IRRIGATION AND DRAINAGE
Irrig. and Drain. **68**: 50–58 (2019)
Published online 22 August 2018 in Wiley Online Library (wileyonlinelibrary.com) **DOI**: 10.1002/ird.2275

ADAPTATION TO CLIMATE CHANGE: IMPACT OF CAPACITY BUILDING, INDIA†

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ABSTRACT

Climate change adversely affects the determinants of agriculture. Adaptation serves as an important strategy to reduce the adverse effects of climate change (variability) and vulnerability of the people. Adaptation through an innovation programme was implemented for 4 years during 2012–2016 to improve the adaptive capacity in agriculture and the water sectors through capacity building and implementation in the Krishna River Basin, India. Primary data were collected from 178 farm households of the Nagarjuna Sagar Project command area covering both adopters and non-adopters of water-saving interventions from the study area. The double difference method was used to analyse the impact of adaptation through capacity building and implementation. The water-saving interventions include alternate wetting and drying (AWD) in rice, a modified system of rice intensification (MSRI) and direct seeding of rice (DSR). The capacity building and water saving increased crop yields by 0.96, 0.93 and 0.77 t ha^{-1} through AWD, MSRI and DSR respectively. The three practices have increased farmers' income and decreased the cost of cultivation in DSR by Rs.11 000 (US$169) ha^{-1}. The methods can be more focused in canal commands on a larger scale for equal distribution of water to all the head, middle and tail-end regions. © 2018 John Wiley & Sons, Ltd.

KEY WORDS: adoption through innovation; climate change; village knowledge centres; water-saving methods; double difference method

Received 16 December 2017; Revised 18 June 2018; Accepted 22 June 2018

RÉSUMÉ

Le changement climatique affecte négativement les déterminants de l'agriculture. L'adaptation est une stratégie importante pour réduire les effets néfastes du changement climatique (variabilité) et la vulnérabilité des populations. L'adaptation par le biais d'un programme d'innovation a été mise en œuvre pendant quatre ans en 2012-2016 pour améliorer la capacité d'adaptation dans les secteurs de l'agriculture et de l'eau grâce au renforcement des capacités et à la mise en œuvre du bassin de Krishna en Inde. Les données primaires ont été recueillies auprès de 178 ménages agricoles de la commande du projet Nagarjuna Sagar, couvrant à la fois les adoptants et les non-adoptants des interventions d'économie d'eau de la zone d'étude. La méthode de la double différence a été utilisée pour analyser l'impact de l'adaptation à travers le renforcement des capacités et la mise en œuvre. Les interventions d'économie d'eau comprennent l'alternance d'humidification et de séchage (AWD) dans le riz, le système modifié d'intensification du riz (MSRI) et le semis direct du riz (DSR). Le renforcement des capacités et les économies d'eau ont augmenté les rendements des cultures de 0,96, 0,93 et 0,77 t ha-1 respectivement par AWD, MSRI et DSR. Les trois pratiques ont augmenté le revenu des agriculteurs et réduit le coût de la culture en DSR de 11 000 roupies (US $ 169) par hectare. Les méthodes peuvent être plus concentrées dans les commandes du canal à plus grande échelle pour une distribution égale de l'eau en tout point des commandes. © 2018 John Wiley & Sons, Ltd.

MOTS CLÉS: adoption par l'innovation; changement climatique; centres de connaissances villageois; méthodes d'économie d'eau; méthode de double différence

INTRODUCTION

Climate change is gradual but affects many parts of the world influencing people's life adversely, in areas such as agriculture, food security, water resources and biodiversity

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as a whole. Its impact on agriculture has great significance for the world economy (Food and Agriculture Organization of the United Nations (FAO) 2008; Turral et al. 2011). Climate change increases rainfall variability and average temperatures, affecting both the supply and demand sides of irrigation. Higher temperatures will increase evaporation so that crops will use more water. Although the effects will vary from place to place, farmers will generally need to adapt to less soil moisture and higher evaporation. Enhanced climatic variability will have impacts on the effectiveness of water storage systems (International Water Management Institute (IWMI) 2009). Production of rice, wheat and maize in the past few decades has declined in many parts of South Asia due to water stress arising partly from increasing temperature, increasing frequency of El Niño and reduction in the number of rainy days (Cruz et al. 2007).

