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A study on farmers' crop management practices and opportunities for drought alleviation in rainfed lowland rice systems

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Abstract
Rainfed agriculture is characterized by uncertainty in amount, frequency and duration of rainfall. The farmers are well aware of these limitations and have, over the years, managed their cropping practices so as to minimize the yield losses. Field experiments and farmers' survey were carried out in the rainfed lowland rice systems of Northwest Bangladesh, in order to understand the present farming practices and the opportunities for drought alleviation. It was evident from the study that the traditional transplanted rice technology has failed to alleviate the droughts that occur during the crop growth period. Rainfall probability analysis has shown that the water availability from rainfall is only about 78% in an average year and drops down to about 50% during the dry years. Opportunities for technological interventions for drought alleviation, like water harvesting through on-farm reservoirs and dry seeded rice, have been explored. Because of physical limitations, the water harvesting technology has been neither suitable nor acceptable to the farmers. But, the dry seeded rice has proved to be superior over the traditional transplanted rice in mitigating the droughts. If dry seeded, the water availability from rainfall is nearly 100% in an average year and nearly 90%, even in the dry years. The agronomic and socio-economic issues that affect the wider adoption of the dry seeding technology by the farmers need further research.

INTRODUCTION

Rainfed agriculture covers a wide range of physical environments resulting in many diverse forms of production systems. Rainfed lowland rice is grown in bunded fields where the water depth does not exceed 50 cm for more than 10 days and the fields are inundated for at least part of the crop season. Such fields have no access to irrigation system and the crop water requirement is totally met by rainfall. The uncertainty in rainfall (in amount, frequency and duration) and the resulting risks of flood and drought have motivated the farmers to adopt a very conservative low input-low output farming system. Thus, the impact of green revolution (modern seeds and improved cultural practices) in this system is less than that in similar irrigated cropping system.

Rainfed lowland rice area comprises about 25% of the world's rice area but produces only about 17% of the total output. Most of the rainfed rice area is in South and Southeast Asia. In Bangladesh, about 50% of the rice areas are rainfed and most of these areas suffer from either flood or drought or both. After reaching a peak during the mid-eighties, the rate of investment in irrigation is falling off fast in Bangladesh because of both economic and technical constraints (Zeigler and Hossain, 1995). It is now certain that the majority of the farmers in rainfed system will continue to remain in flood-drought prone environment in the foreseeable future. Research is therefore needed to address the complex issues of productivity and sustainability of these fragile rice ecosystems. This study is therefore an attempt in understanding the agro-hydrology of the rainfed lowland rice areas, assessing the constraints to higher productivity and studying the opportunities of technological intervention for achieving sustainable production.

STUDY AREA

The study was carried out in three Districts, namely Rajshahi, Magura and Rajbari of the Northwest region of Bangladesh. The region in general is drought prone and receives a seasonal rainfall of about 1000-1200 mm during the five monsoon months of June-October (Hussain and Sultana, 1996), which is the lowest in the country. Such rainfall amount has been classified as low for a rainfed ecosystem (Garitty et. al., 1986). The average daily evaporation varies from about 2.3 mm in January to about 6.3 mm in April. The four months when the rainfall exceeds evaporation are June to September. The averages of the maximum and the minimum temperatures in the region are 39^0C and 10^0C respectively, and occur in the months of April and January. The location map of the study areas along with distribution of total seasonal rainfall during the monsoon in Bangladesh is shown in Figure 1.

