

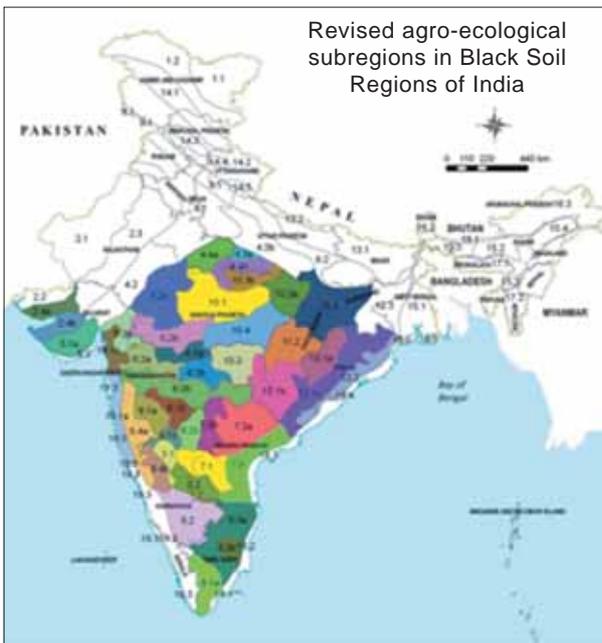


2. Soil and Water Productivity

Dependence of agriculture on natural resources such as soil and water is profound. The Natural Resources Management programme offers innovative management systems for efficient utilization and conservation of these resources. In particular, aspects relating to input use efficiency and economizing input use in agriculture, reducing nutrient losses, and conserving soils and water for achieving food, nutritional, livelihood and environmental security in the country are focused.

