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Water harvesting and better cropping systems for the benefit of small farmers in watersheds of the East India Plateau

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Abstract

This paper discusses an integrated approach for water resource management to improve rural livelihoods in the East India Plateau. This has involved linking hydrological, agronomic and social aspects to increase access to water, improve water use efficiency and develop capacity within the villages for better decision making regarding use of the available resources. To this end, the research adopted a participatory, action-learning approach, with villagers joining in developing research questions, executing and [illegible] collecting data and sharing in their interpretation, as well as planning intervention work designed to [illegible] to water, particularly in the early dry season. The focus of this paper is on the integration of the [illegible] of water resource management, with particular emphasis on the social issues. This included [illegible] women's self-help groups and village watershed committees, and specific efforts to engage women in [illegible] and related development activities. The result has been an improved capacity within the village for managing water resources, including improved self-perceptions as farmers (especially women), better understanding of the potential resources and any constraints (e.g. soil fertility) and knowledge of how to manage the [illegible] (e.g. fertilisers), as well as a better understanding of the social capacities within the village.

Key words: agronomy, hydrology, integrated water management, [illegible] watershed development

INTRODUCTION

The Government of India has accorded high priority to integrated [illegible] ment (IWM) as a key strategy for poverty reduction and improved natural resource [illegible] results of studies conducted by different agencies on watershed management have sh[illegible] ent of surface and ground water availability after implementation of the projects [illegible] *al.* 1987; Samra 1997; Gaur *et al.* 1998, Sikka 2000). These projects general[illegible] opportunities, augment irrigated area and cropping intensity as well as [illegible] oil and water resources (Joshi *et al.* 2005). Water harvesting (WH) projects [illegible] ase the availability of water resources and reduce the risk associated with [illegible] chnology for agricultural development and livelihood improvement.

Accurate assessment of water resources is crucially important [illegible] al development as well as for resolving upstream-downstream conflicts. Wa[illegible] y be used to improve understanding of the constraints and opportunities [illegible] offers to farmers (Cornish *et al.* 2010).

The region

The East Indian Plateau (EIP) comprises much of the state of Jharkhand [illegible] of adjoining West Bengal, Bihar and Orissa. The landscape is mostly undulating, with drainage [illegible] and near streams comprising lowlands ('bohal') which rise to local uplands ('tanr') with relief [illegible] m. Hydrologically, uplands are recharge areas whilst lowlands are local discharge areas [illegible] recharged shallow ground-water. The narrow band of medium lowlands ('kanali') bet[illegible] a discharge area in wetter years only. Bohal has been cropped [illegible] centuries, but [illegible] ion pressure land upslope has been terraced and bunded progressively to create medium u[illegible]).

The region is said to have 'high potential' with its rainfall of 1,200–1,600 mm [illegible] – Sept.) but 'low productivity' because soils are acid and infertile [illegible] low water holding ca[illegible] *et al.* 2009), and sometimes long dry spells within the monsoon. There is little irrigation infr[illegible] high runoff and soil erosion, terraced mono-cropped paddy lands and subsistence agriculture. [illegible] post-rainy season (rabi) is limited by the lack of irrigation resources, which are generally r[illegible] lthier farmers, and uncontrolled grazing. Uplands are degraded and make little contribut[illegible] oductivity.

The main crop is rainfed rice, and generally very small areas of pulses, oilse[illegible] Most rice is now grown on medium uplands using lowland varieties. Where rabi crops a[illegible] are small areas of fully irrigated crops of rice, vegetables, wheat, pulses and oilseeds. [illegible] echanisation, and the use of fertiliser and other inputs is generally low. The use [illegible] bited by the extreme risk-aversion of these poor farmers, combined with the inhere[illegible] rming in this area with variable climate and little irrigation.

The problem

Yields are generally low (rice <2 t/ha, pulses <0.6 t/ha) showing little im[illegible] years, unlike the irrigated regions of India. Despite high rainfall, the single rice [illegible] ne to drought. Agricultural development in the region lags behind the rest of [illegible] of three contributing factors: the lack of irrigation infrastructure that fuelled [illegible] elsewhere; the area, which has a high Tribal population, was not until rece[illegible] et for development by the Government and because the rural poor are so risk-[illegible] invest in the inputs associated with development. There is a high dependency on [illegible] ort programs which have mixed success and in the long-term are not sustainable.