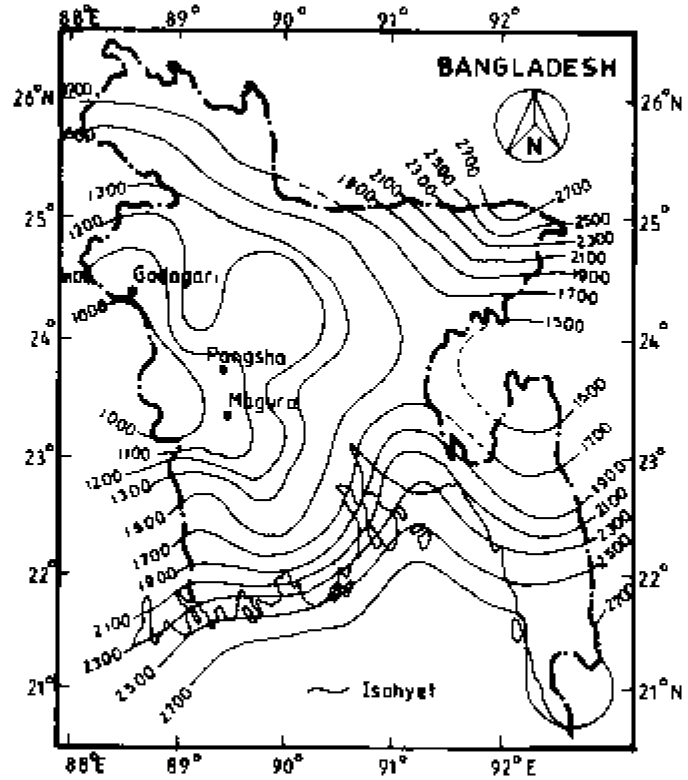

Figure 1. Location map of the study areas and distribution of monsoon rainfall (June- October) in Bangladesh.

In Rajshahi, the study was carried out at Rajabari Union of Godagari Thana. The area has an undulating topography with grey terrace soil. The soil texture of the area varies from silt loam to silty clay loam. The mean annual rainfall at Godagari is about 1300 mm and the rainfall during the five monsoon months is about 1000 mm. The area is drought prone and the predominant cropping pattern is Fallow-Transplanted Aman (monsoon) Rice-Fallow. In some areas, depending upon the availability of residual soil moisture, chick pea, linseed and wheat are grown during the Rabi or dry (December-March) season.

In Magura, the study was carried out at Kashinathpur Union of Magura Thana. The area has a flat topography and the texture of the soil is sandy loam. The mean annual rainfall at Magura is about 1700mm and the five-month monsoon rainfall is about 1130mm. The area is moderately drought prone and the predominant cropping pattern is Jute-Transplanted Aman Rice-Wheat. Jute and wheat are grown during the pre-monsoon (April-June) and Rabi seasons, respectively.

In Rajbari, the study was carried out at Maspara Union of Pangsha Thana. The texture of the soil of the area is sandy loam. The area has a flat topography and lies in the flood plain of the Ganges. As such, the area is vulnerable to floods. The mean annual rainfall at Pangsha is about 1650mm and the five-month monsoon rainfall is about 1150mm. This area is also moderately drought prone and the predominant cropping pattern is Mixed Broadcast Rice-Fallow. The mixed broadcast rice is grown during the pre-monsoon and monsoon seasons. Depending upon the availability of residual soil moisture during the Rabi season, lentil and mustard are grown in some areas.

METHODOLOGY

The study was carried out during the five Aman (monsoon) seasons of 1994-98: two seasons (1994-95) at Godagari and three seasons (1996-98) each at Magura and Pangsha. The study was focussed on understanding the crop production practices of rainfed farmers of three different agro-hydrologic zones, without any interference or intervention on cropping systems or crop production practices. The objectives behind this approach were to find answers to- what the farmers do? Why they do it? How they do it? And, the successes and failures of their endeavours.

The crop production practices of 50 randomly selected farmers in each of the three study sites were surveyed during the study period using a pre-designed questionnaire in order (a) to gain qualitative information on farmers' practices in crop establishment, crop management and production limitations, and (b) to collect quantitative information on timings of farming activities, input use and productivity of crops. For quantitative analysis of the field water status and crop water use, 30 farms were closely monitored in each of three sites by installing 100 cm long PVC tubes (50 cm perforated), 20 cm above and the rest below the ground surface. Water level readings in the PVC tubes (standing or perched water table) were taken every day. Changes in the standing water levels during rainless days were used in order to estimate the seepage and percolation (S&P) loss from the rice fields.

Daily rainfall data were measured by installing rain gauges at the study sites and pan evaporation data were taken from nearby weather stations (Godagari, Magura and Pangsha). For the analyses of rainfall, long term rainfall data (1963-95) of Godagari, Magura and Pangsha were collected from Bangladesh Water Development Board. The rainfall probability analysis was carried out with long term rainfall data by using the Gamma distribution.

The water availability from rainfall during the crop growth season was determined by using the concept of relative water supply (RWS), which is defined as the ratio of supply of water to the demand by the crop (Levine, 1982). Thus, the RWS for a given period t can be written as:

$$RWS_t = R_t / (ET + S\&P)_t \quad (1)$$

where, R is the rainfall and ET is the crop evapotranspiration at time t. A RWS value greater than 1 indicates that the supply is adequate, where as, a value less than 1 indicates deficit or drought.

