East India Plateau – Basket Case, or Future Food Basket?

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Abstract

The 'green revolution' brought national-level food security to India, but not to East India which remains one of the most densely populated, least developed and poorest regions on Earth. Rainfall is high (~1200 mm/yr) but seasonal, and there is little water for irrigated crops after the staple of rainfed rice, traditionally grown in the monsoon (kharif) on small fields on or adjacent to the valley floor (lowlands). Population pressure has forced rice onto nearby terraced and bunded 'medium uplands' where soil water measurements and crop modelling support farmers who say that water is insecure for rice. Frequent crop failures are unavoidable. Severe nutrient deficiencies were shown to reduce yield in good years. Participatory research with farmers developed options for better use of land and water resources, including crops for uplands (once seen as low value), alternatives to flooded rice in medium uplands, harvesting of rainfall for 'rescue irrigation' in the kharif and/or irrigation in the rabi, and rabi cropping using soil water left by rice. Farmers readily adopted new crops and intensive cropping when provided with options *and* personal experience that built confidence and local knowledge. Almost year-round systems now include vegetables, upland rice, mustard and wheat.

Key Words

Food security, farming systems, rice, vegetables, crops, water harvesting

Introduction

The 'green revolution' brought food security to India, mainly through irrigated agriculture (Punjab, Fig. 1). There has been little impact on mainly rainfed East India, the most densely populated, least developed and poorest region of India, with rice yields barely improving in 50 yrs (Bihar, Fig. 1). The regional food deficit is ~ 50% (ICARDA/CARE 2002 unpublished) for >250 million people: ~70% are subsistence farmers, with a high proportion of tribal people for whom agriculture is relatively new. This paper is set in the East India Plateau (EIP), which is largely mono-cropped to rainfed rice with variable yields, despite high rainfall (1,100-1,600 mm). With little irrigation, there is negligible cropping outside the monsoon, so with low rice yields food security is a major issue. Many people have asked why development bypassed the EIP, with such good rainfall. Here we (i) examine biophysical reasons for this (ii) consider opportunities offered by rainfall (iii) report selected soil data that relate to the constraints to, and opportunities for, effective use of land and water resources, and (iv) overview crop options developed with farmers. These insights come from a project to establish water-harvesting principles and to develop new cropping systems for improved livelihoods. Work centred on Pogro and Amagara sub-catchments in Purulia District (West Bengal) on the eastern edge of the EIP at an average altitude of c. 280 m. A participatory process was central to the research (Lawrence et al. 2006) but here we briefly discuss only the outcome, which is the adoption of new cropping systems.

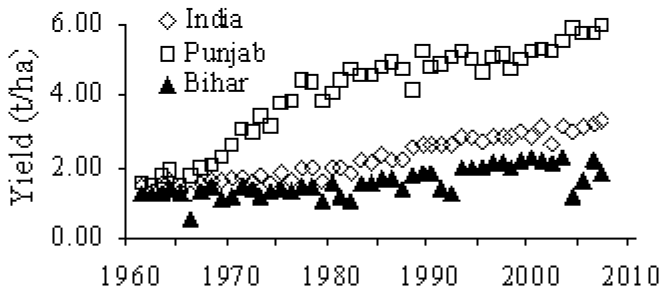

Figure 1. Rice (paddy) production comparing all India, the Punjab and Bihar state, 1970-2008 (Source: FAO).

Agro-ecological background and assessment of risks and opportunities

The EIP rises south from the eastern Indo-Gangetic Plain and west of the coastal plain of the Bay of Bengal at an average elevation of ~600 m, with occasional higher peaks. The landscape is mostly undulating, with drainage lines and land near streams comprising lowlands ('bohal') which rise to local uplands ('tanr') with relief typically <30 m. Hydrologically, uplands are recharge areas whilst lowlands are local discharge areas for seasonally recharged shallow ground-water. The narrow band of medium lowlands ('kanali') between them is a discharge area in wetter years only. Bohal has been cropped to rice for centuries, but with population pressure land upslope has been terraced and bunded progressively to create medium uplands ('baid') which are now the most extensive areas for rice. Frosts are rare and crops can be grown year-round if water is available. Fertiliser use is low, mostly compost, urea and some DAP. The region is said to have "high potential" with its rainfall of 1,200-1,600 mm (80% in June-Sept.) but "low productivity" because soils are acid and infertile with low water holding capacity (Sikka et al. 2009). Such generalisations undoubtedly hide significant variability in this landscape. The only accessible soil data are in maps at scales not relevant to individual fields (arable fields typically <500 m^2). The mostly granite soils are Alfisols (Haplustalfs), or more correctly Anthroposols arising from ongoing human construction (terracing and bunding) and the impact of puddling and flooding for rice. Lowland depositional soils now receive less sediment as terraced upslope areas receive more. To assess the constraints, risks and opportunities offered by rainfall, we used a water balance model plus extensive soil surveys to assess soil resources.

