# Economic Viability of Rice-Rice Cropping as Influenced by Site-Specific Nutrient Management

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**Averaged over study locations, the best system (two crop) grain yield under site-specific nutrient management (SSNM) was 12,850 kg/ha in comparison to 10,270 kg/ha under farmer practice (FP) – a 25% increase in productivity. SSNM resulted in an additional produce value of US$607 (gross) and US$464 net after deducting costs for extra inputs. These results clearly establish the importance of responsible nutrient management for breaking the prevailing situation of yield stagnation.**

India's intensive rice-rice cropping covers more than 6 million (M) ha and represents the country's most important food production system. Continued slowdown in the growth of yield within this intensive irrigated system is a serious cause for concern (Yadav et al., 2000). Incidence and expansion of multi-nutrient deficiencies in the soils under intensive cropping in general, and in rice-based cropping systems in particular, can be linked to inadequate and unbalanced nutrient input and are considered major reasons for observed declines in productivity associated with fertilizer use (Dwivedi et al., 2001). The common tendency for farmers to practice N-driven fertilizer management not only aggravates the extent of soil fertility depletion, but is also harmful in terms of low nutrient use efficiency, poor quality of produce, and enhanced susceptibility of crops to biotic and abiotic stresses. It is also a potential groundwater pollution threat due to excessive leaching of nitrate beyond the root zone (Dwivedi et al., 2003; Singh et al., 2005).

Unfortunately, the fertilizer recommendations being adopted in most states inadvertently promote unbalanced fertilization as they fail to account for crop yield goals or emerging multi-nutrient deficiencies (Dwivedi et al., 2006). In these circumstances, development of a site-specific nutrient supply package seems to be the only way to enhance nutrient use efficiency and arrest the ever-increasing occurrences of soil nutrient deficiencies (Dobermann et al., 2004).

Multi-locational on-station research was initiated to evaluate the significance of soil test-based SSNM in breaking yield stagnation. Field experiments were conducted during 2003-04 to 2005-06 to evaluate rice-rice cropping at seven locations spread across India. The soils were alluvial sandy clay loam at Jorhat (Assam - Humid Ecosystem), deep black red sandy soil at Coimbatore (Tamil Nadu - Semi-arid Ecosystem), medium black to deep black at Maruteru (Andhra Pradesh) and Navsari (Gujarat-Coastal Ecosystem), red soil of deltic origin of Karjat (Maharashtra) and Thanjavur (Tamil Nadu-Coastal Ecosystem), and Bhubaneswar (Orissa-Subhumid Ecosytem). By and large, soils were neutral to slightly alkaline in nature (pH 6.0 to 8.2) but acidic at Maruteru (pH 5.2) and Jorhat (Assam) (pH 4.8), low to medium in available N, K, B, and Mn, and medium to high in available P, S, Zn, Cu, and Fe. The initial ASI soil analysis was done as per methods described by Portch and Hunter (2002) and SSNM recommendations were developed for pre-set yield targets of 10 t/ha of hybrid rice. A similar approach was adopted successfully to achieve yield goals of 10 t/ha of rice and 6 t/ha of wheat in a rice-wheat system (Singh et al. 2008). These approaches and recommendations were different from the conventional approach used by soil testing laboratories in India as all the deficient nutrients were considered, including all major, secondary, and micronutrients which were deficient (**Table 1**). Both crops in the system received NPK while S and micronutrients were applied to *kharif* rice only and the succeeding *rabi* rice benefited from residual amounts. The efficacy of the SSNM treatment was compared with State fertilizer recommendation (SR) and FP at each location.

**View** of farmer practice plot.

Fertilizer application at planting included the entire quantities of P, K, S, micronutrients, and one-third of total N. The remaining N was top-dressed in two equal splits. The best available hybrid rice variety (cv. PHB 71) was grown at all the locations. Crops were raised under optimum management conditions and apart from differences in nutrient application rates, all other management practices were the same for SSNM, SR, and FP plots. The crop was harvested manually at maturity and the yield results reported here are an average of 3 years.