A 5-day time period, as was used by Saleh and Bhuiyan (1995) was used in this analysis. Since rainfall during one day may be adequate for the entire period, the chances of water deficit (drought) are higher if the period is longer than five days. As soil-water may be available to the rice roots two to three days after standing water has disappeared, a shorter duration was not considered. The 5-day period water balance is written as follows:

$$H_t = R_t + H_{t-1} - ET_t - (S\&P)_t \quad (2)$$

where, H and is the bund storage and subscripts t and t-1 denote time in 5-day time steps (present and previous 5-day, respectively). R, ET and (S&P) are all expressed in mm/day (in each 5-day time step). Thus, the incidence of either drought (RWS < 1) or adequacy (RWS > 1) of water supply was determined by the following criteria:

if $(R_t + H_{t-1} - ET_t) < 0$; then $(S\&P)_t = 0$; $H_t = 0$; there is drought; (3)
if $ET_t < (R_t + H_{t-1}) < ET_t - (S\&P)_t$; then $H_t = 0$; the supply is adequate; (4)
if $R_t + H_{t-1} - ET_t - (S\&P)_t > 0$; $H_t > 0$; the supply is adequate; and (5)
if $R_t + H_{t-1} - ET_t - (S\&P)_t > H_{max}$; $H_t = H_{max} =$ 20 cm; the supply is adequate. (6)

RESULTS AND DISCUSSION

Farming Activities in Relation to Rainfall

The timings of farming activities (first plowing, seeding, transplanting and harvesting) for 50 sample farmers of Godagari during 1994 and 1995 Aman seasons are shown in Figure 2. Farmers initiated the first plowing and seeding activities earlier in 1994 because of the 60 mm rainfall in April. But transplanting could not be carried out until July, when there was enough rainfall for land preparation and puddling. In 1995, the first plowing and seeding started late because of low rainfall at the beginning of the season (20 mm in April). Heavy rainfall from the beginning of June resulted in quick completion of the farming activities and transplanting was completed by the end of July. The time of completion of first plowing by 50% of the farmers was 19 May and 19 June in 1994 and 1995, respectively, but the corresponding time of completion of transplanting was 18 July in 1994 and 20 July in 1995. The time difference between first plowing and transplanting was 60 days in 1994 but only 31 days in 1995. This shows that, with adequate rainfall at a later stage, the farmers can expedite the farming activities (as in 1995) in order to timely transplant the crop. During the period from first plowing to transplanting, the amount of rainfall was about 400 mm in both the years. Rice was harvested by 50% of the farmers by 14 November and 28 November in 1994 and 1995, respectively. Heavy rain (50 mm as shown in Figure 2) delayed the harvesting in 1995.

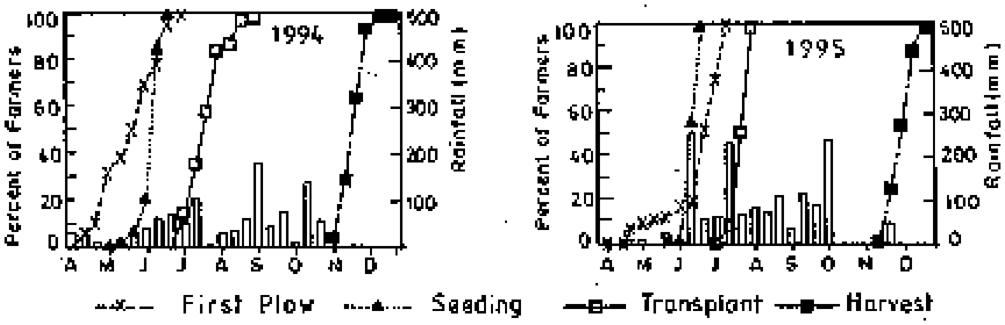

Figure 2. Progress of farming activities during 1994 and 1995 Aman (monsoon) seasons at Godagari, Rajshahi.

The timings of farming activities for 50 sample farmers at Magura during 1996-98 Aman seasons are shown in Figure 3. The effect of rainfall on the farming activities is also evident from the figure. Unlike Godagari, the farmers of Magura grow a pre-monsoon crop (jute) and hence the fields are occupied till the crop is harvested. With adequate rainfall the transplantation was completed by 50% of the farmers by 27 July in 1996. But in 1997, due to inadequate rainfall in June (about 120 mm) and in 1998, due to inadequate rainfall in May (about 80 mm), the transplantation was delayed (15 August and 10 August, in 1997 and 1998, respectively). Again, the minimum rainfall during the three-year period, which was required to complete the land preparation and puddling, leading to transplantation was about 400 mm. This amount of rainfall is not only required for transplanting, but also for harvesting and extraction of jute fiber from the stalk. Harvesting was completed by 50% of the farmers by 21 November, 24 November and 25 November in 1996, 1997 and 1998, respectively.

