

Empowering farmers through selective interventions in salt affected agro-ecosystems of Ghaghar plains

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Location

Sodicity affected villages, viz. Mundri, Geong, Kathwar, Sampli Kheri and Bhaini Majra of the district Kaithal, Haryana were purposively selected for the CSSRI led Farmer

FIRST project. Cropping systems included Rice–Wheat and Sugarcane–Sugarcane-Wheat (2 year rotation). The households of the area included marginal and small (2255), medium (87), and large (26)

households. Out of this, 1-2 farmers were in pisciculture and 1-3 in commercial dairy in each village and almost 90% of the total households (3167) reared milch animals.

NRM based module

Delineation and assessment of salt affected soils and water quality in salt affected Ghaghar plains in Haryana

Spatial variability assessment of soil fertility status using GIS technique

Drainage-cum-recharge structure for augmenting groundwater and improving its quality by harvesting excess rainwater into aquifer

Pressmud application in rice-wheat system for the management of sodic soils and high RSC waters

Integrated use of gypsum and pressmud in rice-wheat system for the management of sodic soils and high RSC waters

- Geo-referenced digital thematic maps delineating soil sodicity (soil pH) and residual alkalinity (RSC) in irrigation waters were prepared.
- Out of total 3247 ha area, about 40.1% area was sodicity (soil pH>8.2) affected [Sampli Kheri (53.5%) > Geong (42.6%) > Kathwar (40.9%) > Bhaini Majra (40.2%) > Mundri (33.5%)].
- Bicarbonate dominated irrigation water residual alkalinity (RSC>2.5 me/l) was a major problem in nearly 90% area (62.7% alkali, 17.4% marginally alkali and 9.2% highly alkali).
- Nitrogen was deficient (<250 kg N/ha) in whole area while 27.1% area had deficient organic carbon (<0.4%). Phosphorus was in medium to high (10-20 kg/ha) range while available K was high (>110 kg K/ha).
- Nearly half of the area was deficient in available zinc (<0.6 ppm Zn) while B deficiency (<0.5 ppm) was quite critical in 87% area. Iron (≥ 18 ppm Fe), manganese (≥ 3.5 ppm Mn) and copper (≥ 0.4 ppm Cu) was in sufficient to high range.
- 334 Soil health cards (SHCs) had been digitized in the form of an ICT-based user friendly mobile app Salinity Expert under 'Mitti avum Jal Prikshan Vishleshan'- a Login ID (Aadhaar/ Mobile) enabled SHC including farmers' basic information, soil fertility and water quality status.
- Six cavity type individual farmer's based recharge structure were installed in low lying areas for managing the localized drainage and saving the submerged crops particularly during the periods of intense rains.
- Rise in water table to an extent of 2-3 m beneath the structure during monsoon months. Improved water quality as a consequence of reduction in RSC by 2-3 meq/l.
- Heavy rainfall (≈ 150 mm) events resulted in 35-40% crop damage in open-fields while only 5-15% damage where recharge structure was installed, significantly decreasing the additional cost towards re-transplanting and compensated the yield losses.
- Though the initial capital investment cost was relatively high, but lesser payback period (2 years) and significantly higher IRR (145), BCR (1.93) and NPV (13% higher) indicated the economic feasibility of investment on recharge structure.
- 14% yield enhancement in system productivity with pressmud (PM) application @ 10 t/ha [Range: 8.9% (soil pH₂<8.25) to 18.2% (soil pH₂>9.25)].
- Despite added cost of ₹ 6730/ha incurred towards PM application, the rice-wheat system provided incremental income of ₹ 10961/ha with an incremental input-output ratio of 2.62.
- PM amelioration complemented towards reduction in RSC water induced soil sodicity (average soil pH₂ ≈ 8.64 , N=105), which otherwise could have increased to 8.89 with unamended control (farmer's practice) as against the initial soil pH₂ of 8.77
- 16% yield enhancement in system productivity with integrated use of gypsum (GR₂₅) + pressmud @ 5 t/ha [Range: 8.5% (soil pH₂<8.25) to 23.9% (soil pH₂>9.25)].
- Despite added cost of ₹ 6,998/ha, incremental income of ₹ 13,226/ha was recorded with an incremental input-output ratio of 2.89.
- Integrated use of gypsum (GR₂₅) + pressmud @ 5 t/ha PM complemented towards reduction in RSC water induced soil sodicity (average soil pH₂ ≈ 8.62 , N=44), which

