Agricultural Economics Research Review 2020, 33 (1), 87-97
DOI: 10.5958/0974-0279.2020.00010.5

Drip irrigation technology in Karnataka, India

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Abstract This study assesses whether the practice of drip irrigation in Karnataka reduced the usage of groundwater. It finds that while drip irrigation does reduce the quantity of groundwater used per acre, the quantity of the groundwater used per farm does not fall concomitantly, because the irrigation intensity of drip irrigation is greater. Therefore, limiting the area under drip irrigation would make the adoption of the technology sustainable and address food security, and the government should complement the practice of drip irrigation. There is no rebound effect or instance of the Jevons paradox.

Keywords Drip technology, Jevons paradox, Average treatment effect

JEL codes Q12, Q15, Q16, Q25

In India, the population is growing, and the growth has enormously increased the demand for food; however, the arable land decreased from 0.34 hectare per capita in 1961 to 0.12 hectare per capita in 2014 (Munir et al. 2016). The growth in demand and the decrease in arable land paved the way for the green revolution. Its technological innovations are water-intensive, however the demand for water has grown to overwhelm the current water supply and threaten rural livelihoods and food security in the country.

Drip irrigation, a green revolution technology, has been documented to reduce the tillage requirement and increase the efficiency of water use by 40–80% (Drija and Salagean 2012; Goyal, 2015). Compared to other conventional irrigation methods, drip irrigation technology raises the yield and the net returns (Sivanappan 1994). It is profitable, but farmers must be able to afford the initial investment needed to adopt drip irrigation technology. The central and state governments offer farmers subsidies and institutional credit to adopt drip irrigation technology and use it, but farmers grow more crops per season or year instead of reducing water use by growing more plants per drop of water. This consequence is an example of the Jevons paradox. It occurs when the rebound effect is 100%—a 10% rise in energy efficiency raises energy consumption by 2%, and the use of energy-efficient technologies increases energy use by 2% instead of reducing energy consumption. Thus, the economic loss of benefit is 120% (Yorka and McGeeb 2015). If efficiency increases by x%, resource consumption may increase or decrease by y%; for example, a 6% increase in energy efficiency may increase energy consumption by 4% (Yorka and McGeeb 2015).

In the condition of economic efficiency, resources are allocated optimally to serve each individual, entity, or objective in the best way and minimize waste or inefficiency (Alain 2004). But technological efficiency does not always lead to the conservation of resources; it may lead to an increase in resource use and the production of more units (Jevons 1865)—the rebound effect. The rebound effect of technological efficiency leads to counterproductive results. When the demand for a product is inelastic, consumption falls. Water consumption depends on the elasticity of demand for irrigation. The demand for groundwater for the purpose of irrigation is elastic, as water use increases every day. The use of drip technology reduces the water used per unit of crop yield, but farmers use the water saved to grow more crops.

Technological innovations prove the Jevons paradox or rebound effect in agricultural land intensification (Lambin and Meyfroidt 2011); green irrigation practices (Gomez and Dinisio 2015); the practice of using dropped nozzles to increase irrigation efficiency (Pfeiffer and Cynthia 2013); and irrigation technologies in Europe (Berbel and Mateos 2014). Conversely, studies indicate that innovations in irrigation technology conserve water (Dumont et al. 2013; Patil et al. 2015). These studies depict the counterintuitive results of innovations in irrigation. From above review of literatures shows that drip irrigation technology in irrigation has been documented the groundwater conservation and exploitation; however the study on Jevons paradox in drip technology applied research methods, (Patil et al. 2015) are not taken consideration of sample error and assumed normal distribution principle for purposive sampling dataset. Thus, this study aims to address the research gap and overcome the limitation. The study tests the Jevons paradox in drip irrigation technology, especially in the hard rock areas of Karnataka.