The economics of the various fertilizer treatments was calculated for individual crops and the complete cropping system. Comparisons included analysis of the extra fertilizer costs, value of extra produce, net return, and net return per unit invested in applied nutrients under the SSNM.

**Abbreviations and notes for this article:** N = nitrogen; P = phosphorus; K = potassium; S = sulfur; Zn = zinc; B = boron; Mn = manganese; Cu = copper; Fe = iron.

**Table 1.** Experimental location and the nutrients applied in the rice-wheat cropping system

| | | Nutrient applied, kg/ha | | | | | |
|---|---|---|---|---|---|---|---|
| | | *Kharif* rice | | | *Rabi* rice | | |
| Location | State | SSNM | SR | FP | SSNM | SR | FP |
| Jorhat | Assam | $N_{150}P_{100}K_{150}B_5Zn_{40}\ Cu_{10}\ Mn_{20}$ | $N_{100}P_{40}K_{40}$ | $N_{25}\ P_{40}$ +1 t FYM | $N_{150}P_{100}K_{150}$ | $N_{100}P_{40}K_{40}$ | $N_{25}\ P_{40}$ |
| Bhubaneswar | Orissa | $N_{150}P_{100}K_{40}S_{40}Zn_{40}\ B_5$ | $N_{80}P_{40}K_{40}$ | $N_{60}P_{30}\ K_{30}$ | $N_{150}P_{100}K_{40}$ | $N_{80}\ P_{40}K_{40}$ | $N_{60}P_{30}\ K_{30}$ |
| Karjat | Maharashtra | $N_{150}P_{100}K_{150}S_{60}Mn_{30}$ | $N_{100}P_{50}K_{50}$ | $N_{45}P_{45}K_{45}$ | $N_{150}P_{100}K_{150}$ | $N_{100}P_{50}K_{50}$ | $N_{45}P_{45}K_{45}$ |
| Navsari | Gujarat | $N_{150}P_{80}K_{120}S_{25}Zn_{40}\ Fe_{40}$ | $N_{150}P_{75}K_{60}$ | $N_{100}\ P_{30}$ +5 t FYM | $N_{150}P_{80}K_{120}$ | $N_{150}P_{75}K_{60}$ | $N_{100}\ P_{30}$ +5 t FYM |
| Maruteru | Andhra Pradesh | $N_{150}P_{80}K_{120}B_5$ | $N_{60}P_{40}K_{40}$ | $N_{80}\ P_{40}$ | $N_{150}P_{80}K_{120}$ | $N_{60}P_{40}K_{40}$ | $N_{80}\ P_{40}$ |
| Coimbatore | Tamil Nadu | $N_{150}P_{80}K_{60}S_{50}$ | $N_{150}P_{60}K_{60}\ Zn_{25}$ +12.5 t FYM | $N_{150}P_{50}K_{50}$ | $N_{150}P_{80}K_{60}$ | $N_{150}P_{60}K_{60}\ Zn_{25}$ +12.5 t FYM | $N_{150}P_{50}K_{50}$ |
| Thanjavur | Tamil Nadu | $N_{150}P_{30}K_{100}S_{60}Mn_{30}$ | $N_{80}P_{34}K_{96}S_{93}\ Zn_{25}$ | $N_{120}P_{50}K_{50}\ Zn_{25}$ | $N_{150}P_{30}K_{100}$ | $N_{80}P_{34}K_{96}S_{93}$ | $N_{120}P_{50}K_{50}$ |

Sources of N, P, K, S, Zn, B, Mn, Cu, and Fe were urea (46% N), diammonium phosphate (18% N and 46% $P_2O_5$), potassium chloride (60% $K_2O$), elemental S, zinc sulfate (21% Zn and 10% S), Borax (10.5 % B), manganese sulfate (30.5% Mn, 17.5%), copper sulfate (24% Cu, 12% S) and iron sulfate (19% Cu, 10.5% S), respectively.
SSNM = Site-specific nutrient management; SR = State recommended fertilizer dose; FP = Farmer practice.
P and K amounts are expressed as $P_2O_5$ and $K_2O$.