Gender bias in watershed development (WSD) is another problem nee[illegible] d. WSD programmes tend to be primarily land-based and landowner focused, a[illegible] focused', given the control of land-ownership in India, and does not take a[illegible] of the role women play in management of natural resources (Arya 2007). Tho[illegible] actors in land and water development activities and agriculture, they rarely [illegible] are not recognised as farmers; the term 'farmer' is usually treated as mascu[illegible]

Quite apart from these socio-economic factors, poor farmers appe[illegible] rnatives to rainfed transplanted (lowland) rice, which appears to be a risky [illegible] medium uplands. Identifying the constraints to rice and exploring alternatives [illegible] research.

The opportunity

WH has the potential to make local water resources available, red[illegible] ated with investment in improved technology and possibly creating the oppor[illegible] ing after rice, and setting some of the poorest people in India on the path to development. The high rainfall, yet low cropping intensity and periodic dry periods in the monsoon, together point to significant opportunities to improve the livelihoods of poor villagers through WSD. These opportunities need to be better understood and appropriate technology developed to capture them. To assess the constraints, risks and opportunities offered by rainfall, we used a water balance model plus extensive soil surveys to assess soil resources.

The key to food security is not to bring more marginal land into cultivation, but to improve productivity from existing areas of cultivation. With yields of rice and pulses being well below the potential for monsoon (kharif) crops, it is clear there is also huge potential to improve livelihoods through more efficient use of water, but this requires the risk of investment in inputs to be reduced. Access to water can do this.

WSD in India has been largely restricted until now to the semi arid tropics, although the NGO PRADAN has successfully trialled WH in Jharkhand and West Bengal (Purulia District). At the time the research reported here commenced, WH design principles and well-documented demonstrations of success were needed for the EIP region. In addition to this, options needed to be developed for the most efficient and effective use of harvested water. Also, it is important that any out-of-catchment impacts resulting from scaling-up be evaluated.

METHODS

The adopted approach in this study has been highly participatory and followed an action learning approach. An underlying principle has been that participation has been 'Interactive participation' (Pretty 1995), in which 'people participate in joint analysis, development of action plans, and formation or strengthening of local institutions'. As a principle, we have seen participation as a right, not just the means to achieve project goals. As Pretty considered, the process has involved interdisciplinary methodologies that sought multiple perspectives and made use of systemic and structured learning processes. Villagers have participated throughout the recurring action learning cycle (Plan, Do, Observe, Reflect) which guided the overall project as well as most activities.

The project has the 5 research themes: Resource assessment; Developing social capacity; Improving farmers agronomic knowledge and skill (human capacity); and Developing crop options and farming systems. The purpose of this is improved water resource management through integration of hydrological, agronomic and social knowledge. Developing social and human capacity was achieved through: engaging villagers in all activities (developing research questions, choosing sites for and conducting experiments, collecting data, sharing risks as well as benefits, designing project activities), conducting workshops (action learning activities) to improve knowledge of fertilisers, crop options and weed control; field walks and exposure visits; starting a 'learning cluster' in Pogro to learn how to facilitate the change to improved access to water; forming and supporting women's self help groups (SHGs); and gender studies (including group meetings and surveys).

Research Strategy

Project activities have been located in two watersheds (each given the name of the major village (Pogro and Amagara) and in the wider Purulia district. Work in the Amagara village was focused on the intervention 'process' and technical aspects of crop management, crop choice and rabi crop irrigation strategies were researched. The Pogro study site was an implementation watershed where an advanced approach to WSD was developed during a pre-intervention period (March 2006 – December 2008) of initial baseline monitoring and hydrologic research, culminating in the development of an intervention plan which could be compared with the plan normally developed by

PRADAN. This was followed by a post intervention period of monitoring (January 2009 to September 2011). The Pogro watershed has within it a hydrologically separate sub watershed used as a 'control', in which no interventions were made after the initial monitoring period.

Hydrology

Measurements of the fluxes and storages of water were used to develop models of catchment behaviour at a hillslope scale, and the impact WSD work would have on catchment response. The models were used to develop guidelines for improving the efficiency of WSD projects (Croke *et al.* 2008).

