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Research Article

Improving Water Productivity in Rice – A Response to Climate Change and Water Stress in Pakistan

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Abstract | Rice is an important crop of Pakistan occupying an area of 2.74 million hectare and production of 6.802 million tons. Rice is not only an important staple food crop of Pakistan but it is also an export commodity earning precious foreign exchange for the country. However, rice is a water intensive crop compared to other cereal crops. In view of climate change, water management for agriculture encompasses all technologies and practices leading to water productivity enhancement to address increasing irrigation water demand and declining water resources. One of such technology known as laser land leveling was introduced in Pakistan in 1980s. More recent introduction is of another water efficient technique known as The Alternate Wetting and Drying (AWD) technology evolved by International Rice Research Institute (IRRI). AWD intervention in conjunction with laser land leveling is made through Water Productivity (WAPRO) project in Muridke *tehsil* of district Sheikhupura Punjab Pakistan. This study has been conducted with the aim to determine the irrigation water use efficiency at rice farms as a result of adopting AWD and laser land leveling technology by the respondent farmers. The data were collected from the three selected villages using focused group discussions and individual interviews of 21 beneficiary rice producers. Out of 21 farmers, 7 farmers were selected each from head, middle and tail of the water channels located at Joyianwala, Saikhum and Kathianwala villages. The baseline data were collected in July 2017 while post technology adaptation data were collected in December 2018 from the same beneficiary farmers. The data collected were analyzed using MS-Excel. The analysis of the data reflected that although canal water was available but about 80% at head, 50% at middle and 20% at tail. Thus remaining irrigation water requirement i.e. about 20% at head, 50% at middle and 80% at tail was met through tube well operation. The result from before and after AWD technology and laser land leveling technology adaption shows that 24.24% tube well operation time was reduced at the head, 19.4% reduced at middle and 24.4% reduced at tail. The reduction of hours in operating tube well results in dual benefits of savings in the quantity of irrigation water extraction particularly keeping in view the climate change scenario and saving in cost of energy that is used for tube well operation ultimately adding to profitability of the farmers. These results are in line with a number of earlier studies. The respondent farmers also claimed improvement in paddy yield but along with AWD technique and laser land leveling there might be other agronomic factors adding to yield improvement as this study did not isolate yield and AWD technology and laser land leveling from other factors that may be studied in future research studies. The laser land leveling is already attracting huge investment from the government but AWD technology is yet to get its place in government priority. It is therefore recommended that AWD technology should be up-scaled to address water constraints in agriculture sector.

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Introduction

Rice is an important crop of Pakistan. It occupies an area of 2.74 million hectare in 2018, second to wheat crop in the country. The rice production recorded in 2018 was 6.802 million tons (Bureau of Statistics, 2016). Area wise, 65% rice cultivation is only in Punjab province of Pakistan. Rice is not only an important staple food crop of Pakistan but it is also an export commodity earning precious foreign exchange for the country. In the year 2015-16, the rice export earned more than US$1376 million (Finance Division, 2017). At the same time however, rice is a water intensive crop. Therefore, water productivity counts a lot for a developing country like Pakistan which is already a water stress country. Increasing water productivity in agriculture is essentially meeting the goal related to food security. Conceptually water productivity means value or benefit resulting out of the water use (Molden, 2013). Traditional rice cultivation needs 300 to 500 liters of irrigation water to produce one kg of rice (Claro, 2019). While Hoekstra (2008) argued that on the worldwide average, one kilogram of rice production consumes 3400 liters of water that shows that rice a highly water-intensive crop. The International Rice Research Institute (IRRI) stated that it takes an average of 1432 liters of evapo-transpired water for production of one kg of rice (IRRI, 2010). Bauman (2008) referring to IRRI studies has argued that rice crop is grown under a range of water applications that transpired 500-1,000 liters of water for production of one kg of rice. Referring to some other studies Bouman (2008) stated that on average, about a quantity of 2,500 liters of water is required (by rainfall and/or irrigation) to a rice field for producing one kg of rice. These 2,500 liters account for all the outflows of evapo-transpiration, seepage and percolation. The overall average quantity is estimated out of the data collected from a big number of experimental work at the individual field levels across the Asia. This average is based on a large individual level variability that ranges from about 800 liters to above 5,000 liters. The variability may be due to a number of factors including crop management (such as fertilization application techniques, variety of crop grown and disease and pest control methods), weather, and soil properties. At the field level, water inputs to rice fields are 2-3 times those of other major cereals.