## Effect on Productivity

***Kharif* Rice** — The mean grain yield obtained through SSNM was 6,240 kg/ha as compared to 5,660 kg/ha from SR fertilizer use and 5,210 kg/ha under FP. On average, SSNM out-yielded FP by 1,030 kg/ha (+20%) and SR by 450 kg/ha (+9%). The extra yield obtained by growing *kharif* rice through SSNM (over FP) ranged from 340 kg/ha at Maruteru to 2,500 kg/ha at Jorhat (**Table 2**). The yield advantage was 10% or more in *kharif* rice at four out of seven sites. In terms of rice productivity, the SSNM treatment out-yielded FP by more than 1 t/ha at two out of seven locations (i.e., Jorhat and Karjat).

***Rabi* Rice** — The mean grain yield of *rabi* rice in this rice-rice system was 6,630 kg/ha under SSNM and 5,080 kg/ha under FP. On average, the SSNM plots out-yielded FP by 1,570 kg/ha (+31%). The extra yield obtained through SSNM (over FP) ranged from 600 kg/ha at Thanjavur to 2,800 kg/ha at Maruteru, indicating an almost four-fold difference among locations. This yield advantage was 25% or more at four out of seven sites. The magnitude of yield improvement by SR over FP was smaller, and ranged from 3% at Thanjavur to 25% at Jorhat. Results further indicated that the yield advantages accrued from SSNM were more in *rabi* rice compared with *kharif* rice at all locations except Jorhat and Thanjavur. The higher rice productivity during *rabi* season at different locations may be ascribed to more hours of sunshine and increased photosynthetic rates compared to the *kharif* (rainy season) crop. Also, there is relatively more incidence of pests (insects, diseases and weeds) during *kharif* compared to *rabi* season.

**Rice-Rice System** — Averaged over locations, the best system grain yield was 12,850 kg/ha under SSNM. Average yield under FP was 10,270 kg/ha. Although a mean yield productivity of 10 t/ha grain under FP is itself substantial, on average, SSNM out-yielded FP by 2,580 kg/ha (25%). The extra grain yield obtained from both rice crops through SSNM over FP ranged from 1,180 kg/ha at Thanjavur to 4,530 kg/ha at Karjat, indicating an almost four-fold difference. The yield advantages accrued due to SSNM was more in *rabi* rice compared with *kharif* rice at all locations except Jorhat and Thanjavur.

## Economic Analysis

SSNM in *kharif* rice involved an average additional expenditure of US$93/ha over FP and among sites ranged between US$47 to US$155/ha (**Table 3**). However, these additional expenditures generated an average extra produce value (grain + straw) of US$233/ha and varied from US$76/ha at Maruteru to US$562/ha at Jorhat. The added net return per ha also varied among locations ranging from US$15/ha at Navsari to US$425/ha at Jorhat. After deductions for additional SSNM costs, the resulting average extra net return was US$140/ha, with a benefit-to-cost ratio (BCR) of 1.3.


**Farmer practice** plot (left) and SSNM plot.

**Table 2.** Grain yield response to SSNM and state recommended fertilizer doses over farmer nutrient management practice.