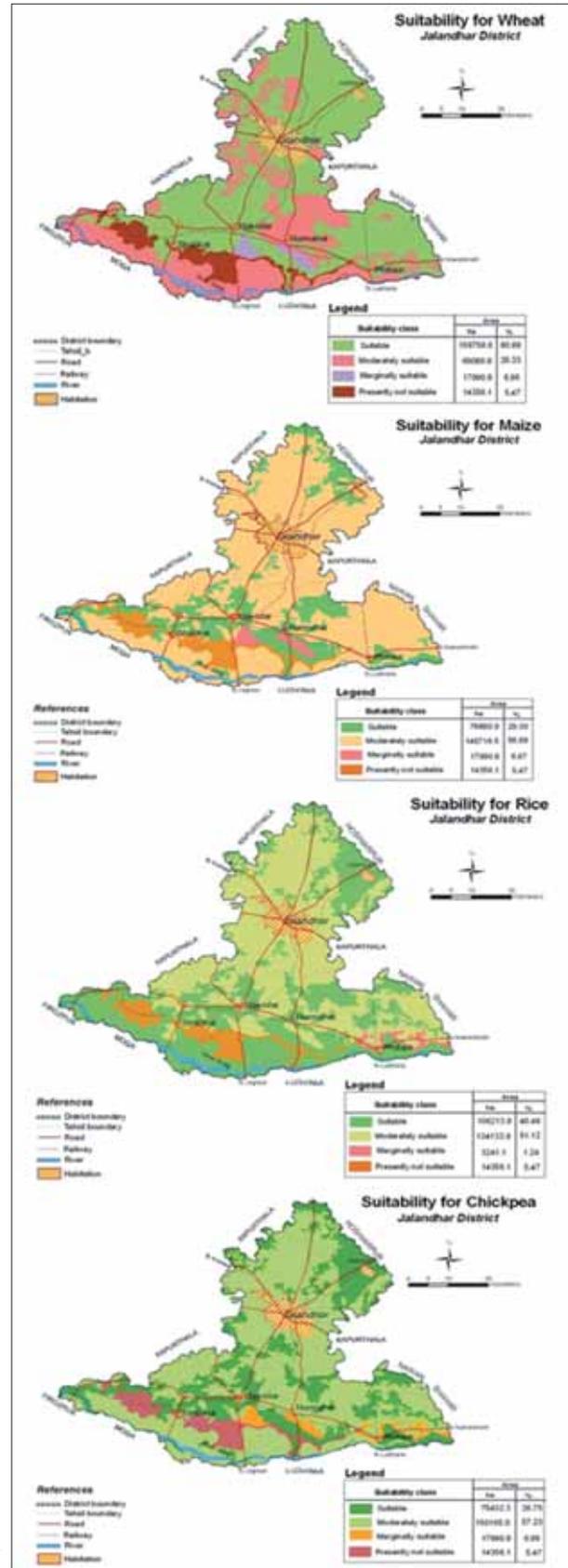
Soil resource inventory and management

Revision of Agro-ecological Sub-region (AESR) map of Black Soil Region (BSR): Black Soil Region (BSR) is an important food production region of the country. The NBSS&LUP published Agro-ecological Sub-region (AESR) map of BSR in 2002, which was revised by incorporating the latest soil database, newly calculated Length of Growing Period (LGP) data and quantitative drainage map. Previously there were 36 AESRs in the BSR, which after revision have become 54. The revised AESR map will facilitate more sound, specific and realistic regional level planning.



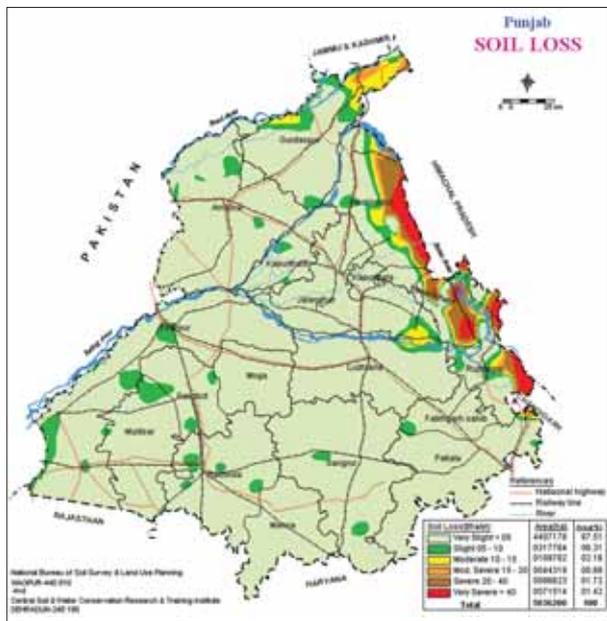
Soil-site suitability criteria for major crops of Jalandhar district, Punjab: Suitability of dominant crops of Jalandhar district, Punjab, namely rice, wheat and chickpea was assessed based on soil-site suitability criteria. Accordingly, 60% of the area in the district is highly suitable for wheat, 40% for rice, 29% for maize and 29% area is suitable for chickpea. Similar exercise is underway in other districts also.

Suitability maps for dominant crops, →
Jalandhar district, Punjab





Assessment of soil erosion in Punjab: Soil erosion map of Punjab at 1:250,000 scale was developed using soil resource inventory and soil loss data. It revealed that more than 85% area (47,248 sq km) is under slight erosion, about 5% (2,396 sq km) experiencing moderate to severe erosion and 10% (5,751 sq km) area falls under the category of very severe erosion.