Data and methodology

Data

This study analyses the efficiency of groundwater use under the drip and conventional irrigation systems and compares the two. Farmers who practise drip and conventional irrigation constitute the respondents, and a purposive random sampling technique was employed to choose them.[1] The data pertains to the crop year 2015–16. Between January 2015 and December 2015, the annual rainfall in the study area was 1,088 mm (Directorate of Economics and Statistics 2016)—more than the mean annual rainfall of 719 mm. To avoid the farm size effect, we collected data only from marginal farmers (size of landholding less than 1 ha), small farmers (1–2 ha), and semi-medium farmers (2–4 ha). We conducted face-to-face interviews using well structured questionnaires. Several studies indicate that the productivity and resource use of large farmers (>5 ha) varies widely from that of other categories of farmers, due to the size effect (Chand et al. 2011; Shenggen and Connie 2005; Carter 1984). Also, marginal, small, and medium farmers account for more than 70% of the farmers in Karnataka and in India (Directorate of Economics and Statistics 2011). Therefore, we limit our data to semi-medium farmers. The study sampled 185 farmers; 109 of them practised drip irrigation and 76 practised conventional flood irrigation.

Analytical tools

This study analyses the efficiency of groundwater use of drip irrigation technology by comparing the water use efficiency of farmers who practised drip irrigation (treatment group) to that of the farmers who practised the flood irrigation method (control group).

To balance the sampling, we used propensity score matching (PSM), an analytical technique used to establish the effect of an intervention, programme, innovation, or technology by comparing the characteristics of the treatment and control groups in a non-randomized experiment (Peter 2011). The PSM method is used widely to find the causal effect of a treatment, the average treatment effect (ATE), when the sampling frame is not completely randomized. The PSM method aims to minimize the inefficiency and selection bias of the estimated ATE.

The probit regression model is estimated by considering the binary action of treated (farmers following drip irrigation, X=1) and non-treated conditions (farmers following flood irrigation, X=0). The main assumption of the PSM method is that the characteristics 'S' influence the adoption of the technology. Therefore, the propensity score is M(s) on the treated action = 1 by considering the 'S' characteristics are constant for both group.

$$M(s) = P(X = 1, S = s) \qquad \ldots(1)$$

In the study, 'S' comprises socio-economic characteristics, crop cultivation elements, and irrigation system features (Table 1 the independent variables used for probit analysis). The socio-economic characteristics

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[1] We categorized farmers who practised both drip and conventional irrigation by the type of irrigation they practised on the larger area.

Table 1 Description of independent variables used for probit analysis

	Variable	Variable type	Unit of measurement	Variable description
1	Percent area under plantation crop	Continuous	Percentage	Share of perennial crop out of total gross cropped area of a farmer
2	Crop type	Dummy	Code	Crop type grown by farmers 1= plantation crop, 0 = seasonal crop
3	Age	Continuous	Years	Age of the farmer
4	Year of education	Continuous	Years	Year of schooling of farmer considered as year of education
5	Total distance to market	Continuous	Kilo meter	Total distance to their products markets from farmer's village
6	Family size	Continuous	Number	Family size of a farmer
7	Average power of pump used to lift groundwater	Continuous	Horse power	Average power of pump used by farmer to lift groundwater from borewell
8	Average distance to water source	Continuous	Meter	Average distance to the nearest water source from farmer's bore well
9	Average distance between two neighbouring borewells	Continuous	Meter	Average interference distance between two neighbouring bore wells of the famer
10	Distance to loan institution	Continuous	Kilo meter	Distance from farmers' village to bank institution where they borrowed loan
11	Loan amount	Continuous	INR	Amount borrowed by farmer from bank/s
12	Number of milk-yielding animals	Continuous	Number	Number of milk-yielding animals owned by farmer
13	Farm size	Continuous	Acres	Farm area owned by farmer

Source Authors

are farmer age, education, and caste[2]; family and farm size; and access to credit. The aspects of crop cultivation considered are the proportion of the share of the area under perennial crops to the gross cropped area; crop type (seasonal or perennial); and access to market (distance from a farmer's village to a product market). The features of the irrigation system are the average depth of borewell drilled; the average distance to the nearest water source from the farmer's borewell; and the average interference distance between two neighbouring bore wells of the farmer.

