

Management of calcareous soils of Ushar lands of North Bihar plain

Samar Kumar Gangopadhyay¹, Siladitya Bandyopadhyay^{1*} and Asru Kumar Maitra¹

¹ICAR-National Bureau of Soil Survey and Land Use Planning, Regional Centre, Kolkata, West Bengal 700 091

Calcareous soils of Ushar lands of North Bihar under Indo-Gangetic plain were characterized for their management towards boosting up livelihood security of the farmers of the region. High pH (> 8.5), high calcareousness (> 35%) and low organic carbon (< 0.5%) along with severe flood hazards and siltation are the major constraints for agricultural production. As per the land suitability assessment, crop diversification is highly promising in young alluvial plains. However, in meander plains and active flood plains (Tall lands), there have been certain physical and chemical limitations for crop choices. Makkhana, organized bund fishery and integrated paddy-fishery are the good replacement for sugarcane in meander plains and Tall lands. Mango and litchi plantation is highly promising in young alluvial plains. Char lands (Diara lands) can be grown for rabi vegetables with appropriate soil and water conservation measures. Impact assessment of soil resource inventory based land use plan with best management practice (BMP) has shown an increase in annual net returns by 93.2% and benefit to cost ratio by 20.6% from the traditional land use system with poor level of management.

Keywords: Calcareous soils, Diara, Impact assessment, Land use plan, North Bihar, Tall lands, Ushar

THE Indo-Gangetic Plains (IGP) has been regarded as one of the most fertile lands in India, occupying about 0.7 million km² area of the subcontinent. Its least fertile part is commonly known as *Ushar Bhumi*. In Bihar, *Ushar* lands predominantly occur in Northern, North Western and North Frontier parts of the state. The physiographic sub division is the North Bihar plains and Awadh plains (Extension from Uttar Pradesh). The soils of the region suffer with severe constraints of high pH, high calcareousness, frequent flooding, heavy siltation and impeded drainage situation damaging the crop growth. The four major tributaries of mighty Ganga namely, Gandak, Burhi Gandak, Kosi and Mahananda are responsible for frequent flood hazards and heavy siltation in the region, every year. The sediments carried and deposited by these tributaries from Nepal-Himalayas

are the major causes of formation of salt affected soils. This belt is popularly known for rice-wheat, maize-wheat and maize-maize based cropping systems as the major agricultural practices. Anonymous records for past few decades revealed that there is a sharp decline in productivity of major crops, which has imposed a serious impact on the livelihood security of farmers of the region. Traditional and faulty agricultural practices with low input management might have caused severe physical and chemical degradation of soils, too.

There has been a necessity to look after the causes of soil degradation and to assess suitable cropping practices in the region. Henceforth, a shift is required to new cropping/ plantation/ allied systems from the traditional practices to increase farm level productivity. Soil resource inventory based alternate land use plan can provide the impetus

towards agricultural sustainability to enhance livelihood security of the farmers of the region.

Methodology

The study area is situated in Motihari block of Purvi Champaran district, Bihar, encompassing 23,577 ha area. It represents the agro-ecological sub region of 13.1 i.e., North Bihar and Avadh plains, hot moist sub-humid eco-region with an annual precipitation of 1202 mm. Detailed soil resource inventory was conducted using Sentinel-2 multispectral imageries. Representative soils were selected from different landforms viz., meander plains, young alluvial plains, active flood plains and Char lands (point bars) (Fig. 1). Representative soils were examined for their morphological properties through free survey technique and physical and chemical properties through standard analytical

protocols. The study area has been marked with several ox-bow lakes, covering about 5% of the geographic area of the block. They mostly occurred in low-lying (depressed) areas of meander plains, due to meandering course of the river Burhi Gandak.

It was noted that sugarcane was sporadically grown in active alluvial plains, whereas, maize and wheat were the common crops in young and old alluvial plains. Depressed lands were cultivated for sugarcane and paddy. The farmers get poor economic returns from existing cropping systems because of low input management and soil related constraints. Land Resource Inventory (LRI) based alternate land use options were suggested based on land suitability assessment for crops, plantation and fishery components. Participatory Rural appraisal (PRA) technique was adopted to investigate socio-economic status of the farmers. Data on existing crop yields were collected from farmers' fields. Yield data for crops under best management practices (BMP) were collected from experimental research stations of local Krishi Vigyan Kendra and SAUs. Benefit to cost ratio and net returns from the land use systems were estimated based on standard guidelines of ICAR.