	otherwise could have increased to 8.93 with unamended control (farmer's practice) as against initial soil pH_2 of 8.79.
Crop based module Crop/variety diversification for sustainable yield in sodic agro-ecosystems: Adaptation of salt tolerant wheat variety KRL 210	• Problematic soils having soil $pH_2 > 8.7$ irrigated with high RSC waters ($RSC \geq 4.0$ meq/l) should be cultivated with salt tolerant wheat variety KRL 210 to counter yield reduction under salty environments. • Overall yield advantage of 4.13% with KRL 210 (N=308) under sodic conditions with 5-7 days earliness, higher per day productivity, better factor (fertilizer N) productivity and chapatti quality as well as tolerance to water stagnation in comparison to traditional HD 2967. • Lesser yield reduction (770–1100 kg/ha) with KRL 210 for each unit increase in soil pH_2 compared to HD 2967 (1,300–1,590 kg/ha). The corresponding decrease in yield to the tune of 292–328 kg/ha was observed in KRL 210 for each unit increase in RSC as against the 372–479 kg/ha in HD 2967.
Crop/variety diversification for sustainable yield in sodic agro-ecosystems: Adaptation of salt tolerant rice variety CSR 30 Basmati	• Farmers should be advocated to cultivate salt tolerant CSR 30 Basmati in problematic soils having soil $pH_2 > 8.3$ and irrigation water with $RSC > 3.5$ me/l for sustainable yield production and profitability margins under sodic environments. • Lesser yield reduction of 726–922 kg/ha equivalent to ₹ 28,863–36611/ha with CSR 30 Basmati (N=580) was recorded for each unit increase in soil pH_2 compared to Pusa 1121 (1298–1454 kg/ha with ₹ 45,127–49293/ha). Furthermore, for each unit increase in RSC, the economic loss was lesser i.e. ₹ 7,278–8,456/ha in CSR 30 basmati compared to ₹ 11,241–13404/ha in Pusa 1121.
Managing reproductive sterility through boron (B) application in rice	• Boron deficiency was critically higher in $\approx 90\%$ of the total area (3,247 ha). • B application helped in managing the reproductive sterility. Soil application of boron @ 2.5 kg/ha through borax (20% B) provided 2% ($B > 0.5$ ppm, medium) to 3.7% ($B < 0.25$ ppm, extremely low) yield advantage compared to no-B application (farmer's practice) resulting in 4.7% increase in profitability (net returns).
Role of optimum plant population for sustainable rice yield under sodic agroecosystems	• The optimum plant population plays very important role under salt affected soils where the seedling mortality rate remains relatively higher compared to normal conditions for getting satisfactory yield levels. • In farmer's managed plots (random planting and 1 seedling/hill), the final plant population remained only $\approx 56\%$ of the optimum (33 plants/m²). However, crop transplanted under improved practice (20 × 15 cm and 2 seedlings/hill) had 82% plant population of the optimum. • Yield advantage to the tune of 9 to 25% (N=7) with a mean value of 16% and incremental input-output ratio of 5.95 for each rupee invested towards managing optimum plant population was observed under improved practice.
Leaf colour chart (LCC) based N management in rice-wheat system	• Farmers are using comparatively higher fertilizer N in both rice (195–253 kg N/ha) and wheat (165–224 kg N/ha) crops. LCC based N management provided 17 and 19% savings in fertilizer N use in rice and wheat, respectively compared to farmer's practice. • LCC based N management had better NUE of 38 and 31 kg/kg N applied in rice and wheat, respectively as against the 32 and 25 kg/kg N applied under farmer's practice.
Herbicide based weed management for the control of resistant Phalaris minor in wheat	• About 68% of the farmers use more than the recommended dose (X) of herbicides while half of the farmers apply double dose (2x) and 4% even apply three times (3x) of recommended dose. • Improved technological interventions (N=156) including PE application of pendimethalin @ 2 lt/acre followed by post-emergence application of recommended herbicide (clodinafop/pinoxaden at recommended dose) resulted in better weed control efficiency and improved wheat yield by 6% over the farmer's practice (2–3 times higher dose of recommended herbicides).
Role of potassium (K) application in enhancing wheat yield under sodic environments	• Foliar spray of K (0:0:50) done at 5–10% heading and 15–20 days of first spray in wheat resulted in 4620 kg/ha wheat yield as against the 4469 kg/ha yield obtained under farmer's practice (absolute control) indicating 3.38% yield superiority over the later. • The per cent yield increase due to K application ranged between 2.1 (soil $pH_2 < 8.25$) to 4.8% (soil $pH_2 > 9.25$) for variable soil sodicity. • Economic analysis revealed additional returns of 2,103 ₹/ha and incremental benefit-cost ratio of 3.12 for each rupee invested toward the cost of K application in wheat.
Mechanization based module SSMS based rice residue management in rice-wheat cropping system	• The <i>in situ</i> disposal of paddy residue has turned out to be a huge problem due to short time span (hardly 10–15 days) between rice harvesting and wheat seeding is hardly 10–15 days, enforcing farmers to opt for open-field burning of crop residues. More than 90% area under rice crop is mechanically harvested. • A total of 185 ha of land was harvested with the SSMS equipped combine harvester saved 6.32 tonnes of N, 0.58 tonnes of P_2O_5, 3.75 tonnes of K and 0.54 tonnes of S. In addition, 1890.7 tonnes of CO_2, 77.7 tonnes of CO, 2.6 tonnes of SO_2 and 3.9 tonnes of PM might have generated in farmer's practice (open-field rice residue burning).
Direct wheat seeding with happy seeder in rice-wheat cropping system	• Use of happy seeder resulted in timely sowing of wheat and had lesser incidence of Phalaris minor, required less water and encountered less crop lodging under aberrant weather situations. • About 3% higher yield was recorded with happy seeder sown wheat (N=30) compared to conventional wheat sowing (4285 kg/ha).
Horticulture based module Diversifying rice-wheat system through	• Total crop growth duration under diversified cropping system including short duration

