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# Adoption and impact of water-saving technologies in the Nagarjuna Sagar Project area of Andhra Pradesh

**M Balasubramanian[1]*, P Anbukkani[1], M L Nithyashree[1], K Krishna Reddy[2] and T Arivelarasan[3]**

[1]ICAR-Indian Agricultural Research Institute, New Delhi 110012, India
[2]National Institute of Rural Development & Panchayathi Raj, Hyderabad, Telangana 500030, India
[3]Tamil Nadu Agricultural University, Coimbatore 641003, Tamil Nadu, India

*Corresponding author: bala.sbrmnn@gmail.com

**Abstract** Under the Climate Change and Adaptation (ClimaAdapt) programme, in the Nagarjuna Sagar Project area of Andhra Pradesh, water-saving interventions were conducted. To examine their impact, a study was carried out in the districts Nalgonda (Telangana) and Guntur (Andhra Pradesh). In all three water-saving interventions—alternating wetting and drying, modified System of Rice Intensification, and direct sowing of rice—capacity-building raised crop yield and farmer income. The direct seeded rice method reduced the cost of cultivation by about INR 11,000 per hectare.

**Keywords** Adoption, impact of climate change, water-saving interventions (WSI), Village Knowledge Centre (VKC), capacity-building

**JEL classification** Q54, Q25, Q58

Climate change has increased the frequency of extreme weather events in many parts of the world, and it adversely and significantly affects agriculture, food security, water resources, and biodiversity. Climate change increases rainfall variability and average temperature, and affect both the supply and demand side of the irrigation equation. Higher temperatures increase evaporation, and crops use more water. The effects vary by location; however, because enhanced climatic variability reduces the effectiveness of water storage systems, farmers must adapt to lower soil moisture and higher evaporation (IWMI 2009).

Worst affected are South Asia, Southeast Asia, and sub-Saharan Africa, where depending on the location temperatures are likely to rise by 2°C–4°C. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change IPCC (2007) projects that temperatures in South Asia will rise by 0.5°C–1.2°C rise by 2020, 0.88°C–3.16°C by 2050, and 1.56°C–5.44°C by 2100 (Cline 2007). Over the past few decades in many parts of South Asia, the production of rice, wheat, and maize has fallen because of water stress, arising partly from increasing temperature; the increasing frequency of El Nino; and a drop in the number of rainy days (Cruz et al. 2007).

Farmers practise soil conservation techniques and undertake water-saving irrigation practices. They plant trees, change the sowing time, and change crops or varieties. These adaptation strategies mitigate climate change impacts and the vulnerability of people; enhance the sustainable use of natural resources; and enrich the ecosystem and keep it healthy (Baig et al. 2016). Compared to conventional paddy cultivation, new rice-growing techniques use less water, and their water productivity is higher. Some of these new techniques are the System of Rice Intensification (SRI) (Stoop, Uphoff, and Kassam 2002) and alternating wetting and drying (AWD) (Bouman, Lampayan, and Tuong 2007; Lampayan et al. 2015).

The Indian sub-continent has a large population; agriculture predominates and the resource base is poor. That is why it is one of the regions most vulnerable to climate change. Since 1950, India has been experiencing a warming climate, a decline in monsoon spells, and frequent droughts; and the frequency of high-intensity rainfall in the past three decades is proof of the consequences of climate change. Steps have to be taken to mitigate its effects. In Andhra Pradesh and Telangana, several adaptation strategies were proposed: capacity-building on awareness of climate change; and implementation of water-saving practices such as direct seeded rice (DSR), mechanized or modified System of Rice Intensification (MSRI), and AWD; the use of Azolla as green manure and livestock feed; and weather index insurance.

To implement these techniques, cluster approach methodologies were used to scale the adaptation and mitigation strategies, and adaptation strategies were implemented in the Climate Change and Adaptation (ClimaAdapt) project area over four years to improve the resilience of the agriculture and water sectors of the Krishna and Cauvery river basins in three states—Andhra Pradesh, Telangana, and Tamil Nadu. This project—funded by the Ministry of Foreign Affairs, Royal Norwegian Embassy, New Delhi—was implemented from 2012 to 2015.