Water usage plays a key role in adaptation to climate change both by enhancing water security and agricultural productivity. Agricultural adaptation to climate change is a complex, multidimensional and multi-scale process that takes on a number of forms (Bryant et al. 2000). Farmers' ability to adapt to climate change is not evenly distributed among or within nations. In India, for example, both climate change and market liberalization are changing the context of agricultural production (Adger et al. 2007). Some farmers may be able to adapt to these changing conditions, while many may not. Adaptation enriches the healthy functioning of the ecosystem (Baig et al. 2016). Among those who have adapted to climatic change, the most common strategies include use of different crops or varieties, planting trees, soil conservation, changing planting dates, and water-saving irrigation practices.

Researchers and policy makers are also providing mitigation and adaptation strategies for climate change through the National Action Plan of the Ministry of Environment, Forest and Climate Change. The Indian Council of Agricultural Research, state agricultural universities and international institutes are proposing various adaptation strategies to farmers (www.nicra-icar.in; www.ccafs.cgiar.org; www.climarice.com; www.climaadapt.org). The ClimaAdapt Project (funded by the Ministry of Foreign Affairs, Royal Norwegian Embassy, New Delhi) was implemented from 2012 to 2016 to improve the resilience of the agriculture and water sectors in the states of Andhra Pradesh, Telangana and Tamil Nadu. The main objective of the project was to improve the adaptive capacity of stakeholders and farmers' groups.

Water-saving technologies, alternative livelihood practices, capacity-building programmes and stakeholder integration were proposed in the project areas. In Andhra Pradesh and Telangana, capacity building on awareness of climate change, implementation of water-saving practices such as direct seeding of rice, a mechanized/modified system of rice intensification, alternate wetting and drying, azolla as green manure and livestock feed and weather index insurance was proposed for implementation in a cluster approach to develop methodologies for upscaling of the adaptation and mitigation strategies. Consequently, adaptation strategies have been implemented in the project area for the last 4 years (Kakumanu et al. 2017). The present

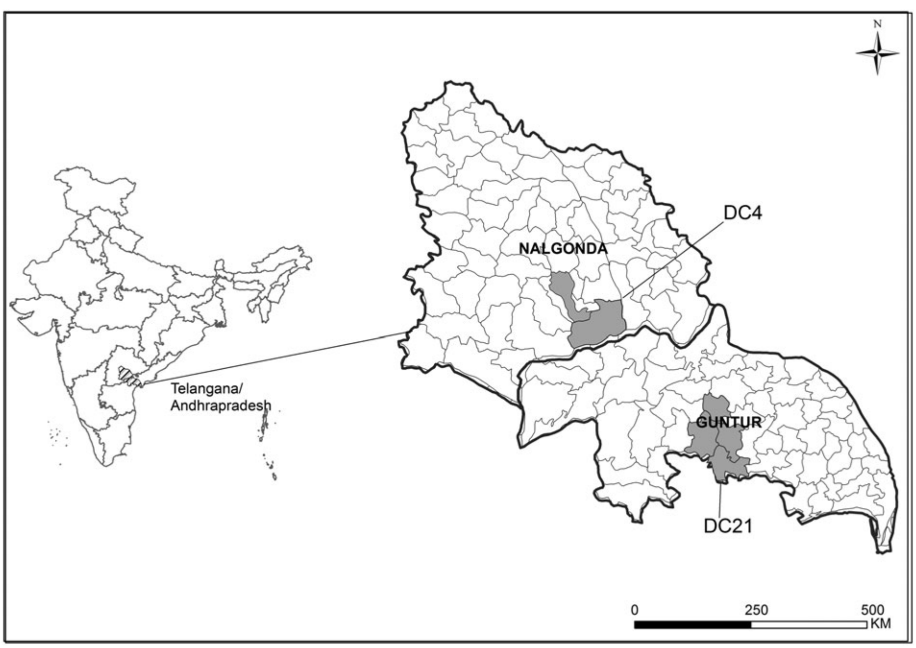

Figure 1. Location of the study area.

study aims to discover the impact of adaptation on water-saving techniques by farmers in response to climate change in the Nagarjuna Sagar area in the programme.