Consider that X_i represents drip technology adoption by farmer; drip adoption is a binary dependent variable in the model of interest. Thus, the resulting equation of the probability of drip adoption decides by independent variables 'S_i', where 'i' indicates farmer. In addition, 'u' is the error terms of binary probit model; error term represents the additive effect of the omitted variables on the farmer's adoption of drip technology. Therefore, the probability that a farmers to adopt drip technology is derive from specified linear probit model in equation (2)

$$X_i = f(S_i) + u \qquad \ldots(2)$$

Where, X_i represents the binary dependent variable. Probability of drip adoption by farmers is result of equation (3).

$$\Pr(X_i = 1|S_i) = E(X_i \mid S_i; \beta) \qquad \ldots(3)$$

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[2] Caste is a hereditary class of Hindu society. It is distinguishable by relative degrees of ritual purity. In India, education and job opportunities are based on the caste-based reservation system. Scheduled Castes (SC) and Scheduled Tribes (SC) are considered to be historically the most disadvantaged social groups in India, and considerable part of higher education seats and job opportunities are reserved for them than for Other Backward Classes (OBC) or the General category (Sheth 1987).

Where, β is a K × 1 vector of parameter of S_i derived from equation (2).

One of the main assumptions of the PSM method is conditional independence. The assumption indicates that all variables which affect the probability of drip adoption are included in S_i. This implies that control group to be used to construct an unbiased counterfactual for treatment. In other words, the treatment assignment is independent and conditional on the independent variables 'S_i', in the equation (2). In the context of irrigation, following Gabriel (2017), there is an endogeneity problem associated with loan access and technological adoption; we take a similar approach to estimate the propensity scores—we use instrumental variables in a linear probit model, and we consider the adoption of drip irrigation as a dependent variable. Using instrumental variables is the common approach taken to overcome the endogeneity problem, and it is preferable when estimating casual effect (Freedman and Sekhon 2010).

The distance from a farmer's village to a loan institution is an important variable as it decides the ease of access to credit and explains a farmer's loan amount. Easier the access, greater the transactions with banks; the ease of access improves financial inclusion and helps farmers to form a good working relationship with banks.

Another important variable that explains the loan amount is the distance to a product market. Shorter the distance to a product market, better the farmer's marketing opportunities. If a farmer has to travel only a short distance to a product market, their cost of transport falls; access to inputs rises; and choice of crops widens to include perishables such as vegetables, fruits, flowers, and other commercial crops.

Farmers need to invest in inputs (seeds, fertilizers, labour, greenhouse structures, and irrigation infrastructure); therefore, they need finance and bank loans. The distance to market and the total distance to product market are correlated with the loan amount. We tested the relevance of instrumental variables by correlation (Table 2 Correlation of instrumental variables with farmers' bank loan). We choose the distance to a loan institution and the total distance to a product market as the instrumental variable for a farmer's bank loan amount

Let us consider the distance to a loan institution and the total distance to a market as Z_i, where, Z_i should be correlated with L_i, where L_i represents the loan amount borrowed from bank/s by farmers and exogenous from error term 'v'. As L_i will be the function of N_i independent variables other than farmer's bank loan amount and instrumental variables Z_i.

Thus, S_i is redefined as N_i by removing the endogenous variable (a farmer's bank loan amount). Then, the probability of drip adoption is estimated with two linear equations (4) and (5).

$$Li = a + \Upsilon_1 N_i + \Upsilon_2 Z_i + v \qquad \ldots(4)$$

In equation (4), Z_i represent the instrumental variable/s which should explains the loan amount and uncorrelated with the error term 'v', Υ_1 and Υ_2 are the coefficients of N_i and Z_i respectively. Let L_i^p is the predict value of L_i obtained from equation (4).