This study of the socio-economic impacts of the selected WSI in the ClimaAdapt programme aims to understand the farmers' awareness, perceptions, and attitude about climate change. We also estimate the impact that adopting water-saving techniques had on farmers and identify the constraints that adopters and non-adopters faced.

## Data and methodology

### Study area, sample size, and data collection

The study was taken up in the Nagarjuna Sagar Project area of the Krishna river basin. Nalgonda district from Telangana and Guntur district from Andhra Pradesh, where the ClimaAdapt project was implemented, were selected for the study, focusing particularly on the distributary committees (DC) 4 and 21 in the respective districts. DC-4 covers an area of 8,497 hectare (ha) and DC-21 covers 9,652 ha. In Nalgonda district, Miryalaguda and Damaracherla mandals were selected purposively for this study; in Guntur district, Narasaraopet, Chilakaluripet, Muppalla, and Nadendla mandals were chosen. From the chosen mandals, 178 farm households were purposively selected; these included 138 adopters and 40 non-adopters (which were used as the control). For analysing the impact of adaptation measures and training, we selected farmers who adopted water-saving practices like AWD, MSRI, and DSR. A well-structured schedule was used to collect the required information.

### Analytical tools

We used standard cost concepts to calculate the cost of cultivation and returns separately for adopters and non-adopters. The gross margin was calculated to suppress the fixed cost effect in the revenue. In the overview, the gross margin and yield parameters were given more significance than other variables. The 'before and after' approach was used to assess the impact of water-saving techniques for adopters and non-adopters; it was compared over the period from 2012 to 2015. The situation prior to ClimaAdapt was assessed through a detailed baseline survey of 1,000 farmers from the distributary channels of Telangana (DC-4) and Andhra Pradesh (DC-21).

## Results and discussion

### Socio-economic profile of households

The average age of the sample farmers is 45 years, and the difference in the ages of adopters and non-adopters is significant (Table 1). Among the sample farms, the average operational area of non-adopters is 1.68 ha, which is a little higher than that of the adopters (1.20 ha). Canals are the only source of irrigation for 62% of the adopters and 77.5% of the non-adopters; therefore, more non-adopters than adopters cannot afford alternate sources (Table 1).

### Source of irrigation for sample farmer

The availability of canal water in any crop season is the same as for the command area, but between the head and tail the reach varies hardly between 20 and 25 days. In the kharif season, the only source of irrigation for 65% of the farmers in the sample is canal water. Canal water is available for 113 days in the kharif season on average; adopters report that it is available for 137 days but non-adopters say it is available only

**Table 1 Socio-economic characteristics of adopters and non-adopters**

| Variable | Description | Adopter | Non-adopter | All |
|---|---|---|---|---|
| Age (years) | | 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) |
| | Borewell | 21(15) | 9(22.5) | 21(12) |
| | Both | 32(23) | - | 41(23) |
| | Average number of days canal water available | 134 | 93 | 113 |
| Rabi season | Canal | 72(52) | 32(80) | 104(63) |
| | Borewell | 19(14) | - | 19(11) |
| | Both | 36(26) | 8(20) | 44(26) |
| | Average number of days canal water available | 83 | 93 | 88 |

*Source* Authors' calculation based on field survey
*Note* Figures in parentheses represent the percentage

for 90 days. There is less water in the Nagarjuna Sagar Project area in the rabi season, and canal water is available for 88 days only; the other parameters are mostly the same (Table 2). All the adopters get their first-hand information about canal water from the respective Village Knowledge Centres (VKC) developed by ClimaAdapt. The adoption of new technologies is not influenced much by the average age of farmers, experience in farming, or family size.

### Awareness of climate change and adaptation

Climate change is a broad concept, but farmers feel its effects—an increase in the day or night temperature; erratic rainfall, including late or early onset of monsoon; frequent dry spells in the monsoon period; monsoonal shock; and a greater frequency of droughts and floods. These effects can complement the results of simulation and econometric models. Farmers were asked about each effect mentioned (Table 3). About 95% of the farmers are aware of climate change and 97% of the sample households are aware of ClimaAdapt. Of all the effects, erratic rainfall was realized by many of the farmers. In DC-4, DSR farmers had felt 100%, whereas only 40% of sample farmers felt all the effects of climate change. Nearly 50% of the sample farmers feel the effects of climate change, which is higher than in the adopter group.