The timings of farming activities for 50 sample farmers at Pangsha during 1996-97 Aus (pre-monsoon) and Aman seasons are shown in Figure 4. Although the farmers seeded the crop in 1998, because of heavy flooding the crop was totally damaged. The farmers of the area grow local variety broadcast mixed rice (two rice varieties are sown at the same time but harvested at different times; one early maturing and another late maturing).

The field is generally dry plowed and the broadcasting is completed immediately after the first showers. In 1996, 50% of the farmers completed seeding by 1 May. But both in 1997 and 1998, because of early rains, the seeding was completed by 50% of the farmers by 13 April and 18 April, respectively. The first rice crop was harvested by 50% of the farmers by 6 August and 15 August in 1996 and 1997, respectively. The second rice crop was harvested by 50% of the farmers by 18 November and 22 November in 1996 and 1997, respectively.

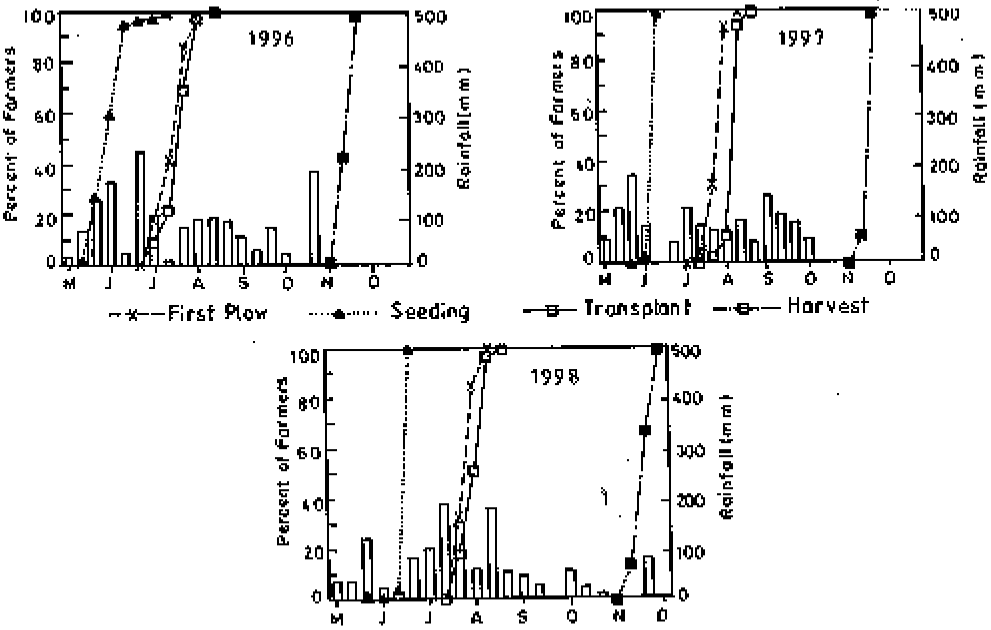

Figure 3. Progress of Farming activities during 1996, 1997 and 1998 Aman (monsoon) seasons at Magura.

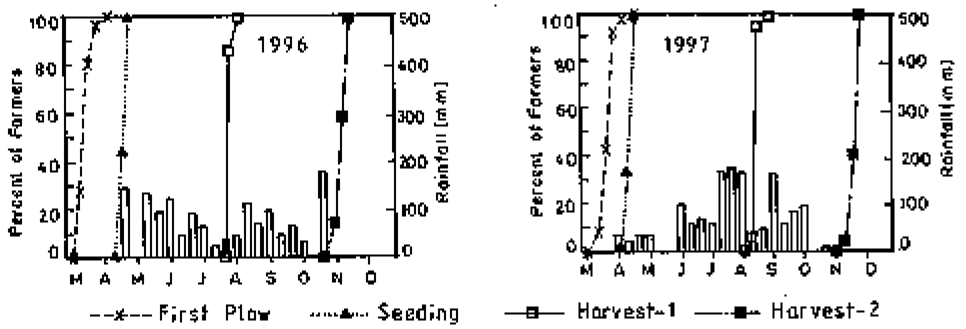

Figure 4. Progress of farming activities during 1996 and 1997 Aman (monsoon) seasons at Pangsha, Rajbari.

