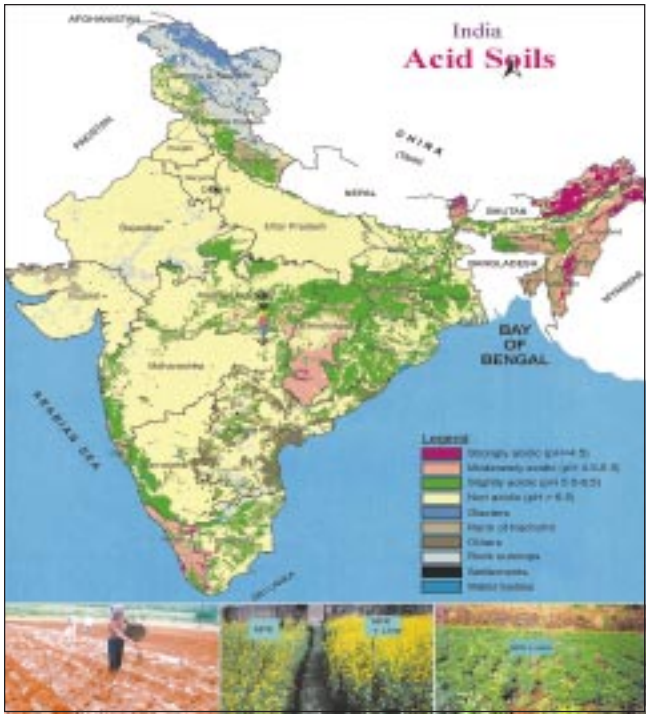
Natural Resource Management

Soil-resource survey

Soil-resource survey and mapping on 1:50,000 scale of 12 districts belonging to Jharkhand, West Bengal, Madhya Pradesh, Arunachal Pradesh, Bihar, Kerala, Uttaranchal, Punjab and Uttar Pradesh covering 3.3 million hectares has been done for their land-use planning. Atlases 126 at the division level for 11 districts of Andhra Pradesh covering 130.48 lakh hectares have also been prepared. And for land-use planning detailed soil surveys of 15 watersheds/farms on 1 : 10,000/1 : 5,000 scale have also been completed, covering 93,460 hectares.

Acid soil mapping

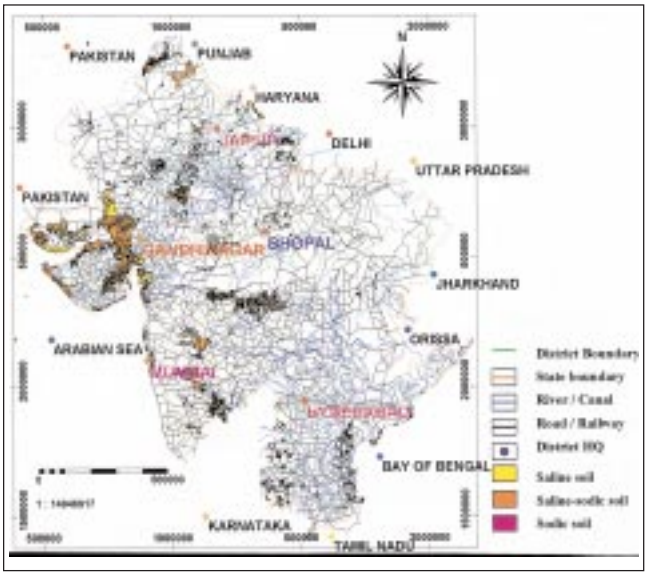
An acid-soil map has been prepared depicting extent and distribution of soil acidity in the country. The map will be useful to planners, researchers and farmers in formulation of appropriate amelioration strategies for the soils for enhancing their productivity.



Acid soil map of India. Twenty-five million hectares of cultivated lands with pH < 5.5 are critically degraded acid lands with low productivity

Salt-affected soils digitized

Computerized databases in digital format for salt-affected soils of Rajasthan, Madhya Pradesh, Gujarat and Andhra Pradesh on 1 : 250,000 scale have been prepared using Integrated Land and



Digitized map of salt-affected soils of Rajasthan, Gujarat, Madhya Pradesh, Maharashtra and Andhra Pradesh

Water Information System (ILWIS) software. The analogue maps were geo-referenced, and polygons of the salt-affected soils have been digitized and rasterized. The Survey of India maps with 1 : 1 million scale were geo-referenced and their different features such as state and district boundaries, road, railway, canal, river, state and district capitals were digitized to prepare thematic layers

- For land-use planning, soil-resource survey and mapping done for 12 districts belonging to Jharkhand, West Bengal, Madhya Pradesh, Arunachal Pradesh, Bihar, Kerala, Uttaranchal, Punjab and Uttar Pradesh
- Direct-seeded rice (DSR) technology standardized and demonstrated in farmers' participatory approach
- For preparing broad-bed-and-furrows evolved an indigenous cost-effective technique, replacing costly BBF-maker
- Continuous contour trenches performed better due to more moisture availability in trenches

The National Bureau of Soil Survey and Land-Use Planning, Regional Centre, Bangalore, has demarcated the state into following 6 Agroecological zones (I-VI in figure). These zones have been further divided into 17 agroecological subzones for efficient planning of crops.

I. Northern Karnataka Plateau

This receives a mean annual rainfall of 430 to 992 mm and is divided into 4 zones with LGP ranging from < 90 days, 90–120 days, 120–150 days and 150–180 days.

II. Southern Karnataka Plateau

This receives a mean annual rainfall of 450 to 925 mm and is divided into 4 zones with LGP ranging from < 90 days, 90–120 days, 120–150 days and 150–180 days.