DATA AND METHODOLOGY

Study area, sample size and data collection

The study was taken up under the Nagarjuna Sagar Project (NSP) of the Krishna River Basin (Figure 1). The NSP provides 7.47 Mm^3 (million cubic metres) of water to irrigate 0.89 Mha (million hectares) in five districts (Khammam, Krishna, Nalgonda, Guntur and Prakasam) covering both Telangana and Andhra Pradesh. The NSP has two main canals: Jawahar (right canal) and Lal Bahadur (left canal). The right canal flows through 203 km and the left 172 km, irrigating 0.47 and 0.42 Mha, respectively. Nalgonda district from Telangana and Guntur district from Andhra Pradesh were selected for the study where the ClimaAdapt Project was implemented, focusing in particular on distributary committees (DCs) 4 and 21 in the respective districts. DC 4 covers an area of 8497 ha and DC 21 covers 9652 ha. In Nalgonda district, Miryalaguda and Damaracherla mandals (administrative areas) were selected for the present study. In Guntur district, Narasaraopet, Chilakaluripet, Muppalla and Nadendla mandals were chosen.

The 178 selected farm household samples had 138 adopters and 40 non-adopters (control). Farmers adopting water-saving practices such as alternate wetting and drying (AWD), a modified system of rice intensification (MSRI) and direct sowing of rice (DSR) were selected for analysis of the impact of adaptation and training. A structured questionnaire was used to collect information from the fields on general farming details, awareness about climate change, details of training attended, adaptation strategies and their benefits, information about village knowledge centres (VKCs) and water users' associations (WUAs), cost of cultivation of paddy and constraints faced.

Analytical tools

In the present study, costs of cultivation particulars were observed for both the adopter and non-adopter categories. It included expenditure on land preparation, seed costs for different water-saving practices, nursery preparation, transplantation, weeding, manuring, plant protection, cost of irrigation, which includes both electricity and manual labour costs, harvesting either mechanical or manual, transportation, interest on variable costs with that fixed costs like rental value of own land and land tax also covered.

Gross margin was calculated to suppress the fixed cost effect in the revenue, which had more value in turn, offsets the current effect. In overview, gross margin and yield parameters were given more significance than other variables.

Double difference (DD) method

For the present study, the information was collected for the pre and post-project period and compared with the control. Hence, the approach is a combination of both with and without and before and after approach, i.e. the double difference method Table I.

Data were collected from farmers who participated in the capacity-building programme and adopted the water-saving interventions and those who participated in the training programme but did not adopt. This enables use of the double difference method to study the impact of the capacity-building programme on water-saving intervention methods. The resulting measures can be interpreted as the expected

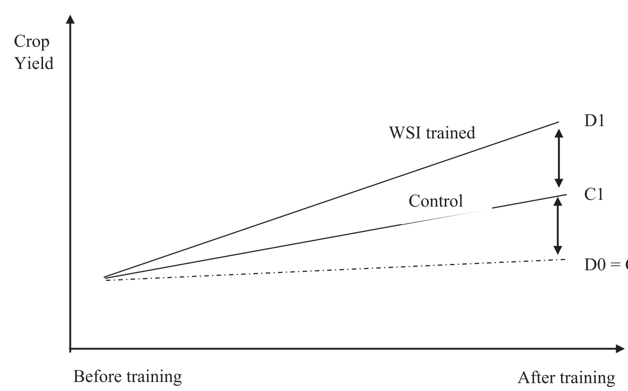

Figure 2. Impact of capacity-building programme by the double difference method.

Table I. Impact assessment of WSI by double difference method

Sl. No.	Particulars	Adopters	Non-adopters	Differences across groups
1	After adopting WSI method	D1	C1	D1 – C1
2	Before adopting WSI method	D0	C0	D0 – C0
3	Difference across time	D1 – D0	C1 – C0	Double difference (D1 – C1) – (D0 – C0)

Note: The figures in parentheses explain the net impact of the WSI or the difference of after and before between the adopting and control groups (D1 − C1) − (D0 − C0).

effect of implementing the capacity-building programme on the water-saving intervention method. The columns distinguish between groups with and without the programme and the rows distinguish between before and after the programme. Before the capacity-building programme, one would expect the average yield of paddy crop could be similar for the two groups, so that the quantity (D0 − C0) would be close to zero. Once the capacity-building programme has been implemented, however, one would expect yield differences between the groups as a result of the improvement in knowledge of farmers about the water-saving techniques due to the programme. The impact of the programme, however, would be better assessed by considering any pre-existing observable or unobservable differences between the two randomly assigned groups, i.e. the double difference estimate, which is obtained by subtracting the pre-existing differences between the groups, (D0 − C0), from the difference after the programme has been implemented (D1 − C1). This is illustrated in Figure 2.

