Can Agriculture Provide Food Security and Decent Livelihoods in East India?

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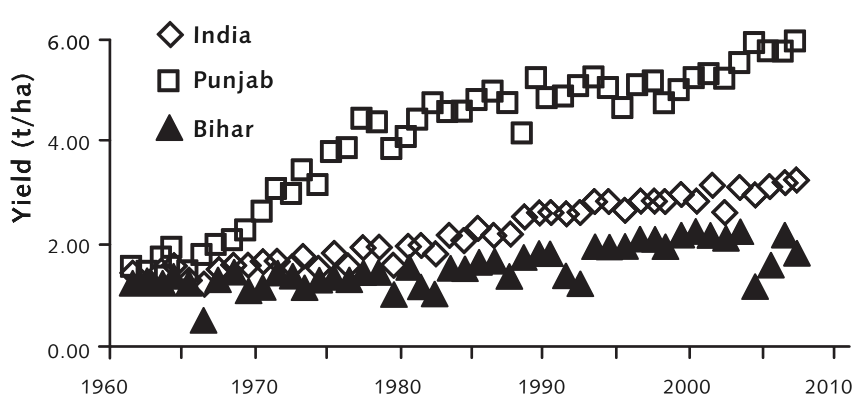
Efficient use of water and land, including the storing of excess run-off and the cultivation of alternative crops to lowland rice such as vegetables and pulses, are some of the ways to ensure food security and decent livelihoods for the subsistence farmers in the East India Plateau.

The Green Revolution brought food security to India mainly by increased productivity through irrigated agriculture. In Punjab, the average rice yields have increased three-fold since the 1960s (Figure 1). Sadly, productivity has improved little in parts of India where agriculture is mostly rain-fed. In Bihar, for example, rice yields for predominantly subsistence farmers have barely improved in 50 years (Figure 1). Therefore, despite the national food security, East India suffers from a severe food deficit and is the most densely populated, least developed and poorest region of India, with around 70 per cent of the people not enjoying food security at all. For subsistence farmers, who use no irrigation methods and who depend on rainfall, drought is also an ever-present risk. This is despite having an average rainfall that is so high it is the envy of farmers elsewhere in India. Does it need to stay this way?

Figure 1: Rice (Paddy) Production for All India, Punjab and Bihar, 1970–2008



Participatory research with farmers by PRADAN, in partnership with Australian scientists and the Indian Council for Agricultural Research (ICAR), has shed light on why productivity remains low, and why farmers are so at risk of drought on the East India Plateau (EIP). It also points to ways by which such situations can be improved.

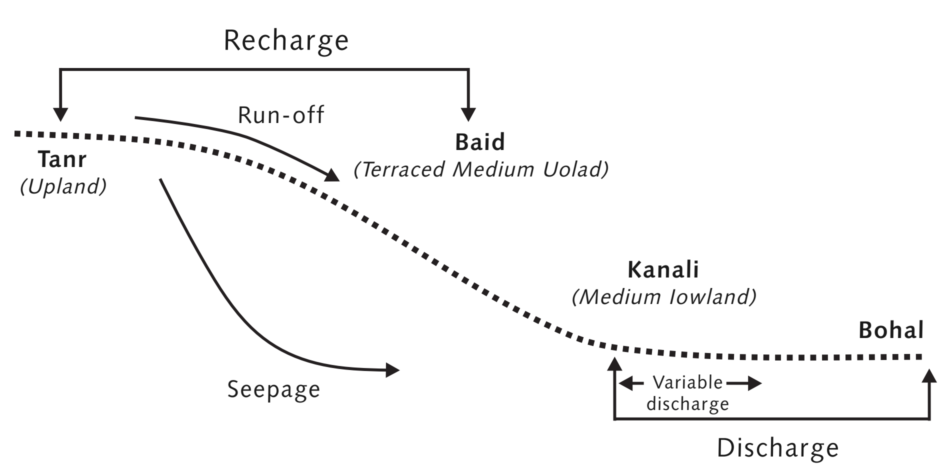
> *If poor farmers are to achieve improved livelihoods, based on agriculture, they must make more efficient use of water and, of course, the land. Understanding water is one of the keys that will unlock the path to development for poor farmers.*

The project is funded by the Australian Centre for International Agricultural Research. The project aims at developing water harvesting principles, based on PRADAN's long-standing work, and at developing new cropping systems that make best use of the water resources for improved livelihoods. This article focuses on the risks and opportunities relating to rainfall.

