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Soil and Water Productivity

Soil Resource Inventory and Management

District-level land-resource inventory for farm planning: Soil-resource inventory of Lohardaga district (149,100 ha), Jharkhand, was prepared on 1:50,000 scale and 26 soil series were identified under two broad physiographic units, viz. hills (36.6%) and plateau (62.2%). The soil resource data were mapped into 35 mapping units at soil series association level. The soils of Lohardaga district belong to 3 orders, Alfisols being the most dominant (45.09%) followed by Inceptisols (28.03%) and Entisols (16.58%).

Evaluation of land capability, irrigability and soil-site suitability for various crops showed that majority area (33.1%) of the district was under capability class IIIw which is mostly in low-lying area of the district. About 31.3% area is under capability class VII, which is mostly in hilly terrain. The available water-holding capacity of the soils of 51.8% area of the district is high.

Soil erosion map of Kota, Rajasthan: The digitized soil erosion map of Kota (Rajasthan) has been generated from soil loss value estimates for each of 10 km grid point using universal soil loss equation (USLE). Despite relatively low annual rainfall, water-induced erosion is a serious problem in the region. About 66% area has annual soil loss higher than 10 tonnes/ha and about 15% of the area show severe erosion rates with soil loss rates exceeding 40 tonnes/ha/year. The relatively higher rates of erosion per unit of rain energy are primarily due to poor ground cover during the monsoon season and slope steepness of the rolling and hilly terrain.

Four grass barriers, *Vetiveria zizanioides* (*khus*), *Saccharum munja* (*munj*), *Cenchrus ciliaris* (*dhaman*) and *Dichanthium annulatum* (*karad* grass) were evaluated for their conservation value and compatibility with rainfed sorghum and soybean on 1% slope at Kota, Rajasthan. *C. ciliaris* and *D. annulatum* were the most effective in reducing runoff with significant grain (~23%) and straw (~13%) yield of sorghum and soybean besides providing about 0.4-0.5 tonne/ha air dry forage.

Soil erosion map of Pauri Garhwal district, Uttarakhand: Digitized soil erosion maps of Pauri Garhwal district, on 1:50,000 scale, have been generated. The soils are mostly moderately shallow, excessively drained, sandy loam, occur on very steep slopes, very severely eroded, largely

Land degradation status in arid desert

Land degradation under different land uses in the arid desert of western Rajasthan and Gujarat, covering 28.5 million ha area, was mapped on 1:0.5 million scale using remote-sensing technique. It revealed that ~76% area of western Rajasthan was affected by wind erosion, encompassing all the major land uses but mostly croplands and dunes/sandy areas, while water erosion affected ~2% area (mostly in croplands and scrublands), salinization ~2% (mostly in croplands) and vegetation degradation ~3% (especially in scrublands and forests). Mining activities have spoiled so far only 0.10% area, and degraded rocky areas covered 1% area. About 18% area was severely degraded and 66% slightly to moderately, while 16% area was not affected by degradation. The mapping showed that ~1.3 million ha area of croplands in western Rajasthan was under severe wind erosion (mostly unirrigated).

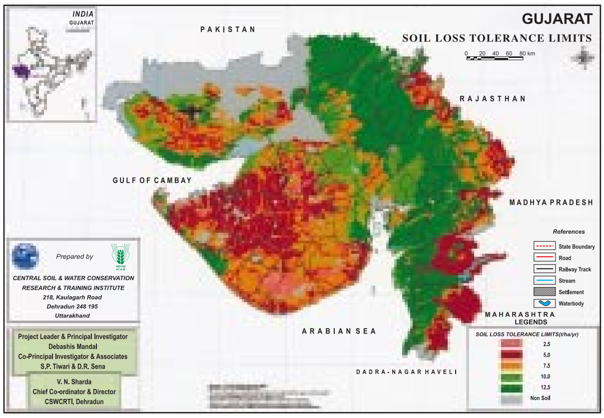
In arid Gujarat, water erosion was the most dominant process, affecting ~43% of the total area (mostly in croplands), followed by salinity (38%), while vegetation degradation (10%) and wind erosion (5%) covered smaller areas. About 44% area was severely affected, 53% slightly to moderately, and 3% not affected. Large area under severe degradation was due to the huge area of the Great Rann of Kachchh and the Little Rann that have high natural salinity.

stony, slightly acidic and dominantly rated as class III lands.