$$\text{Double difference} = E\left(Y_1^T - Y_0^T \middle| T_1 = 1\right) - E\left(Y_1^C - Y_0^C \middle| T_1 = 0\right) \quad (1)$$

where $Y_t^{\mathrm{T}}$and Y_t^{C}respectively denote the outcome responses for the trained and control groups at period t (= 0, 1) where the time period $t = 0$ corresponds to the period before programme implementation and the period $t = 1$ corresponds to after programme implementation. Further, $T_1 = 1$ means presence of the programme at time $t = 1$ and $T_1 = 0$ means absence of the programme. The first term in Equation (1) represents the average difference between before–after for the trained group and hence is given by

$$= E\left(Y_1^{\mathrm{T}} - Y_0^{\mathrm{T}} | T_1 = 1\right) = \frac{1}{N_{\mathrm{T}}} \sum_{i\varepsilon T} \left(Y_{i1} - Y_{i0}\right) = \bar{y}_{r1} - \bar{y}_{r0} \quad (2)$$

Similarly, for the control group the second term is given by

$$= E\left(Y_1^{\mathrm{C}} - Y_0^{\mathrm{C}} | T_1 = 1\right) = \frac{1}{N_{\mathrm{C}}} \sum_{j\varepsilon C} \left(Y_{j1} - Y_{j0}\right) = \bar{y}_{c1} - \bar{y}_{c0} \quad (3)$$

Substituting these values in Equation (1), the impact of the programme can be obtained as

$$\text{Impact} = \left(\bar{y}_{r1} - \bar{y}_{r0}\right) - \left(\bar{y}_{c1} - \bar{y}_{c0}\right) \quad (4)$$

The same results can be obtained by following a regression approach as follows. For each observation i, let us define a variable δ_i as $\delta_i = 0$,if the observation is from the control group and $\delta_i = 1$,if it is from the trained group. Similarly for each observation i define a variable $T_i$as $T_i = 0$ if the observation belongs to time $t = 0$, that is before the WSI implementation and capacity-building programme and $T_i = 1$ if the observation belongs to time $t = 1$, that is, after the programme. Now form the regression equation by using Equation (4):

$$y_i = a + b\delta_i + cT_i + d\delta_i T_i \quad (5)$$

$$\text{Impact of the programme} = ((\mathrm{a} + \mathrm{b} + \mathrm{c} + \mathrm{d}) - (\mathrm{a} + \mathrm{b})) - ((\mathrm{a} + \mathrm{c}) - \mathrm{a}) = \mathrm{d} \quad (6)$$

As per Table II and Equation (6), ‘a’ is nothing but C0 and a + c is C1 representing the control group before and after the programme. Similarly, a + b = D0 and a + b + c + d = D1 representing the adopter group before and after the training programme.

Table II. Regression coefficients for assessing the impact of interventions

Observation belongs to	Δ	T	yi
Control group before the programme	0	0	$\bar{y}_{co} = a$
Control group after the programme	0	1	$\bar{y}_{c1} = a + c$
Trained group before the programme	1	0	$\bar{y}_{ro} = a + b$
Trained group after the programme	1	1	$\bar{y}_{r1} = a + b + c + d$

RESULTS AND DISCUSSION

Socio-economic profile of households

Data for the adopter and non-adopter households were analysed and are presented in Table III. The average age of the sample farmers is 45 years and there is a significant difference in the ages of adopters and non-adopters. Most of the adopting farmers (34%) have secondary school education, and they do not have secondary occupation. More than 50% of the non-adopters are matriculates and graduates. Among the sample farms, the average operational area of non-adopters is 1.68 ha, which is little higher than adopter farmers’ area, i.e. 1.20 ha. Among the farms, 62 and 77.5% of adopters and non-adopters, respectively, have a canal as the only source of irrigation. This implies that an alternative source is not affordable by non-adopters (Table III).

