A Proposal for Improving Pastures in Subsistence Farming Systems on the East India Plateau

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A proposal for improving pastures in subsistence farming systems on the East India Plateau

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Introduction

The East India Plateau (EIP) experiences deep poverty despite high rainfall (>1200 mm). Livelihoods, once derived from Sal (*Shorea robusta*) forest, now depend on agriculture. Subsistence farmers practice monoculture rice-fallow on small, fragmented landholdings (total <1 ha). Rice in the undulating landscape was traditionally grown in lowland drainage lines (Fig. 1) but population pressure has forced it onto adjacent terraced slopes (medium-uplands) that now comprise >80% of the rice area (>50% of land area). Rice is protected from grazing, but the watershed is otherwise grazed as common land with no pasture management. Grazed uplands are often degraded and unproductive, receiving no inputs. Livestock are limited to large animals providing draft power (males) and manure (fuel, compost), and goats for emergency finance.

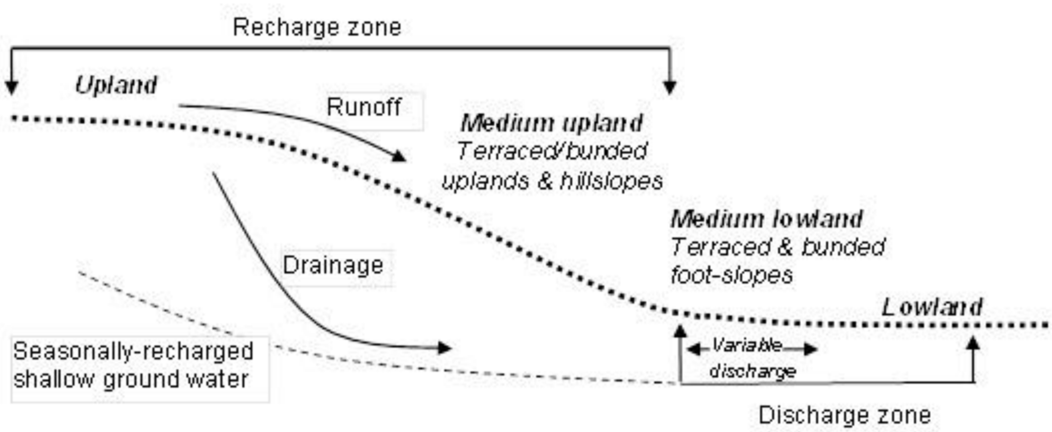

Fig. 1: Micro-watershed land classes (area typically <10 sq km, relief <50 m).

Rainfall is not the primary constraint to production from micro-watershed ecosystems of the EIP - improved rainfed cropping would deliver immediate substantial benefits, without watershed development (Cornish *et al.*, 2015a); although low soil fertility requires attention (Agarwal *et al.*, 2010). The next step in development requires a strategy for poor, risk-averse smallholders to improve grazing land. This paper develops a proposal for evaluation, using a soil fertility survey of seven watersheds combined with botanical observations and published work.

Materials and Methods

Sampling included all land classes in the 7 micro-watersheds, except remnant forest, using stratified random sampling of six fields/land class/watershed, *viz*. lowlands, medium-lowlands and medium-uplands (all cropped to rice), uplands cropped regularly (to vegetables, near homesteads) or occasionally (subsistence crops), and grazed (degraded) upland. Samples (0-10 cm) along diagonals in each field were bulked and analyzed for pH, available P (Bray), K, cation exchange capacity (CEC), and organic carbon (OC) (Walkley-Black). Detailed data for P only are reported. Observations were made on the presence of potential grazing or browse species, and the relevant literature consulted.

We assumed that nutrient cycles in a watershed-ecosystem are essentially closed with subsistence farming. Little fertilizer is used (this is changing) and most of the food produced is consumed internally. The main nutrient export (except N) is in runoff.

Results and Discussion

Available P was generally far below thresholds for plant response (Table 1). Results within land class/watershed were highly variable, confirming Cornish *et al*. (2010) and highlighting the need to generalize cautiously about fertility. Much of this important variability is lost in soil maps that are typically based on coarse grid sampling (*e.g.* 2.5 km grid, Agarwal *et al*., 2010).

Table 1. Available P (Bray, mg/kg). Means of six fields per land class per watershed. Main effects and interaction were P<0.05. Typical threshold values are ~ 9 mg/kg (rice) and ~20 mg/kg (other crops/pastures).