Risks and opportunities – Soil water balance modelling

The water balance for rainfed-rice monoculture (rice-weedy fallow) in the all-important medium upland was estimated using a simple model (after Cornish and Murray 1989) with 1994-2001 rainfall and average daily estimated potential evaporation from nearby Shahrajore dam, and for 2006-09 using Pogro data. Components of total water for average medium upland are shown in Fig. 2, with 75 mm allowance for ponded water.

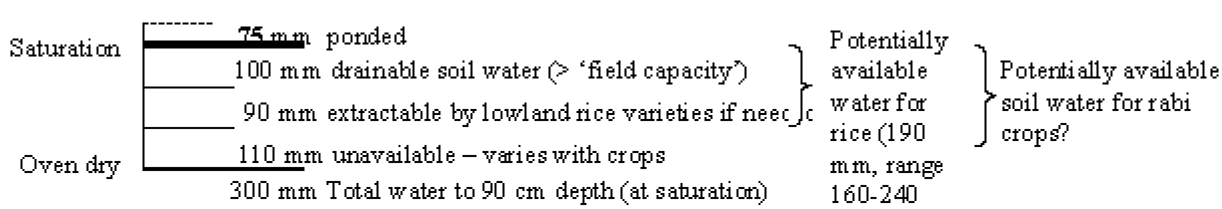

Figure 2. Components of water for average medium uplands ('baid') (0-90 cm).

The upper limit of soil water (not 'field capacity') for modelling was determined by gravimetric sampling from 10 fields (3-4 locations in each) in all land classes after rice harvest in a 'wet' year (2007) with fields at or near saturation. The lower limit of extraction for rice was similarly determined after harvest in 2008, regarded by farmers as a ‘dry’ year as the monsoon ended early. The 2007 samples were used to estimate bulk density, assuming all pores were occupied by water, and specific gravity of soil particles was 2.65g/cm^3 (verified with sampling rings at 4 sites). Water content between these limits was 160-240 mm. The mean of 190 mm was used for modelling. Drainage rate was 3 mm/d based on measured changes in soil water in weed-free baid over 2 months after rice in 2007. This reflects K_{sat} of the profile below the puddled surface. Predictions were checked against post-harvest water data, and by local development professionals to ensure broad capture of patterns of inter-and intra-seasonal variation in water, and in particular that predictions of drought conditions were reasonable. Predictions were used to evaluate risks and opportunities, not as a basis for simulating crop growth and yield. The *risks* associated with rice on the medium upland are clear (Fig. 3).

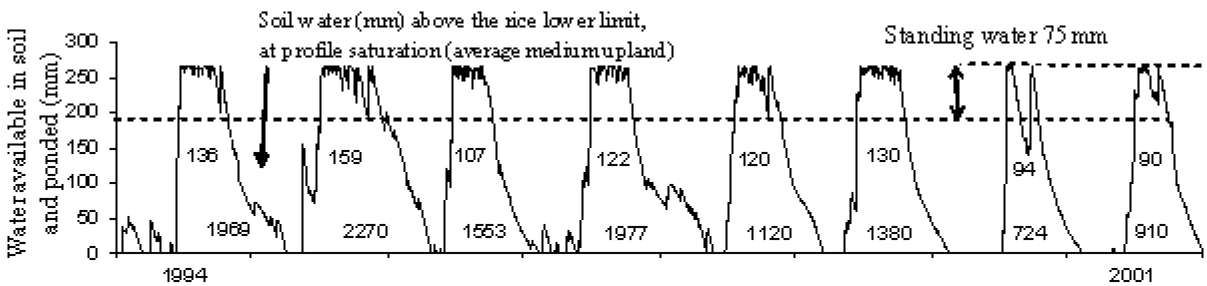

Figure 3. Water balance to 90 cm depth for 1994-2001 in best medium upland (baid) rice. (Assumes: 190 mm between saturation and rice lower limit, max. ponded water 75 mm, no net run-on, no upward flux in this landscape position, drainage of 3 mm/d when wetter than ‘field capacity’. Numbers above x-axis are annual rainfall; below dashed line, duration (d) of ponded water disregarding temporary deficits (Data: Shahrajore dam, Purulia Dist.,WB).