III. Southern transitional region

This receives a mean annual rainfall of 750 to 1,030 mm and is divided into 2 zones with LGP from 150 to 180 days and 180–210 days.

IV. Northern transitional region

This receives a mean annual rainfall of 585 to 830 mm and is divided into 2 zones with LGP from 120 to 150 days and 150 to 180 days.

V. Hilly region

This receives a mean rainfall of 1,070 to 3,812 mm and is divided into 3 zones with LGP from 180 to 210, 210 to 240 days and > 270 days.

VI. Coastal plain

This receives a mean annual rainfall of 3,220 to 4,850 mm and is divided into 2 zones with LGP from 180 to 210 days and 210–240 days.

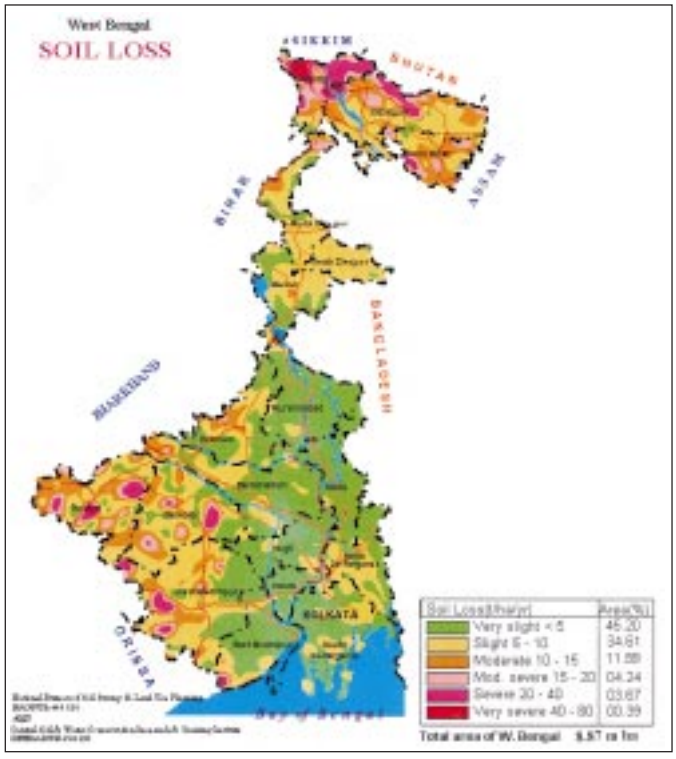
Zero tillage in rice and wheat

In Bihar, 25 hectares in 21 villages (covering 74 farmers) was brought under zero-tilled rice. Similarly, 9.5 hectares was brought under puddled direct-sown rice with 22 farmers. Even under erratic rainfall and late canal-water supply, establishment of rice during June 29–July 17 was possible with zero tillage. Under puddled broadcast, it was possible between July 11 and 20, and under puddled condition, transplanting was possible between July 15 and August 25. The average yield of rice under zero-tillage direct-seeded condition was 5.036 tonnes/ha. And under puddled direct-seeded condition was 3.7 tonnes/ha, which was found lower than conventional also (3.940 tonnes/ha). Similarly, under zero-tillage wheat, 22 districts were covered. There was a gain of Rs 2,260/ha with zero tillage in wheat. Savings were in land preparation/sowing (Rs 1,700), first irrigation (Rs 360) and seed (Rs 200). More than 80% farmers reported increase in wheat yield under ZT compared to conventional-sown wheat; 22% farmers reported 0.2–0.4 tonnes/ha increase in yield. The Govt of Bihar has announced 25% (maximum limit of Rs 5,000) subsidy for purchase of ZT machine.

for base map. These were then overlaid with a layer of salt-affected soils for preparing state maps of the salt-affected soils.

Soil-erosion maps

Soil-erosion map of West Bengal has been generated based on the soil-loss data at 10 km × 10 km grid. In major coastal belt

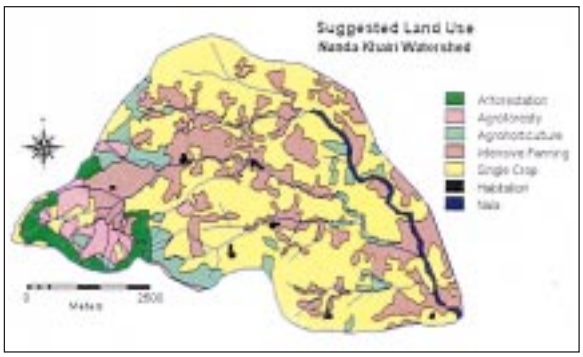


Land-use-planning in rainfed ecosystem

The climate was variable in all the 16 watersheds, covering 5,258 hectares from dry semi-arid to sub-humid. And the soils belonged to 5 orders with rainfed rice, oilseeds, cotton and coarse cereals-based production systems. Following eco-friendly and sustainable land-use models were identified for these watersheds.

Suggested land-use planning of Nanda Khairi watershed

Nanda Khairi watershed suggested land use map has been generated by integrating physiography, soil and slope. The present land use/land cover includes afforestation, agroforestry, agro-horticulture, single crop and intensive cultivation areas.