### Training on crop and allied activities

Under ClimaAdapt, VKCs provided strategy training programmes on WSI, crop management practices, allied activities, and risk management strategies. Under WSI, farmers were trained on climate change and water use efficiency; under risk management strategies, they were trained on the weather-based crop insurance scheme. Data were collected on farmers' perceptions about these programmes (Table 4). Of all the training and awareness programmes conducted on climate change and its impacts, WSI strategy has 100% turnout; that indicates the importance of this programme.

### Training on WSI

Farmers were trained on water-saving interventions—AWD, MSRI, and DSR—for improving water use

**Table 2 Irrigation particulars of sample farmers**

| Season | Kharif | | | | Rabi | | | |
|---|---|---|---|---|---|---|---|---|
| Particulars | Water source | | | Average number of days canal water is available | Water source | | | Average number of days canal water is available |
| Type of farmers | Canal | Borewell | Both | | Canal | Borewell | Both | |
| DC-4 AWD | 9 | 15 | 20 | 99.7 | 9 | 13 | 22 | 70.5 |
| DC-21 AWD | 11 | | 1 | 137.5 | | | 1 | 87.5 |
| DC-4 MSRI | 4 | 1 | 5 | 171 | 4 | 1 | 5 | 87 |
| DC-21 MSRI | 28 | | 1 | 135.5 | 27 | | 2 | 90 |
| DC-4 DSR | 5 | 4 | 3 | 126.7 | 4 | 4 | 4 | 78.33 |
| DC-21 DSR | 28 | 1 | 2 | 136.3 | 28 | 1 | 2 | 85.87 |
| DC-4 Non-adaptors | 16 | | 4 | 90 | 17 | | 3 | 90 |
| DC-21 Non-adaptors | 15 | | 5 | 96.5 | 15 | | 5 | 96 |
| Adaptors | 85(62) | 21(15) | 32(23) | 134 | 72(52) | 19(14) | 36(26) | 83 |
| Non-adaptors | 31 (77.5) | | 9(22.5) | 93 | 32(80) | | 8(20) | 93 |
| DC-4 | 34(39) | 20(24) | 32(37) | 122 | 34(39) | 19(22) | 34(39) | 81 |
| DC-21 | 82(89) | 0 | 10(11) | 126 | 70(77) | 1 | 21(23) | 90 |
| Total | 116(65) | 21(12) | 41(23) | 113 | 104(63) | 19(11) | 44(26) | 88 |

*Source* Authors' calculation based on field survey
*Note* Figures in parentheses represent the percentage

**Table 3 Awareness of climate change and adaptation by farmers in the study area**

| Type of farmer | Awareness of climate change | Effects of climate change felt by farmers | | | | Awareness of Clima Adapt |
|---|---|---|---|---|---|---|
| | | Increase in temperature | Erratic rainfall | Drought and flood | All | |
| DC-4 AWD | 44 | 5 (11) | 12 (27) | 8(18) | 30(68) | 44 |
| DC-21 AWD | 12 | 4(33) | 10(83) | 0 | 1(8) | 12 |
| AWD | 56 | 9(16) | 22(39) | 8(14) | 31(55) | 56 |
| DC-4 MSRI | 10 | 2(20) | 0 | 1(10) | 7(70) | 10 |
| DC-21 MSRI | 29 | 12 (41) | 25(86) | 10(34) | 0 | 29 |
| MSRI | 39 | 14(36) | 25(64) | 11(28) | 7(18) | 39 |
| DC-4 DSR | 12 | 0 | 0 | 0 | 12(100) | 12 |
| DC-21 DSR | 29 | 11(35) | 21(68) | 11(35) | 2(6) | 31 |
| DSR | 41 | 11(26) | 21(49) | 11(26) | 14(33) | 43 |
| Adopters | 136 | 34(25) | 68(49) | 30(22) | 52(38) | 138 |
| DC-4 NA | 20 | 2(10) | 2(10) | 2(10) | 15(75) | 18 |
| DC-21 NA | 14 | 5(25) | 11(55) | 9(45) | 4(20) | 17 |
| Non-adopters | 34 | 7(17) | 13(32) | 11(27) | 19(47) | 35 |

