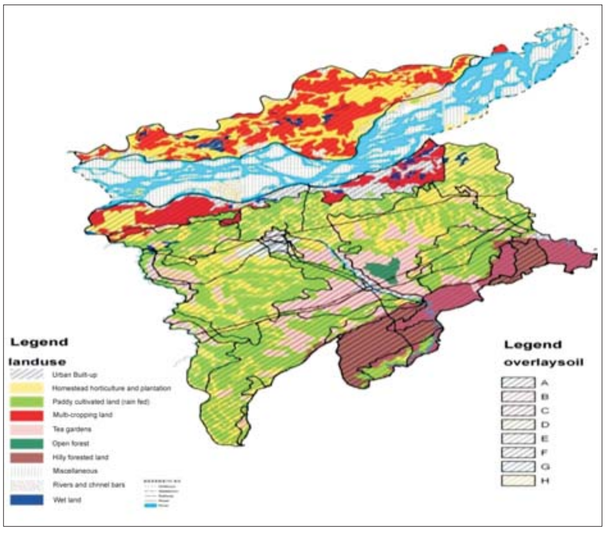
2. Soil and Water Productivity

The Natural Resource Management programme offers innovative management systems for efficient utilization and conservation of natural resources, especially related to agriculture, water, forest, biodiversity and soil management.

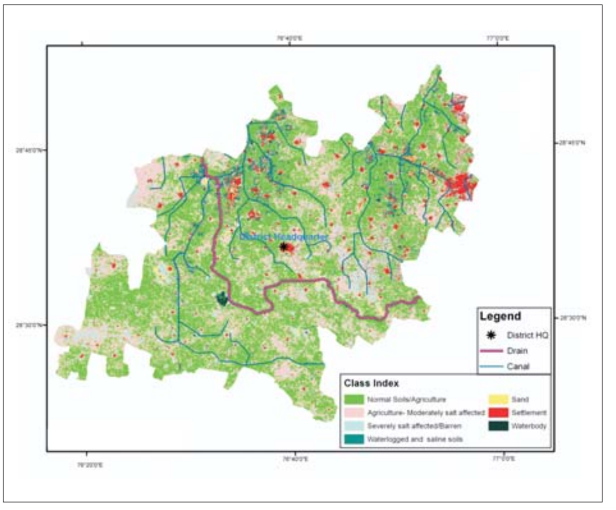
Soil resource inventory and management

Land-use planning of Jorhat district, Asom: Eight Land Management Units (LMU) of Jorhat district have been identified. The constraints and potentials of each LMU along with yield gap for various crops have been analyzed adopting Multiple Goal Linear Programming approach. The optimized cropping rotations recommended for higher productivity and profitability includes paddy-mustard-blackgram, paddy-blackgram-paddy and paddy-potato.



Land management unit map of Jorhat district, Asom, under rainfed ecosystem

Salt-affected and waterlogged soils mapped: The salt-affected soils of Jhajjar district, Haryana, were identified and mapped using IRS P-6, LISS III images of 2006 and 2007 with a resolution of 23.5 m. The SOI topographic maps on 1:50,000 scale were used for geo-referencing and base map preparation. Spectral signatures of each sample site were collected and the ISODATA algorithm was used to cluster the pixels into similar classes. There were 6 × 6 pixels for each class. Training sites were decided for different classes with the maximum likelihood algorithm for supervised classification degradation. The severely salt-affected/barren soils covered 159.5 km^2. Moderately salt-affected lands supporting agriculture covered 621.6 km^2. Waterlogged and saline soils covered 129.87 km^2. The classification produced an accuracy of 87.2%.



Classification of IRS P6 LISS III satellite image of Jhajjar district, Haryana

Model to predict runoff from watersheds: Soil and Water Assessment Tool (SWAT), a river basin GIS-based model for predicting runoff and soil loss from watersheds was applied to seven differently located watersheds, namely Choe Gauging watershed, Chandigarh; W3A, W3B and Sainji watersheds, Dehradun (Uttarakhand); Kokam and Navamota watersheds, Vasad (Gujarat); and KG-4 watershed, Udhagamandalam (Tamil Nadu). It requires preparation of digital elevation model (DEM), land use and soil maps, and weather data for watersheds. Accordingly, the maps/files were prepared for application of the model for these micro-watersheds. The calibrated and validated output of the model was found to be matching reasonably with the observed values with model efficiency varying from 66 to 92% for calibration and from 67 to 97% for validation for all the seven watersheds, indicating the superiority of this model in predicting runoff from micro-watersheds.