Region	Sustainable land-use models
Akola	Sesame + castor in Vertisols
Anantapur	Groundnut in Alfisols with reduction in P usage
Arija	Maize + blackgram (2 : 2)
Bellary	Groundnut – *vamu* in Vertisols
Indore	Citrus + soybean–wheat in Vertisols
Kovilpatti	Coriander and chickpea + senna/ inter-relay crops for Vertisols
Rajkot	Groundnut + blackgram; cotton + sesame in Vertisols
Rewa	Soybean + pigeonpea (1 : 1)
Sardar Krushinagar	Pearl millet + greengram (3 : 1)
Sholapur	Safflower with compartmental bunding for deep Vertisols
Varanasi	Rainfed rice–pigeonpea in Inceptisols

(75%), potential soil loss through water has been estimated at less than 5 tonnes/ha/yr. In many pockets of the west coast, particularly, in Maharashtra, Karnataka, Goa and Kerala, annual soil loss was found to be more than 4 tonnes/ha/yr.

Sustaining rice-wheat system through direct-seeded rice (DSR) and conservation technology

Direct seeding of rice can overcome the problem of dependence on labour for nursery raising and transplanting operations. The DSR technology has been standardized and demonstrated in farmers' participatory research. It has showed potential of improving water productivity by 15–18% (as puddling requires lots of water), and of system profitability by 10–15%. Further, a significant improvement in the soil health has been recorded under the aerobic rice-based production systems. The DSR and *Sesbania* co-culture (brown manuring), followed by zero-till wheat and other upland crops (chickpea/lentil/mustard) have exhibited tremendous scope for their acceptability in the rice-wheat production system.

Amelioration of acid soils

Apply lime at 0.2–0.4 tonne/ha in furrows at the time of sowing along with the recommended fertilizers. This enhanced yields of

Application of lime in furrows at Bhubaneshwar, Orissa

Liming acid soils. Liming enhances their nutrient-use efficiency by saving 50% of chemical fertilizers, particularly in oilseeds and pulses (Pigeonpea, Bhubaneshwar, Orissa)

various crops by 49–189% over farmers' practices, and also saved chemical fertilizers by about 50%, particularly in oilseeds and pulses. Mean benefit : cost ratio of the practice was 2.5. The adoption of this cost-effective technology on 25 million hectares of critically degraded acid soils can contribute an additional 25 million tonnes of foodgrains to the national food basket per annum.

Integrated tillage, land and residue management in rainfed situation

Reduced tillage (one harrowing and one intercultural operation with pre-emergence herbicide), followed by broad-bed-and-furrow (BBF) planting of rainfed cotton applied with recommended dose of fertilizers, incorporation of green manure and location-specific deficient nutrients gave 32.6% higher cotton-seed yields compared to farmer's practice of rainfed-cotton cultivation on flat-beds with conventional tillage involving one summer ploughing, followed by 2–3 harrowings and with numerous intercultural operations and application of about 70% of the recommended fertilizer dose. The net returns/benefits to farmers from this improved practice were in the range of Rs 4,955 in Kovilpatti (Tamil Nadu) to Rs 18,536 in Khargone (Madhya Pradesh) per hectare. The practice also improved soil physical and chemical properties. An indigenous cost-effective technique replacing costly BBF maker has also been evolved for preparing BBFs. Furrows of 40–50 cm top width could be opened with country plough by fixing a wooden attachment to plough to widen furrows and for rounding top edges.

Soil- and-water conservation technologies

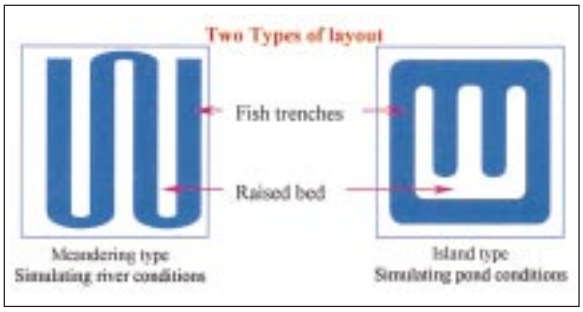
In semi-arid black soils, *Dichanthium* showed superiority to vetiver in soil- and-water conservation. Runoff and soil losses were 52.3 mm (71% reduction) and 0.5 tonne/ha with *Dichanthium annulatum* and were 83.7 mm and 1.6 tonnes/ha with vetiver. And these losses were 181.8 mm and 6.6 tonnes/ha from the bare plot.

Continuous contour trenches (CCT) with *Stylosanthes scabra* + *Gliricidia maculata* as vegetative barriers were most effective in minimizing runoff (3.95%) and soil losses (0.7 tonne/ha/yr). Cashew growth was also better with CCT and vegetative barrier. The better performance in the CCT was due to more soil-moisture availability in the trenches.

- In Patna, 37% farmers preferred fish-cum-horticulture system in waterlogged areas
- OPTALL model use facilitated optimal releases of canal-water
- Kinnow-plants mulched with *sal* leaves produced better quality fruits than *lantana* mulch
- Crop yields with sewage irrigation could be sustained with only 50% of the recommended nitrogen and phosphorus

Land- and-water productivity enhancement through multiple water uses

Productive utilization of seasonally waterlogged areas through multiple uses of water was investigated at the experimental farm of the ICAR-RCER, Patna. The preliminary results of the first year were quite encouraging. Two secondary reservoirs (40 m × 20 m at bottom) were constructed, and fish culture along with the horticulture/vegetables on the bunds was carried out. Economic analysis indicated a net profit of about Rs 44,000/ha from the system. The benefits are expected to increase further with production of banana/guava/lemon and duck eggs. In waterlogged areas



In waterlogged areas (water stagnation 0.3–1.0 m), fish trenches-cum-raised-beds with meandering-type trenches simulating river and continuous trenches surrounding island of raised-bed simulating pond are found profitable

(water stagnation 0.3–1.0 m), fish trenches-cum-raised bed with meandering-type trenches simulating river and continuous trenches surrounding island of raised-bed simulating pond were evaluated. The area under fish trenches was around 770 m^2 and was 444 m^2 under the raised-beds. Economic analysis indicated a profit of Rs 65,000 per hectare during the 1st year. For rice-fish culture in nylon-pens under waterlogged areas, field level was raised to enhance rice production, using soil excavated to construct fish-refuge (Central refuge) in 10% of the rice-area. It produced 6 tonnes/ha of paddy along with 153 kg of fish/ha. The profitability increased by 10% with the introduction of fish in the rice field. Fish-cum-horticulture in waterlogged area was preferred by 37% farmers. Nineteen per cent respondents liked fish-pond-cum-secondary reservoir and rice-cum-fish cultivation; only 15% farmers were reluctant to adopt any fish-production technologies.