Agronomy and farming systems

Water balance modelling supported by extensive soil water measurements was used to explore the agricultural opportunities and constraints related to rainfall. Detailed soil surveys were carried out with farmers to assess soil chemical fertility and soil physical properties related to the storage of water in the root zone and its availability to crops (Cornish *et al.* 2010). Participatory experiments investigated fertiliser responses and developed new crop options for farmers to use at different times of the year, to take advantage of new water resources made available by WH. These experiments were also designed to build agronomic knowledge and skills and build farmer's confidence.

Gender issues

The focus of this component of the project was on learning how women can have a significant role in decision making around agriculture-based livelihoods. The approach involved conducting surveys and focus groups to determine the role women play in the village, and their perceptions of this role. Women's SHGs were established, and a village core committee (VCC) from members of the SHGs. The role of the SHGs is to provide the members training and support in managing resources. The VCC meets weekly to plan, manage and monitor the activities of the village. Effort was made to engage and re-engage women *as farmers* in training and planning activities.

Monitoring and evaluation

The effect of the project activities has been tracked at 3 different levels (Output, outcome and impact) and used not only to assess project progress but also as a project management tool to ensure the project remains focused, responsive and effective. Monitoring and evaluation (M&E) activities helped individuals in self-reflection, to track the progress of the project as a whole, to do mid-term corrections (as required) and also to design new interventions as per the need of the project.

Results of all the agronomic trials have been discussed and analysed along with staff and also with the farmers at least twice a year. The trial results and the analysis were discussed and validated with the field level experiences of the farmers. This discussion also led to the learning on agronomic practices. It also helped to take decisions on the kind of trials to be taken up for the next time. This has been done after each season (kharif, rabi).

RESULTS AND DISCUSSION

The risks and opportunities associated with rainfall

Water balance modelling reveals that, because of rainfall variability, transplanted rice in the medium uplands in most years will either be sown late, suffer periodic water stress during the monsoon, or suffer terminal water stress. This is because the medium uplands, compared with the traditional rice land (the lowlands) do not benefit from runoff early in the monsoon, or seepage following the monsoon. Therefore the medium uplands are much more drought prone than lowlands. Low yields and frequent crop failures are inevitable, doing much to explain low yields and entrenched poverty in the region (Cornish *et al.* 2010).

Monsoon rainfall greatly exceeds evaporation in all years, generating substantial runoff in most years (Croke *et al.* 2008), confirming WH has potential (Sikka *et al.* 2009). WH in essence 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 but may be secured by controlling weeds after rice to conserve water left at the end of the monsoon in small areas designated for pre-monsoon cropping the next year. 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 high, often of the order of >200 mm. 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

Selected surface properties (0–10 cm) for rice fields are reported in Table 1.

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.

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

Land class	Organic C (%) Mean	Organic C (%) Range	pH (water) Mean	pH (water) Range	P (Bray) (mg/kg)[a] Mean	P (Bray) (mg/kg)[a] Range	Exch. K (mg/kg) Mean	Exch. K (mg/kg) Range
Medium upland (baid)	0.61	0.30–1.38	5.5	4.7–6.7	6.3	Trace–24.2	93	[illegible]–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

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

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*. 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. We stress, however, that such intensification of agriculture is not without risk, especially in variable climates, and farmers need to learn about these risks and how to manage them, a future area for our research.

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.

The productivity of rice can be greatly increased with proper attention to nutrition and plant protection – many farmers in our study area now routinely achieve 6 t/ha regardless of land class, except in 'dry' years when baid crops suffer or even fail disastrously. Increased rice yields not only contribute in a major way to improved livelihoods, but may also make it easier for farmers to experiment with new crop options.

Gender Issues

Imparting training specifically focused towards illiterate women has advanced them in the decision making hierarchy in Pogro and Damrughutu. The men and the women of these villages visited Amagara to observe the successful experiments and the role the SHG institutions played in streamlining the watershed activity. This encouraged the community to engage in SHG strengthening and the VCC was formed. The VCC comprises women representatives from each SHG of a village, and meets weekly to plan, manage and monitor the activities of the village. A capacity building event was organised with the VCC members. This event gave the illiterate women confidence to do proper planning and the motivation to implement the program effectively and efficiently. There was a mock session as to how to do the planning. As a result of this, the women of the VCC could engage with all the family members of each SHG, thus ensuring participation of the community. During January to June, 2009 the VCC oversaw the planning and implementation, including: construction of WH structures (e.g. seepage pits, runoff control structures); 10 ha mango plantation (2,500 trees); and degraded land reclaimed through land levelling for very poor farmers with small land holdings. The work was undertaken in a very short time, within 20 weeks, and involved the VCC investing INR.1,475,330 ($US30736). This is a remarkable achievement given the background of the people concerned.