| | *Kharif* rice | | | *Rabi* rice | | | Rice-rice system | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Response | | | Response | | | Response | |
| Treatment | Yield, kg/ha | kg/ha | % | Yield, kg/ha | kg/ha | % | Yield, kg/ha | kg/ha | % |
| Jorhat | | | | | | | | | |
| SSNM | 5,470 | 2,500 | 84 | 3,530 | 1,410 | 66 | 9,000 | 3,910 | 77 |
| SR | 3,840 | 870 | 29 | 2,650 | 530 | 25 | 6,490 | 1,400 | 28 |
| FP | 2,970 | – | – | 2,120 | – | – | 5,090 | – | – |
| Bhubaneswar | | | | | | | | | |
| SSNM | 5,240 | 570 | 12 | 5,890 | 1,010 | 21 | 11,140 | 1,590 | 17 |
| SR | 4,970 | 300 | 6 | 5,070 | 190 | 4 | 10,040 | 490 | 5 |
| FP | 4,670 | – | – | 4,880 | – | – | 9,550 | – | – |
| Karjat | | | | | | | | | |
| SSNM | 7,770 | 2,060 | 36 | 7,720 | 2,470 | 47 | 15,490 | 4,530 | 41 |
| SR | 6,320 | 610 | 11 | 6,210 | 960 | 18 | 12,530 | 1,570 | 14 |
| FP | 5,710 | – | – | 5,250 | – | – | 10,960 | – | – |
| Navsari | | | | | | | | | |
| SSNM | 5,150 | 380 | 8 | 7,400 | 1,320 | 22 | 12,350 | 1,500 | 14 |
| SR | 5,030 | 260 | 5 | 6,620 | 540 | 9 | 11,650 | 800 | 7 |
| FP | 4,770 | – | – | 6,080 | – | – | 10,850 | – | – |
| Maruteru | | | | | | | | | |
| SSNM | 3,980 | 340 | 9 | 7,580 | 2,800 | 59 | 11,560 | 3,130 | 37 |
| SR | 4,160 | 520 | 14 | 5,300 | 520 | 11 | 9,460 | 1,030 | 12 |
| FP | 3,640 | – | – | 4,780 | – | – | 8,430 | – | – |
| Coimbatore | | | | | | | | | |
| SSNM | 6,840 | 830 | 14 | 6,980 | 1,380 | 25 | 13,820 | 2,200 | 19 |
| SR | 6,250 | 230 | 4 | 6,290 | 690 | 12 | 12,540 | 920 | 8 |
| FP | 6,020 | – | – | 5,600 | – | – | 11,620 | – | – |
| Thanjavur | | | | | | | | | |
| SSNM | 9,260 | 570 | 7 | 7,310 | 600 | 9 | 16,580 | 1,180 | 8 |
| SR | 9,050 | 360 | 4 | 6,880 | 170 | 3 | 15,930 | 530 | 3 |
| FP | 8,690 | – | – | 6,710 | – | – | 15,400 | – | – |
| Mean over location | | | | | | | | | |
| SSNM | 6,240 | 1,030 | 20 | 6,630 | 1,570 | 31 | 12,850 | 2,580 | 25 |
| SR | 5,660 | 450 | 9 | 5,580 | 520 | 10 | 11,230 | 960 | 9 |
| FP | 5,210 | – | – | 5,060 | – | – | 10,270 | – | – |
| CD at 5% | 450 | – | – | 510 | – | – | 900 | – | – |

CD = critical difference

Moving from FP to SSNM within the *rabi* season involved an additional fertilizer expenditure of US$50/ha with the range being between US$13 to US$86/ha across locations. In general, lower additional investment was needed in *rabi* rice compared to *kharif* rice because all costs incurred for S and micronutrients were debited to the *kharif* season. Since *rabi* rice benefits from the residual value of nutrients applied to *kharif* rice, the net return would be affected proportionally. On average, the value of additional *rabi* rice produce was US$374/ha with a net return of US$324/ha. At five of seven locations, the additional returns were above US$250/ha with the highest being at Maruteru (US$605/ha). These additional net returns were associated with a BCR of 8.2, with a range of 2.9 to 18. The improvements over FP were made at a BCR of 5 or more at five of seven locations. The higher BCR in *rabi* rice compared to *kharif* can be ascribed to the additional input cost debited to *kharif* rice and the higher yield responses in *rabi* rice.