Model for canal-water management developed

A water allocation plan was prepared by employing OPTALL model for Patna canal.

In some weeks canal-water supply was excessively higher than requirement, and in other weeks it was excessively lower than demand. The use of the OPTALL model, however, has facilitated

optimal releases of water. This model could help in regulating gate opening and corresponding water releases from canal system for optimal and equitable distribution of water in canal commands.

Fertigation in banana

Drip irrigation coupled with fertilizers advanced flowering of banana-plant and improved its quality and yield. Fruit size was bigger under drip irrigation (35–45-mm diameter for Harichal variety) in comparison to non-drip irrigated crop (28–37 mm). Yield increase was 273% in drip-irrigated crop over surface-irrigated one. The drip has improved overall profitability of the system.

Supplemental irrigation and mulching

Kinnow irrigated at 80-mm net cumulative pan-evaporation produced highest fruit yield (0.13 tonne/plant). The long-run plants raised with *sal* or *lantana* mulch also produced almost similar yields. Fruit quality improved with increased frequency of irrigation. Kinnow-plants mulched with *sal* leaves produced better quality fruits than *lantana* mulch.

Urban and industrial effluents use in agriculture

The build-up of organic matter and nutrients in soils with sewage irrigation improved yields by 12–24% of vegetables (cabbage–ridge-gourd), fodders (berseem–sorghum), grains (rice-wheat) and agroforestry (rice–wheat with poplar)-based systems. And the yields with sewage irrigation could be sustained with only 50% of the recommended nitrogen and phosphorus.

Quality of produce of *Lepidium* with saline irrigation

Chemical analysis of *Lepidium* oil revealed no effect of saline irrigation on its fatty-acid composition. Erucic acid, which is harmful to health, and present in most of the crucifers, has not been detected in *Lepidium* oil; hence, this oil could be compared with canola oil. In this, monounsaturated fatty acids (MUFA) and poly-unsaturated fatty acids (PUFA), which are good for health are found in high amounts. This oil possesses antioxidant properties, and can be used as the natural preservative.

Lepidium being raised in degraded calcareous soils with saline water

SUCCESS STORY

Participatory water management in foot-hills of western Himalayan Region

In a village in Raipur block of Dehra Dun district with the harvesting subsurface water-flow into a dug-out pond (260 cum) in a participatory mode (farmer's share 35%), and its utilization through lifting and underground pipeline system, 42 hectares could be irrigated for the first time; benefiting 125 families. And the cost of the system could be recovered within two years. Another tank of 350 m^3 capacity was constructed at village Bhopalpani. Water conveyance from pond was through gravity using underground PVC pipeline system. The farmers' contribution was over 51%.

Excellent crop and horticulture interventions in IVLP villages (Dehra Dun)

Harvesting and storage of subsurface flow through underground pipeline under the IVLP (Dehra Dun)

In Uttaranchal, the concept of participatory water-resource development is catching up even in villages not covered under the TAR-IVLP. The economic analysis of TAR-IVLP Project was worked out by considering 30 years project life at 10% discount rate with taking productive benefits from crop and horticulture sectors only. This revealed that project would yield net present value to the tune of Rs 127.69 lakh with a benefit : cost ratio of 1.55 : 1. The whole cost of the project can be recovered within 4 years due to the high internal rate of returns (105%).

Regional-scale watershed plans and methodologies – case studies

- An action plan was generated for Nagarinala watershed (1,312 ha) in Kusumi-Dahuka in Nayagarh district of Orissa with GIS and remote sensing. The engineering measures included construction of percolation tanks, water-harvesting structures (WHSs), check-dams, contour-bunds/ contour-trenches, land modification, open dug-wells, diversion-weir, loose boulder structure, and renovation of WHS. Percolation tanks and WHSs enhanced groundwater level in micro-watershed, and also an increase in command area to 25 hectares in *kharif* and 27 hectares in *rabi*. Contour-bund cum-trench of 100-m length helped in storing water and sediments in degraded land, making it suitable for plantation. Construction of stone masonry spillway prevented soil erosion and crop damage in 7 hectares of upland. With open dug-wells, farmers grew different vegetables during *rabi* and rice in *kharif*. The profits obtained by farmers were enough to bear construction cost of wells. Construction of diversion-weir with three gates saved around 25 hectares of *kharif* rice.