Therefore, the new model with correction of endogeneity is

$$P\,(Xi) = \alpha + N_i\beta_1 + L_i^p\beta_2 + \varepsilon \qquad \ldots(5)$$

Where, ε represents the error term and β_1 and β_2 are the coefficients of N_i and L_i^p respectively.

Equation (5) is the linear probit model estimated with two-stage regression (2SLS). After getting propensity scores from equations (1) and (5), we need to find the ATE of drip irrigation on quantity of groundwater used by the farmers.

Table 2 Correlation of instrumental variables with farmers' bank loans

Particular	Loan amount borrowed by farmer from bank	Total distance to loan institution from farmer's village	Total distance to product market from farmers village
Loan amount borrowed by farmer from bank	1.00	0.56	0.43
Total distance to loan institution from farmer's village	0.56	1.00	0.03
Total distance to product market from farmer's village	0.43	0.03	1.00

Source Author

The second part of the PSM method deals with the specific interest of the study: the effect of drip irrigation on the quantity of irrigation water used for crop cultivation. Thus, the groundwater used is the dependent variable. The quantity of groundwater used is based on the depth of irrigation and the area irrigated. The pump used to lift groundwater is an important factor, and it is captured in the water yield of borewells and the quantity of water emitted by drippers. However, the depth of irrigation varies with the soil conditions, cropping patterns, weather, and other external factors.

The study estimates the groundwater use as follows:

Groundwater used in conventional irrigation system

Groundwater used for each crop per year (acre-inches) = [(area irrigated per crop) * (frequency or number of irrigations per month) * (duration of irrigation given to crop in months) * (number of hours given to each irrigation) * (Average yield of bore well in gallons per hour)] / 22611.

Where, 22611 is a factor to convert from gallon per hour to acre-inches.

Groundwater used in drip irrigation system

Groundwater used for each crop per year (acre-inches) = [(number of drippers or emitters per cropped area) * (groundwater discharge per emitter in litres per hour) * (frequency or number of irrigations per month) * (duration of irrigation given to crop in months) * (number of hours given to each irrigation)]/ 4.5/ 22611.

Where, 4.5 is a factor to convert from litres per hour to gallon per hour.

Groundwater used per farmer (acre-inches) = Sum of groundwater used per each crop

Groundwater used per acre per farmers (acre-inches) = (sum of groundwater used per each crop / gross irrigated area per year)

The ultimate objective of the study is to measure the effect of drip irrigation (x) on the quantity of groundwater used (y). The treatment effect is to be found by balancing the treatment and control farmers with 'N_i' and by considering the Z_i characteristics as the constant. Let us consider N_i and Z_i are independent variables as 's'; thus, equations (6) and (7) represent the mean groundwater used by farmers for crop cultivation with treatment and control respectively.

$$E(y^0 \mid s,x) = E(y^0 \mid s) \quad \ldots(6)$$

$$E(y^1 \mid s,x) = E(y^1 \mid s) \quad \ldots(7)$$

The actual outcome of the treatment can be derived from equation (7):

$Y_i(0)$ and $Y_i(1)$ are the potential outcome of groundwater used for control and treatment respectively in the study sample. Each farmer of the sample will receive either control or treatment. As per equation (2), X_i be the variable indicating the treatment received ($X_i = 0$ for control, $X_i = 1$ for treatment). Only one outcome observed for each subject received treatment is as follows:

$Y(Y_i = X_i, Y_i(1) + (1 - X_i) Y_i(0))$

Where, i represent each farmer.