Soil loss tolerance limits for Gujarat: Gujarat, covering an area of 19.6 million ha was divided into three major physiographic regions, viz. Central High Lands, Western Hills and West Coast Kathiawar. Major area (42.4%) of the state falls under SLTL class IV and V, i.e. 10.0 to 12.5 tonnes/ha/year. About 20.0% area falls in SLTL class I and II, i.e. 2.5 to 5.0 tonnes/ha/year. About 35.7% area falls under soil tolerance class III, i.e. 7.5 tonnes/ha/year. The soil loss tolerance limit (SLTL) map has been developed for Gujarat state.

Integrated Water Management

Assessment of water harvesting potential in rainfed areas: Assessment of rainwater harvesting potential across the major rainfed crop growing districts for providing supplemental irrigation using FAO water balance model revealed that about 10.6 million ha area under coarse cereals, 6.4 million ha area under rice, 4.1 million ha area under cotton, 10.5 million ha area under oilseeds, 7.2 million ha area under pulses totalling 39 million ha could generate about 114 billion m^3 surplus water capable of providing supplemental irrigation in major part of rainfed areas. Based on the available surplus, the area that can be provided with single supplemental irrigation of 100 mm at reproductive stage of the crop was estimated for both normal rainfall and drought years. Out of 114 billion m^3 available as surplus, about 28 billion m^3 (19.4%) is needed for one supplemental



Soil loss tolerance limits for Gujarat

irrigation on an area of 25 million ha during normal monsoon year, thus leaving about 86 billion m^3 (81.6%) to meet river/environmental flow and other requirements. During drought years also, about 31 billion m^3 is still available even after making provision for irrigating 20.6 million ha. By introduction of supplemental irrigation (with 'Business as Usual' scenario), the crop production can be enhanced by a total of 28-36 million tonnes from an area of 20 -25 million ha during drought and normal monsoon periods which accounts for about 12% increase over the present production. The benefits could be still higher if initiatives like improved cultivars, SRI cultivation in rice, crop and land use diversification, use of improved irrigation techniques like drip and micro-sprinkler (which further increase water-use efficiency etc.) are taken up. Thus supplemental irrigation through water harvesting would be a viable option in major part of rainfed area which otherwise have no environmental problems like waterlogging etc. These areas are more in the sub-humid climatic zone of the country.

Micro-tubewell for coastal saline area: In coastal saline area of Orissa in Astarang block of Puri district, micro-tubewell was constructed which was helpful for small farmers irrigating their *rabi* crops/vegetables. The groundwater was saline beyond 20 m (4.8 dS/m). Hence, the depth of tube-well was limited to 10 m to 12 m depth and the diameter of tube well was limited to 5 to 7.5 cm. The energy for drawing the water was limited to 2 HP.The discharge from the tube-well varied between 3.5 to 5 lps. The aquifer, full of fresh water from deltaic rivers and huge monsoon rainfall, is a perched one and it extends from 3 m below ground level onwards. Top 3 m is clayey zone and rest is sandy zone. The cost of 7.5 cm diameter tubewell with 12 m depth is Rs 4,800 only and it irrigates almost 1 ha vegetable crops. The water productivity varies from Rs 2.87/m^3 to Rs 4.52/m^3 in case of 10:90 (farmers share: project share) participation. The water productivity increases from Rs 3.65 to Rs 5.46 when the participation of farmer increases up to 30%.

Long-term effects of sewage irrigation: Intensification of industrialization has resulted in effluent and wastewater production in large

Bio-engineering measures for protection of river banks

Seasonal rivers (torrents) cause a huge damage to the life and property due to flash floods during the monsoon season in the Shiwaliks and foothills of outer Himalayas. Cost-effective bio-engineering structures (spurs, protection walls and embankments) were developed and locally adaptive flow-resistant vegetative species identified for training the river flow, bank erosion control and protection of the agricultural land and other property along the banks. Nearly 2.2 km stretch on Song river near Dehradun was recently protected through construction of 93 spurs. The technology is being extended to the other development agencies. The silvi-pastoral system consisting of *Grewia optiva* (managed under three lopping practices), *Chrysopogon fulvus* and *Panicum maximum* was also developed on old riverbed lands for their productive utilization.