  The cropping programme included high-yielding upland rice variety Vandana, medium-land rice variety Surendra and lowland rice variety Gayatri. Sex pheromone traps were used under integrated pest management. Green manuring with *dhaincha* was practised to partially substitute chemical-N fertilizer. The anti-termite treatments were beneficial to farmers in controlling crop damage. Pigeonpea and urdbean on bunds of rice gave extra income to farmers, besides increasing soil fertility.
- A short-term study in participatory mode for SS Pally micro-watershed of Nalagonda District, Andhra Pradesh was conceptualized. Based on the geo-hydrological parameters, runoff diversion channels, waterways, gully plugging by gabion structures, recharging of pits, percolation ponds and sand-bag checks were constructed/installed at appropriate places for preserving rainwater and reducing soil losses. Groundwater monitoring exercise showed 1 m increase in groundwater level of this watershed and there was 50% reduction in runoff. About 4 tonnes of soil was conserved by gabion structures and check-dams and 15 hectares were saved from soil and gully erosion. Green capping of bunds/ waterways by *Urochloa*, *Panicum*, *Cenchrus* and *Stylosanthes* and introduction of sweet-orange, sapota, mango and curry-leaf and avenue plantation of *jamun*, tulip-tree, cassia and sissoo resulted in making watershed greener; that was otherwise a scrub jungle.

Balanced fertilization

Balanced application of N, P, K, S and Zn at the recommended rates (120 kg N, 60 kg P_2O_5, 20 kg K_2O, 20 kg S and 5 kg Zn/ha) increased wheat-grain yield by 15–24% over farmers' practices in Geelakhedi (Rajgarh district), Mugaliahat (Bhopal district) and Rangai (Vidisha district) villages (two experiments in each village) of Madhya Pradesh. Skipping application of P (NKSZn treatment) and S (NPKZn treatment) had resulted in reduction in wheat

Site-specific nutrient management (SSNM) in rice–wheat system

A field experiment at the PDCSR, Modipuram, with hybrid rice (*cv*. PHB 71) and wheat (*cv*. PBW 343) in sandy-loam, mild alkaline soil was conducted for SSNM. The soil contained 0.7% organic matter and was deficient in available N, K, S, Mn, B and Zn. The SSNM recommendations for a yield target of 10 tonnes of rice/ha and 6.5 tonnes of wheat/ha were 170 kg N, 30 kg P_2O_5, 80 kg K_2O, 20 kg S, 17 kg Mn, 7 kg Zn and 0.6 kg B per hectare in rice and 150 kg N, 30 kg P_2O_5 and 80 kg K_2O per hectare in wheat. In rice, SSNM schedule gave grain yield of 10.5 tonnes/ha, against 6.7 tonnes/ha under farmer's practice. The application of K at 80 kg K_2O/ ha gave 1.38 tonnes/ha of additional rice compared to no K. Skipping S and micronutrients brought yield reduction by 1.24 to 2.75 tonnes/ha. Similar trend was recorded in wheat also.

- Highest wheat yields in Madhya Pradesh could be sustained by adopting integrated nutrient management
- In Gujarat, application of Zn+S+B increased pod yield of groundnut by 32%.
- Mixed biofertilizers inoculation in pearl millet with 75% of recommended dose of N at farmers' fields at Hisar, Bhiwani, Jajjhar, Mahendergarh and Rewari increased its grain yield by 5% and fodder yield by 6%

Leaf colour chart (LCC) for nitrogen management

Leaf colour chart measuring leaf colour intensity is recommended for efficient fertilizer-N management in rice;

Leaf colour chart (LCC) is a simple, rapid and cheap tool for managing N fertilizers efficiently

avoiding under or over fertilization. Its use, effecting saving of 15 kg N/ha in rice has successfully been demonstrated in three villages of Patna (Bihar).

yield. Similarly, wheat-grain yields were reduced significantly at 3 sites when Zn was not applied. The results clearly indicate that higher wheat yields could be sustained by encouraging farmers to correct N, P, S and Zn deficiencies by adopting appropriate nutrient-management practices.

Crop response to micro and secondary nutrients

In Gujarat, with 5 kg Zn/ha higher pod yield of groundnut was obtained. Seed treatment with 3% ZnO increased pod yield of groundnut by 3.3% and application of Zn + S + B increased pod yield by 32%. On blackgram, in Zn, and S-deficient swell-shrink soils of village Karkbel, district Narsinghpur, at one of the sites, net increase in yield of 0.17 and 0.37 tonne/ha was observed with 5 kg Zn/ha and 5 kg Zn + 40 kg S/ha, respectively. At another site, net increase was 0.15 and 0.31 tonne/ha with 5 kg Zn and 5 kg Zn + 40 kg S/ha, respectively. Higher B/C ratios of 3.53 and 4.28 were obtained with 5 kg Zn + 40 kg S/ha at the two sites respectively.

Formulation and testing of mixed biofertilizers

Azospirillum + phosphate-solubilizing bacteria (PSB) + plant-growth promoting rhizobia consortium developed for rice in Tamil Nadu, gave 10–15% higher yield at the recommended dose of NP (100%). And when these were used along with 75% NP, it saved 25% NP and produced yields at a par with 100% NP. This was effective for blackgram also. Mixed biofertilizers inoculation to pearl millet on farmers' fields at Hisar, Bhiwani, Jajjhar, Mahendergarh and Rewari at the 75% of the recommended dose of N resulted in increase in grain yield by 5% and fodder yield by 6%; giving additional net monetary returns of Rs 780/ha. In drylands, at Bawal in Haryana, inoculation of pearl millet, wheat and mustard with *Azotobacter*, *Azospirillum* and *Pseudomonas* at 75% of the recommended dose of nitrogen gave 10–22% higher yield. In three farmers' fields, experiments were conducted on vegetables. Inoculation of *Azotobacter*, *Azospirillum* and PSB strains on okra, brinjal and tomato in strongly acidic (pH 5.2–5.6) sandy-loams in Orissa, increased yields of these vegetables by 9–14% over and above the recommended nutrient management. Apparent nutrient-use efficiency increase for N was 12–36%, for P was 18–28%, for K was 9–15% and for S was 16–18%.