Characteristics of soils of Ushar lands

Meander plains occupy nearly 45% of the total geographic area (TGA) of the block. Soils of meander plains were very deep, somewhat poorly drained, coarse silty (silt loam) in textural class, highly calcareous (CaCO_3 equivalence 35-44%), moderately to strongly alkaline (pH 8.0-8.8), medium in electrical conductivity (EC) (1.8-2.6), medium in organic carbon (0.56-0.72%) and high in base saturation (90-94%). They comprise low available nitrogen (160-270 kg/ha), low available phosphorus (17-19 kg/ha), medium available potassium (185-270 kg/ha) and were deficient in available zinc (0.40-0.55 mg/kg). High calcareousness is the cause of strong alkalinity and deficiency of macro- and micronutrients in soils. Despite these, soils comprise medium EC due to frequent flooding hazards and prolonged submergence of soils with high ground water table due to the flat relief (0-1% slope) of the meander plains. High calcareousness may not be due to stratification of calcium rich silt materials transported by Burhi Gandak river and / or from the runoff from foot hills of Nepal-Himalayas. They were classified as *coarse silty (calcareous) Fluventic Endoaquepts*. Maize, wheat and sugarcane are the common crops grown with low productivity from

national average. Young alluvial plains encompass nearly 33% of the total geographic area of the block. Soils were very deep, somewhat poorly drained, coarse silty (silt loam), moderately calcareous (CaCO_3 equivalence 25-28%), slightly to moderately alkaline (pH 7.6-8.0), low to medium in electrical conductivity (EC) (0.9-1.3), medium to high in organic carbon (0.54-0.88%) and high in base saturation (82-86%). They comprise medium available nitrogen (340-435 kg/ha), low available phosphorus (9-12 kg/ha), medium available potassium (180-190 kg/ha) and were sufficient in available zinc (0.60-0.65 mg/kg). The soils might have formed much earlier than that in meander plains, active flood plains and *char* lands. They occur in relatively higher topographic situation (1-3% slope) than the soils on other landforms. Crop diversification is most promising in this landform. As a consequence, young alluvial soils have better crop productivity as compared to the so called *Tall* lands in the region. They were classified as *coarse silty (calcareous) Typic Haplustepts*. Active flood plains constitute of only 5% of the TGA of the block. They have very deep, somewhat poorly to poorly drained, coarse loamy (sandy loam to loamy sand) soils with slightly alkaline reaction (pH 7.6-7.8), moderate to high calcareousness (28-30%), low to medium organic carbon (0.40-0.54%) and high base saturation (85-98%). The soils comprise low available nitrogen (210-270 kg/ha), low available phosphorus (9-10 kg/ha), medium available potassium (235-245 kg/ha) and were deficient in available zinc (0.50-0.55 mg/kg). Maize and sugarcane are the common crops grown with deprived level productivity due to very frequent flooding hazards. They were classified as *coarse loamy (calcareous) Aquic Ustorthents*. These soils may be compared with popularly known *Tall* lands of Central Bihar (especially in Begusarai district) in terms of similarities in characteristics. maize-wheat, maize-maize and sugarcane are the common cropping systems



Mango and Litchi (Young alluvial plains)



Paddy-fallow (*Tall* lands)



Vegetable farming (*Diara* lands)



Fallow-maize (*Char* lands)

Fig. 1. Major land uses under different landform situation of the study area.

in the region. Only 2% of TGA of the block consists of *Char* lands (Point bars) on the bank of Burhi Gandak river. They have very deep, moderate well to somewhat poorly drained soils with fine silty (silty clay loam) textural class, slightly alkaline reaction (pH 7.6-7.8), moderate calcareousness (15-25%), medium organic carbon (0.54-0.58%) and high base saturation (86-88%). The soils comprise medium available nitrogen (350-430 kg/ha), medium available phosphorus (23-26 kg/ha), medium available potassium (180-235 kg/ha) and were sufficient in available zinc (0.65-0.72 mg/kg). This land is eminent for maize and vegetable cultivation during *rabi* season. This land has quite similarities with popularly known *Diara* lands of Central Bihar as discussed earlier. They were classified as *fine silty (calcareous) Fluventic Haplustepts* (Fig. 2).