District soil fertility maps: GIS-based soil fertility maps (for both major and micronutrients) for 62 major districts of the country have been prepared using 30,000 geo-referenced soil samples. Almost all soils of different zones are deficient in available N. Majority of the soils in north zone are medium to high in available P and available K status. In west zone, majority of the soils are low to medium in available P except Gujarat. About 92-100% area in Gujarat is high in available P. Altogether only 10-33% area in west zone is low in available K. Most of the soils in Gujarat and Maharashtra are high and in Rajasthan are medium in available K. In east zone, most of the area in Odisha (73-97%) is low in available P. Majority of the soils of Asom and West Bengal are medium to high in available P status of soils. Majority of the soils in east zone are medium in available K except Khurda district in Odisha where 58% of the area is low in available K. In south zone, majority of the soils in Andhra Pradesh, Tamil Nadu and Kerala are high in available P. In Karnataka, most of the soils are medium in available P. Maximum soils of Tamil Nadu, Karnataka and Kerala are medium and majority of the soils of Andhra Pradesh are high in available K.

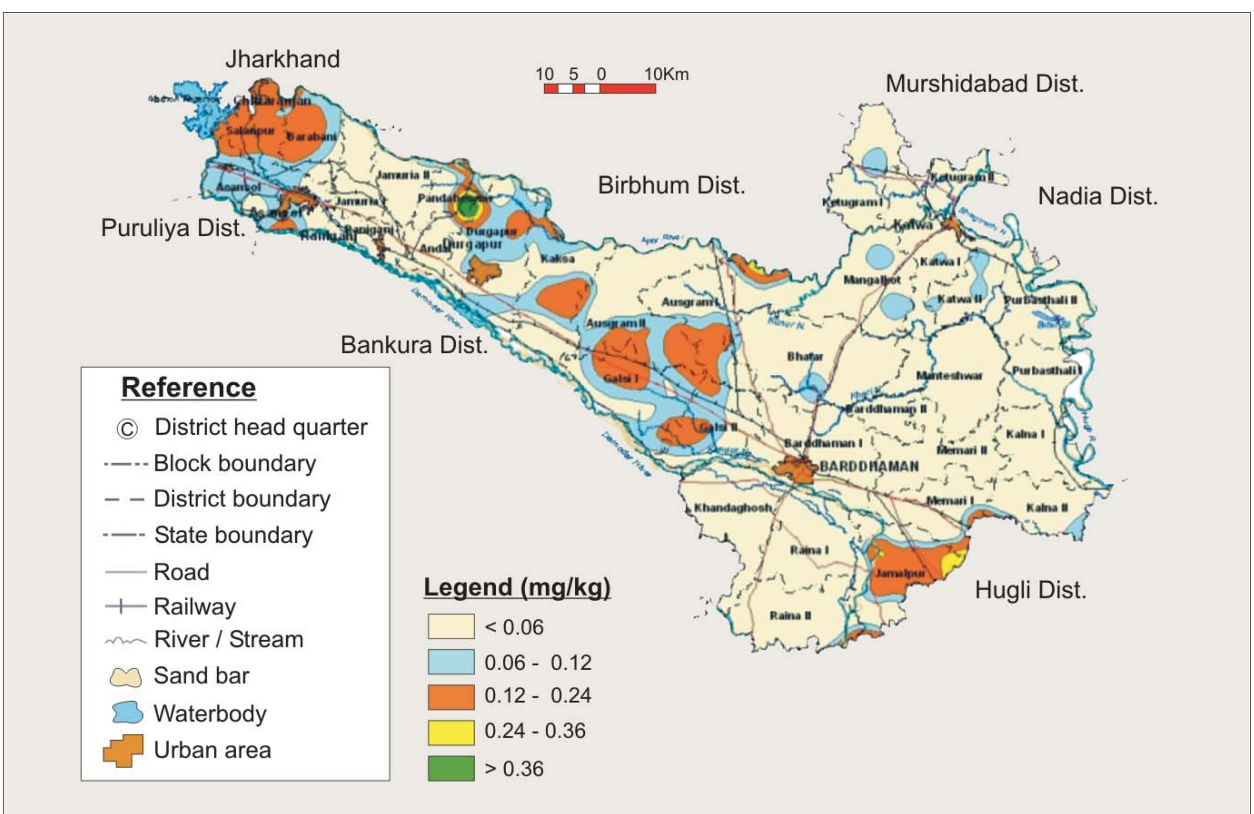
With respect to micronutrient status, almost all the soils in Punjab, Haryana and Himachal Pradesh in north zone are high in available Zn, whereas majority of Uttar Pradesh soils are medium in available Zn. Most of soils of this zone are high in available Fe, Cu and Mn with minor exceptions. Manganese deficiency is widespread (15-56%) in 4 districts of Punjab. Fe deficiency was observed over an area of 25-61% in Fatehabad and Hisar districts. In west zone, Zn and Fe deficiency is widespread in Maharashtra. Otherwise, majority of soils are sufficient in available Zn, Fe, Cu and Mn. The most of soils in east zone are high in available micronutrients. Zn deficiency was observed only in West Bengal. In south zone, majority of soils of Andhra Pradesh, Karnataka, and Kerala are sufficient in available micronutrients. In Tamil Nadu, about 80-95% of the area is low in available Zn and 10-15% deficient in Cu. All soils of Wayanad district in Kerala are deficient in Mn.