Performance of different crops under sewage irrigation

quantities, which has become a matter of serious concern in terms of their safe disposal. These wastewaters have high nutrient value and the irrigation potential for increasing crop production, but due to heavy metal and pathogen loads these waters have to be used judiciously, otherwise will pollute our natural resources. Long-term field studies on development and refinement of low cost-management practices of sewage and agro-industrial wastewater under different cropping systems (vegetable, fodder, cereal and agro-forestry based systems) indicated that the yields of most crops like Egyptian clover and wheat increased by 10 to 28% when sewage water was used for irrigation. Further, sewage irrigation supplemented with N and P at 50% of recommended levels and tube-well water irrigation with recommended levels of both nutrients produced almost similar yields. In the 5th year, rice productivity in association with poplar was 73% less than the rice yield in the open.

Integrated Nutrient Management

Site-specific nutrient management: The verification trials with rice (JR 201) – wheat (GW 273) and soybean (JS 93-05) – wheat (JG 273) systems were conducted on Vertisols at Jabalpur. All the crops received recommended dose of N, P and K, while rice received FYM @ 5 tonnes/ha. In rice-wheat system, the average grain yields with target yield approach with and without Integrated Plant Nutrient Supply System (IPNS) were 8.5 and 10.97 tonnes/ha, respectively, compared to 6.35 tonnes/ha with general recommended dose (GRD). The net returns due to IPNS target yield approach over GRD were Rs 10,787/ha in paddy and Rs 24,689/ha in wheat. In soybean-wheat system, the average annual seed yields with and without IPNS target yield were 8.56 tonnes/ha and 6.68 tonnes/ha, respectively, compared to 6.3 tonnes/ha with GRD.

Crop-residue management in farmers' field: In irrigated areas, about 90% of wheat is cultivated after harvest of rice and cotton. Accordingly, there is short time for land preparations for establishing wheat due to late-maturing long-grain rice varieties. It normally takes 2-3 weeks for rice fields to become workable for land preparations due to antecedent moisture. The delay in planting of wheat after 20 November results in reduction of potential wheat yield by about 1% per day. Moreover, farmers cultivate land often without achieving suitable seedbed conditions for planting wheat, which results in poor crop yields.

The on-farm evaluation trial was conducted (12 farmers) during 2006-07 by using the second generation machineries as Happy and Turbo Seeder in condition of 6 tonnes/ha of rice residues left on the field which was to be cultivated for the next wheat crop. Wheat was sown with these machines under zero-till condition. There was increase in wheat grain yield with both Happy Seeder (5.75 tonnes/ha) and Turbo Seeder (5.8 tonnes/ha) over conventional method (5.55 tonnes/ha). Further, resource saving was also recorded when both the seeders used for sowing. About 7-10 days time saving was recorded with Happy and Turbo seeder as compared to conventional method. About Rs 1,500-2,000 and Rs 1,200-1,800 were saved, respectively, owing to use of Happy and Turbo seeders. Besides, use of these seeders under standing residue conditions saves 20-30 % irrigation water in the case of first irrigation after sowing and 10-15 % in subsequent events.

Field test kit for determination of sodicity level and reclamation material: A field test kit was developed for easy determination of soil sodicity level and amount of reclamation material required, for the sodic soil of Uttar Pradesh to be used by farmers/extension worker. Determination of soil sodicity has been proposed by way of turbidity, dispersion and swelling tests for their categorization into sodic , moderately sodic and non-sodic soils. To reclaim such types of salt-affected soils, suitable amendments are required based on the soil-test value. Ten surface (0-15 cm) soil samples per hectare at random locations are to be collected from the field during April-May for determination of the extent of soil sodicity and the amount of reclamation materials required. The recommendation for amendments required for different sodicity classes are as follows:

Non-sodic: No amendment recommended.

Moderately sodic: An amendment of 6 tonnes/ha sulphitation pressmud is recommended.

Sodic: An amendment of 12 tonnes/ha gypsum or 6 tonnes/ha gypsum along with salt-tolerant rice and wheat varieties is recommended.

Improving biofertilizer quality: The widely used carrier based inoculants have a short shelf-life of up to 6 months and are of variable quality.