Optimizing land use plan

Land suitability assessment for crops and plantation were made based on the FAO guidelines. Soils

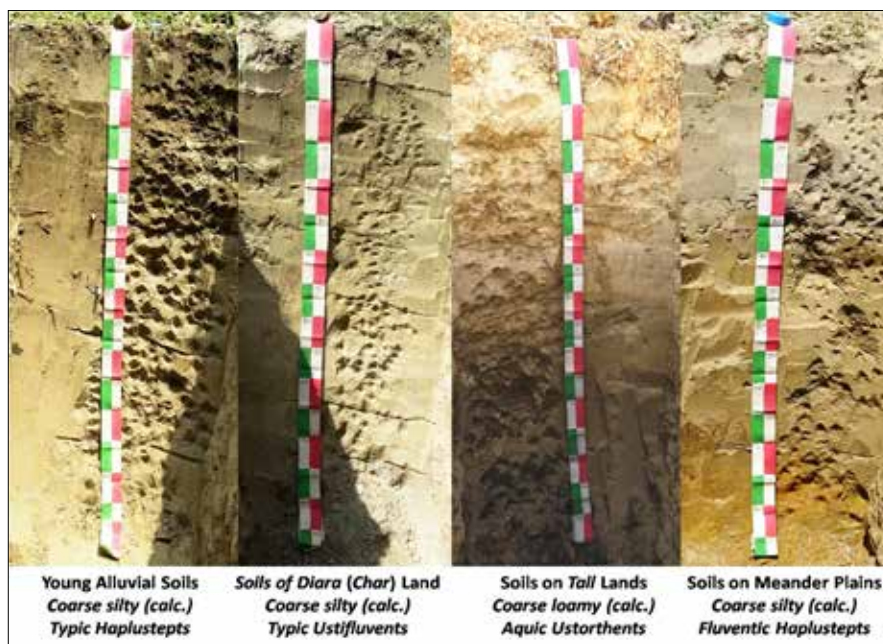


Fig. 2. Representative soils under different landform types of the study area.

on young alluvial plains are suitable for major crops and plants. Rice, wheat, maize, *rabi*-pulses, *rabi* vegetables and guava, mango and litchi are highly suitable in this zone. Soils on meander plains are moderately suitable for wheat, maize (*rabi*) and *rabi* pulses and marginally

suitable for guava, mango and litchi with limitations of high silt content, high calcareousness and high pH. Soils on active flood plains (*Tall* lands) are moderately suitable for wheat and maize (*rabi*) and marginally suitable for *rabi*-pulses and *rabi*-vegetables due to the constraints

Table 1. Major constraints and land suitability assessment of the study area

Landform	Major land use	Constraints	Land suitability with best management practice (BMP)
Meander plains	Paddy-Fallow Maize-Fallow Sugarcane	Moderate to severe flooding, strong soil alkalinity and high calcareousness of soils, low OC, low availability of nitrogen and phosphorus and Zn-deficiency in soils	Paddy- S3fns; Wheat-S2fns; Maize-S2fns; <i>Rabi</i> -Pulses-S3fns; <i>Rabi</i> -Vegetables-S3fns; Makhana-S2fn; Mango/Litchi-S3fnw BMP- Conservation tillage, Ridge and furrow, Recommended dosage + 25% Extra N+P, Zinc sulphate @ 25 kg/ha, Phosphate solubilizing bacteria and Blue Green Algae (<i>Nostoc</i> , <i>Scytonema</i> , <i>Microcoleus</i> sp.) @ 5 kg/ha, FYM @10-15 t/ha.
Young alluvial plains	Paddy-Maize Maize-Maize Maize-Wheat Orchard Plantation (Mango/ Litchi)	Moderate flooding, moderate calcareousness, slight to moderate soil alkalinity, low availability of phosphorus in soils	Paddy-S2fs; Wheat-S1; Maize-S1; <i>Rabi</i> -Pulses-S2fs; <i>Rabi</i> -Vegetables-S2fs; Mango/ Litchi-Guava-S1 BMP- Conservation tillage, Ridge and furrow, Micro-irrigation for <i>rabi</i> crops with low lifting 5 HP pump sets, Recommended dosage of N+P, Zinc sulphate @ 15-20 kg/ha, Phosphate solubilizing bacteria and Blue Green Algae (<i>Nostoc</i> sp.) @ 5 kg/ha, FYM @ 5-10 t/ha.
Active flood plains (<i>Tall</i>)	Fallow-Maize Fallow-Wheat Sugarcane	Severe flooding, strong soil alkalinity and high calcareousness of soils, low OC, low availability of nitrogen and phosphorus and Zn-deficiency in soils	Wheat-S2fns; Maize-S2fns; <i>Rabi</i> -Pulses-S3fns; <i>Rabi</i> -Vegetables-S3fns; Makhana-S2fn BMP- Raised bedded furrow, Micro-irrigation for <i>rabi</i> crops with low lifting 5 HP pump sets, Vegetative mulching, green manuring with <i>Sesbania</i> sp., Recommended dosage + 25% Extra N+P, Zinc sulphate @ 25 kg/ha, Phosphate solubilizing bacteria and Blue Green Algae (<i>Nostoc</i> sp.) @ 5 kg/ha, FYM @10-15 t/ha.
Char lands (<i>Diara</i>)	Fallow- <i>Rabi</i> Vegetables Fallow-Maize	Moderate flooding, moderate calcareousness, slight to moderate soil alkalinity	Wheat-S2fsw; Maize-S2fsw; <i>Rabi</i> -Pulses-S2fsw; <i>Rabi</i> -Vegetables-S1; Makhana-S2f; Mango/ Litchi-S3fnw BMP- Raised bedded furrows, Micro-irrigation for <i>rabi</i> crops with low lifting 5 HP pump sets, Grass vegetative strip, Vegetative mulching, green manuring with <i>Sesbania</i> sp., Recommended dosage of N+P, Zinc sulphate @ 15-20 kg/ha, Phosphate solubilizing bacteria and Blue Green Algae (<i>Nostoc</i> sp.) @ 5 kg/ha, FYM @ 5-10 t/ha.