For the complete rice-rice system, adoption of SSNM involved an additional expenditure of US$143 and resulted in additional produce value of US$607 (gross) and US$464 after extra input costs are considered. This improvement was achieved at an average BCR of 3.5 – meaning that for every extra unit invested in nutrients, 3.5 in extra crop value (net) was harvested. Any technology with a BCR of such a high magnitude would be highly remunerative and sustainable for large-scale adoption within India's rice-rice systems.

**Table 3.** Changes in economic returns while shifting from farmer nutrient management practice to SSNM in rice-rice cropping system.

| | | SSNM vs. Farmers' practice | | | |
|---|---|---|---|---|---|
| Location | Crop | Extra cost of fertilizer, US$/ha | Value of extra produce, US$/ha | Net return, US$/ha | Net return, US$/US$ extra invested in nutrients |
| Jorhat | Kharif | 137 | 562 | 425 | 3.1 |
| | Rabi | 86 | 337 | 251 | 2.9 |
| | System | 223 | 899 | 676 | 3.0 |
| Bhubaneswar | Kharif | 105 | 129 | 24 | 0.2 |
| | Rabi | 54 | 240 | 186 | 3.4 |
| | System | 160 | 370 | 210 | 1.3 |
| Karjat | Kharif | 155 | 463 | 308 | 2.0 |
| | Rabi | 70 | 595 | 525 | 7.5 |
| | System | 225 | 1,058 | 833 | 3.7 |
| Navsari | Kharif | 70 | 85 | 15 | 0.2 |
| | Rabi | 56 | 313 | 257 | 4.6 |
| | System | 126 | 398 | 272 | 2.2 |
| Maruteru | Kharif | 57 | 76 | 19 | 0.3 |
| | Rabi | 55 | 660 | 605 | 11.0 |
| | System | 111 | 735 | 624 | 5.6 |
| Coimbatore | Kharif | 47 | 186 | 139 | 3.0 |
| | Rabi | 17 | 328 | 311 | 18.0 |
| | System | 65 | 513 | 448 | 6.9 |
| Thanjavur | Kharif | 81 | 128 | 47 | 0.6 |
| | Rabi | 13 | 144 | 131 | 10.3 |
| | System | 94 | 273 | 179 | 1.9 |
| Mean over location | | | | | |
| | Kharif | 93 | 233 | 140 | 1.3 |
| | Rabi | 50 | 374 | 324 | 8.2 |
| | System | 143 | 607 | 464 | 3.5 |

Prices of different nutrients used were Rs.10.5/kg N Rs.16.5/kg $P_2O_5$, Rs.26.5/kg S, Rs.20/kg zinc sulfate, Rs.30/kg manganese sulfate, Rs.13/kg copper sulfate Rs.8/kg ferrous sulfate, and Rs.34/kg borax. Grain price: Rs.7.60/kg, Straw price: Rs.1.0/kg; Rs.1 = US$0.02

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**View** of SSNM plot.

## References

Dobermann, A., et al. 2004. Increasing productivity of intensive rice systems through site-specific nutrient management. Science Publishers and IRRI. pp. 410.
Dwivedi, B.S., et al. 2001. Development of farmers' resource-based integrated plant nutrient supply systems: experience of a FAO-ICAR-IFFCO collaborative project and AICRP on soil test crop response correlation. Bhopal: Indian Institute of Soil Science. pp. 50-75.
Dwivedi, B.S., et al. 2003. Field Crops Res. 80, 167-193.
Dwivedi, B.S., et al. 2006. Soil fertility evaluation- A potential tool for balanced use of fertilizers: IARI New Delhi and PPI/PPIC India Programme. pp 1-60.
Portch, S. and A. Hunter. 2002. Special Publication No. 5. PPIC China Program, Hong Kong. pp 62.
Singh, V.K., et al. 2008. Better Crops with Plant Food. 92, No. 3, 28-30.
Singh, V.K., et al. 2005. Field Crops Res. 92, 85-105.
Yadav, R.L., et al. 2000. Field Crops Res. 68, 219-246.