The duration of inundation varied from 94-159 d, disregarding periodic water deficits. However, rice fields are predicted to have dried of free water in 3 of the 8 years, showing the riskiness of rice on this land class. It illustrates the potential for upland rice varieties (these are locally available) or rainfed alternatives to rice in the kharif. Short duration is no protection against within-season stress, but it would have been useful in some years with short duration of flooded conditions. Much of the baid land has less water between the rice lower limit and saturation than the 190 mm assumed here and is therefore even riskier. With a thinly spread extension service, low levels of literacy, high levels of risk aversion and poor self perceptions (Kumbhkar unpublished), it is no surprise that most farmers have grown mainly rice with which they are familiar and which by repute needs little fertiliser and its weed management is relatively easy.

The *opportunities* are illustrated in Fig. 4. Farmers said that for rice in medium uplands these years were: 2006, poor despite a wet start; 2007 very good; 2008 poor with a dry finish; and 2009 was disastrous with delayed transplanting and an early end to the monsoon. ‘Ponding’ ranged from 50-100 days.

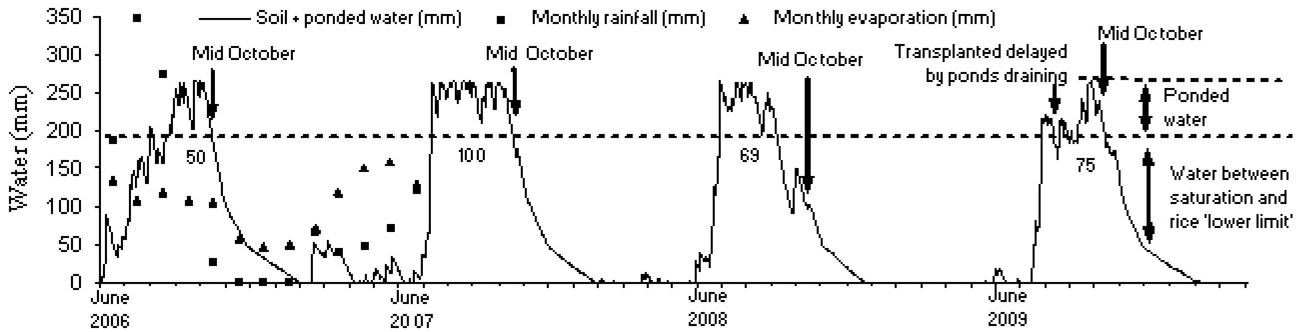

Figure 4. Rainfall, evaporation and soil water, Pogro catchment (Eo, rainfall for 2006 only, to simplify graph)

Monsoon rainfall greatly exceeds evaporation in all years, generating substantial runoff except for 2006 (Croke, unpublished project data), so 'water harvesting' has potential (Sikka et al. 2009). It is promoted by PRADAN and is being further developed in our project. It aims to convert some runoff to transpiration by (1) using structures to slow/detain runoff and retain more water in the landscape in the monsoon and (2) using it *in situ* for plantation crops; or captured in surface storages for 'rescue irrigation' if needed in the monsoon; or 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 sustainably 'harvest' seepage water.

Showers often precede the monsoon and are commonly used to prepare land for rice. They could be used to grow alternative early monsoon crops. Water at this time is uncertain (Figs. 3, 4) but may be secured by controlling 'fallow' weeds to conserve water left at the end of the monsoon (arrows in Fig. 4) in small areas designated for later pre-monsoon cropping (on flat fields, no erosion risk). This is analogous to the 'wet start' fallow used for winter crops in Australia's northern grains zone. Water may also be made more reliable by storing any runoff from the pre-monsoon rains in small ponds for 'rescue irrigation' of early sown crops.