The contemporary method of producing irrigated rice in most of the Asian rice growing fields require large quantity of irrigation water. For instance, in case of Philippines and India, on average around 3,000 liters of irrigation water is needed for producing one kg of rice (IRRI, 2018). The increasing water shortage in irrigated areas due to the lack of water conservation practices and the need of water for the industrial, domestic and other non-agriculture sectors, emphasis that the current rice crop cultivation techniques should be improved for better irrigation water efficiency. Water use efficiency is one of the important climate smart agricultural strategies (Sapkota et al., 2015). Kumar and Gautam (2014) argued that in case of India, farmers need to produce 50% more grain by 2020 to meet its demand while CCAFS (2013) stated that for enhancing food production under changing climatic conditions requires the reorientation of agriculture from current practices to more sustainable and environment friendly practices with more focus on climate smart production techniques. In view of climate change, water management for agriculture includes technologies and practices that sustain optimum soil moisture conditions for plant growth (FAO, 2011) implying water productivity enhancement to address increasing irrigation water demand and declining water resources. For the most part, existing readymade crop patterns can substitute one crop for another, for example, dry rice (FAO, 2011). In order to address farmers' needs to save water, energy and fuel in irrigated rice, IRRI has developed the Alternate Wetting and Drying (AWD) technology, which has been introduced in Bangladesh in 2004. AWD is a water-saving technology that rice farmers can benefit by adopting to reduce irrigation water needs in irrigated rice fields. In AWD technique, irrigation water is applied to flood the rice fields a certain number of days after the disappearance of ponded water. The number of days of non-flooded soil in AWD between irrigations can vary from 1 day to more than 10 days. The threshold of 15 cm water depth (below the surface) before irrigation is called "Safe AWD" as this will not cause any yield decline. In Safe AWD, water savings are in the order of 15- 30%.

In order to address emerging water constraints in Pakistan particularly due to impact of climatic changes, AWD technology in conjunction with laser land leveling has recently been introduced in Pakistan. Although Laser land leveling technology is in use in Pakistan since 1980s (OFWM Punjab, 2018) but AWD technology is new. Laser land leveling was introduced to address over irrigation problems. Unleveled fields normally resulted in over irrigation (Corey and Clyma, 1973). This means an excessive loss of irrigation water and a reduction in irrigation water application efficiency (Sattar et al., 2003). Laser land leveling helps even distribution of irrigation water (Khan, 1986), increases cultivable land area (Choudhary et al., 2002; Jat, 2006), improves crop standing, (Rickman, 2002) and also saves irrigation water (Jat et al., 2003; Khattak et al., 1981; Ali et al., 1975).

The AWD technology in combination with laser land leveling is executed through Water Productivity (WAPRO) project that is funded by Global Programme on Food Security (GPFS) of the Swiss Agency for Development and Cooperation (SDC) and multiple international companies. WAPRO is implemented by Helvetas Swiss Intercooperation (Helvetas) and MARS Food (MARS through Rice Partners Limited) in Muridke *tehsil* of district Sheikhupura Punjab Pakistan. Under WAPRO project, multi-stakeholders join forces to enhance water productivity. WAPRO has introduced an innovative approach to increase water productivity in rice through Push-Pull-Policy approach (Helvetas, 2018). The producers (rice farmers) are motivated to change production and irrigation practices.

To assess the impact of WAPRO project, this study has been conducted with the aim to determine the irrigation water use efficiency as a result of adopting AWD technology including application of precision land leveling through laser technology prior to using AWD by the beneficiary/respondent farmers.

Materials and Methods

For the collection of data, three villages were purposefully selected from *tehsil* Muridke of district Shakhopura of Punjab Province. The rationale behind purposeful selection of villages was based on the fact that WAPRO interventions were initiated in these villages to demonstrate water efficient rice production technology. The data was collected using Focused Group Discussions (FGDs) and randomly selected 21 individual farmers who were the beneficiary/ contact farmers of the WAPRO project. These were the same 21 farmers from whom baseline data was collected in July 2017 when they were producing rice with conventional water application techniques. From the same 21 farmers post technology adaptation data was collected in December 2018 as part of this study and for unbiased pre and post efficient water technology adoption results. Analysis using same group for pre and post scenario is a common practice (Marsden, 2004). Out of 21 farmers, 7 farmers were selected each from head, middle and tail of the water channels located at Joyianwala, Saikhum and Kathianwala villages. The farmers interviewed are those who adopted land leveling and Alternate Wetting and Drying (AWD) tubes along with advisory services through WAPRO project. The analysis is mainly based on irrigation water application before adopting and after adopting AWD technology. In addition to the farmers, the staff of RPL and Helvetas were also interviewed for collecting data on support being provided by WAPRO and for triangulation of information. The data collected were analyzed using MS-Excel.