vegetables for sustainable yield under sodic agro-ecosystems

Enterprise based module

Entrepreneurship through aquaculture in sodic environments

vegetables [rice (PB 1509)-pea (Kashi Ageti)-okra (Kashi Kranti)] increased to 299 days as against 267 days under traditional rice (CSR 30 Basmati)-wheat (HD 2967) system.

- Diversifying rice-wheat cropping system (N=4) through short duration vegetables (pea and okra) in place of wheat resulted in 24.4 t/ha of wheat equivalent yield (WEY) with production efficiency (PE) of 81.7 kg/ha/day and net returns (NR) of 3.0 lakh/ha in comparison to 15.3 t/ha WEY, 57.5 kg/ha/day PE and 1.97 lakh/ha NR obtained under traditional rice-wheat cropping system.
- Aquaculture is an appropriate alternative land use option in areas having relatively low production, excavated/low lying areas and sodic areas. Fish (Catla and Rohu) production of about 2231 kg (₹ 1,78,500) and seed of ₹ 53,000 from the diversified farming generated net revenue of ₹ 54,692 with a B:C ratio of 1.3. If the same area would have been cultivated with traditional rice-wheat system with business as usual, it would have generated only ₹ 52,000-60,000 owing to its low productivity. Economically, the returns from the fish farming matched the traditional cropping system in the first year of technological inception.

