Sustainable rehabilitation, bridging yield gaps and increasing farmers’ income in salt affected rice–wheat agroecosystems: A farmers’ participatory assessment

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INTRODUCTION

With shrinking land resources, sustainable restoration of degraded lands is vital to ensure food security and address livelihood concerns in arid and semi–arid regions worldwide. Continuous use of bicarbonate dominated poor quality water results in the build–up of sodium saturated soil colloids and dispersion of clay particles causing soil sodicity/alkalinity problems and negatively impacting agricultural productivity. To improve current understanding and stabilize crop production, it is imperative to assess the farmers’ traditional salinity management strategies and also develop a climate resilient integrated soil–crop management system to harness the potential of salt–affected soils.

METHODOLOGY

The present study focuses on small–scale production systems in sodicity–affected Ghaghar basin of Kaithal district in Haryana (India) where input–intensive, highly mechanized rice–wheat rotation is followed for more than two decades (Figure 1). Five villages adopted under CSSRI Farmer FIRST Project were purposively selected on account of prevalence of sodic soils (40% area; soil pH>8.5) and high residual alkalinity in groundwater (90% area; RSC_{iw}>2.5 me L^{-1}) (Fig 1).

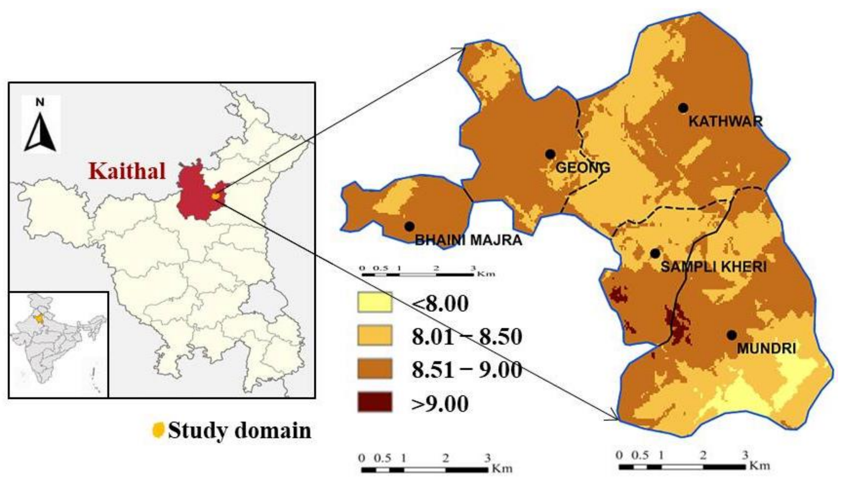


Fig. 1 Extent and distribution of soil sodicity in salt-affected Ghaghar Basin of Haryana
Location: 29.762°–29.838° N and 76.426°–76.518° E

To validate the synergy among selected management practices and their associated impact in alleviating the sodicity stress and improving plant physiological relations, yield traits and economic feasibility; paticipatory trials were conducted at farmers’ fields representing variable sodicity stress (soil pH: 8.56–9.52; RSC_{iw}: 2.6–6.1 me L^{-1}).

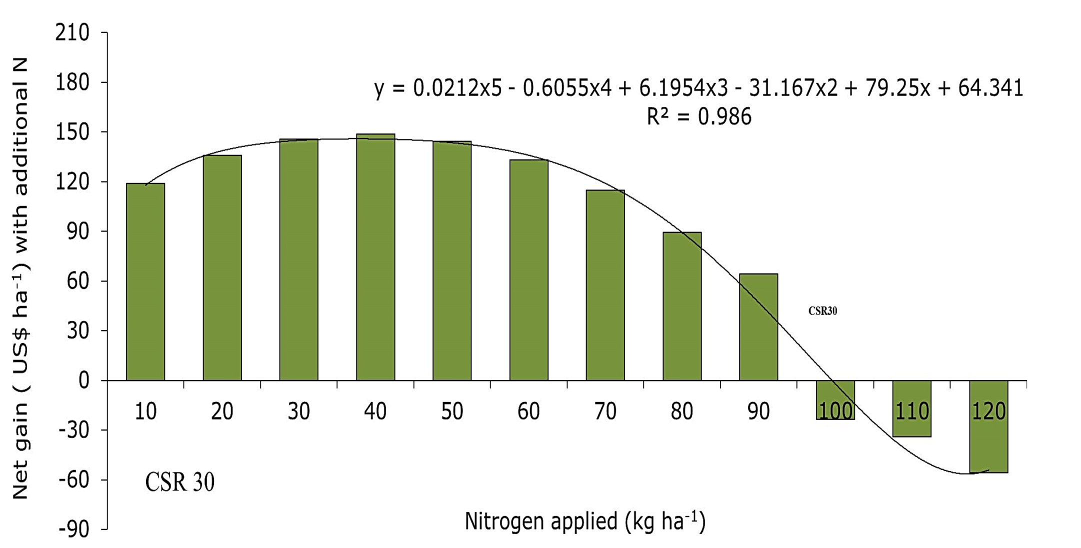
Table 1. Catalogue of management practices in rice-wheat rotation.