Comparing DCs 4 and 21 in terms of the source of irrigation, the latter has more share from canal rather than any alternative source, which is 89% compared to 39% for the former. DC 4 has more bore wells for farming purposes. In the *kharif* season, 65% of sample farmers use canal water as the only source for their irrigation. Availability of canal water in *kharif* is as low as 90 days reported by non-adopters, against 137 days given by adopters. *Rabi* season canal water is available for 88 days; it is because of less water in the NSP. All the adopters get their first-hand

Table III. Summary statistics for demographic variables

Variable	Description	Adopter	Non-adopter	Total
Age		48	42	45
Level of education				
	Illiterate	25 (18)	9 (22.5)	34 (19)
	Primary	14 (10)	2 (5)	16 (9)
	Secondary	47 (34)	6 (15)	53 (30)
	Matriculation	40 (29)	12 (30)	52 (29)
	College	12 (9)	11 (27.5)	23 (13)
Family size				
	Adult	4	2	3
	Children	3	2	3
	Average size	4	2	3
Operational holding		1.2	1.68	1.44
Irrigation source				
Kharif season	Canal	85 (62)	31 (77.5)	116 (65)
	Bore well	21 (15)	9 (22.5)	21 (12)
	Both	32 (23)	–	41 (23)
Avg. no. of days canal water available		134	93	113
Rabi season	Canal	72 (52)	32 (80)	104 (63)
	Bore well	19 (14)		19 (11)
	Both	36 (26)	8 (20)	44 (26)
Avg. no. of days canal water available		83	93	88

Note: Values in parentheses indicate percentage of sample.

information about canal water from respective VKCs developed by the climate change and adaptation programme. The average age of farmers, experience in farming and family size do not have much influence in adopting new technologies.

Awareness of climate change and adaptation

The study found that 95% of farmers are aware about climate change and interestingly 97% of sample households are aware of the climate change and adaptation (ClimaAdapt) programme (Figure 3). Among the training and awareness programmes provided on climate change in the study area, the WSI strategy has 100% turnout, indicating the importance of this programme (Figure 3). Among the various training on WSI, alternate wetting and drying (AWD) has the unique feature of having an on–off method of irrigation, which saves water by about 20% compared to the normal method of irrigation. MSRI was practised by using mechanical transplanters instead of the normal SRI practice, i.e. line marking and hand transplantation. MSRI was taken up in both DCs and was followed by groups of farmers for easy operation. The study observed that 83% of the sample farmers attended training on the AWD method, followed by 55% on DSR and 47% on MSRI including the non-adopter category. Under the risk management training, 84% of farmers paid attention to the weather-based crop insurance scheme (WBCIS) due to high uncertainty about rainfall and weather conditions (Figure 4).

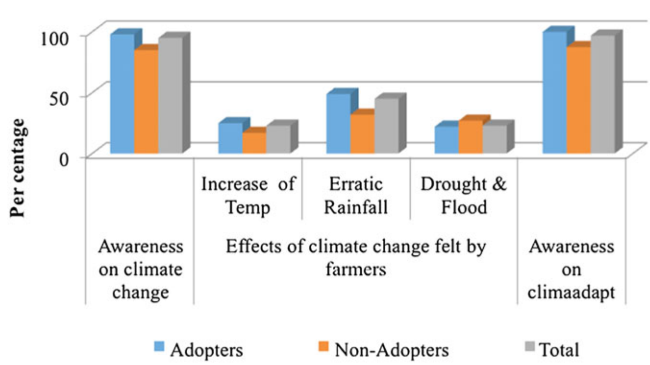

Figure 3. Awareness of climate change and adaptation by farmers. [Colour figure can be viewed at wileyonlinelibrary.com]

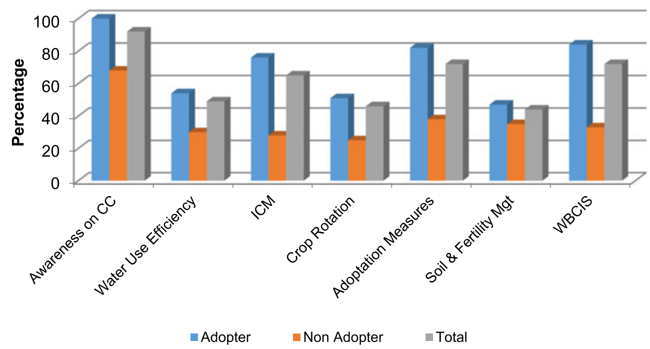

Figure 4. Farmers trained in various adaptation strategies in the study area. [Colour figure can be viewed at wileyonlinelibrary.com]