New biofertilizer strain isolated for apple

A PGPR strain *Bacillus megaterium* has been isolated from rhizosphere of apple seedlings from Solan, Himachal Pradesh, that can fix atmospheric nitrogen, solubilize phosphorus and inhibit pathogen, *Dematophora necatrix*, the causative organism of white-rot of apples.

- Pearl millet–potato–groundnut found promising in North-West Zone of Gujarat with highest pearl millet equivalent yield of 17,606 kg/ha/yr, productivity of 48.2 kg/day/ha and net returns of Rs 36,046/ha/yr
- Water-use efficiency of chickpea was greater in broad-bed furrow (BBF) than flat on grade (FOG)
- Growing carnations in low-cost greenhouses is a good option for landless and marginal farmers of Nilgiris
- *Karonda*, *bael* and *aonla* successfully established with saline water and high saline water at Bir Forest, Hisar

Improving cropping intensity through varietal improvement

Fingermillet genotype VR 708 and barnyard genotypes PRB 9602, VL182 and VL 187 are found promising with short-maturity period of around 80-85 days, ensuring double cropping and higher production in the rainfed valley of the north-west hilly region.

Goa, being a tourist destination, has a large scope for confectionery groundnut with value-addition. Varieties ICGV 98412, ICGV 98402 and ICGV 97049 have showed promise, yielding nearly 23 tonnes/ha against check ICGS 76 (16 tonnes/ha), corresponding to an increase of about 160%. These types with

Henna. The Khedbrahm accession of henna has been found high-yielding with 1.87% lawsone content

Guggal (*Commiphora wightii*), a gum-resin-yielding shrub, once used to grow in abundance in rocky habitat around Jaisalmer, is now a threatened species. Studies are undertaken for its propagation

consistent performance can be recommendated as the suitable crop in hilly terrains or as an intercrop in the cashew plantations.

Twenty clones of henna (*Lawsonia inermis*) from different parts of Rajasthan and Gujarat were evaluated for morphological traits, dry-leaf yield and lawsone content. The Khedbrahm accession of henna has been found high-yielding with 1.87% lawsone content.

Guggal (*Commiphora wightii*), is a gum-resin-yielding shrub that once used to grow in abundance in the rocky habitats around Jaisalmer but is now becoming extinct due to overexploitation and difficulties associated with its propagation. Studies at Jodhpur have showed that dipping of guggal-plant cutting for a few seconds in 5,000 ppm IBA solution is enough to initiate good growth. Early March is the best period for raising plants through cuttings. More than 500 cuttings, raised through this technique, have been transplanted successfully in the field.

Crop diversification

Pearl millet-based cropping systems in Gujarat: In North-West Zone of Gujarat, pearl millet–potato–groundnut system was found promising with highest pearl millet equivalent yield of 17,606 kg/ha/yr, productivity of 48.2 kg/day/ha, net returns of Rs 36,046/ha/yr, economic efficiency of Rs 98.8/ha/day and irrigation water-use productivity of 146.7 kg of grains/ha-cm of water. The next best choice was castor-pearl millet giving estimated total pearl millet equivalent yield of 9,924 kg/ha/yr, productivity of 27.2 kg/day/ha, net returns of Rs 20,188/ha/yr, economic efficiency of Rs 55.3/day/ha and irrigation water-use productivity of 141.8 kg of grains/ha-cm of water.

Pearl millet-based cropping systems in Haryana: In Western Zone of Haryana, pearl millet–potato–greengram system was better in production and productivity. But, considering profitability and nutrient-use productivity, pearl millet–pea–maize fodder and cotton–wheat were equally good with net returns of Rs 24,625 and Rs 24,793/ha/yr, economic efficiency of Rs 67.5 and 67.9/day/ha, nutrient-use productivity of 36.9 and 38.4 kg of grains/kg of nutrients and irrigation water-use productivity of 165.4 and 148.0 kg of grains/ha-cm of water.

Pearl millet-based systems in Rajasthan: In Semi-arid Eastern Plains Zone of Rajasthan, clusterbean–onion system was identified better with highest production of 18,098 kg/ha/yr, productivity of 49.6 kg/day/ha, net returns of Rs 50,767/ha/yr, economic efficiency of Rs 139.1/ha/day, nutrient-use productivity of 58.4 kg of grains/kg of nutrients applied and water-use productivity of 258.5 kg of grains/ha-cm of water.

Pearl millet-based cropping systems in Uttar Pradesh: In South-Western Semi-arid Zone of Uttar Pradesh, mainly representing Agra region, the green manure–potato–sunflower system was found suitable and viable choice, to replace existing pearl millet–wheat system, with highest production of 12,711 kg/ha/yr, productivity of 34.8 kg/day/ha, net returns of Rs 21,114/ha/yr, economic efficiency of Rs 57.9/ha/day, nutrient-use productivity of 28.9 kg of grains/kg of nutrients used. Pearl millet–wheat system can be further diversified through greengram

SUCCESS STORY

Drought mitigation by crop diversification in rainfed uplands of eastern India

In deficit-rainfall years (2000, 2002) in Dhenkanal (Orissa), when productivity of upland rice was very low, much higher returns were obtained from diversified cropping systems. Highest net returns per annum were obtained from maize (Rs 19,500 to 26,000/ha), followed by groundnut+pigeonpea (Rs 20,124 to 21,592/ha), sole groundnut (Rs 15,420 to 18,960/ha), sole pigeonpea (Rs 13,325 to 16,200/ha), sole blackgram (Rs 9,648 to 11,650/ha); sole rice gave nil to Rs 5,400/ha. Rice substituted crops recorded much higher rainwater-use efficiency (6.3 to 13.4 kg/ha-mm) as compared to rice (1.61 kg/ha-mm). Rice-based intercropping with pigeonpea, blackgram and groundnut recorded much higher rainwater-use efficiency (3.3-3.9 kg/ha-mm).