Management practices	Reclamation amendments†	Variety	Planting techniques	Fertilizer management	Weed Management
FMPs	GR_{50} mediated soil amelioration	Rice: CSR 30 Wheat: HD 2967	Rice: 1 seedling hill^{-1}, random planting (18–25 plants m^{-2}) Wheat: Conventional/zero–till/broadcasted using 100–120 kg seed ha^{-1}	Rice: 96.7–0–5 kg N–P–Zn ha^{-1} Wheat: 175–26 kg N–P ha^{-1}	Rice: Pretilachlor @ 1 kg ha^{-1} within 2–3 DAT Wheat: Tank mix application of 2–4 times higher dose of post–emergence herbicides 35–75 DAS
GMPs	GR_{50} mediated soil amelioration	Rice: CSR 30 Wheat: KRL 210	Rice: 2 seedlings hill^{-1}; 20 × 15 cm spacing Wheat: Zero–till sown (22.5 cm row spacing) using 125 kg seed ha^{-1};	Rice: 75–13–5 kg N–P–Zn ha^{-1} Wheat: 150–26 kg N–P ha^{-1}; foliar sprays of 1 kg K ha^{-1} each at 5–10% heading and 15–20 days of first spray –50 kg N–P–K ha^{-1}	Wheat: Sequential application of pendimethalin at 1.5 kg ha^{-1} after sowing with clodinafop 60 g/pinoxaden 50 g ha^{-1} at 35–40 DAS
MMPs	$GR_{25}+PM_5$ mediated soil amelioration	Same as GMPs	Same as GMPs	Rice: 90–13–5 kg N–P–Zn ha^{-1} Wheat: 172–26 kg N–P ha^{-1}; foliar sprays of 1 kg K ha^{-1} each at 5–10% heading and 15–20 days of first spray	Same as GMPs

FMPs: farmers’ management practices; BMPs: best management practices, MMPs: matching management practices; †reclamation amendments were applied only in rice crop before transplanting; GR_{50}: soil sodicity (pH)–based 50% gypsum requirement; $GR_{25}+PM_5$: soil sodicity (pH) and irrigation water residual alkalinity (RSC_{iw})–based 25% gypsum requirement + pressmud at 5 t ha^{-1}

RESULTS

- Sodic soils amelioration with $GR_{25}+PM_5$ accelerated the reclamation process, improved plants salt tolerance and enhanced rice–wheat system performance by 26% compared to unamended control and by 5% over GR_{50}.
- Curve Expert model revealed genotypic variation in N requirements attaining economic optima at 90 kg ha^{-1} in CSR30 Basmati, 140 kg ha^{-1} in PB1121, 173 kg ha^{-1} in KRL210 and 188 kg ha^{-1} in HD 2967.
- Transplanting rice using 2 seedlings hill^{-1} at 20 × 15 cm spacing, managing multiple resistance in *Phalaris* minor through sequential herbicides and foliar K–nutrition in wheat maximized opportunities for optimal resource–use and sustainably enhance yields and profit margins compared to farmers’ practice of randomly transplanting one seedling hill^{-1}, sole dependency on post–emergence herbicides and ignorance to foliar K fertilizers.
- Integrated approach involving gypsum and pressmud–mediated sodic land reclamation, use of stress tolerant varieties and crop–specific agronomic manipulations (denser planting, balanced nutrition, effective weed control) in rice–wheat system displayed appreciable reductions in soil sodification, improved plant physiological and growth traits, and enhanced system yields, profit margins and benefit:cost ratio (8.29 t ha^{-1}, 2103 US$ ha^{-1} and 3.21) in comparison to existing recommendations (7.86 t ha^{-1}, 1943 US$ ha^{-1} & 3.05) and farmers’ practices (6.63 t ha^{-1}, 1503 US$ ha^{-1} & 2.60), respectively.