The study revealed that 78% of adopters and 50% of non-adopters attended training on agronomic practices conducted by the various institutes. Among training on allied activities, 97% of the adopters from WSI attended training on azolla cultivation while 30% of the non-adopters attended the same. In case of BGA, 32% of WSI-adopting farmers and 48% of non-adopting farmers attended training. In total, 82% of farmers attended azolla training followed by 51% of farmers attending training on Vermi composting. In the study area, the important source of information regarding climate vulnerability, adaptation and mitigation strategies was VKCs followed by newspapers, TV and radio with 62, 56 and 49%, respectively. Nearly, 10% of the sample used internet services for first time with the help of VKCs. The services from VKCs can be continued by making it sustainable to learn and spread the gained information to non-adopters in the villages.

Cost of cultivation for paddy under different WSI

Paddy is cultivated predominantly under irrigated conditions where crop failure seldom occurs. Unlike for many other crops, the minimum support price (MSP) scheme is effectively implemented for paddy. The partial analysis of

Table IV. Cost of cultivation for the WSI and control methods: 2012 (before); 2015 (after) (Rs ha^{-1})

Sl. No.	Particulars	AWD		MSRI		DSR		Control	
		Before	After	Before	After	Before	After	Before	After
1	Land preparation	9 230	11 800	9 710	13 360	6 290	790	7 530	10 700
2	Seed cost	1 300	1 810	1 090	860	1 440	1 940	1 800	2 410
3	Nursery	920	1 460	1 342	1 940	2 200	0	2 160	2 920
4	Weeding	5 670	9 140	5 059	8 240	4 750	4 860	4 290	5 830
5	Fertilizer	8 120	11 270	7 628	12 000	5 680	7 150	8 300	11 380
6	Plant protection	7 020	9 760	5 125	8 420	3 700	5 160	6 010	9 350
7	Irrigation	750	1 140	742	1 330	610	680	780	940
8	Harvesting	9 220	12 750	7 615	10 350	7 800	9 820	6 610	10 370
9	Transportation	1 740	3 230	1 794	2 740	2 100	3 400	2 650	4 070
10	Interest on variable cost	4 620	71 70	4 211	6 800	3 630	4 710	4 210	6 070
11	Total variable cost	48 590	69 530	44 317	66 040	38 200	38 510	44 340	64 040
12	Rental value	23 390	26 470	24 342	27 860	24 430	28 660	24 750	27 340
13	Land tax	370	510	357	500	360	500	360	510
14	Interest on fixed cost	2 850	3 510	2 964	3 690	2 970	3 790	3 010	3 620
15	Total fixed cost	26 610	30 490	27 663	32 050	27 760	32 950	28 120	31 470
16	Total cost	75 200	100 020	71 979	98 010	65 960	71 460	72 460	95 510
17	Yield (t ha^{-1})	5.3	6.4	5.8	6.9	5.5	6.5	5.6	5.7
18	Price (Rs t^{-1})	12 340	16 340	10 470	13 810	12 860	16 870	11 550	15 620
19	Straw income	7 140	13 500	13 191	27 140	8 660	21 660	7 560	16 940
20	Total revenue	72 530	119 050	74 306	122 640	80 150	130 500	71 250	106 250
21	Gross margin	23 940	49 520	29 989	56 600	41 950	91 990	26 910	42 210
22	Net revenue	−2670	19 030	2 326	24 550	14 190	59 040	−1 210	10 740

Note: 1 USD = 65 Indian rupees.

economic impacts showed that economic benefits in general by applying the technology were actually perceived by 81% of farmers. The number of irrigations was reduced by 28% on average. Such a level of monetary profit, however, was observed only in cases where the payment system for irrigation is consumption-based compared to a fixed-rate system. Weeds, however, behaved differently in the AWD regime, which often led to increased occurrence of weeds resulting in increased expenditure on hired labour for hand weeding. Farmers under DSR effectively managed the increased weed growth through the application of herbicides. Yields of rice increased by about 0.4–0.5 t ha^{-1}, which is equivalent to about 10%. In addition, farmers often mentioned that rice crops under AWD look stronger and healthier, and develop more tillers and panicles. In Telangana DC-4 area, the cost of cultivation of the paddy crop had a similar value to its counterpart as DC-21. In the case of direct sowing the rice yield level did not improve like AWD or MSRI. But the costs of cultivation per ha for DSR adopters were lower than for the other two methods (Table IV). The net revenue for the DSR was also higher than for the other two interventions due to the reduced cost. Particulars about the cost of cultivation for all three methods are presented in Table IV.