Boron in West Bengal: Fiftyfour per cent area in West Bengal is deficient in soil available boron. Hugli, Barddhaman, Birbhum and Nadia districts are severely affected with more than 90% area; Murshidabad, Dakshin Dinajpur, Bankura and Puruliya with 70 to 90% area; Kooch Behar, Maldah, and Paschim Medinipur 50 to 70% area; Darjeeling, Jalpaiguri and Uttar Dinajpur with 30 to 50% area and remaining districts with less than 30% area.

Integrated water management

Runoff potential of rainfed Alfisols: A Surface Water Yield Model (SWYMOD) was developed to generate a lumped hydrologic parameter called curve number for estimating the runoff potential of rainfed micro-watershed in Alfisols of Southern Telangana. The SWYMOD works on iteration process by integrating soil conservation service (SCS) method with farm pond water balance. The model requires input data on daily rainfall, evaporation, seepage, and observed pond water depth. The output module generates the plotted graph between observed and predicted pond water depths and calculates model efficiency. The tolerance limit for model efficiency used in the model was > 90% for a set of curve numbers selected in the input module. The model was tested and validated over a micro-watershed having a catchment of 14.5 ha having agriculture, forest and farm roads as major land uses. The simulated curve numbers were 75, 33 and 77 for agriculture, forest and farm roads, respectively, with model efficiency of 94%.

Multiple water use: Multiple use of water in the water-harvesting structures, in terms of pisciculture in the pond, on-dyke horticulture, vegetable cultivation, poultry farming and honey-bee culture on participatory basis in Dhenkanal district of Odisha, showed positive impact on rural livelihood. The yield of paddy within



Spatial distribution of available boron in Barddhaman district, West Bengal the command area was enhanced by 120% in comparison to 2.2 Mg/ha outside the command area. The benefit : cost ratio of the system was 1.52 and overall water productivity of the system was ₹ 3.3/m^2 water which enhanced by 136% over the farmers' practices.

Increased water productivity through integrated SRI: The water productivity of rice grown with SRI method along with fish culture in the refuge at Bhubaneshwar (rainfall 1,500 mm) and provision of supplementary irrigations to the rice crop during flowering and grain-filling stages using the run-off harvested water was enhanced to ₹ 2.59/m^3, i.e. by 193% as compared to conventional farmers' practices of growing rice.

Integrated system of rice intensification (SRI) with fish culture

Mini sprinkler irrigation system for betel vine: Mini-sprinkler demonstration was conducted in betel vine plantation in the farmers' fields in Jadua Barai Tola, district Vaishali, Bihar, in an area of 1,180 m^2. The water productivity with mini sprinkler irrigation was ₹ 400/m^3 which was 40 and 30% higher over irrigation through PVC pipe (3.8 cm diameter) and splash irrigation respectively.