Land Suitability Classes: S1 - Highly Suitable; S2 - Moderately Suitable; S3 - Marginally Suitable. Limitations: f-soil fertility (OC, NPK, Zn); s-soil physical; (siltation), n-salinity/alkalinity; w-wetness (drainage/flooding).

of high pH, high calcareousness and low organic carbon. *Char* lands (*Diara* lands) are comparatively more fertile than active flood plains and meander plains. Soils on *Char* lands (*Diara* lands) are moderately suitable for wheat, maize, *rabi*-pulses, *rabi* vegetables if raised bedded farming system is adopted. Orchard plantations may also be encouraged in upper terraces of Burhi Gandak river using raised bedded grass vegetative strips (lemon grass) as barrier. The ox-bow

lakes in meander plains can be used for organized bund fishery and may also be encouraged for Makkhana cultivation for boosting economic returns of the farmers. Apart from ox-bow lakes, Makkhana cultivation can also be promoted in scattered water bodies in other parts of the block considering its nutritional quality and high market value in the state as well as in other parts of the country. Although, sugarcane has been grown sporadically in the block, its economic returns are

declining day-by-day. Its market value is also deprived because of lack of industries in the region. Organized bund fishery, integrated paddy-fishery and Makkhana can be the good replacements of sugarcane in the region.

Enhancing livelihood security through impact assessment

Based on constraints and potentialities of soils and land suitability assessment, alternate land use options were suggested

Table 2. Impact assessment of land resource inventory (LRI) based land use plan (LUP)