For each farmer, the effect of drip irrigation on the quantity of water used is

$Y_i(1) - Y_i(0)$

The ATE is defined as is the average effect at the population level of moving the entire population from the untreated category to the treated category (Peter 2011). The ATE can be represented as

$E[Y_i(1) - Y_i(0)]$

The average effect of drip irrigation technology on the amount of groundwater pumped for crop cultivation over the conventional method of irrigation will decide whether the technology reduced or raised water consumption. The matching methods used to estimate the ATE are radius matching, kernel matching, and nearest neighbourhood matching. In radius matching, a radius with the highest propensity scores, the caliper, is created, and the treatment and control units within the radius are compared to the caliper. In kernel matching, the weight of each control unit is estimated based on the difference of the propensity scores between treatment and control units; higher the weight, nearer the control unit to the treatment units. In nearest neighbourhood matching, the treatment and control units with the nearest propensity scores are matched, and the non-similar scores of treatment and control units are dropped.

Results and discussion

We use several variables to estimate the ATE of groundwater use and estimated mean and standard

Table 3 Mean and standard deviation

Particulars	Drip	Flood
Farm size	2.97 (1.35)	2.48 (0.93)
Family size	6.32 (3.05)	5.61 (1.90)
Age of farmer	41.68 (7.45)	42.63 (7.14)
Education	8.99 (5.53)	7.28 (5.41)
% area under plantation	79.17 (20.64)	85.00 (15.27)
Power of pump	14.71 (5.46)	12.78 (5.16)
Distance to water source	882.29 (995.55)	1132.00 (755.52)
Distance between neighbouring borewells	327.45 (328.86)	321.00 (308.32)
Loan amount	99477.06 (123252.10)	58866.67 (74744.81)
Distance to loan institution	14.39 (9.19)	14.23 (7.65)-
Distance to market	39.51 (24.88)	55.75 (44.08)
Number of milk yielding animals	1.50 (1.79)	1.84 (1.49)
Irrigation intensity (%)	153.76	137.42

Source Author; Figures in parentheses indicates the standard deviation

deviation for those variables (Table 3 Mean and standard deviation). The values of a few variables—average farm size, family size, year of education, the power of the pump used to lift groundwater and the amount of institutional loan—are greater for farmers who practise drip irrigation. The values are higher for farmers who practise flood irrigation for the variables mean distance to product market, the distance of borewell to the nearest water body, interference distance between bore wells, the percentage of area under plantation crops, age of farmer, and the distance to a product market. The cropping intensity is 153.76% for drip irrigation farmers and 137.42% for flood irrigation farmers.

We conduct 2SLS estimation to select the instrumental variables (Table 4 Estimates of endogenous variable with instrumental and other independent variables of drip adoption in study area). We find that the amount of a farmer's loan was influenced by their caste and the distance to a loan institution at 1% significance level. The loan amount was influenced also by farm size, the percentage area under perennial crops, crop type (plantation = 1, seasonal = 0), mean distance to the nearest water source from a farmer's borewell, and the total distance to a product market at 5% significance level. The mean power of a pump used to lift groundwater influenced the loan amount at 10% level. The model is significant according to the Wald test of exogeneity, as the chi square test is significant ($p < 0.05$), and the use of the variable distance to a loan institution; therefore, the model validates the instrumental variables. The instrumental variables are uncorrelated with the other independent variables in the model and the error term of the variables omitted in the model.

Another important variable that explains the loan amount is the total distance to a product market from a farmer's village. We use the linear probit 2SLS model to conduct a probit test for the adoption of drip irrigation (farmers practising drip irrigation = 1, farmers practising flood irrigation = 0) and find that $p < 0.05$; therefore, the model is significant (Table 5 Estimates of probit regression on drip irrigation adoption in the study area) and the loan amount significantly affects a farmer's adoption of drip irrigation. Ceteris paribus, for every additional unit of amount available for borrowing, the probability of drip adoption increases by 0.00123%, and for every one-horsepower increase in the power of the pump used to lift groundwater, the probability that a farmer will adopt drip irrigation increases by 0.03% at 5% significance level. The mean interference distance between two neighbouring borewells and the mean distance from a farmer's borewell to the nearest water source positively influence a farmer's adoption of drip irrigation at 10% significance level.