Water-saving techniques for dry season crops: Under rice-based cropping system, groundnut grown in paired rows on beds spaced at 45 cm during dry season in Khurda district of Odisha saved 40% of irrigation water and enhanced crop water-use efficiency (WUE) by 42% over the flat method of planting which received 17.8 cm of irrigation water and recorded crop WUE of 3.84 kg pod/ha-mm water. This method of planting enhanced the groundnut pod yield by 18-20% over flat method, which yielded 1,356 kg/ha. Similarly, potato grown on paired row planting at 75 cm × 20 cm spacing (paired row at 25 cm) enhanced crop WUE by 9% and reduced the irrigation water requirement by 22% when compared with normal planting of 50 cm × 15 cm, which recorded crop WUE and total irrigation water requirement of 41.1 kg tuber/ha-mm water and 21.9 cm respectively.

Water saving in commercial aquaculture: The water requirement, water productivity and feeding management for improving water quality and triggering compensatory growth performance of Indian major carps, giant freshwater prawn and black tiger shrimp in grow-out culture system was estimated for coastal districts of Odisha. The concept of feed restriction and refeeding that triggers compensatory growth enhanced yield by 16-18% and maintained water quality, thus minimizing the water requirement for exchange. This also helped in enhancing water productivity, preventing wastage of water and operational cost by 20-25% in grow-out aquaculture. Further, the water requirement (without hampering the growth, yield and water quality) was estimated to be 13.5 m^3/kg biomass in composite freshwater fish and prawn culture and 9.97 m^3/kg biomass in mono-culture of black tiger shrimp at a stocking density of 5,000 fingerlings/ha and 100,000 post-larvae/ha respectively. When adopted in a larger scale, this will give a new dimension to aquaculture industries and would help in minimizing the wasteful use of water in grow-out aquaculture.

Integrated nutrient management

INM for rice-based cropping: Application of Biofertilizer Enriched Compost (primed rockphosphate and biofertilizer agents *Azospirillum* and phosphate-solubilizing bacteria) at 2 Mg/ha reduced the recommended N and P fertilizer up to 75% and resulted in rice yield of 4.2 and 4.1 Mg/ha in rice-toria and rice-wheat sequence, respectively, compared to 4.3 and 3.8 Mg/ha with recommended inorganic fertilizers in soils of Asom. Application of Biofertilizer Enriched Compost also exhibited better soil health in terms of greater microbial carbon, higher dehydrogenase, phosphomonoesterase and flourescein diacetate hydrolytic activity (FDA) in soil.

Nano-rockphosphate for crops: A high-energy ball mill (pit mill) with zirconium oxide balls (approximately 10 mm in diameter) and bowls (1,000 ml) was used for grinding rockphosphate particles to get bulk amount of nano-particles. The grinding process was performed in a continuous regime in air during 6 hr at the basic rotation speed of 120 rpm and rotation speed of bowls at 300 rpm. After uniform milling, the different rockphosphates from Udaipur attained different sizes, ranging from ~ 70.9 nm to ~106.6 nm. The Sagar rockphosphate also achieved particle size ~110.1 nm. A series of solution culture experiments conducted with maize, soybean, wheat and barley crops established that P from nano-rockphosphate particles can easily be taken up by the crops and was used similarly to the P supplied through water-soluble P fertilizers. The extent of P solubilization from different nano-rockphosphate increased from 8 to over 30% due to inoculation with fungal (black and green pigmented spores) and bacterial *(Pseudomonas striata)* cultures.

The pot culture experiment conducted with maize crop on four diverse soils (Vertisol, Alfisol, Aridisol and Inceptisol) showed relatively higher yield response to nano-rockphosphate in all the soils as compared to micron-sized rockphosphates. A field experiment was also conducted with sorghum and finger millet wherein the crops were fertilized with nano-rockphosphate at the rate of 50 kg P_2O_5/ha in water suspension (265 litres/ha) stabilized with 150 ml of linear alkyl benzene sulphonate (LAS). The yield of sorghum and finger millet increased from 1,350 to 2,228 kg/ha and 640 to 1,048 kg/ha, respectively, owing to nano-rockphosphate application.

Technology for preparation of enriched compost: A technology for the preparation of P, K and S enriched compost using wheat straw, cattle dung, phosphate rock, waste mica and mineral gypsum was developed and demonstrated on farmers' fields at Geelakhedi village, Rajgarh district. The quantities of ingredient materials required for preparation of one tonne (1,000 kg) of enriched compost and its composition are given below.