The work centres on Pogro and Amagara sub-catchments in Purulia district in West Bengal on the eastern edge of the EIP. The area enjoys high rainfall (1,100–1,600 mm) although 80 per cent falls within the monsoon between June and September. Because there is little irrigation, there is negligible cropping outside the monsoon and the region is largely mono-cropped with rain-fed rice. So, with the low rice yields, few other crops and the rising population, food security is a critical issue. The landscape is mostly undulating (Figure 2), with drainage lines and land near streams comprising lowlands (*bohal*) that rise to the local uplands (*tanr*), with relief typically <30 m.

There is much more rainfall in the monsoon than plants can use; so all the 'excess' either runs off or seeps into the local shallow groundwater (Figure 2). The uplands are 'recharge' areas whereas the lowlands are the local 'discharge' areas for seasonally recharged groundwater. The narrow band of medium lowlands (*kanali*) between them is a discharge area in the wetter years only. *Bohal* has been cropped with rice for centuries;

Figure 2: Schematic Landscape Showing Land Classes and the Movement of Water



Modelling is a way of estimating soil water without having to dig holes. It can give an estimation of soil water content continuously even when there are no measurements at all.

however, with the pressure of the increasing population, the up-slopes have been terraced and bunded progressively to create medium uplands (*baid*). Medium uplands are now the most extensive areas for rice. Farmers readily identify *bohal* as their best land if they have any because lowland rice grows well there. Farmers also understand the patterns of run-off and drainage in their landscape and adapt to this by growing shorter duration rice varieties in the medium uplands.

RAINFALL AND WATER: RISKS AND OPPORTUNITIES

When asked about their greatest needs, poor farmers invariably say, "Give us water and we can do anything." From a scientific viewpoint too, the availability of water creates opportunities as well as sets boundaries on what farmers can achieve. If poor farmers are to achieve improved livelihoods, based on agriculture, they must make more efficient use of water and, of course, the land. Understanding water is one of the keys that will unlock the path to development for poor farmers.

A farmer's water resources, or at least potential water resources, lie not only in the current rainfall but also in the run-off that may be captured in ponds. Moreover, seepage water makes the *bohal* the safest for lowland rice and provides a potential source of irrigation water. 'Water harvesting' aims to capture the run-off and seepage water that is usually lost. A less obvious resource is the water stored in the soil. All crops, both rain-fed and irrigated, depend on water held in soil. Even rice depends on water stored in the soil after the fields have been drained and before maturity, or in the dry periods. Rain-fed crops depend on soil water whenever it is not raining, often for long periods of time.

Equally important as it is to know about the rainfall is to know how much water is in the soil. Astute farmers manage the irrigation by maintaining soil water within acceptable limits. In order to cultivate 'lowland' rice varieties, it is important to know how long the water remains 'ponded', and whether short periods of drying occur. Knowing this may help to explain why rice crops fail so often. We will see later that knowledge of soil water can also *identify opportunities* for farmers to safely grow productive crops when it is too dry for rice.

KNOWING SOIL WATER: MEASUREMENT AND 'MODELLING'

Not all of the water held in the soil can be used by plants; scientists talk about a lower limit, that is, how far plants can dry out the soil if they need to (sometimes called the 'permanent wilting point'). There is also an upper limit to the amount of water a soil can hold (saturation, for rice paddy; 'field capacity' for other crops). Between the upper and lower limits is the 'available' soil water. This is referred to in the same way as rainfall, that is, in millimetres (mm). The maximum amount of available soil water depends on the type of soil as well as the type of plant, because plants with deeper roots explore a greater volume of soil. Many people are surprised by how much available water can be held in soils. For agricultural plants, it can be as much as around 250 mm. Rain-fed crops can grow for weeks or even months, using water held in the soil, without rainfall at all. The amount of water held in the soil is highest after heavy rains and lowest after long dry periods during which plants absorb the water through their roots, which often extend to over one metre deep in the soil. When cultivating rice, the water is meant to 'pond' above the soil surface for much of the crop growing period.