Watershed	**Lowland**	**Med. lowland**	**Med. upland**	**Upland crop** Homestead	**Upland crop** (a) Subsistence	**Grazed upland** Mostly degraded	**Mean**
	Rice lands						
Gumla	1.3	5.0	3.3	4.3	2.9	7.3	**4.0**
Lohardaga	2.1	3.6	2.4	2.5	1.2	3.8	**2.6**
W. Singhbhum	0.4	4.3	na	6.0	5.0	7.6	**5.6**
Khunti	2.1	1.4	0.6	4.8	1.9	1.0	**2.0**
Dumka	1.1	2.3	2.3	22.2	1.1	3.3	**5.4**
Godda	1.7	5.3	1.6	26.6	7.8	4.2	**7.8**
Bankura	1.6	2.1	5.8	2.1	2.3	1.3	**2.5**
Mean	**1.4**	**3.4**	**2.7**	**9.8**	**3.2**	**4.1**	**4.3**

(a) Mostly degraded upland, with subsistence crops receiving no inputs and giving very low yields.

Differences between land classes partly reflect nutrient removal from rice fields (in grain, straw) and their accumulation around homesteads, with some nutrients being redistributed in compost for crops. Also, some dung is collected from grazed areas and used in compost or fuel (fire residues added to compost).

Low P in lowlands reveals the critical need for fertilizer for rice on most fields (little is used), and suggests: (i) long-term P depletion by rice, (ii) farmer-perceptions of fertile lowlands reflect reliable water more than nutrients, and (iii) plants using residual water after rice will be P-limited (confirmed by Cornish *et al*., 2015b). Higher P in medium-lowlands and medium-uplands (cf. lowland) may reflect shorter cropping histories plus deposition of sediment from eroding uplands (originally deposited in lowlands). P in uplands (mean 5.7 mg/kg) was generally higher than where rice was grown (3 mg/kg). In two watersheds, some homestead uplands were cropped with vegetables for market using diammonium phosphate, resulting in higher P (~24 mg/kg).

Other results (not reported) confirmed preliminary findings (Cornish *et al*., 2010) of low pH, marginal K, low CEC and low OC, but in all cases results were variable, especially within land class/watershed. As OC was generally low, we assumed that total N was also low, based on Islam and Weil (2000) who reported C/N ratios in Sal forest soils varied little (P>0.1), from 8:1 (forest) to 12:1 (converted to grassland) and 9:1 (cultivated).

Unsown legumes with grazing or browse potential included various *Acacia*, *Albizia*, *Crotolaria*, *Mucuna*, and *Cajanus*, but it was the ubiquitous annual or short-lived perennial *Desmodium triflorum* that appeared to hold most promise for improved grazing (Anon., 2015), although it was always inconspicuous without improved fertility. Grasses included *Bothriochloa*, *Chrysopogon*, *Cynodon* and *Themeda*.

We suggest that although soils were acid, K was sometimes marginal, and N was undoubtedly low, P is most likely the primary constraint to watershed-ecosystem net primary production, as with other geologically old (nutrient depleted) landscapes (Menge et al., 2012). The omnipresent although inconspicuous forage and browse legumes suggest N is unlikely to be the primary constraint, and for much of the year it is not water (Cornish *et al*., 2015a). Both *D. triflorum* and pulse crops (*Vigna mungo* in uplands) responded strongly to P-fertilizer and had roots with pink Rhizobium nodules, so they have the potential to inject N into the ecosystem provided P deficiency is addressed. Acute P-deficiency evidently limits legume growth and N-fixation across the landscape, and limits animal production.

Any strategy for pasture improvement on the EIP needs to consider the poverty and risk-aversion of farmers and the primary reliance on crops for livelihoods. Wolfe and Lazenby (1972) showed that relatively small inputs of P on grazing land can boost legumes and subsequently increase grass production in mixed pastures, leading to forage of greater quality and quantity. Accordingly, we postulate that P application to uplands will promote indigenous legumes and N-fixation, thus promoting grasses, increasing animal production and injecting N into the ecosystem, ultimately benefiting non-legume crops as nutrients cycle.

Vigna mungo and similar pulses are grown as subsistence crops on uplands with broadcast seed, no fertilizer, and no post-emergence weed management (yields < 0.3 t/ha), but they can be grown profitably with line planting, adequate P-fertilizer (~20 kg P/ha) and hand weeding (yields > 1.5 t/ha) (unpublished data). We suggest that upland pulse cultivation would leave P residues in soil, economically promoting the growth of regenerating indigenous legumes. As small fields of pulses rotate around suitable uplands, soil P will increase, leading to pasture succession (Wolfe and Lazenby, 1972). Greater P inputs will be possible in more developed villages. Grazing can be managed if community institutions are strong (Cornish *et al*., 2015b).

Conclusion

P limits ecosystem productivity. Increasing soil P should initiate ecological succession by promoting indigenous legumes and N-fixation, thus promoting grasses and overall improvement in grazing capacity. For poor risk-averse farmers, P can be increased economically by applying it to pulse (or other) crops rotated around uplands.

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