Results and Discussion

The analysis of the data collected from the head of the water channel reflected that canal water availability at head was quite better. The canal water availability at head was estimated 75% to 80% of the irrigation water requirement at the head. The remaining 20% to 25% irrigation water requirement at the head was met through tube well operation. Before adaption of AWD techniques (by using AWD tubes) and laser land leveling, the tube well operation at the head used to be 14.52 hours per acre. However, after adaption of AWD technology and precision leveling, the farmers maintained optimum moisture requirement that reduced tube well operation time from 14.52 hours per acre to 11 hours per acre as shown in Figure 1.

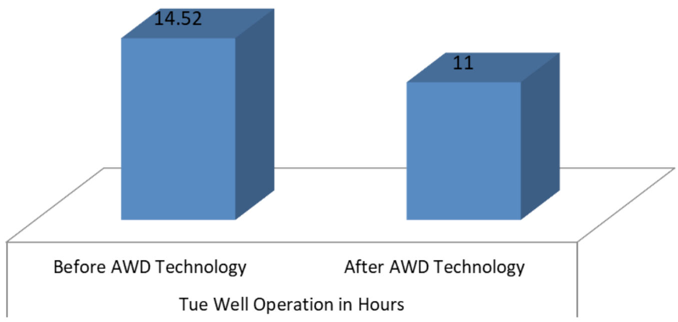

Figure 1: *Impact of Alternate Wetting and Drying (AWD) Tubes Technolog at Head of Water Channel.*

The Figure 1 reveals that about 24.24% tube well operation time has been reduced at the head. This shows that even if canal water application is considered constant before and after using AWD technology and laser land leveling; there has been a deduction in tube well water application to the tune of 24.24%. It is pertinent to mention that respondent farmers claimed improvement in paddy yield. However, along with AWD and laser land leveling, there might be other agronomic factors adding to yield improvement as this study did not isolated yield and AWD tube technology and laser land leveling from other factors that may be part of future studies.

The results of this study are similar to that of Hasan (2016) that reported 20.44% to 23.01% reduction in irrigation water application at various locations studied and an increase in rice yield due to use of AWD technology. Rejesus (2010) reported about 38% reduction in irrigation hours without any decrease in yield. Saving in irrigation water due to laser land leveling was reported by a number researchers such as (Jat et al., 2003; Khattak et al., 1981; Ali et al., 1975). The reduction of hours in operating tube well results in dual benefits of savings in the quantity of irrigation water extraction particularly keeping in view the climate change scenario and saving in cost of energy that is used for tube well operation ultimately adding to profitability of the farmers.

The analysis of the data collected from the middle of the water channel reflected that canal water availability at middle was quite better. The farmers at middle of the channel were also better off as they were able to get around 50% of irrigation water requirements out of canal water and the remaining 50% irrigation water requirement at the middle was met through tube well operation. Before adaption of AWD techniques and laser land leveling, the tube well operation at the middle used to be 32.75 hours per acre. However, after adaption of AWD techniques and laser land leveling the farmers maintained optimum moisture requirement that reduced tube well operation time from 32.75 hours per acre to 26.40 hours per acre as shown in Figure 2.

The Figure 2 shows that about 19.4% tube well operation time has been reduced at the middle. This reflects that even if canal water application is considered constant before and after using AWD techniques and laser land leveling, there has been a reduction in tube well water application to the tune of 21.4%. These results are in line with Hasan (2016) and Rejesus (2010). It is pertinent to mention that respondent farmers claimed improvement in paddy yield but along with AWD and laser land leveling there might be other agronomic factors adding to yield improvement as mentioned earlier.