Table 4 Estimates of endogenous variable with instrumental and other independent variables of drip adoption in the study area

Dependent variable - loan amount of the farmers with the bank/s (in INR)

Independent variables	Coefficient
Farm size	13380.57**
% of plantation area	849.2594**
Crop type (Seasonal=0, Perennial=1)	–55915.78**
Age	1395.421
Family size	–2223.864
Average power of pump used to lift groundwater	–2068.109*
Average distance between two neighbouring borewells	–20.82957
Average distance to the nearest water source from farmer's bore well	–19.50998**
Number of milk yielding animals	5735.854
d1 caste (Scheduled tribe)	54098.11**
d2_caste (Other backward classes)	58514.52***
d3 caste (General)	105838.5**
Years of education received	6360.721***
Years of education received * d1 caste	–4439.619
Years of education received * d2 caste	–4291.399
Years of education received * d3 caste	–10254.6**
Distance to loan institution	4444.527***
Total distance to product market	–234.4584**
Intercept	–39138.87
Athrho	–1.29069
Insigma	11.2925
Wald test of exogeneity	10.57
Prob> chi2	0.0011

Source Author; *Note* *** < 0.01 significance level and ** <0.05 significance level

We take SCs as the base caste category; OBCs have a 0.7% lower possibility of adopting drip irrigation and the General caste category has a 1.13% lower possibility at 10% significance level, and there is no difference between SCs and STs in adoption. The result shows the relatively more drip adoption by farmers belongs to SCs than other categories. This is may be because of institutional support to backwards classes SCs and STs, it subsidizes the initial investment in drip adoption and greenhouse construction; the government also offers special assistance through public distribution programmes (Sheth 1987; Jangir 2013). However, OBCs and the General caste category receive less institutional encouragement.

Some studies indicate that the adoption of drip irrigation technology is positively and significantly influenced by the power of the pump used to lift groundwater, years of schooling, and the dependency ratio (Namara et al. 2007); and by the age of the farmer, farm size, crop spacing, and non-farm income (Goyal 2015). The possibility of drip adoption increases with an increase in the depth of a borewell, higher share of fruits, vegetables, plantation crops more the rate of adoption and socio-economic variables made a significant effect on drip technology implementation (Namara et al. 2007). The implementation of micro-irrigation is decided also by crop cultivation elements and physical, socio-economic, and financial variables. The area under cereals cultivation negatively affected adoption (Namara et al. 2007). Adoption is not influenced by the type of crop, area under plantation crops, farm or family size, or farmer age or education in the study area.

Table 5 Estimates of probit regression on drip irrigation adoption in the study area
Treatment is the dependent variable (0 = farmers following flood irrigation, 1 = farmers following drip irrigation)

Independent variables	Coefficient
Loan amount	0.000012***
Farm size	0.137887
% of plantation area	.003996
Crop type (seasonal=0, perennial=1)	.435503
Age	–0.016641
Family size	.030107
Average power of pump used to lift groundwater	.037194**
Average distance between two neighbouring bore wells	.000461*
Average distance to the nearest water source from farmer's bore well	.000189*
Number of milk yielding animals	.013909
d1 caste (Scheduled tribe)	–.453525
d2 caste (Other backward classes)	–.708106*
d3 caste (General)	–1.135900*
Years of education received	.040776
Years of education received * d1 caste	.012587
Years of education received * d2 caste	.043659
Years of education received * d3 caste	.080631
Intercept	–.498840
Log pseudo likelihood	–2429.8297
Number of observations	185
Wald chi2(17)	199.12
Prob> chi2	0.0000

Source Author; *Note* *** < 0.01 significance level, ** < 0.05 significance level, *< 0.1 significance level; Loan amount equals to Distance to loan institution(bank) and total distance to product market from farmers' village