It is evident from the preceding discussions that the initiation of the farming activities (both for broadcasting and transplanting) is totally dependent on the onset of the monsoons. The dependency on rain is more for transplanting (because of the need of water for land preparation and puddling) than for broadcasting. The farmers want to transplant the rice timely so that the crop can be harvested before the monsoon has receded. Thus, the rainfed lowland farmers are in a dilemma; they can not transplant early unless there is adequate rainfall for land preparation and if they transplant late then the crop is destined to be affected by drought at the later stages of crop growth.

The situation can be explained for Godagari where the farmers grow high yielding variety (HYV) rice with crop field duration of about 120 days (transplanting to harvest). It has already been discussed that the farmers need about 400 mm of water for transplanting. The rainfall probability analysis has shown that, this amount required for transplanting, is expected to be available by 15 July in an average year at Godagari. But, in 2 out of 10 years (dry years), the transplanting may be delayed till 15 August, as the required rainfall may not be available before then. Because of delayed transplantation in such years, the crop is likely to be affected by drought at the later stages of crop growth. The farmers' survey also revealed that 65% of the farmers would like to complete transplantation by 15 July so as to harvest by 15 November.

In the following sections, the detail analyses of crop water availability from rainfall and opportunities for drought alleviation at Godagari site are presented. As earlier transplanting is not possible at Magura (the fields are occupied with Jute) and at Pangsha, the crop is both flood and drought prone, crop productivity at these sites can be increased only by the improving the rice variety (short growth duration for Magura and resistance to both flood and drought for Pangsha).

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Water Availability During Crop Season

A detail analysis of crop water availability from rainfall was carried out at Godagari site. The average crop water requirement (sum of S&P and evapotranspiration) during the crop season was ascertained from the PVC tube readings as 8.5 mm/day. As for lowland rice, pan evaporation data are good indicators of crop evapotranspiration (Tomar and O'Toole; 1980), the average S&P loss was estimated as 5.5 mm/day (the average pan evaporation during the season was considered as 3 mm/day).

The 5-day rainfall at 50% and 80% probabilities at Godagari are shown in Figure 5. The crop water availability during each 5-day of the crop season (15 July-15 November), except the last 15 days before harvest when no water is required, was calculated using equations 1 and 3-6. The results of the analysis show that, in an average year, when the rice is transplanted by 15 July, the average RWS is 0.78. This means that even in an average year, only about 78% of the crop water requirement can be expected to be available from rainfall. From July till the end of September, the rainfall is adequate to meet the crop water requirement. But, from the beginning of October there is little or no rain to meet the crop water requirement, when the crop is at the beginning of the grain filling stage. Water deficit at this stage would affect the crop yield. In a dry year, when transplantation is delayed (by 15 August) because of inadequate rainfall, the RWS drops to 0.5. Thus, in dry years, only about 50% of the crop water requirement can be expected to be available from rainfall and this would have detrimental effects on the crop yield.

The above analysis has shown that for sustainable production of rice in the rainfed lowlands, drought alleviation measures are imperative.