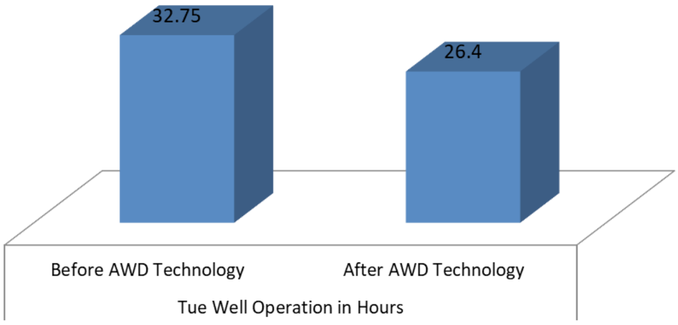

Figure 2: *Impact of Alternate Wetting and Drying (AWD) Tubes Technolog at Middle of Water Channel.*

The analysis of the data collected from the tail of the water channel shows that canal water availability at tail was quite low. The farmers at tail of the channel were facing constraints in receiving canal water and they were able to get around only 20% of irrigation water requirements out of canal water and the remaining 90% irrigation water requirement at the tail was met through tube well operation. Before adaption of AWD technique and laser land leveling, the tube well operation at the tail used to be 50.63 hours per acre. However, after adaption of AWD technique and laser land leveling, the farmers maintained optimum moisture requirement that reduced tube well operation time from 50.63 hours per acre to 38.40 hours per acre as shown in Figure 3.

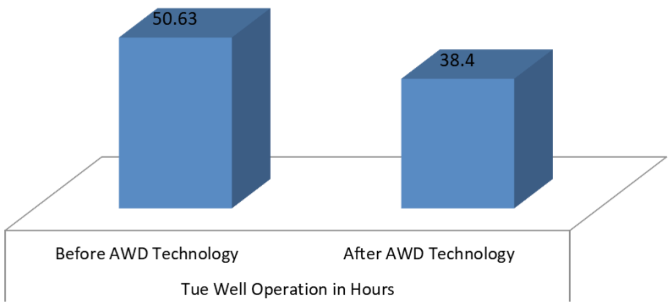

Figure 3: *Impact of Alternate Wetting and Drying (AWD) Tubes Technolog at Tail of Water Channel.*

The Figure 3 indicates that about 24.4% tube well operation time has been reduced at the tail. This shows that even if canal water application is considered constant before and after using AWD technique and laser land leveling, there has been a reduction in tube well water application to the tune of 24.4%. These results are in line with Hasan (2016) and Rejesus (2010). The respondent farmers claimed improvement in paddy yield but along with new technology there might be other agronomic factors adding to yield improvement as mentioned earlier.

Conclusions and Recommendations

Rice is not only an important staple food commodity of Pakistan but it is also an export commodity earning precious foreign exchange for the country. However, rice is a water intensive crop compared to other cereal crops. The traditional rice growing in irrigated areas in most of the Asian rice farms requires large amount of water. However, enhancing food production under changing climatic conditions requires the reorientation of agriculture from current practices to more sustainable and environmental friendly practices with more focus on climate smart production techniques requiring less water. In view of climate change, water management for agriculture covers technologies and practices leading to water productivity enhancement to address increasing irrigation water demand and declining water resources. One of such technology known as laser land leveling was introduced in Pakistan in 1980s. More recent introduction is of another water efficient technique known as AWD technique evolved by the International Rice Research Institute (IRRI). The AWD intervention in conjunction with laser land leveling is made through Water Productivity (WAPRO) project in Muridke *tehsil* of district Sheikhupura Punjab Pakistan. The analysis of the data reflected that although canal water was available but about 80% at head, 50% at middle and 20% at tail. Thus remaining irrigation water requirement i.e. about 20% at head, 50% at middle and 80% at tail was met through tube well operation. The result from before and after AWD technology and laser land leveling technology adaption shows that 24.24% tube well operation time reduced at the head, 19.4% reduced at middle and 24.4% reduced at tail. The reduction of hours in operating tube well results in dual benefits of savings in the quantity of irrigation water extraction particularly keeping in view the climate change scenario and saving in cost of energy that is used for tube well operation ultimately adding to profitability of the farmers. The respondent farmers claimed improvement in paddy yield but along with AWD technique and laser land leveling there might be other agronomic factors adding to yield improvement as this study did not isolate yield and AWD technology and laser land leveling from other factors that may be studied in future research studies. The laser land leveling is already attracting huge investment from the government but AWD technology is yet to get its due place in government priority. It is therefore recommended that AWD technology should be up-scaled to address water constraints in agriculture sector, particularly rice production regime.

Novelty Statement

This piece of research is innovative and adding new knowledge as assessing water productivity through the application of AWD technology along with laser land leveling in Pakistan which is a beginning of opening new avenues of climate change related research.

Author's Contribution

Arjumand Nizami: Conceived research theme and analysis of data.
Muhammad Zulfiqar: Data collection, interpretation of results and finalized article.
Jawad Ali: Data collection and prepared draft of the article.
Naushad Khan: Literature review and developed abstract.
Imran Sheikh: Facilitated field work and reviewed results.

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