*Source* Authors' calculation based on field survey
*Note* Figures in the parentheses represent the percentage

**Table 4 Trainings attended by farmers on various adaptation strategies in the study area**

| Type of farm households | Water-saving interventions | | Crop management | | Allied activities | | Risk strategy |
|---|---|---|---|---|---|---|---|
| | Awareness on climate change | Water use efficiency | Integrated crop management | Crop rotation | Adaptation measures | Soil and fertility management | Weather-based crop insurance scheme |
| DC-4 AWD | 44 | 44 | 44 | 42 | 45 | 40 | 45 |
| DC-21 AWD | 12 | 3 | 11 | 3 | 11 | 3 | 9 |
| DC-4 MSRI | 10 | 6 | 8 | 5 | 8 | 5 | 8 |
| DC-21 MSRI | 29 | 4 | 11 | 4 | 12 | 4 | 16 |
| DC-4 DSR | 12 | 7 | 9 | 8 | 9 | 7 | 13 |
| DC-21 DSR | 31 | 11 | 22 | 9 | 28 | 6 | 25 |
| Adopter | 138(100) | 75(54) | 105(76) | 71(51) | 113(82) | 65(47) | 116(84) |
| DC-4 NA | 16 | 12 | 11 | 10 | 12 | 11 | 13 |
| DC-21 NA | 11 | 0 | | | 3 | 3 | 0 |
| Non-adopter | 27(68) | 12(30) | 11(28) | 10(25) | 15(38) | 14(35) | 13(33) |
| Total | 164(92) | 87(49) | 116(65) | 81(46) | 128(72) | 79(44) | 129(72) |

*Source* Authors' calculation based on field survey
*Note* Figures in the parentheses represent the percentage of total sample farmer in each category

efficiency and income under a changing climate scenario. In AWD, the on–off method of irrigation is used; this unique method saves about 20% of water compared to the normal method of irrigation. In the MSRI, a mechanical transplanter is used in addition to normal SRI in DSR method; the nursery is not practised, which saves a considerable amount of labour, fuel, and water. Avoiding flood irrigation in all these WSI will help reduce methane emission from submerged paddy fields.

These trainings were organized by project partners in collaboration with government departments—the International Water Management Institute, Professor Jayashankar Telangana State Agricultural University, Acharya N G Ranga Agricultural University, Water and Land Management Training and Research Institute, and the M S Swaminathan Research Foundation (MSSRF).

The MSSRF promotes VKCs at the village level to spread new techniques through capacity-building programmes, observation, and dissemination of weather parameters and providing online services to farmers in villages. It has increased the awareness about climate change and induces the reading and listening habit among farmers at the village level. About 86% of adopters attended training in AWD, followed by 70% in the DSR method and 43% in MSRI (Table 4). In total, 83% of sample farmers attended training in AWD, followed by 55% on DSR and 47% on MSRI, including the non-adopter category.

**Farmers' learning**

About 97% of farm households in the study area learned for the first time about practising AWD with perforated tubes; few were aware about other methods like direct seeding, MSRI, green manuring, crop rotation, or vermin composting (Table 5). About 63% of farmers learned of Azolla cultivation, and 28% of blue green algae, first through the training programmes. About 20% of the farmers learned for the first time to use water measurement sensors and monitor readings. These sensors were installed in the field of selected farmers to update and predict weather information on time. Nearly 10% of the sample used internet services for the first time with the help of VKCs. Continuing their services will help non-adopters learn about water-saving and other interventions.