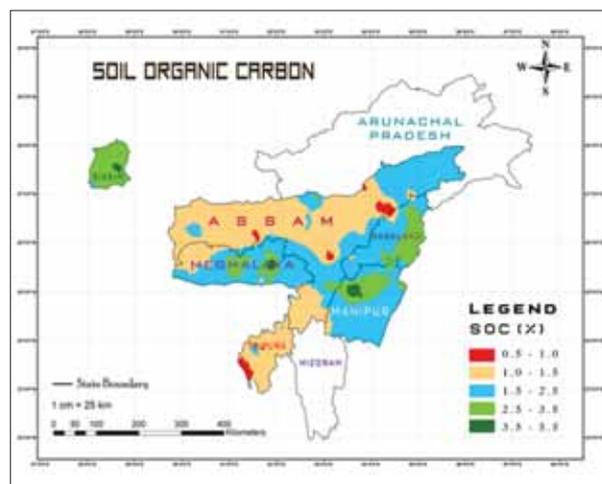


Management of medium-deep ravinous lands: Staggered trenching in the medium-deep ravines of Chambal region was advantageous for aonla + grass horti-pastoral system. *Cenchrus ciliaris* grass was planted in the interspaces of aonla (NA 7 or *Chakaya*) and bamboo (*Dendrocalamus strictus*). The system reduced runoff and sediment yields significantly while giving an aonla fruit equivalent yield of 7.46 tonnes/ha/year.



Staggered contour trenching for horti-pastoral land use in medium deep ravines – Kota

Distribution of organic carbon stocks in the soils of North-East India: Geographical Information System (GIS) based Soil Organic Carbon (SOC) map of six north-eastern states (Assam, Manipur, Meghalaya, Nagaland, Sikkim and Tripura), covering 15.61 million ha, has been prepared. Results show that 98.54% of



the area had >1% SOC content, of which 14.4% area had > 2.5% SOC content. Similarly, 76.5% area was having SOC density of 20 to 40 Mg/ha while 8% area was having very high SOC density of 40 to 60 Mg/ha. A total SOC stock of 339.8 Tg (1Tg= 10¹²g) was estimated for an area of 10.10 million ha surface soils representing all major land use systems, with forest soils accounting for more than 50%. Complex interaction of geographic location, rainfall, soil texture and land use practices significantly influenced the spatial distribution of SOC content, density and stock. The SOC content was highest for Sikkim followed by Nagaland, Manipur, Meghalaya, Assam and Tripura.

CSR-BIO: a potential bio-growth enhancer for higher and sustainable crop productivity in normal and sodic soils: A cost-effective bio-growth enhancer CSR-BIO in liquid and solid formulations comprising two compatible bacterial strains CSR-B-2 (*Bacillus pumilus*), CSR-B-3 (*Bacillus thuringiensis*) and one fungal strain CSR-T-1 (*Trichoderma harzianum*) was tested on different crops like banana, gladiolus, wheat, and okra grown in sodic soils. It promoted root and shoot growth, increased crop productivity and quality, water and nutrient use efficiency and acted as a soil conditioner and bio-catalyst. The formulation gave 22, 25 and 27% more yields in banana, tomato and okra respectively. The solid formulation costs about `50/kg while the liquid preparation costs `70/L. A unit has been established at CSSRI, RRS, Lucknow for commercial production of CSR-BIO.

Integrated water management

In-situ moisture conservation through ridge planting: In the Alfisols of Telangana region of Andhra Pradesh, which experience intermittent dry spells during the crop season, conservation furrow is recommended as an *in situ* conservation practice. Such furrows, usually made after first weeding, i.e. 30–45 days after sowing (DAS), although conserve moisture thereafter, do not conserve moisture from the preceding runoff. Therefore, a ridge planter was designed and fabricated for seeding and opening of conservation furrows simultaneously. The furrows conserve an additional 100–250 cubic meters of rainwater during the crop season depending



Ridge planter in operation and castor crop planted with ridge planter

upon rainfall, and width and depth of furrow. The ridger planter gave an yield increase of 15 to 20% in crops like castor, cotton, maize and sorghum with a one-time investment of ` 60, 000 towards the cost of machine.

Effect of growth regulators and crop water functions for wheat: Two trials were conducted to develop crop water functions and their interactions with bioregulators and fertilizer N for wheat (HD 2189). As expected, crop yield was a function of the amount of water applied and the decline in grain yield was 84, 72, 53, 32, 22 and 7% for treatments receiving 32.6, 28.4, 22.2, 15.2, 12.5 and 6.9 cm water, as compared with 37.9 cm as control. Bioregulators, in particular thiourea, alleviated the negative effects of water stress especially under medium and severe conditions. For example, with 12.5 cm applied water, yield was 48, 44, 31, 26 and 20 % with thiourea, GA₃, silixol, salicylic acid and control, respectively, compared with the treatment receiving 37.8 cm water.