SUCCESS STORY

Vegetable based diversified farming enhanced farm profitability under sodic environments

Shri Pyarelal Singh is an innovative farmer from Kathwar village of Kaithal district in Haryana state. Mr. Singh owns 4.5 acres of land and cultivating field crops such as rice, wheat, fodder sorghum and berseem, and rearing 3 milch

animals. He is a hardworking and progressive farmer who motivated himself to take new initiative of diversifying the traditional system including short duration vegetables in marginal sodic soils and improve his farm profitability. For the business as usual (farmer's practice), Shri Pyarelal would have



Name	: Pyarelal
Age	: 58 years
Land holding	: 4.5 acres
Specialization	: Crop diversification, resource conservation technologies

opted for cultivating 4 acre of land with traditional rice (CSR 30 Basmati)-wheat (HD 2967) system, and reaming half acre under sorghum-berseem sequence for fodder requirement of animals. To explore the bio-economic feasibility through vegetables and confidence building, only one acre of land was put under crop diversification replacing traditional CSR 30 Basmati with short duration PB 1509 and wheat with short duration vegetables. Within occupied area, cereal (rice-garden pea-onion) and fodder (sorghum-cauliflower-okra) based cropping sequences were designed in such a way that need based household and fodder requirements of the concerned farmer be fully justified without much variation from the traditional farming practice.

Under diversified cropping sequence (2017-18), after the harvest of *kharif* sown early maturing rice (PB 1509), garden pea (Kashi Ageti) was sown on Oct 13 on half acre of land and harvested on Dec 25, 2017. Later, onion seedlings (L 28) were transplanted on 15 Jan and harvested on May 25, 2018. Mr. Singh also gained additional monetary benefits through the sale of onion seedlings to the neighbouring farmers. On another half acres of land, he took fodder sorghum as the first crop in *kharif* season for fodder purpose, later transplanted cauliflower (hybrid) seedlings on 25 Oct, 2017. After cauliflower, okra (Kashi Kranti) was sown on Mar 5 and harvested on June 8, 2018. The same cropping sequence was followed during 2018-19. All the crops were grown with recommended package of practices with regular consultation/guidance from CSSRI experts.

Most of the cultivated vegetables were sold at the farm itself to the retail vendors besides meeting his household requirements. The economic analysis of diversified cropping sequences *vis-a-vis* traditional rice-wheat system is presented in Tables 1 and 2. An additional expenditure of ₹ 40,885 was incurred towards diversifying one acre area with vegetables as against the traditional farming of cultivating rice and wheat crops in sequence on total 4.5 acres of land. However, an additional income of ₹ 1,11,903 was generated with incremental benefit cost ratio of 3.74 for each rupees incurred towards the cultivation of vegetable crops compared to traditional rice-wheat system. Further, the productivity of partially diversified system remained 63.2 q/ha as against the 43.6 q/ha with traditional farming practice (Table 2). The production efficiency was quite high (1.86 q WEY/ha/day) compared to 0.86 q WEY/ha/day under the traditional rice-wheat system.

For enhancing income of reclaimed or marginal sodic lands irrigated with alkali water, vegetable based partial crop diversification module was synthesized at farmer's field under Farmer FIRST Project. Out of total 4.5 acres land area, only one acre was converted into vegetable and fodder based diversified cropping systems depending on the farmer's resource base and family size/labour availability. Two crop sequences including short duration vegetables in cereal (rice-garden pea-onion) and fodder (sorghum-cauliflower-okra) based cropping systems enhanced productivity and profitability margins with an additional income of ₹ 1,11,903 and incremental benefit cost ratio of 3.74 for each rupees incurred towards the cultivation of vegetable crops compared to traditional rice-wheat system.

SUCCESS STORY

Aquaculture in sodic environments: A step towards prosperity

Crop diversification, in which the farmers' resources are re-allocated to various farming activities, reduces risk arising due to changing consumer demands, changing demographics and external environmental shocks. Fish production in India has great potential and proves to be holding more offers in generating employment opportunities, especially in rural areas and strengthen the rural economy. Aquaculture is an appropriate alternative land use option in areas where there is relatively low production of the other crop systems like wheat and rice.