**Comparison between training attended vs adapted farmers**

Training programmes were conducted for farmers on four adaptation strategies—WSI, crop management, allied activities, and risk management. All the farmers

**Table 5 Topics farmers learned about**

| Type of farm households | AWD | Azolla | Blue green agae | Sensor reading | Crop insurance | Climate change | Internet use |
|---|---|---|---|---|---|---|---|
| DC-4 AWD | 43 | 42 | 18 | 7 | 4 | 4 | 2 |
| DC-21 AWD | 10 | 4 | 0 | 1 | 0 | 1 | 2 |
| DC-4 MSRI | 11 | 7 | 1 | 1 | 1 | 1 | 1 |
| DC-21 MSRI | 29 | 4 | 0 | 3 | 1 | 1 | 5 |
| DC-4 DSR | 12 | 5 | 1 | 1 | 1 | 1 | 0 |
| DC-21 DSR | 31 | 15 | 7 | 2 | 1 | 2 | 6 |
| DC-4 NA | 16 | 6 | 10 | 1 | 1 | 0 | 1 |
| DC-21 NA | 18 | 29 | 12 | 4 | 3 | 1 | 0 |
| Total | 172(97) | 112(63) | 49(28) | 20(12) | 12(7) | 11(6) | 17(10) |

*Source* Authors calculation based on field survey
*Note* Figures in the parentheses represent the percentage of total sample farmers in each category

**Table 6 Training attended vs adopted rate in the study area**

| Type of farm households | Trainings attended | | | | Technologies adopted | | | |
|---|---|---|---|---|---|---|---|---|
| | Crop | WSI | Allied | Insurance | Crop | WSI | Allied | Insurance |
| DC-4 AWD | 42 | 44 | 42 | 41 | 42 | 44 | 42 | 16 |
| DC-21 AWD | 10 | 12 | 9 | 7 | 6 | 12 | 3 | 8 |
| DC-4 MSRI | 10 | 10 | 9 | 9 | 7 | 10 | 6 | 3 |
| DC-21 MSRI | 25 | 29 | 14 | 26 | 5 | 29 | 14 | 16 |
| DC-4 DSR | 10 | 12 | 10 | 11 | 8 | 12 | 7 | 6 |
| DC-21 DSR | 26 | 31 | 23 | 27 | 10 | 31 | 14 | 21 |
| DC-4 NA | 12 | 20 | 16 | 15 | 0 | 0 | 0 | 0 |
| DC-21 NA | 11 | 20 | 1 | 1 | 0 | 0 | 0 | 0 |
| DC-4 | 74 | 86 | 77 | 76 | 57 | 86 | 55 | 25 |
| DC-21 | 72 | 92 | 47 | 61 | 21 | 92 | 31 | 45 |
| Adopters | 123 | 138 | 107 | 121 | 78 | 138 | 86 | 70 |
| Non-adopters | 23 | 40 | 17 | 16 | 0 | 0 | 0 | 0 |
| Total | 146 | 178 | 134 | 137 | 78(53) | 138(77.5) | 86(64) | 70(51) |

*Source* Authors' calculation based on field survey
*Note* Figures in the parentheses indicate the percentage of each sample category

who attended the programmes did not adopt the interventions, however (Table 6); adoption differs by socio-economic condition, technology, the perceived benefit of technology, etc. Mostly DC-4 farmers followed the AWD method, for example, and many DC-21 farmers followed the DSR and MSRI methods. WSI were adopted by 77.5% of the trained farmers, crop management practices by 53%, allied activities by 64%, and risk management strategies by 51%, most of whom from the DC-21 area.

**Benefits due to the adoption of crop management strategies and WSI**

Farmers adopted agronomic practices like green manuring and crop rotation techniques. These increased their yields compared with non-adopters. If the farmer followed any one or both methods at his field for the past two years or more, the main crop yield was higher. Adopting WSI reduced the occurrence of pests and diseases slightly, as per anecdotal evidence, and the AWD method saves 15%–25% of water for the next

**Table 7 Effects of WSI and crop management to the adopters in DC-4 and DC-21 areas**

| Type of farm households | Water saving | Increase or decrease of women labour days | | | Yield (quintal per hectare) | | |
|---|---|---|---|---|---|---|---|
| | Percentage | Before | After | Difference | Before | After | Difference |
| DC-4 AWD | 24 | 12 | 19 | 7 | 50 | 62.5 | 12.5 |
| DC-21 AWD | 25 | 7 | 16 | 9 | 54 | 67.5 | 13.5 |
| DC-4 MSRI | 26 | 8 | 4 | 4 | 40 | 53 | 11 |
| DC-21 MSRI | 21 | 7 | 3 | 4 | 27.5 | 39 | 11.5 |
| DC-4 DSR | 28 | 10 | 5 | 5 | 35 | 42 | 7 |
| DC-21 DSR | 23 | 9 | 3 | 6 | 27.5 | 35 | 7.5 |
| Total | 24.5 | | | | | | |