Wheat under line source sprinkler system

Phytoremediation for removal of heavy metals in poor quality water: The efficacy of weed-based phytoremediation facility for removing heavy metals from industrial wastewater was tested. The fast growing giant reed (*Arundo* spp.) was planted hydroponically



Waste water carrying drain; *Inset:* *Arundo* grown in angular gravel media (without soil)

Reclamation of salt-affected sugarcane fields

An innovative system was designed to reclaim recently abandoned and low productive sugarcane fields through aquaculture and sub-surface drainage system in the four districts of Western Maharashtra, where more than 1.0 lakh ha sugarcane fields have become saline in the last 50 years. The productivity of such fields enhanced to 65.70 tonnes/acre by this innovative technology, and the sub-surface drain water collected in a pond used for carp culture achieved a production of 3.75 to 4.50 tonnes/ha.



Productive sugarcane fields through sub-surface drainage system



Sub-surface drain water collected in pond for carp production

in the tanks. Fe, Cd, Pb and NO₃ concentrations in treated water was reduced by 68.2, 51.4, 76.9 and 88.4% respectively compared with untreated drain water, implying the usefulness of *Arundo*-based wetland system for removal of heavy metals (Cd and Pb) from industrial drain water before it is used for irrigation purposes.

Microbial bioremediation of wastewater for heavy metals: Higher removal of Cu, Cr and Zn from liquid medium (40 to 60 ppm concentration) by fungi and bacteria was observed, than at lower concentration of 20 ppm. Pressmud, pressmud plus rice husk and rice straw inoculated with microbial consortium of six fungi and one bacterium removed substantial quantities of heavy metals like Cu, Ni and Zn from industrial effluents.



Integrated nutrient management

Pine oleoresin coated slow release urea: Urea was coated with pine oleoresin (3.8-4.4% pine oleoresin and 44.1-44.3% N), having levopimaric, palustric, 1-abietic and neoabietic acids in different proportions. The resin not only acts as physical barrier around the urea granules reducing the release of N, but also inhibits urease activity through antibacterial properties, and being acidic in nature it also inhibits volatilization by reducing alkaline microsites. Time required for hydrolysis of 90% material increased from 88.6 to 328.9 hr in the presence of pine oleoresin. Volatilization loss of pine oleoresin coated urea from a Vertisol also decreased from 16.9% to 10.1% after 240 hr, implying that pine oleoresin coated urea can substitute neem coated urea.

Slow release urea fortified with nano-micronutrients: Urea granules was fortified with a consortium of nano-particles of Zn, Cu, Fe, Si using oleoresin to deliver nano-particles of micronutrients along with urea. The nano-particles coated urea contained 43.8% N, 2.2 mg Zn/g urea, 1.1 mg Fe/g urea, 0.7 mg Cu/g urea and 1.1 mg Si/g urea. Application of such urea (200 kg/ha) can supply 440 g Zn, 220 g Fe, 132 g Cu and 212 g Si along with 87.7 kg N/ha to the crops and is also less hygroscopic than the normal urea.

Nano-ZnO fortified customized seeds for Zn deficient areas: Seeds of maize, soybean, pigeonpea and okra were coated with micron-scale (<30 μm) and nano-scale (<100 nm) ZnO powder @ 25 mg Zn/g seed and @ 50 mg Zn/g seed. Crop growth of ZnO coated seeds was at par with that of soluble Zn treatment ($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ @ 2.5 ppm Zn). Seed coating with nano-ZnO also did not exert any adverse osmotic effects on seed germination in pot culture studies, implying that total Zn requirement of the crop can be loaded on to the seed itself. ZnO coating also inhibited bacterial

and fungal infection of the seed at the time of germination possibly because of pine oleoresin which was used as a binding agent. This protocol of seed coating with ZnO can be used by the seed companies to produce customized seeds for Zn deficient areas.