Engaging in typically male-domain work like watershed implementation and successfully managing the programme, increased the confidence and self esteem of the women. Subsequently, they were involved in agronomic research activities directly. The men accepted them joining and gradually playing the key role, as they have experienced the quality of work these women implement. The women were put into the forefront. Planning meetings for experiments were not held without these women. Women in their weekly VCC meetings generated the list of farmers to participate in the

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research trials, took stock of the progress, discussed any problems and concerns, and with understanding made out required solutions. They were equal partners with the men in grounding the trials and ensuring work execution was timely. These women were taken into designed field visits to the research trials, where they made their observations and analysed these jointly. Learning's from these activities were shared with all women through weekly SHG meetings. At the end of trials, the learning's were shared with the villagers, where the presence of women in large numbers was integral.

Develop guidelines for designing WSD intervention plans using models, monitoring (and a dose of common sense)

Guidelines for the design of WSD have been built based on models that represent the behaviour of the different structures, including the interactions between structures, coupled with basic understanding of hydrologic response. The guidelines are designed to assist the planner in deciding the type and arrangement of structures to be installed on a site ranging from a hillslope to a small catchment. This is achieved by understanding how the structures operate, what factors might limit their effectiveness as well as the likely limits to the volume of harvestable water.

With all WH structures, the trapping efficiency (fraction of retained water that can be successfully extracted) needs to be considered. Some water will flow through, around or under the structures depending on the local terrain, geology, etc… This flow past the structure becomes available for downhill/downstream users. The guidelines adopt a 20% trapping efficiency as a rough guide. Thus, if 150 mm of water has been retained by the WSD structures, the available water for irrigation is estimated at 30 mm. This limits the amount of land that can be irrigated, and reduces the risk of running out of water, hence increasing security for the farmers.

CONCLUSIONS

There is no question that major improvements in livelihoods have been achieved, that extend to villagers who have not participated in our experiments. This arises from improved rice yields, diversification to vegetables, the introduction of double or even triple cropping (in the rabi). Such intensification is not without risks, however, that farmers need to understand and manage. Engaging with women as farmers and introducing them to new livelihood-generation experiences with men has been effective in promoting more equal participation in decision-making and agricultural activities, and challenging in a positive way the cultural norms about roles of women in tribal society. The findings contribute significantly to the global debate about the role of SHG's, supporting the view that their role should be broadened to include improving agricultural activities (not just micro finance and women's issues such as health). In particular, the successful implementation of the watershed activity broke the prejudice that women cannot play a decision making role in land and water development programmes.

On-farm research should be undertaken using a rigorous action-learning approach in which participation is seen as a right, not just the means to achieve project goals. Professionals and farmers/villagers should participate in joint development, implementation and analysis of action plans, and include formation/strengthening of local institutions. It will involve interdisciplinary methodologies that seek multiple perspectives and make use of systemic and structured learning processes. That the purpose of such a participatory, action learning approach be taken up explicitly to help farmers to change perceptions of themselves, their resources and about agriculture as a source of livelihood. It is necessary to include rigorous evaluation that establishes, *inter alia* whether fundamental changes in self perception and perceptions about agriculture as a livelihood have occurred. Such work should incorporate principles of social engagement including the core role of women's SHGs, family-wise planning and implementation, and engaging with women as farmers, not merely as members of an SHG.

It is important to reduce climate-production risk associated with late or false starts to the monsoon and early recession of the monsoon by developing crop options and management tactics for responsive cropping. The concepts of sustainability and stability of agricultural systems need to be redefined, having regard to the paradox that increased system productivity requires increased crop water use and, as water use increases, so production must vary as it more closely follows inter-annual variation in rainfall – stability must fall and risk increase. Further, increased variability in production will require a range of investment and production strategies to sustain livelihoods. There is a need to avoid excessive debt incurred through unrealistic expectations of what WH and improved agronomy can deliver, especially where new technology is developed in a series of good years and climate variation has not been considered. In addition, improved management of soils is needed. There is also need for research on institutions, processes and tools that might be used to develop and manage a watershed management plan most effectively following intervention, to ensure equitable sharing of water and optimum utilisation of the total water resource with low risk of over-exploitation.

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