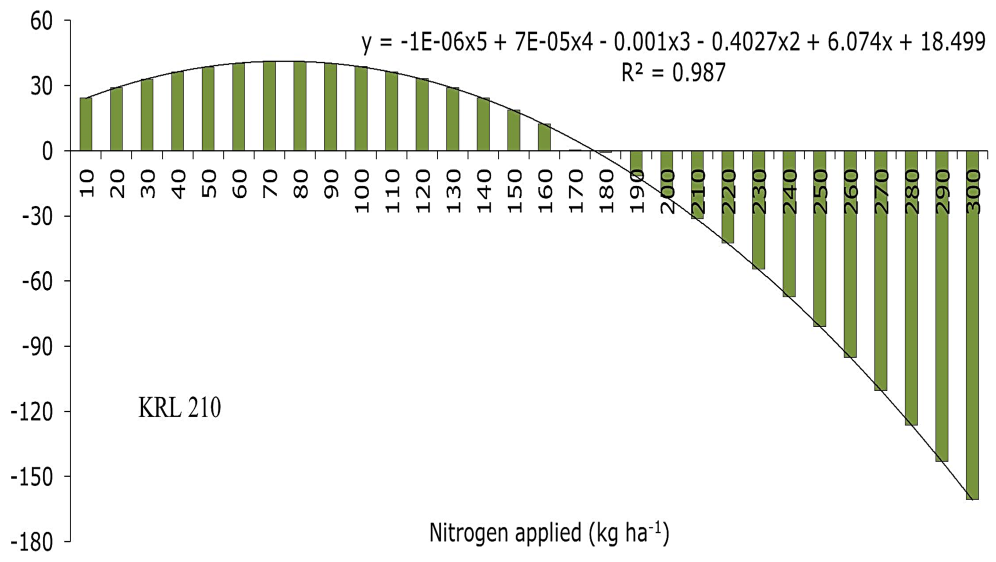


Table 2. System productivity and economic analysis of management practices.

Parameters	FMPs	BMPs	MMPs
Grain yield (t ha^{-1})			
Rice	2.86^{c}	3.35^{b}	3.54^{a}
Wheat	3.77^{c}	4.51^{b}	4.75^{a}
Rice–wheat system	6.63^{c}	7.86^{b}	8.29^{a}
Economic indicators‡			
Variable cost (US$ ha^{-1})	429	437	438
Total cost (US$ ha^{-1})	942	950	951
Gross margins (US$ ha^{-1})	1503^{c}	1943^{b}	2103^{a}

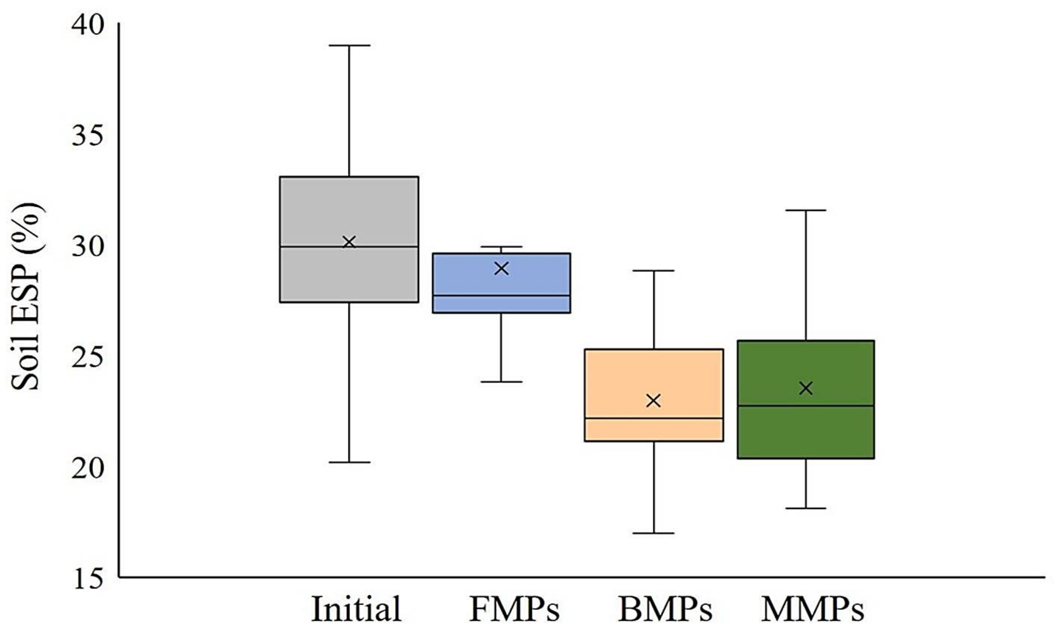


Fig. 2. Changes in soil ESP in response to management practices.

CONCLUSIONS

This study highlights the need of devising ecosystem–based approach involving combinations of genetic tolerance with affordable soil, crop and nutrient management practices in alleviating the sodicity stress, bridging yield gaps with optimal resource use, socio–economic development and eventually achieving the UN–SDGs of land degradation neutrality, food security and environmental protection. Sustainable use of sugarcane pressmud compensating 25% gypsum requirement provided an affordable alternative for reclaiming sodic soils. Yield enhancement with added N beyond the existing recommendations suggests upward revision and corrective N applications to compensate sodicity stress. Effective management of resistant *Phalaris minor* weed through sequential use of herbicides and foliar–K nutrition provided affordable options to sustainably enhance wheat yields compared to farmers’ dependency on post–emergence herbicides and ignorance to foliar fertilizers.

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