Soil water remaining after rice may be used by rabi crops, but with a perception that rabi crops need full irrigation, none are grown. The potentially available soil water at this time is illustrated in Fig. 2 ('field capacity' is largely irrelevant). Rabi crops race against time to use water draining from the profile at ~3 mm/d. Timely planting is crucial. Figs. 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 hold ~150-200 mm water that may be available to 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 is central to improved cropping systems in medium upland. 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 supplementally 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-fertiliser available, see below.

Soil fertility

Data were derived from a stratified random survey of 10 fields in each of the 4 land classes, repeated for 3 years in both catchments. Selected surface properties (0-10 cm) for rice fields are reported in Table 1. The results paint a clear picture of (1) low organic matter, (2) P deficiency and (3) likely K deficiency, but not in all fields. Soils are generally less acid than most sources suggest. High variability renders useless any general prescriptions of fertiliser requirement. Many of these fields were split for K, P or both (and sometimes N) in farmers' experiments in a powerful catchment-based test of response to these nutrients.

Farmers warmed to test strips as a way of determining fertiliser requirement. An example of rice response to P and K in participatory experiments is given in Table 2.

Table 1. Soil fertility of rice fields from a representative site/year (Pogro/2006).

Land class	Organic C (%)		pH (water)		P (Bray) (mg/kg)[1]		Exch. K (mg/kg)	
	Mean	range	Mean	range	Mean	range	Mean	Range
Medium upland (baid)	0.61	0.30-1.38	5.5	4.7-6.7	6.3	trace-24.2	93	?-253
Medium lowland (kanali)	0.64	0.42-1.03	6.0	5.1-7.0	4.2	1.5-16.1	107	54-175
Lowland (bohal)	0.73	0.44-1.20	7.2	5.9-8.3	3.5	1.1-5.9	79	44-124

[1] Critical concentration for lowland rice is ~6-8 mg/kg, most other crops ~20-25 mg/kg.

Table 2. Yield of rice (kg/ha) - responses to additional P or K (example from Pogro, 2007)[1]

Farmer P	Plus 30 kg/ha P	Farmer K	Plus 30 kg/ha K
4358	5368	3619	4458
P<0.01		P<0.05	

[1] Note that split-field designs have evolved into omission trials with no more than 3 treatments

Fertiliser experiments were also undertaken with kharif pulses and wheat and mustard in the rabi. Striking responses to P were found in rabi crops, presumably as a consequence of prior rice culture, as well as a dry soil surface in the rain-free rabi season. In most fields there is little or no yield without P. As P-fertiliser use is low on the EIP, this may help explain why farmers who have tried rabi crops believe they will not grow, blaming lack of irrigation. P fertiliser and irrigation explain almost half the yield variation of mustard. For example, Amagara in 2006: $Y = -990 + 60P$ (kg/ha) $+ 34Irrig - 0.79 P^2 - 0.2 Irrig^2$ ($r^2 = 0.44$, $P<0.05$).

Crop options and cropping system change

As well as learning together about water and fertiliser requirements, these experiments provided farmers with hands-on learning about improved agronomy and crop options that are new to them although not new *per se*. (see Lawrence et al. 2006). These crops and their average yields in farmers' fields include: mustard (1.2 t/ha) and wheat (4 t/ha) in the rabi; and upland rice (4 t/ha) and pulses (being developed as cash crops not subsistence crops) in the kharif. Vegetables have been introduced as cash crops, but also to help us learn about how to change villagers' self-perceptions and perceptions of their resources - farmers now say that previously disregarded uplands are their best land as they can produce valuable cash crops, even if they are poor for rice. In addition, rice agronomy has improved and along with it crop yields, to the point where farmers can consider crops other than lowland rice to improve incomes. The result has been an extraordinary change, documented in linear studies of crop intensity and diversity in project catchments, from monoculture rice to complex systems in which short-duration rice creates opportunities for rabi wheat and mustard, and vegetables grown from the pre-monsoon period until April.

Family case studies reveal improved food security, reduced forced migration, and modest cash income spent on schooling, medical care and discretionary items such as weddings and house improvements.

Conclusions

Despite high rainfall, *lowland* rice is risky on medium uplands that most families depend on - alternatives to it include upland rice, vegetables and pulses. Uplands are a hitherto untapped resource where, with increased confidence, knowledge and skills, farmers have adopted 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 recognise ‘development’ as a worthy *profession*, and for Universities to develop relevant courses.

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