Landform	Kharif crops	Rabi crops	Kharif yield	Rabi yield	Kharif NR	Rabi NR	Annual NR	Average BCR
<i>Traditional/ Existing land Use Systems (Low Input Management)</i>								
Meander plains	Paddy	Maize	1.45	3.00	16750	24400	41150	1.73
	Maize	Maize	2.50	3.00	20333	24400	44733	2.25
	Sugarcane		60.90		43070		43070	1.86
Young alluvial plains	Paddy	Maize	1.73	3.00	19984	24400	44384	2.03
	Maize	Maize	2.50	3.00	20333	24400	44733	2.25
	Maize	Wheat	2.50	2.00	20333	22925	43258	2.13
	Mango/ Litchi		63.30		44100		44100	1.88
Active flood plains (<i>Tall</i>)	Fallow	Maize	--	3.00	--	24400	24400	1.67
	Fallow	Wheat		2.00	--	22925	22925	0.97
	Sugarcane		60.90		43070		43070	1.86
Char lands (<i>Diara</i>)	Fallow	Vegetables	--	5.25	--	43633	43633	2.43
	Fallow	Maize	--	3.00	--	24400	24400	1.67
Average							38655	1.89
<i>Land Resource Inventory based Alternate Land Use Options with Best Management Practices (BMP)</i>								
Meander plains	Paddy	Maize	2.00	3.50	23103	34825	57928	2.06
	Black gram	Wheat	0.98	2.50	19700	23875	43575	2.07
	Pigeonpea	Lentil/ Pea	0.95	1.12	20735	21990	42725	2.18
	Black Gram	<i>Rabi</i> -Veg.	0.98	6.13	19700	57750	77450	2.92
	Mango/ Litchi Plantation		9.80		49000		49000	2.00
	Makkhana (Water bodies)		1.53		81000		81000	2.22
Young alluvial plains	Pigeonpea	Maize	0.95	3.50	20735	34825	55560	2.04
	Maize	Lentil/ Pea	3.00	1.12	24400	21990	46390	2.13
	Black gram	Wheat	0.98	2.50	19700	23875	43575	2.07
	Paddy	<i>Rabi</i> -Veg.	2.00	8.35	23103	90750	113853	2.83
	Mango/ Litchi Plantation		12.10		60500		60500	2.45
Active flood plains (<i>Tall</i>)	Makkhana (water bodies)		1.53		81000		81000	2.22
	Integrated Paddy-Fishery		4.80		166300		166300	2.39
	Pigeonpea	Maize	0.95	3.50	20735	34825	55560	2.04
	Pigeonpea	Lentil/ Pea	0.95	1.12	20735	21990	42725	2.18
Char lands (<i>Diara</i>)	Black gram	<i>Rabi</i> -Veg.	0.98	10.13	19700	111430	131130	2.92
	Pigeonpea	Maize	0.95	3.50	20735	34825	55560	2.04
	Pigeonpea	Lentil/ Pea	0.95	1.12	20735	21990	42725	2.18
	Makkhana (water bodies)		1.53		81000		81000	2.22
	Integrated Paddy-Fishery		4.80		166300		166300	2.39
Average							74693	2.28
Increase in Annual NR with respect to Existing Land Use								93.2%
Increase in B: C Ratio with respect to Existing Land Use								20.6%

Yield (t/ha); NR- Net Returns (Rs./ha/Year); BCR-Benefit to cost ratio (Annual Average).

with best management practices (Table 1). Impact analysis was made by comparing the B: C ratio and net returns from LRI based land use options with the existing traditional land use systems (Table 2). It was noted that average annual net returns for the farmers under existing system of land use with low input management was ₹38,655 with average annual benefit to cost ratio of 1.89 only. When, LRI based alternate land use options are adopted with best management practices (BMP), the farmers receives the plentiful options of crop diversification and amalgamation of crops with fishery and other allied components. The LRI based land use plan (with BMP) resulted an annual net returns (NR) of ₹74,693 with annual average B: C ratio of 2.28. As a consequence, impacts on net returns and B: C ratio over existing

land use was revealed as 93.2% and 20.6%, respectively. Keeping in mind the diminishing returns from sugarcane in the region, the cash crop can be replaced by promoting Makkhana, organized fishery and integrated paddy-fishery in water bodies and low-lying depressed lands of meander plains, *Tall* and *Diara* lands. The results revealed that LRI based agricultural land use plan with best management practices would give rise to sharp enhancements in annual income of farmers towards boosting up farmers' livelihood and maintaining a steady agricultural sustainability in the region without compromising soil health.

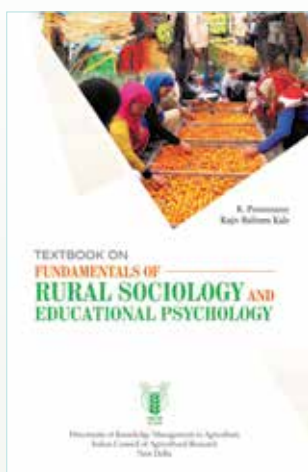
SUMMARY

Calcareous soils of *Ushar* lands of North Bihar under Indo-Gangetic plain were characterized for their

management. High pH (> 8.5), high calcareousness (> 35%) and low organic carbon (< 0.5%) along with severe flood hazards and siltation are the major constraints for agricultural production. As per the land suitability assessment, crop diversification is highly promising in young alluvial plains. However, in meander plains and active flood plains (*Tall* lands), there have been certain physical and chemical limitations for crop choices. Impact assessment of soil resource inventory based land use plan with best management practice (BMP) has shown an increase in annual net returns by 93.2% and benefit to cost ratio by 20.6% from the traditional land use system with poor level of management.

*Corresponding author's e-mail: siladityabandyopadhyay@gmail.com

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TECHNICAL SPECIFICATIONS

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