Name : Naseeb Singh
Age : 38 years
Land holding : 4.5 acres
Specialization : Crop diversification, Fish farming

Frequent discussions with Mr. Naseeb Singh, a farmer from Sampli Kheri, Kaithal motivated himself to taking up fish farming as a mean of crop diversification. The selected area was relatively giving relatively lesser yields (40% of normal) because of the excavated 8-10 feet top soil and native soil sodification. The farmer constructed three ponds covering an area of about 1.6 acre (2 small of size 0.4 acre and one large of 0.8 acre). The available land area was designed in such a way that the reoriented smaller ponds could serve as nursery ponds and the large one as grow-out pond. The farmer was also trained at ICAR-CIFE Regional Station, Rohtak (Haryana) to get acquainted with latest fish farming practices.

Carp spawn (Catla and Rohu) was stocked (1 lakh spawn/acre) into nursery ponds in August, 2018. After four months of growth, the fingerlings were transferred into the grow-out pond. The plankton growth was sufficient to meet the demands of spawn for the one-month post-stocking. Since the natural production of fish food organism does not meet the total food requirement of the stocked spawn, supplementary feeding was done with locally available mustard and soybean cake, rice and wheat polish. Due to the onset of winter season, the feeding rate was reduced accordingly.

The total fixed cost incurred towards leveling of land and construction of ponds was relatively high (₹ 111,700). The farmer sold about 2,231 kg of fish (₹ 178,500) and seed of ₹ 53,000 was generated over a period of one year. The net revenue generated from the diversified farming system was ₹ 54,692 with a B:C ratio of 1.3. If the same area would have been cultivated with traditional rice-wheat system with business as usual, it would have generated an income of about ₹ 52,000-60,000 owing to its low productivity. Economically, the returns from the fish farming matched the traditional cropping system in the first year of technological inception. The aquaculture intervention in degraded lands has been quite advantageous and the production and profitability margins will certainly increase in future culturing more diversified ecosystem with horticulture and vegetables (on dykes) along with traditional farming.

Livestock based module

Enhancing conception rate in dairy animals using artificially inseminated good quality semen

Enhancement of reproductive performance during heat stress using proven bull semen and supplementing mineral mixture

Effect of mineral mixture supplementation to repeat breeder buffaloes

Amelioration of heat stress for enhancing growth and milk production through supplementation of astaxanthin, prill fat and their combination

- Low conception rate due to poor quality of semen/natural service and reproductive problems in buffaloes/cattle is a major livestock problem under field conditions.
- Artificial insemination (N=107) using good quality cryopreserved semen straws procured from NDRI, Karnal enhanced overall successful conception rate of 49% in comparison to ≈ 30-35% under traditional practice.
- Lower growth rate, conception rate and other reproductive problems in animals are related to non-availability of good quality semen and imbalanced rationing.
- Breedable bovine (Cattle-49 and buffalo-259) were inseminated at the proper time of estrus (heat) using the proven bull semen from NDRI, Karnal and subsequently supplemented with mineral mixture @ 50-60 g/day/animal for 3 months. Inseminated animals (checked through rectal palpation) resulted in overall conception rate of ≈ 51%.
- Feeding of area specific mineral mixture is of paramount importance for enhancing reproductive performance of repeat breeders. 18 repeat breeding buffaloes were supplemented with mineral mixture @ 50-60 g/day for three months.
- Conception rate in artificially inseminated animals was 22, 43 and 25% after one, two and three months, respectively. The overall conception rate was ≈ 66%.
- 40 lactating buffaloes (first to fourth parity) were divided into four groups, viz. control (Group-I), astaxanthin supplementation @ 0.25 mg/kg body wt/day (Group-II), prill fat supplementation @ 100g/animal/day (Group-III) and combination of astaxanthin + prill fat (Group-IV).
- The milk yield increased by 5.4% for Group-II, 13.8% Group-III and 15.6% Group-IV over the control, respectively. Combination of astaxanthin and prill fat have additional benefit over the prill fat i.e. improved health and milk yield, but the higher C: B ratio of 1:6.8 with

prill fat supplementation @ 100 g/animal/day (₹ 80/kg) showed its economic feasibility over the combination of astaxanthin + prill fat (1:2.6) owing to higher cost of astaxanthin (₹ 12,500/kg).