The research team used a combination of soil water measurement and modelling to understand better the risks involved and opportunities provided by the rainfall in East India. The direct measurement of soil water involves boring hundreds of small holes in dozens of farmers' fields to the depth that crop roots can grow, say up to one metre. This soil is returned to the laboratory and dried out to determine how much water it holds. We have measured soil water after rice and some *rabi* crops over several years in different land classes to determine the 'lower limit' for these crops in soils typical of the EIP. This is very time consuming, and impractical on any scale. Modelling is a way of estimating soil water without having to dig the holes. It can give an estimation of soil water content continuously even when there are no measurements at all. Actual measurements are used just to check that the model is giving sensible results.

DAILY WATER BALANCE MODELS

Models simply use a sequence of mathematical calculations that mimic what is actually happening in the soil. Models treat the soil like a bank account. Each day, water received from rainfall is added to the soil water carried forward from the previous day, and the water used by the crop that day is withdrawn (meteorological data are used to estimate evaporation and, from this, crop water-use is estimated). The balance is the amount of water available to a plant on that day. This balance is carried over to the next day, when rainfall is added and crop water used is subtracted and so on, to give a running daily water balance.

The 'water balance' model can account for run-off, for drainage below the roots of crops, for ponding above the soil surface and any other factor that affects the amount of available water. The water balance is calculated from data obtained from standard weather stations. Models need to be based on real data and the predictions need to be verified.

THE RISKS OF GROWING RICE

The research team wanted to know how risky it was to grow rice in the medium uplands, on which most poor families depend. To find out, the team estimated the soil water balance for rain-fed monoculture rice (rice-weedy fallow) for the period of our work in Purulia (2006–09). Farmers assessed the rice in medium uplands for these years as follows.

2005: (Before the project commenced) Was a bad year for rice in medium uplands.
2006: Poor despite a wet start.
2007: Very good.
2008: Poor with a dry finish.
2009: Disastrous, with delayed transplanting and an early end to the monsoon.
2010: Looks like another disaster.
Thus, the farmers say that five of the last six years have been bad.

The farmers' assessment of these years is borne out by the measurements and modelling in Figure 3, which gives us some confidence in the model. The continuous line in Figure 3 is the estimated available water on every day for four years. You see it rise with the onset of the monsoon when rainfall exceeds evaporation and fall away at the end of the monsoon.

Note: Evaporation and rainfall are monthly data, and only for 2006, to simplify the graph. The data show excess of rainfall (squares) over evaporation (triangles). The number under the line is the days between the first ponding and the final draining, ignoring any temporary drying of fields.

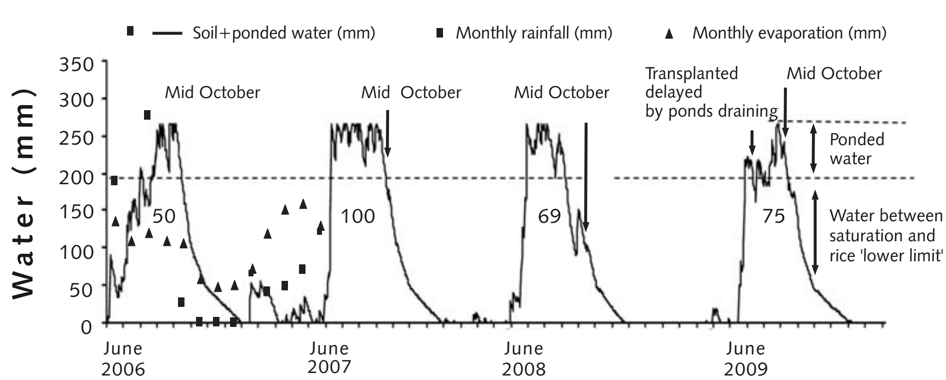
With a thinly spread extension service, low levels of literacy, high levels of risk aversion and poor self perception, most farmers grow mainly rice with which they are familiar and which, by repute, needs little fertilizer and for which it is relatively easy to manage weeds.

Because we are modelling rice fields, we have allowed water to stand during the rice crop, if there is enough rainfall. The top line of dashes indicates the maximum total water storage (soil + standing water) of 265 mm. Below the two lines of dashes is the amount of available water when the soil is saturated. The average depth of ponded water is 75 mm. For most of its growth, rice needs standing water; therefore, the continuous line needs to be above the bottom line of dashes.