Rice substituting crops also gave much faster returns in rainfed uplands. Data showed that maize-cob yielded net returns of Rs 23,391/ha in 70 days (Rs 314/ha/day), whereas sole crop gave only Rs 52.30/ha/day. And it boosted farm productivity and income of poor tribal farmers of Dhenkanal district of Orissa. This technology has potential to raise average productivity of 4.3 million hectares of upland rainfed rice-area of eastern India from 0.75 tonne/ha to about 7.5 tonnes/ha (rice equivalent yield) with average net returns of at least Rs 15,000/ha/annum. Besides increased water-use efficiency and profitability, this technology has a potential to provide regular employment, to supply balanced and quality food to farmers and to sustain soil health in drought-prone areas.

in summer after harvest of wheat; this requires limited additional irrigation facilities.

Changing land configuration for increasing productivity of Vertisols: Broad-bed-and-furrow (BBF) registered 18% and 16.5% greater grain yield of soybean and maize than flat on grade (FOG) land configuration. Total seasonal runoff and soil losses from BBF were lesser than FOG. In winter, grain yield of chickpea was greater in BBF than FOG. Water-use efficiency of chickpea was also greater in BBF than FOG. The total system productivity in order was maize/pigeonpea intercropping ≃ maize–chickpea > soybean/maize intercropping–chickpea > soybean/pigeonpea intercropping > soybean–chickpea in BBF and FOG.

For better livelihood: Following crop diversifications fared well for better livelihood.

- Growing cotton in deep alluvial soils of Agra with one-life saving irrigation at 21 DAS and spacing of 60 cm × 60 cm was more economical than pearl millet. Cotton-seed yield was 1.5 tonnes/ha and gave Rs 7,747/ha higher net returns over pearl millet. Cotton–wheat cropping system gave net returns of Rs 24,881/ha as against Rs 13,956/ha from pearl millet–wheat system.
- Carnation cultivation in low-cost greenhouse can be a good option for landless and marginal farmers of Nilgiris. Economic evaluation for carnation-flower cultivation was carried out by assuming project life as 20 years. Different discount rates of 10, 15 and 25% were used to calculate net present worth (NPW), benefit : cost ratio (BCR) and internal rate of returns (IRR). The BCR was higher at 10% discount rate (2.70), followed by 15 and 25% discount rates (2.48 and 2.05, respectively). The net present worth was higher at 10% discount rate (15.10 lakh), followed by 15 and 25% (9.92 and 4.93 lakh). The IRR was found 75.9%, indicating high managerial enterprise returns. The cost : benefit analysis has indicated that the project can be highly economical.
- Winter maize yield equivalence showed highest value for maize + *satawar* cropping system, followed by tobacco – maize – *dhaincha* (GM), maize + potato – blackgram + elephant-yam, maize + potato – greengram – sesame, maize + potato – green chilies, wheat – greengram – maize, maize – ladiesfinger – horsegram and Indian mustard – greengram – maize systems. The highest net returns were observed from maize + *satawar* (Rs 128,270), followed by tobacco – maize – *dhaincha* (GM) (Rs 77,890/ha), potato + maize – *dhaincha* (GM) (Rs 65,368/ha), potato + maize – greengram – sesame (Rs 65,368/ha), wheat – greengram – maize (Rs 51,548/ha), maize + potato – green chilies (Rs 48,803/ha) and maize – ladiesfinger – horsegram (fodder) (Rs 47,009/ha). The benefit : cost ratio was highest (8.21) under winter maize intercropped with aromatic and medicinal plants, maize + *satawar*, followed by maize + *musukdana* (4.68), maize + *sania* (3.36), maize + *ashwagandha* (2.63) and maize + lemongrass (1.69).

Weed management

Zero-tillage for weed management in rice–wheat system

Zero-till direct-seeded rice (DSR) reduced significantly population and drymatter of *Chenopodium album* in subsequent wheat-crop as compared to transplanted rice. And zero-till wheat reduced *C. album* and *Medicago hispida*, increased soil-moisture content and yielded more compared to conventional tillage. In transplanted rice-wheat system, zero-tillage increased *Avena ludoviciana* and reduced *Phalaris minor* in wheat.

Integrated management of water-hyacinth

Herbicide 2,4-D (1.5-2.0 kg/ha) or glyphosate (2.0–2.5 kg/ha) in strip covering about 15% area at 6 months interval with bioagent culture *Neochetina* sp controlled two waves of infested water-hyacinth in 22 months. Bioagent alone would have taken 24–36 months to control only one wave of water-hyacinth.

Agri-horticulture system for biosaline agriculture

For rehabilitation of calcareous degraded soils at Bir Forest, Hisar, survival rate of *karonda* (*Carissa carandus*) was 97–100%, *aonla* (*Emblica officinalis*) was 83–90% and *bael* (*Aegle marmelos*) was 90–98%. This is indicative of successful establishment of these plants with saline and high saline waters. The plant height ranged from 91 to 123 cm for *karonda*, 126 to 243 cm for *aonla* and 202 to 263 cm for *bael*, after 2 years of plantation. Barley and clusterbean could be raised successfully in interspaces during initial years of their establishment.

