of land and a 4-inch boring to apply for solar pumps for irrigation. The farmer will have to contribute 10 percent of the capital cost of the whole system while the government will cover the remaining 90 percent of the cost. In the first phase, the scheme is open only to farmers in 16 districts of Bihar.[12]

The current promotion policy with a small onetime budgetary allocation, high pro-rata subsidy, and restrictions on the size of the pump and the photovoltaic array that farmers can buy is flawed. High subsidy combined with a small budget for the scheme limits the number of pumps that can be offered at subsidized rates. Only a few farmers will benefit, and even these farmers will be less aggressive in selling water to their neighbors, given the low capital investment from them. It creates a high-margin/low-volume market for photovoltaic systems, just like it did for drip systems in the past. Moreover, the pro-rata subsidy incentivizes cost inflation and gold plating by solar system suppliers instead of creating incentives for cost-cutting innovations.

We propose that the government of Bihar should offer a flat subsidy on solar pumps to all farmers in the state who own a tubewell without any restrictions on the total number of pumps that will be subsidized. The state government should set aside a large fund—of, say, Rs 25 billion—over a five-year period to offer a flat subsidy of Rs 50,000 per kW of solar capacity. This suggested amount is close to the state government's total allocation for the three drought- proofing schemes discussed in Section 5 of the

[11] Results of this study are reported in detail in a forthcoming paper titled "Bringing an Evergreen Revolution in Bihar: The Impact of Access to Solar Pumps in 16 Villages."

[12] These 16 districts are Saharsa, Supaul, Arariya, Kishanganj, Purnea Muzaffarpur, Sitamarhi, Shivahar, East Champaran, West Champaran, Vaishali, Darbhanga, Madhubani, Gopalganj, Madhepura, and Nalanda.

paper. At current costs, a program of this scale can lead to installation of 500 MW solar-powered groundwater pumping capacity, which can replace 0.3 million diesel pump-sets of 5 HP each. The 0.3 million new solar pumps could provide affordable irrigation to 1.2–1.5 Mha of land owned and operated by 4 to 6 million farmers. Creating this irrigation potential would cost Rs 50,000/ha—less than one-fifth of what it costs to create 1 ha of canal command area and close to the per-hectare annual maintenance cost of PTWs. The economics of solar pumps will be even more attractive if they help increase the cropping intensity in Bihar.

5. CONCLUSION

Large parts of Bihar have experienced dry spells in monsoon in four out of the five years from 2009 to 2013. Drought is likely to be declared in 28 districts this year (2014) too. Our analysis shows that droughts have a big negative impact on yield and production of monsoon crops, especially paddy. Reduction in agricultural output pushes millions of people in Bihar into transitory poverty and negates positive effects of the overall economic growth and development in the state. Unfortunately, the two largest social safety net programs, MGNREGS and TPDS, provide little additional help to drought-affected households. Major drought-proofing schemes have also not been very effective in making agriculture in Bihar resilient to vagaries of monsoon. Droughts have a larger impact on crop production and people's welfare in Bihar than in other states of India. We think that this is so because groundwater irrigation is expensive in Bihar. Making irrigation cheaper could be the most effective strategy to make Bihar's agriculture climate-smart. The rapidly falling price of solar panels offers an opportunity to provide widespread access to affordable irrigation in Bihar. However, the state government needs to allocate more resources to promote solar pumps and improve the subsidy design to realize the potential of this new technology.

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NASC Complex, CG Block
Dev Prakash Shastri Road (Opp Todapur)
Pusa New Delhi 110-012 India
Tel.: 91 11 2584-6565
Fax: 91 11 2584-8008 / 2584-6572
Email: ifpri-newdelhi@cgiar.org