What does Figure 3 tell us? Only in 2007 did water remain ponded continuously, for 100 days, which is enough for a rice variety with medium duration. In 2006, the good rainfall in June would have allowed rice nurseries to be planted; however, transplanting in July and August was followed by draining of the fields. The year 2008 had a promising start but the rains faltered in August; the fields dried and there was temporary respite in late September. In 2009, transplanting was delayed because of the faltering monsoon rains.

The model results not only confirm what the farmers say but also give insight into the nature of the problem, whether it is a late onset of the monsoon, an early finish, or periods during the monsoon when the fields drain. Each of these problems requires a different solution. For example, the period between the start of ponding and final draining of fields (the number under the line) was much less than 100 days in three years, even if short dry periods are ignored. This means that even very short duration rice will suffer from either late transplanting or early cessation of monsoon rains—early maturity will not solve the problem, even though

Figure 3: Soil Water and Monthly Rainfall and Evaporation, Pogro Catchment, 2006–2009



farmers have sensibly moved to shorter duration varieties. Above all, any temporary draining of fields at critical times such as flowering worsens the disaster.

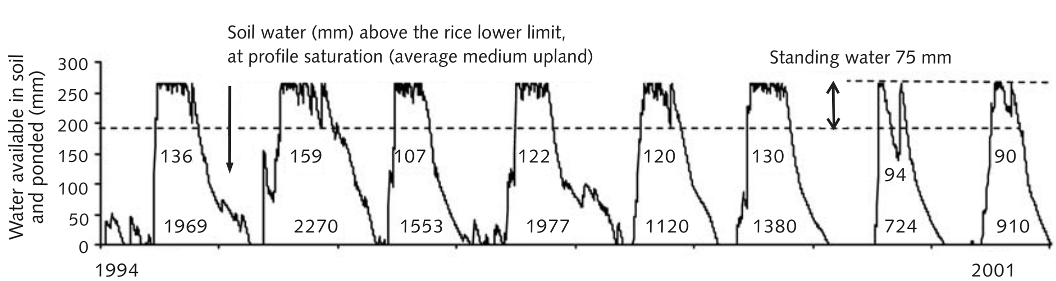
Next, we wanted to know what happens over a greater period of time. For this, we used weather data for 1994–2004 from the nearby Shahrajore dam. The duration of inundation varied from 94–159 days, again disregarding periods of drying during the monsoon that would make the situation worse than simply being a short season. Although there were more 'good' years for rice in the period 1994–2004 than since 2005, in three of the eight years, the rice fields are predicted to have dried of free water, again showing the risk in cultivating rice on the medium uplands. Much of the *baid* land holds less water than the 190 mm assumed here and is, therefore, even riskier.

What does this mean? Does this simply mean that East India is drought-prone and farmers need to face this fact? No, it does not. The region is blessed with high rainfall, and even the 'bad' years such as 2000 (724 mm) have enough rainfall to grow the right kind of crop. Tribal farmers near Hyderabad, who heard about the collaborating farmers in Purulia district, said they must be poor farmers to suffer so badly when they receive so much rain. This is not the problem. What it means is that lowland rice is not a safe crop to grow on the medium uplands of East India. Failed rice crops are unavoidable in most years, even with shorter-duration varieties. Short duration is no protection against within-season stress although it would have been useful in some years with the short duration of flooded conditions. With a thinly spread extension service, low levels of literacy, high levels of risk aversion and poor self perception, most farmers grow mainly rice with which they are familiar and which, by repute, needs little fertilizer and for which it is relatively easy to manage weeds.

Is there an alternative to lowland rice? The results in both figures illustrate the potential for upland rice varieties (these are locally available) or rain-fed alternatives to rice in the *kharif*. Collaborating farmers in Amagara and Pogro have successfully grown alternatives to rice in uplands and medium uplands—so it can be done.