Table V. Rice yield (t ha^{-1}) under different WSI methods by farmers in DC-4 and 21 areas

Sl. No.	Intervention	Sample	Mean	Minimum	Maximum	SD
1	AWD					
	Before	5.6	5.30	4.75	6.50	3.8
	After	5.6	6.43	5.58	7.25	5.3
2	MSRI					
	Before	3.8	5.85	4.30	8.00	8.8
	After	3.8	6.96	5.30	8.80	9.8
3	DSR					
	Before	4.4	5.55	3.80	7.50	7.2
	After	4.4	6.50	5.00	9.50	9.9
4	Control					
	Before	4.0	5.57	3.93	7.50	8.3
	After	4.0	5.74	4.12	7.50	7.3

Impact of the capacity-building programme on the WSI double difference method

The capacity-building programme on WSI created additional knowledge on water use efficiency and water conservation, with the main aim of improving the crop yield. When the yield parameter was taken into consideration, farmers were more interested in adapting new techniques, which had a direct impact on income leading to a betterment of life. Hence the study sample was segregated into four methods of cultivating paddy for further analysis to discover whether the capacity-building and implementation programme created any kind of improvements in yield. The mean yields of the methods are presented in Table V. Farmers adapting to new interventions got a higher yield than the control group. In the present study the double difference method of analysis was used to assess the impact of the capacity-building programme and implementation on WSI methods and crop yield. The three different kinds of WSI methods and one control group were compared and assessed the net impacts of the programme.

From Table VI, it is inferred that of all three methods average maximum yield was obtained from MSRI, followed by DSR and AWD, with 6.96, 6.5 and 6.43 t ha^{-1} respectively. In the case of the control or non-adopters, average maximum yield was 5.7 t ha^{-1}.

Table VI. Mean yield difference of WSI adapted (t ha^{-1})

S.no	Observations from	AWD	MSRI	DSR
1	Trained farmers before (a)	5.30	5.85	5.55
2	Trained farmers after (a + c)	6.43	6.96	6.50
3	Control group before programme (a + b)	5.57		
4	Control group after programme (a + b + c + d)	5.74		
5	Net impact due to capacity building and interventions (d)	0.96	0.96	0.78

Table VII. Regression analysis on impact of the training programme on rice yield

Sl. No	Method	Constant	Δ	T	δT	R^2
1	AWD	55.8 (56.8)	−2.71** (−2.11)	1.67 (1.20)	9.62*** (5.29)	0.34
2	MSRI	55.8 (40.7)	2.60 (1.32)	1.67 (0.86)	9.38*** (3.38)	0.28
3	DSR	55.8 (42.2)	−0.352 (−0.193)	1.67 (0.89)	7.78*** (3.01)	0.18

Note: Figures in parentheses indicate *t* values at 5% (**) and 1% (***) significance levels.

Table VIII. Net impacts due to WSI

Sl.No	Observations	AWD	MSRI	DSR
1	Net impact on cultivation cost (Rs ha^{-1})	1 200	2 380	−11 000
2	Net impact on net income (Rs ha^{-1})	10 300	11 000	26 300

Note: 1 USD = 65 Indian rupees.

The mean yield difference among non-adopters before and after the programme was 0.16 t ha^{-1} (Table VI) due to accumulated knowledge, experience in farming, use of better quality inputs and technology growth. Similarly, the yields for AWD adopters were 5.3 and 6.43 t ha^{-1}, following the yield difference of 1.13 t ha^{-1}. After capturing the effect of training or capacity-building programme on WSI, yield difference was 0.96 t ha^{-1}. Likewise, other methods have been calculated and are presented in Table VI. Net impact due to capacity building and implementation for the DSR method was lower than for the other two methods because of less use of inputs and other cultural practices. The results of the double difference method using regression analysis on rice yield are presented in Table VII.

It is inferred that capacity building with implementation and technology growth by time (T) interaction has a significant impact on all three methods at 1% level. It was represented by the effects of the capacity-building programme on WSI (with and without) and technology growth (before and after), i.e. the combined effect on yield was significant for all three methods, indicating the importance of the capacity-building programme and technology transfer over time. There was a significant difference between adopters and non-adopters in yield of WSI. AWD adoption is able to overcome yield losses by 2.71 times in the study area. Similarly, farmers adopting DSR avoided a yield loss of 0.352 times. MSRI adoption has also significant impact at 1% level in the interaction of the capacity-building programme and technology transfer.