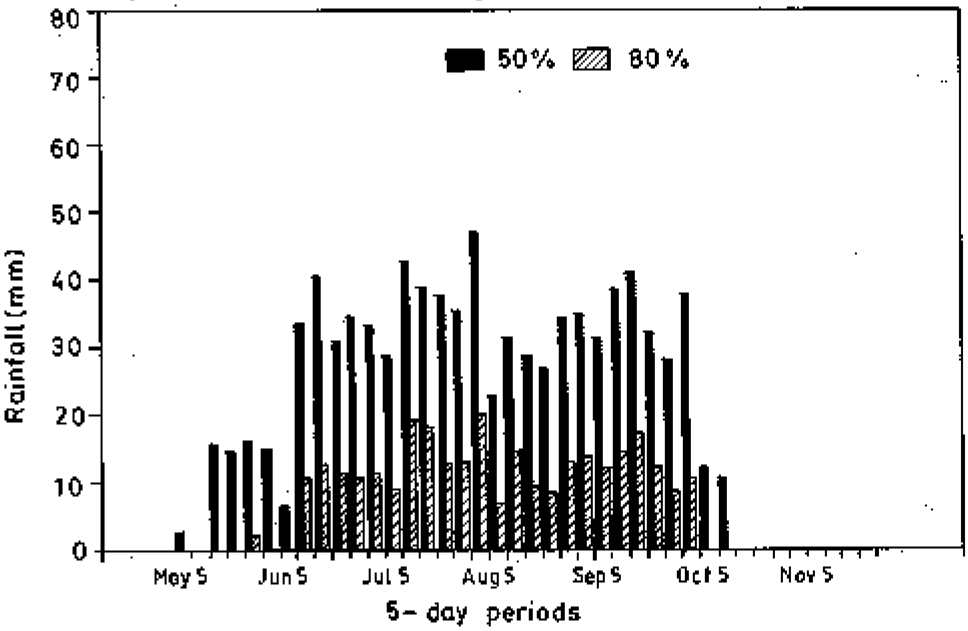

Figure 5. 5-day rainfall at 50% and 80% probabilities during different monsoon months at Godagari, Rajshahi.

Opportunities for Drought Alleviation

The two technological interventions that have had some success in alleviating the drought in rainfed lowlands are (a) rain water harvesting through on-farm reservoirs (OFR) and (b) dry seeding method of crop establishment.

OFR technology is amenable to sloping topography where the runoff from the upper catchment is stored in the OFR and can be used to irrigate the lower catchment. OFRs have been successfully used for drought alleviation in the Philippines, Indonesia and India (Bhuiyan and Zeigler, 1994). The technology is not applicable at Magura and Pangsha where the terrain is flat. But, at Godagari, the OFR technology has been found to be technically and economically feasible for drought alleviation (Islam et. al., 1998). But, as most farmers of Godagari are tenants and because of small and fragmented landholdings, the rate of adoption of the OFR technology by farmers has been slow.

In the dry seeding method of crop establishment, rice seeds are sown on dry tilled unsaturated fields early in the season (about a month before transplantation), which subsequently may become flooded with the onset of the monsoon. Studies on dry seeded rice (DSR) in the Philippines (Saleh and Bhuiyan, 1995; Lantican et. al., 1999) have shown that DSR requires much less rainfall for crop establishment and suffers less drought risks than the traditional transplanted rice. It has also been established that DSR matures 1-2 weeks earlier than the transplanted rice. DSR technology is not applicable for Magura where the land is occupied prior to transplantation. At Pangsha, the farmers are practicing the dry seeding technology but with local variety seeds. As the area is also flood prone, the farmers need modern variety seeds that are both flood and drought resistant for increasing the productivity.

At Godagari, the opportunities for drought alleviation through DSR technology were investigated. Studies in the Philippines have shown that only about 150 mm of rainfall is required for crop establishment through DSR compared to about 600 mm for TPR (Saleh and Bhuiyan; 1995). Rainfall probability analysis of Godagari has shown that, if 150 mm of rainfall is required for establishment of DSR (as in the Philippines with a similar soil texture), then once in two years (50% probability) crop establishment may be possible by the first week of June. But, twice in ten years (80%) probability, the rainfall may be inadequate for crop establishment before the third week of June. If sown by the first week of June, then the average RWS for DSR (with rice maturing 15 days earlier than transplanted rice and with no water required during the last 15 days) at Godagari is 0.99. In dry years, when sowing may not be possible before the third week of June, the average RWS is 0.89. This means that in an average year, the water availability from rainfall for DSR is just adequate to meet the crop water requirement. Even in a dry year, the water availability from rainfall to meet the crop water requirement of DSR is about 90% compared to only about 50% for transplanted rice. Thus, DSR technology has the potential for alleviating drought in the rainfed lowland rice systems. The extrapolation of the technology in other areas and the constraints to adoption of the technology by the farmers need further research.

CONCLUSIONS

The uncertainty and variability of rainfall have been the dominant variables that influence the productivity in the rainfed lowland rice systems. Although the farmers have accepted these realities and have tried to adjust their farming activities in order to mitigate their effects, technological interventions are imperative for achieving sustainable yields in the future. As a floodplain country, water harvesting through on-farm reservoirs has some physical limitations for wider adoption of the technology in Bangladesh. But, dry seeding technology has the potential for alleviation of droughts. Because of earlier crop establishment, lower water requirement for land preparation and effective use of the monsoon rains in the early part of the season, the dry seeding technology has much higher RWS values compared to the traditional transplanted rice. Studies on the effective transfer of the dry seeding technology to the farmers are now necessary for improving the crop productivity in rainfed lowland rice systems.

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