*Source* Authors' calculation based on field survey

season, as observed by the PWD staff, Warangal, Telangana. In DSR, labour and fuel costs are saved. Adopters of WSI and crop management obtained more yield than those following the normal method. Adopters of AWD had the highest yield followed by those of MSRI and DSR methods (Table 7).

Though the DSR method did not increase the yield, it helped reduce non-adopters' use of resources. The yield difference is 3–5 quintals per hectare if all cultivation practices are done in the correct period. The WSI is able to save regular irrigation water with a maximum of 28% for DSR, followed by MSRI in DC-4 and AWD in DC-21. Adoption of WSI saved on average 24.5% of water in the study area, which was on par with that observed by PWD staff. Considering women labour days in the AWD method, an average of eight days was increased due to more weeding operation, whereas in MSRI, and DSR average labour days decreased a maximum of six days in DC-21. In the case of yield difference, significant changes between the three methods were observed.

**Reasons for adopting WSI strategies**

Farmers were asked to rank each reason for practising WSI; the Garrett ranking method was used to analyse the responses (Table 8). Increased yield and reduction in water use motivated them to adopt WSI, and these two variables have the highest, and identical, Garrett scores. Water-saving interventions were taken up through continual training and interaction with experts, but farmers adopted one of the three techniques mainly to increase their yield. The next best reason was the easy handling of WSIs and the reduction of labour. Farmers who adopt DSR see a fall in the cost of fuel and of cultivation, and in the incidence of pests and diseases; the reasons are the timely sowing in DSR, continuous drying and wetting by AWD, and specified spacing for aeration through MSRI.

**Table 8 Reasons for adopting WSIs**

| Reasons | Garrett score | Rank |
|---|---|---|
| Increase in yield | 64.34 | I |
| Reduction in water use | 64.34 | I |
| Easy handling | 56.45 | III |
| Reduction in labour | 51.79 | IV |
| Reduction in fuel | 42.93 | V |
| Reduction in cultivation cost | 41.29 | VI |
| Reduction in pest and disease | 40.91 | VII |

*Source* Authors' calculation based on field survey

**Cost of cultivation for paddy under different WSIs**

Paddy is cultivated predominantly under irrigated conditions, where crop failure seldom occurs. The minimum support price scheme is effectively implemented for paddy, unlike for many other crops. The application of herbicides under DSR effectively managed increased weed growth, and rice yields increased about 0.4–0.5 ton per hectare (about 10%). Farmers often mentioned that rice crops under AWD look stronger and healthier, and they develop more tillers and panicles. In Telangana DC-4 areas, the cost of paddy cultivation had a value similar to that in DC-21. In the case of DSR yield, the level was not improved, unlike AWD, or MSRI, but the cost of cultivation per hectare for DSR adopters was lower than the other two methods. The cost was reduced under

**Table 9 Cost of cultivation for the WSI and control methods during 2012 (before) and 2015 (after): INR per hectare**

| S no. | Particulars | AWD | | MSRI | | DSR | | Control | |
|---|---|---|---|---|---|---|---|---|---|
| | | Before | After | Before | After | Before | After | Before | After |
| 1. | Total variable cost | 48,593 | 69,564 | 44,317 | 65,957 | 38,205 | 45,677 | 44,329 | 64,633 |
| 2. | Total fixed cost | 26,615 | 30,494 | 27,663 | 32,053 | 27,762 | 32,960 | 28,126 | 31,472 |
| 3. | Total cost | 75,208 | 100,058 | 71,979 | 98,010 | 65,967 | 78,637 | 72,455 | 96,105 |
| 4. | Yield (qper hectare) | 53 | 64 | 58 | 69 | 55 | 65 | 56 | 57 |
| 5. | Price (INRperq) | 1,234 | 1,634 | 1,047 | 1,381 | 1,286 | 1,687 | 1,155 | 1,562 |
| 6. | Straw income | 7,143 | 13,500 | 13,191 | 27,138 | 8,659 | 21,659 | 7,563 | 16,938 |
| 7. | Total revenue | 72,531 | 119,046 | 74,306 | 122,638 | 80,150 | 130,498 | 71,254 | 106,248 |
| 8. | Net revenue | -2,677 | 18,988 | 2,326 | 24,628 | 14,183 | 51,861 | -1,205 | 10,143 |