Material	Quantity (kg)	Nutrient content
Wheat straw and other crop residues	1,000	–
Cattle dung	150	–
Phosphate rock	200	5.2% P
Waste mica	200	4.9% K
Mineral gypsum	100	18% S

The organo-mineral compost thus prepared contains about 1% total N, 1% total P, 2.1% total K, and 1.7% total S. On-farm trials conducted on soybean in Geelakhedi village showed that INM (75% NP+3 tonnes organo-mineral compost) resulted in higher soybean seed yield (19.6 q/ha) as compared to recommended fertilizer doses (18.2 q/ha).

Enriched compost heap covered with dung-soil slurry

Coir pith composting: Coir pith compost is a good source of organic manure for dryland agriculture as it can absorb water five times to its weight and thereby enhancing the water-holding capacity of soil. Through the coir pith, the waste from coir industry contains constituents like lignin (30%) and cellulose (26%), which do not degrade quickly but it could be decomposed by using the fungus *Pleurotus sojar-caju* with urea supplementation. Firstly, 100 kg of coir pith was spread and then one bottle of *Pleurotus* spawn was applied over this layer. This procedure of alternate application of *Pleurotus* and urea was done for the whole one tonne of pith. After two months, the coir pith is changed into a well-decomposed black mass with C : N ratio of nearly 24 : 1 and N 1.06%. Later, demonstrations were carried out in Ayalur Model Watershed, Erode district, Tamil Nadu. The soil of the watershed is red lateritic and poor in soil organic matter and nutrient content, low water holding capacity and soil depth. The coir pith compost was applied to the maize crop @ 5 tonnes/ha. Higher growth and biomass production (17%) was observed with coir pith compost compared to normal practice.

Demonstration on coir pith compost at Ayalur Watershed, Tamil Nadu

Biochar for farm carbon sequestration: Production of biochar from crop residues at the individual farm level, in combination with its storage in farm soils, is a potential option to sequester carbon, increase crop productivity, profitability and sustainability of soil systems in rainfed agricultural production systems. The 'biochar' denotes fine-grained carbonized materials of highly porous structure resulting from the incomplete combustion of organic material or biomass. Biochar's climate-mitigation potential stems primarily from its highly recalcitrant nature of carbon with long 'C' turnover or residence time in soils, which could vary from 100 to 10,000 years.

A low-cost portable charring kiln was developed at CRIDA, Hyderabad to produce biochar from maize, castor, cotton and pigeonpea stalks at smaller scale. The highest conversion efficiency of 29.3, 24.4, 26.9, 35.0% was obtained at a loading rate of 8.7, 15.0, 10.8, 18.0 kg and a partial combustion time of 15.0, 17.0, 11.3 and 16.0 minutes for maize, castor, cotton and pigeonpea stalks respectively. Total carbon in biochar was 51, 56, 65 and 71% for maize, castor, cotton and pigeonpea stalks respectively. Application of cotton and pigeonpea stalks biochar @ 6.0 tonnes/ha with recommended dose of fertilizers resulted in increase in yield of pigeonpea by 39.8 and 32.1% over control respectively.

Bionutrient package for rice: Evaluation of bionutrient package (spent mushroom residue or semi-decomposed straw + *Pseudomonas* spp. along with *Azospirillum* sp. and cyanobacteria) for rice at farmers site in Bihar showed significant increase in (four-year experimentation) grain and straw yield (8-20%), saved 50% NPK, improved fertilizer-use efficiency, and enhanced the soil total nitrogen, as well as organic carbon content. Residual effect of microbial inoculants were more pronounced in rice-lentil cropping system than rice-maize cropping system.

Bioinoculant organic package for ragi-berseem: Bioinoculation (*Azotobacter* + *Azospirillum* + PSB) along with application of FYM (@ 5 tonnes/ha) or vermicompost (2.5 tonnes/ha) under ragi-berseem cropping system in acid soil region of Odisha resulted in 19 and 25% increase in grain yield of ragi; and 20 and 25% increase in green fodder yield of berseem over the control yield of 32.2 and 36.6 q/ha ragi grain and 215.4 and 240.6 q/ha berseem fodder owing to integration with FYM and vermicompost (VC) respectively. Liming of acid soil (*p*H 5.1) increased the efficiency of bioinoculants, where the responses increased to the extent of 46 and 35% for ragi and 50 and 43% for berseem with FYM and VC respectively.