Knowledge based module

Mobile enabled decision support system for sodic agroecosystems

'Salinity Expert' is an ICT-based initiative towards 'Digital India' with aim to fast track the dissemination of doable salinity management technologies to the farmers. This is user friendly innovative digital tool compatible with android mobile operating systems. The entire information app is available in Hindi language and can be freely downloaded from the Google play store.

Table 1. Overall income enhancement of farmers of different categories and overall in the village over bench mark

Technological intervention	Net returns (₹/ha)		Per cent increase
	Farmer's practice	Improved practice	
Groundwater recharge structure (considering 5 ha vulnerable area)	69,588	84,738	21.8
Gypsum (GR ₅₀) based management of sodic soils irrigated with high RSC waters in rice-wheat system	97,816	1,14,556	17.1
Press mud (10 t/ha) based management of sodic soils irrigated with high RSC waters in rice-wheat system	85,545	1,05,769	23.6
Gypsum (GR ₅₀) + Pressmud (5 t/ha) based management of sodic soils irrigated with high RSC waters in rice-wheat system	93,261	1,10,907	18.9
Popularization of salt tolerant wheat variety KRL 210 in sodic agroecosystems (soil pH ₂ ≥8.7)	40,327	44,839	11.2
Popularization of salt tolerant rice variety CSR 30 Basmati in sodic agroecosystems (soil pH ₂ ≥8.5)	62,951	70,838	12.5
Role of optimum plant population for sustainable rice yield under sodic agroecosystems	72,500	88,760	22.4
Managing reproductive sterility through boron (B) application in rice	82,477	86,314	4.7
Herbicide based weed management for the control of resistant <i>Phalaris minor</i> in wheat	43,526	45,185	3.8
Foliar application of potassium (K) in wheat	52,230	54,333	4.0
Amelioration of heat stress for enhancing milk production through supplementation of astaxanthin @0.25 mg/kg body weight/day + prill fat @100 g/animal/day	391*	428*	9.6

*Calculated on ₹/day basis.

TRAINING

In 2017-18, six trainings involving 580 participants were conducted along with 901+107** demonstrations covering 563 ha area. The trend continued to 2018-19 with 8 trainings (727 participants) and 1215+364** demonstrations covering 489 ha area. And in 2019-20, 4 trainings (457 participants) and 797+407** demonstrations covering 480 ha area were organized [Note: Six recharge structure covering installed initially covering 300 ha area not counted in 2018-19 and 2019-20; **animals sample size].

IMPACT

- Increased awareness towards soil and water testing helped farmers in applying gypsum based on both soil sodicity (soil pH) and irrigation water quality (RSC levels), otherwise the farmers were applying gypsum based on soil pH only.
- Increased awareness regarding farm level recharge –cum–drainage structures for augmenting

groundwater and improving its quality by harvesting excess rain water into aquifers

- Field applicability of sugar industry waste byproduct 'pressmud' not only helped in achieving sustainable agricultural production but also served as affordable alternative source while reducing the total dependence on chemical amendment (gypsum) in sodic land reclamation. The farming community was really convinced with the introduction of this technology, otherwise disposed-off unsafely.
- Defined threshold (critical) limits for soil sodicity and irrigation water quality helped farmers in selection of suitable salt tolerant varieties instead of traditional ones for getting sustainable yields in problematic (sodic soils irrigated with high RSC waters) areas.
- Residue (rice) management and direct seeding (Happy seeder) of wheat for improved soil and environmental quality.
- Farmers have started using boron

(soil and foliar application) for managing reproductive sterility in rice.

- Use of pre-mergence herbicides for better control of resistant *Phalaris minor* (mandoosi, gulli danda) in wheat.
- Increased awareness regarding crop residue incorporation helped in better soil health and environmental quality.
- Increased awareness regarding use of mineral mixture and artificial insemination for higher conception rate in breedable bovines and repeat breeders.
- Increased use of astaxanthin and prill fat supplementation for enhancing milk production of buffaloes during summer season.
- Village level WhatsApp groups have been created to provide weather based agro-advisories, farm management practices, government schemes related to agriculture and livestock, etc.

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