The propensity scores estimated indicate all the factors and elements that farmers consider for adopting the drip irrigation technology. The common support is the main assumption of the PSM method: the number of propensity scores of the control units should be similar to the scores of the treatment units. While one-to-one matching is advisable, it is difficult in reality; therefore, a common area between two groups is preferred (Glazerman et al. 2003). In the study sample data propensity score between control and treatment indicate a similar pattern distribution of propensity scores between the control units (farmers following flood irrigation = 0) and treatment units (farmers adopting drip irrigation =1) (Figure 1 Matching pattern between farmers practicing drip (treated) and flood (control)). Thus, the propensity scores are valid to estimate the ATE of the quantity of groundwater used by farmers for crop cultivation (Table 6 Average treatment effect (ATE) based on different matching methods).

In the radius matching method, 62 control units matched with 73 treatment units. Assuming that farmers practising flood and drip irrigation share the same socio-economic characteristics, if farmers practising flood irrigation use 10 acre-inches of groundwater on average, farmers practising drip irrigation use 3.285 acre-inch; the mean difference is 6.715 acre-inch. And drip irrigation farmers save 67.15% of the groundwater used by farmers practising flood irrigation farmers, significant at 5%.

In the kernel matching method, 76 control units matched 109 treatment observations; farmers practising drip irrigation used 12.66 acre-inch less groundwater than farmers practising flood irrigation, and they used 63.30% less groundwater, significant at 5% level.

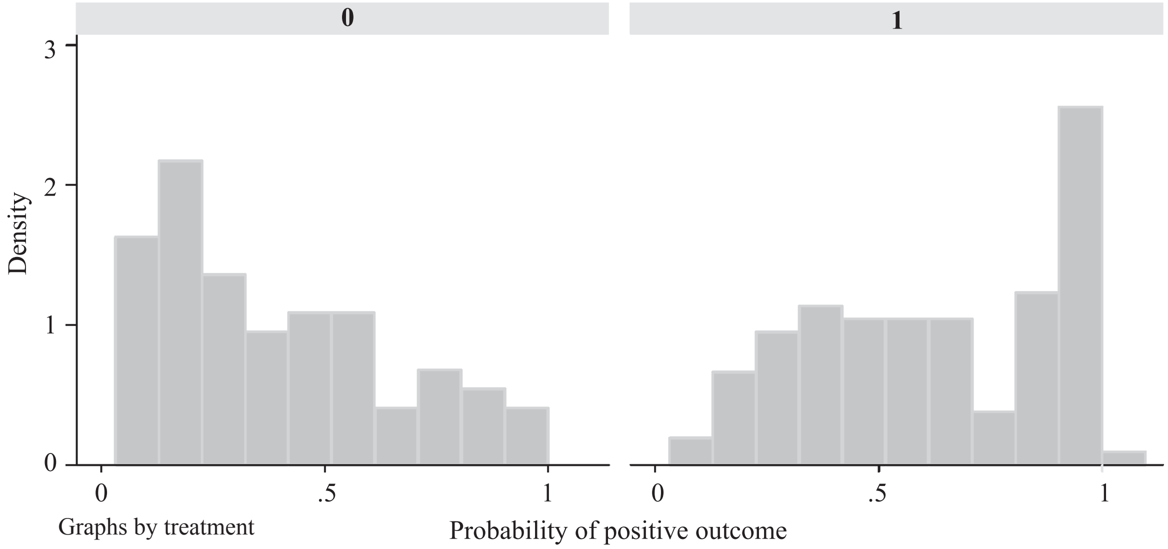

Figure 1 Matching pattern between farmers practicing drip (treated) and flood (control) irrigation in the study area
Source Author

Table 6 Average treatment effect (ATE) based on different matching method

Matching method	Matched control units	Matched treated units	ATT $(Y_1 - Y_0)$	t-Statistic interval of 95%	Confidence
Radius	62	73	–6.715	–2.513 **	–12.724 to –0.618
Kernel	76	109	–12.666	–1.962**	–39.317 to –4.461
Nearest neighbourhood	28	109	–12.856	–1.838 *	–44.424 to –5.028

Source Author; *Note* ** significance at< 5 percent; * significance at <10 percent

In the nearest neighbourhood method, 28 control units matched 109 treatment units. Farmers practising drip irrigation used 12.856 acre-inch less groundwater than farmers practising flood irrigation at 10% significance level.