The implication is that serious effort needs to go into developing crop options for the *kharif* and proving that these are viable to the farmers. This is a challenge as much for researchers as it is for a development NGO such as PRADAN. The arrows in Figure 3 point to mid-October, which is after the finish of the monsoon. Notice how the soil holds a lot of 'available' water, even after a 'bad'

Figure 4: Water Balance to 90 cm Depth for 1994–2001 in the Best Medium Upland (Baid) Rice.



monsoon. This means that a *rabi* crop can be sown with just a little irrigation because most of the water it needs is already in the soil. For this to work, early planting and a short maturity for rice are needed, so that the *rabi* crop can use 'residual' water before it drains away, evaporates or is used by weeds. This requires good management, which is something farmers develop for themselves—it cannot be 'taught' in a workshop or two. Direct seeding of short-duration rice has proven successful in Amagara during the project, most notably in the bad year 2009.

Short duration varieties are central to improved cropping systems in medium uplands. There are high-yielding rice varieties available that mature before mid-October, especially if direct-seeded early when rice nurseries are being prepared.

First, monsoon rainfall greatly exceeds evaporation in all years, generating substantial run-off, except in 2006; therefore, 'water harvesting' certainly has potential, as promoted by PRADAN. It aims to convert some run-off to transpiration by (1) using structures to slow/detain run-off and retain more water in the landscape in the monsoon and (2) using it in *situ* for plantation crops; or (3) captured in surface storages for 'rescue irrigation' if needed in the monsoon; or (4) to recharge shallow groundwater for extraction down-slope in structures located in seepage lines and used to irrigate *rabi* crops. It is important to increase recharge in order to 'harvest' seepage water in a sustainable way.

Second, showers often precede the monsoon and are commonly used to prepare land for rice. This water could be used to grow alternative early monsoon crops. Water at this time is uncertain (Figures 3 and 4) but may be secured by controlling 'fallow' weeds to conserve water left at the end of the monsoon (arrows in Figure 3) in small areas designated for later pre-monsoon cropping (on flat fields with no erosion risk). Water may also be made more reliable by storing any run-off from the pre-monsoon rains in small ponds for 'rescue irrigation' of early sown crops.

Third, soil water remaining after rice may be used by *rabi* crops, as noted already. But because of a perception that *rabi* crops need full irrigation, none are grown at present. Timely planting is crucial. Figures 3 and 4 show soil is mostly near saturation in early October, even in 'poor' years for rice. In most years, soil in medium uplands holds 150–200 mm water, which is available for *rabi* crops. Strategies to use this water depend on planting shorter-duration rice varieties that create the opportunity for a second crop and reduce the risk of crop failure in a short monsoon. Short duration varieties are central to improved cropping systems in medium uplands. There are high-yielding rice varieties available that mature before mid-October, especially if direct-seeded early when rice nurseries are being prepared.

Seepage water that is 'harvested' could be used to fully irrigate *rabi* crops; but a better strategy would be to supplementarily irrigate crops to force them to use the residual water left by rice. In practice, collaborating farmers have had difficulty establishing crops quickly enough after rice to not need irrigation for establishment. In any case, yields have generally been poor without at least some irrigation that makes P-fertilizers available.

SOIL FERTILITY

The project team undertook extensive soil surveys to see how soil fertility constrains productivity as well as many fertilizer experiments with farmers. The results paint a clear picture of low organic matter, P deficiency (even in paddy rice) and likely K deficiency, but not in all fields. Simple prescriptions for all fields are inappropriate. P deficiency is so severe in *rabi* crops that many farmers have observed 'with no phosphate there is no crop'. P-fertilizer use is low on the EIP; this may help explain why farmers who have tried *rabi* crops believe these will not grow, blaming lack of irrigation.

CONCLUSION

Despite high rainfall, lowland rice is risky on the medium uplands on which most families depend. Alternatives to it include upland rice, vegetables and pulses. Uplands are a hitherto untapped resource in which, with increased confidence, knowledge and skills, farmers have adopted the cultivation of various vegetables, timed to gain high market prices. Short-duration rice reduces the risk of failure and creates opportunities for *rabi* crops that yield well with only supplemental irrigation, by using water left by rice. Significant challenges include the severely degraded structure of rice soils, which sometimes limits irrigation rates, and limits root growth and access to residual moisture. More professionals are needed to initiate ongoing farmer-learning: a challenge to India at large to recognize 'development' as a worthy *profession*, and for universities to develop relevant courses.