Barley intercropped in *karonda* plantation during its initial years of establishment with saline-water irrigation

Farming system module developed for dryland agriculture

A farming system module covering 0.53 hectare was initiated on a watershed basis at Hyderabad. Arable cropping systems comprising castor + clusterbean (1 : 1), pearl millet + pigeonpea (3 : 1), sorghum+pigeonpea (3 : 1) and sunflower–horsegram were tested on 0.3 hectare. As a part of the horticulture component, tomato, brinjal (525 m^2), and custard-apple, *amla* (0.08 and 0.1 ha) were also grown. Drumstick, perennial pigeonpea and henna were grown along the bunds. Preliminary results have indicated that the arable crops in different systems under limited irrigation realized a net income of Rs 4,188 and a BC ratio of 2.27 in spite of severe drought experienced during physiological growth stages of crops. Tomato and brinjal recorded a gross income of Rs 402 and 750 respectively.

SUCCESS STORY

Off-season vegetables cultivation

Nursery raising of off-season vegetables in villages of Ranchi comes up as a self-help-group-based micro-enterprise. Each community growing approx 2 lakh seedlings, generated an additional income of Rs 20,000 in three months. Adoption of wilt-resistant varieties of brinjal and tomato helped farmers in early transplanting of seedlings in fields during rains. This, in turn, helped in generating more income per unit area (approximately 167.8 and 228.8% increase in income over traditional varieties) due to higher yield and harvesting of a significant proportion of the total yield in off-season; fetching higher price in the market.

Farming system development interventions

Backyard poultry production with improved breed: Poultry-rearing in backyard is popular among resource-poor farmers, especially backward and tribal communities.

Divyan breed of poultry has been evolved for rearing in the backyard with higher growth rate and egg production. Rearing of this is more economical than indigenous breed in respect of age at first laying and egg production. Egg production is expected to increase up to 325% and age at first laying of eggs may decrease up to 170.6%.

Small-scale duck-farming with improved breed: Khaki Campbell breed of duck was procured from Krishi Vigyan Kendra, Rama Krishna Mission Ashram, Ranchi, Jharkhand, and distributed among farmers. This breed of duck is popular worldwide for higher egg production.

Khaki Campbell duck-rearing was found more beneficial than indigenous breed in age at first laying and egg production. Egg production is expected to increase up to 352.94% and age at first laying of eggs may decrease up to 170.58%.

For having the profit of early-season vegetables, vegetables nursery is raised under low-tunnel polyhouses

Mushroom cultivation: Currently 100 farm-families are growing mushrooms for their own business and home consumption in Patna. Women SHGs in Beeranchak village raised 100 bags of oyster-mushroom. In three successive pickings, average yield of mushroom from one bag was 885 g. In Beeranchak, Dosiya Tola, Bhelura Rampur and Beerpur villages of Patna district more than 40% families are growing oyster-mushroom.

Raising vegetables nursery under low-tunnel polyhouse: Early-season vegetables in summer are more remunerative; but raising of nursery due to low temperature in winter is difficult. A study was conducted to examine the possibility of raising nursery under low tunnel polyhouse and availability of early-season seedlings. Technique of raising vegetable nursery under low-tunnel, iron-formed polyhouse was assessed against usual farmer practice of raising vegetable nursery with the start of summer (March). About 25 farmers were benefited from one polyhouse by getting early-season seedlings (Early Feb.). And farmers got a profit of Rs 2,000 from selling of nursery, besides meeting their own requirements of transplanting. The youth and women can adopt summer vegetable nursery raising under polyhouse for commercial purpose.

Sunflower threshing device

Local method of sunflower threshing for seeds removal caused drudgery to women-workers. To overcome this, a portable threshing device has been developed. It consists of a 750 mm × 750 mm square-frame made of 25 mm × 25 mm × 3 mm angle iron. Small pins of 3 mm dia and 10 mm length are welded (10 mm

Impact of mechanization on dryland crops

Crop	No. of farmers	Area covered (ha)	Machinery utilized	Approx. profit (Rs/ha)
Maize	44	175	CRIDA planter	7,000
Groundnut	64	111	Cultivator, CRIDA planter, sprayer, digger, thresher, decorticator	2,105
Soybean	81	151	CRIDA planter, NRCS weeder	1,300
Rabi sorghum	40	195	Rota till drill, V-blade, cycle hoe	1,400
Castor	14	175	CRIDA six-row planter, tractor-drawn blade hoe, CRIDA castor sheller	4,530
Cotton	32	194	Rotavator, six-row inclined plate planter, interculture with sweep	2,560
Fingermillet	133	800	Tractor-drawn fluted roller drill, tractor-drawn interculture, tractor-drawn reaper and power thresher	6,100
Pearl millet	22	187	Ridger seeder	1,220
Rainfed rice	84	428	Tractor-drawn disc harrow, seed-cum-fertilizer drill, self-propelled reaper, power thresher	7,420

row-to-row and 15 mm pin-to-pin) on to 20 mm flats, which are fixed on the frame. The device is simple and can be locally fabricated. Two women can work at a time and give output of 12–15 kg of grains/hr. It saves 25% of time as compared to local method.

Gas-fuelled automatic control dryer

It consists of a drying chamber coupled with external gas-fired furnace through which hot-air is blown inside using 0.5-hp electric blower. The set temperature inside is controlled through microprocessor-based relay control. The dryer is most suitable for horticulture products like *amla*, curry-leaf, drumstick leaves, and medicinal and dye-yielding plants like senna and henna. The machine dried product maintained its natural colour and quality. This dryer has been well accepted by the industry, and has been commercialized.

- A portable sunflower-threshing device developed to save women-workers from drudgery
- Gas-fuelled automatic control dryer while drying maintained natural colour and quality of products of *amla*, curry-leaf, drumstick leaves and medicinal and dye-yielding plants like senna and henna