The R^2 values are 0.34, 0.28 and 0.18 for AWD, MRSI and DSR, respectively, indicating that 34, 28 and 18% of the variations were explained by the explanatory variables. The intercept indicated the mean yield of the non-adopting farmers. It is evident that there is a significant difference between the yield of adopting and non-adopting farmers in the base period. Similarly, there is a significant increase in yield due to the time period among the non-adopting farmers. It is evident that 0.16 t ha^{-1} increase in yield was realized over the period among the non-adopting farmers. The impact of the capacity-building programme was significant on the expected positive line, which showed that the programme alone increased the crop yield by 0.96, 0.93 and 0.77 t ha^{-1} by AWD, MSRI and DSR, respectively.

From Table VIII, it is inferred that adopting the DSR method reduces the cost of around Rs.11 000(US$169) ha^{-1} compared to non-adopters. Though AWD and MSRI had an additional cost over DSR and also normal cultivation methods, they influence the yield, which further increases the income of the farm households. It can be seen that the DSR income level is higher than for the other two methods due to the performance of the long-duration varieties and high market price favoured by consumers and millers.

CONCLUSION

Climate change is affecting the water resource and agricultural production systems in many parts of the country. To mitigate climate change effects, various adaptation strategies were developed and implemented in the Nagarjunasagar Project in the Krishna River Basin. The present study addresses the impacts of water-saving interventions implemented through capacity- building programmes in the study area. The adaptation interventions enhance the performance of crop water use efficiency and rice yields through awareness and capacity-building programmes. Village knowledge centres established at cluster level play a key role in creating awareness about new interventions and providing online services to farmers. Policy makers can understand the role of VKCs, which can be initiated in other parts of the state and make more sustainable where a similar kind of situation exists. A significant rise in yield between adopters and non-adopters provides sufficient evidence to policy makers to promote more climate adaptation frameworks. This helps in improving water use efficiency and ensuring food security.

ACKNOWLEDGMENTS

The authors wish to acknowledge the Royal Norwegian Embassy, New Delhi, for financial support extended to the ClimaAdapt Project. The administrative support of the state governments of both Andhra Pradesh and Telangana is highly appreciated.

REFERENCES

Adger WN, Agrawala S, Mirza MMQ, Conde C, O'Brien K, Pulhin J, Pulwarty R, Smit B, Takahashi K. 2007. Assessment of adaptation practices, options, constraints and capacity. In Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds). *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press: Cambridge, UK; p 717–743.

Baig SP, Rizvi AR, Pangilinan MJ, Palanca-Tan R. 2016. *Cost and Benefits of Ecosystem Based Adaptation: the Case of the Philippines*. IUCN: Gland, Switzerland; viii + 32 pp.

Bryant RC, Smit B, Brklacich M, Johnston RT, Smithers J, Chiotti Q, Singh B. 2000. Adaptation in Canadian agriculture to climatic variability and change. *Climatic Change* **45**: 181–201.

Cruz RV, Harasawa H, Lal M, Wu S, Anokhin Y, Punsalmaa B, Honda Y, Jafari M, Li C, Huu Ninh N. 2007. In Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds). *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press: Cambridge, UK; p 469–506.

Food and Agriculture Organization of the United Nations (FAO). 2008. Climate change and food security: a framework document. FAO: Rome. http://www.fao.org/forestry/15538-079b31d45081fe9c3dbc6ff34de4807e4.pdf

International Water Management Institute (IWMI). 2009. Flexible Water Storage Options: for Adaptation to Climate Change. IWMI Water Policy Brief 31. Colombo, Sri Lanka; 5 pp.

Kakumanu KR, Kaluvai YR, Nagothu US, Lati NR, Kotapati GR, Karanam S. 2017. Building farm-level capacities in irrigation water management to adapt to climate change. *Irrigation and Drainage* **67**: 43–54.

Turral H, Burke J, Faures J. 2011. Climate Change, Water and Food Security. FAO Water Report 36. FAO, Rome. http://www.fao.org/docrep/014/i2096e/i2096e.pdf