*Source* Authors' calculation based on field survey

**Table 10 Rice yield under different WSI method by farmers in DC-4 and DC-21 areas**

| S no. | Intervention | Sample | Mean | Minimum | Maximum | SD |
|---|---|---|---|---|---|---|
| 1 | AWD | | | | | |
| | Before | 56 | 53.03 | 47.50 | 65.00 | 3.86 |
| | After | 56 | 64.33 | 55.80 | 72.50 | 5.3 |
| 2 | MSRI | | | | | |
| | Before | 38 | 58.57 | 43.00 | 80.00 | 8.8 |
| | After | 38 | 69.60 | 53.00 | 88.00 | 9.8 |
| 3 | DSR | | | | | |
| | Before | 44 | 55.54 | 38.00 | 75.00 | 7.2 |
| | After | 44 | 65.04 | 50.00 | 95.00 | 9.9 |

*Source* Authors' calculation based on field survey

DSR, and therefore net revenue was higher than under the other two interventions (Table 9).

**Impact of technology and capacity-building programme on WSI through before and after method**

The capacity-building programme on WSI, which aims mainly to improve the crop yield, created additional knowledge of water use efficiency and water conservation practices. For further analysis, the sample was segregated into three methods of cultivating paddy. The average maximum yield in quintal per hectare was 69.6 from MSRI, 65.04 from DSR, and 64.33 from AWD (Table 10). The yield in quintal per hectare for AWD adopters was 53.03 before the intervention and 64.33 after; the yield difference, 11.3 quintal per hectare, was the effect of training or capacity-building programme on WSIs. The DSR method makes less use of inputs and other cultural practices, and the net impact due to capacity-building and implementation was lower than in the other two methods.

**Constraints faced by adopters and non-adopters**

Farmers were asked about the constraints they faced in adopting these technologies (Table 11). The most important constraint was labour availability and the high labour wage during the peak season. In AWD, frequent weeding is unavoidable, and mechanical or hand weeding is essential. Non-adopters depend mostly on canal irrigation, where yields are lower, and they cannot afford the initial investment in machinery to be used in water-saving methods.

**Conclusions and recommendations**

Climate change is affecting water resource availability and the agricultural food production system in many parts of the country. To mitigate the effects of climate

**Table 11 Constraints faced by adopters**

| Constraints | Average | Rank |
|---|---|---|
| Adopters | | |
| High cost for labour during peak season | 66.73 | I |
| Marketing risk due to low prices | 56.26 | II |
| Less co-op from government | 50.73 | III |
| Timely no availability of loan | 47.75 | IV |
| Nexus between millers and agents | 47.08 | V |
| Poor cooperation among farmers | 43.54 | VI |
| Hoarding | 37.68 | VII |
| Non-adopters | | |
| High initial cost | 63.27 | I |
| Economic backwardness | 61.56 | II |
| Labour intensive practices | 61.4 | III |
| Lack of support by government | 51.95 | IV |
| Unavailability of water to tail-end farmers | 49.51 | V |
| The skewed distribution of training aids | 48.86 | VI |
| High-interest rate | 41.33 | VII |

*Source* Authors' calculation based on field survey

change, adaptation strategies were developed, and these were implemented through capacity-building programmes under the Nagarjuna Sagar Project area of Krishna river basin. This study estimates the impacts of WSI, and finds that these raised crop water use efficiency and rice yields. Village knowledge centres established at the cluster level are raising awareness of new interventions and providing online services to farmers. Policymakers can consider the intensive extension and follow-up measures used under the project as a model and implement these in other places too for speedy upscaling of technologies.

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