Phosphorus and potassium solubilizing actinomycetes from arid and semi-arid soils: Forty one isolates of actinomycetes were characterized; of which 35 produced indole acetic acid (IAA-1.2 to 5.7 $\mu\text{g/ml}$ culture filtrate), all the isolates solubilized P on Pikovskayas medium (5.3 to 16 mm solubilisation zone) and 18 isolates solubilized K from insoluble mica. Seventeen isolates of actinomycetes were field tested on maize and chickpea; *Streptomyces* strains A1, A2, A6, A10, and A17 gave best response. All were positive for ammonia production and 40% were positive for urease production. Fifty per cent of the isolates also showed biocontrol potential against *Macrophomina phaseolina*, *Sclerotium rolfisii* and *Rhizoctonia solani*, while only 5% isolates were antagonistic to *Fusarium oxysporum*.

Efficacy of mixed biofertilizers

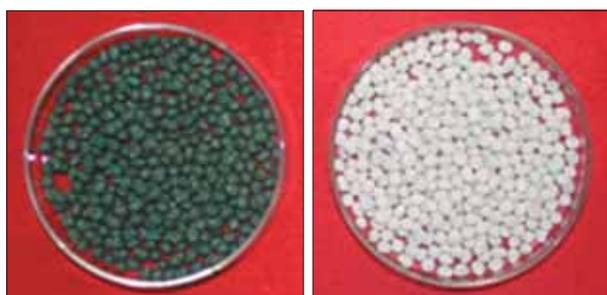
- In field experiments, DAPG (diacetylphloroglucinol)-producing fluorescent pseudomonads were applied to make groundnut soils suppressive to soil-borne fungal pathogens, *S. rolfisii* and *A. niger* causing stem- and collar rot, respectively. Seedling mortality of groundnut (cultivar GG 20) reduced from 70% in control to 35-42% in DAPG treatments. Inoculation with DPAG enhanced pod yield of groundnut (cultivar TG 37A) by 7 to 11% over uninoculated, control at DGR, Junagadh.
- Application of liquid biofertilizers of *Azospirillum* and phosphate solubilizing bacteria (PSB) (300 ml/ac) along with 200 kg of FYM in field experiments gave best response on maize in Alfisols at Amaravathi, Andhra Pradesh. *Rhizobium* and PSB liquid biofertilizer along with organic manure also gave good response on pigeonpea. Wilt incidence reduced wherever biofertilizers were applied in pigeonpea.
- Inoculation of *Gluconacetobacter diazotrophicus* and *Azotobacter* in sweet sorghum in farmers' field trials increased green biomass yield (11%), grain yield (8%) and quality of the juice at MAU, Parbhani.
- Studies on mixed cultures in laboratory revealed that King's B agar, CRYEMA and N-free malic acid medium can be used to enumerate *Pseudomonas*, *Rhizobium* and *Azospirillum* respectively from consortia. Jensen's agar can be used when the consortium contains not more than one nitrogen fixer. None of the media proved to be useful for differentially counting all the members of a given consortium.

Biofertilizers for temperate horticulture

- Eighty five efficient PSB isolates of apple from



Maize



Okra



different districts of Himachal Pradesh exhibited plant growth promoting traits, viz. IAA production (24.2%), siderophore production (25.7%), HCN production (19.4%) and growth inhibition against root rot fungus *Dermatophora necatrix* (29.6%). *Bacillus methylotrophicus* was reported as unique plant growth promoting rhizobacteria (PGPR) in apple rhizosphere at YSPUHF, Solan. *Bacillus*

pumilus, *Bacillus altitudinis* and *Bacillus firmus* from apple rhizosphere reported as PGPR.

- *Aneurinibacillus aneurinilyticus* strain CKMV1 from *Valeriana jatamansi* and *Bacillus subtilis* from *Picrorhiza* have been reported for the first time as PGPR for medicinal plants in YSPUHF, Himachal Pradesh.

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