Farmers practising drip irrigation used 26.06 acre-inch of groundwater, and farmers practising flood irrigation used 30.07 acre-inch of groundwater; 10.14 acre-inch of groundwater is used per acre under drip irrigation and 16.12 acre-inch used under flood irrigation (Table 6 Average treatment effect (ATE) based on different matching methods). Drip irrigation reduces groundwater use per acre by 37.12%. The irrigation intensity under drip irrigation is greater (153.36%) than under flood irrigation (137.42%), and only 13.34% of groundwater is saved at the farm level.

The drip irrigation technology saves groundwater, and the technology interventions reduced the groundwater use; however it subject to limitation on the gross irrigated area (Berbel and Mateos 2014). Whereas, the limitation on gross irrigated may threaten the food security of the society. Thus, balancing food security is an important emerging issue, and irrigation technologies may lead to a change in the cropping pattern from food crops to commercial crops (Pfeiffer and Cynthia 2013). Practising drip irrigation saves groundwater per acre and farm (Tables 6 Average treatment effect (ATE) based on different matching methods and Table 7 Mean ground water used per farm and per acre of the sampled farmers). The irrigation intensity of drip irrigation is greater than of flood irrigation, and the greater irrigation intensity may lead to the rebound effect or the Jevons paradox. In the study area no rebound effect in groundwater use whereas the per-farm groundwater saving is not proportionate with the per-acre groundwater conserved.

Table 7 Mean groundwater used per farm and acre basis of the sampled farmers

Farm type	Groundwater used per acre			Groundwater use at farm level		
	Drip	Flood	% saving	Drip	Flood	% increase / decrease
Marginal	10.03	15.75	36.27	23.96	26.75	10.44
Small	11.40	15.55	26.68	26.77	30.20	11.35
Semi-medium	10.23	17.38	41.16	32.50	39.25	14.46
Mean of drip sampled farmers	10.14	16.12	37.12	26.06	30.07	13.34

The drip irrigation technology reduces the groundwater used per acre and farm—6.715 acre-inch on average. The irrigation technology is reduced the groundwater use. There is no rebound effect of the practice of drip irrigation in the study area, therefore, and the practice is not an instance of the Jevons paradox.

Drip irrigation technology is reduced the use of groundwater resources. Drip and sprinkler irrigation reduce groundwater consumption however subjected to the limitation of the extension of area under irrigation (Berbel and Mateos 2014). The modernization of irrigation in Spain saved 12% of water (Loch and Adamson 2015). Drip technology uses less water than flood or conventional irrigation in India (Patil et al. 2015). Whereas, drip technology adoption sustainability can be compliment with other policies such as restriction of gross irrigated area under drip irrigation, meanwhile balancing the food security is a challenge in front of policy makers.

Conclusions

The adoption of drip irrigation technology is influenced by institutional finance, the power of the pump used to lift groundwater, the average distance between two neighbouring borewells, and the average distance from a farm to the nearest water source. Compared to the conventional practice of irrigation, drip irrigation conserves groundwater; it reduces groundwater use by 67.15% under the radius matching method and by 63.30% under the kernel matching method, and it saves 13.34% of groundwater at farm level. There is no rebound effect or occurrence of the Jevons paradox in the practice of drip irrigation technology in the study area. The practice of drip irrigation reduces the quantity of groundwater used per acre, but the quantity of the groundwater used per farm does not fall concomitantly because the irrigation intensity of drip irrigation is greater. Therefore, limiting the area under drip irrigation would make the adoption of the technology sustainable and address food security. The government should complement the practice of drip irrigation.

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Received: August 2019 Accepted: December 2019