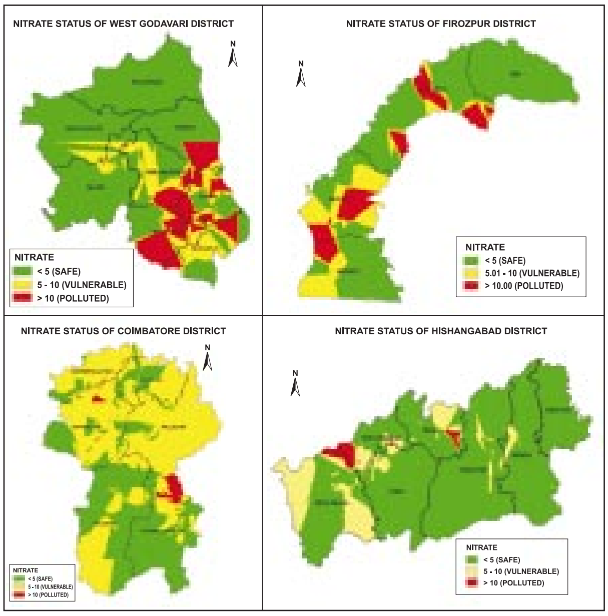
Biofertilizer quality testing kit

A quick method for estimating biofertilizer quality was devised for *Azotobacter, Pseudomonas, Bacillus* and *Rhizobium* bioinoculants which were tagged with a genetic marker encoding for the enzyme ß-galactosudase and the end produce was detected using chromogenic substrate. The amount of enzyme activity was correlated with the viable cell number to estimate the viable cell population in broth as well as charcoal-based inoculants. This test can be performed either quantitatively in liquid culture or qualitatively by using filter paper discs. A quality-assurance kit was developed which can test the quality of biofertilizers in 1-2 hr. The cost of assay is approximately Rs 100/assay.

Liquid cultures containing cell protectants not only maintain high microbial numbers but also promote the formation of resting cells like cysts and spores which result in better resistance to abiotic stresses, thus improving the product shelf-life. Three liquid media formulations containing different concentrations of arabinose, trehalose, glycerol and polyvinyl pyrrolidone (PVP) were devised for *Rhizobium*, *Azospirillum* and P-solubilising *Bacillus megaterium*. Even after one year of storage, in case of *Rhizobium* the liquid medium maintained good titre (2.7×10^8 cells/ml), whereas in lignite carrier it had come down to negligible level (12 cells/g). In case of *Azospirillum* (AZS 303) liquid medium maintained 4.4×10^8 cells/ml, whereas in lignite it had come down to 9.8×10^2 cells/g. In case of phosphate solubilising bacteria (*Bacillus*) the liquid inoculant medium could maintain 1.0×10^8 cells/ml, whereas in lignite it had come down to 145 cells/ml. No contamination was observed until 360 days in any of the liquid inoculants. The dose of 4 ml of liquid *Rhizobium* inoculants per kg of seed could satisfactorily retain the maximum number of viable cells on the seeds up to 24 hr of bacterization.

Biofertilizers for vegetables in tribal areas: Bioinoculants (*Azotobacter* and *Azospirillum*) were developed for tropical vegetables (brinjal, tomato, potato, onion, bean, cowpea, okra, carrot, yam, elephant foot yam, chilli, radish). Bioinoculation in acid Alfisols of Orissa in the tribal areas of Dhenkanal district enhanced yields (8 – 21% for above ground grown crops and 25 – 50% for underground crops and brought fertilizer savings of 20-25 % of plant nutrient cost incurred for N and P. Nutrient-use efficiency improved by 12-36% for N, 18-28% for P, 9-15% for K and 16-18% for S owing to inclusion of biofertilizers. Biofertilization improved produce quality (Vitamin C, curcumin, lycopene). Response of corm and yam to bioinoculation in farmers' fields in acid soils of Majhishahi, Dhenkanal and Orissa.

Nitrate contamination in groundwater: The extent of nitrate contamination in groundwater in six intensively cultivated districts was evaluated. Geo-referenced maps with block boundaries of six target districts, viz. West Godavari (AP), Ferozepur (Punjab), Hooghly (WB), Jalgaon (Maharastra), Coimbatore (TN) and Hoshangabad (MP) have been prepared for delineating nitrate contamination using data of pre-monsoon 2007. While about 20% stratified random samples of West Godavari district had nitrate concentration in groundwater beyond the permissible safe limit of 10 mg NO_3-N/litre, three districts, viz. Ferozepur, Coimbatore and Hoshangabad, recorded moderate level of nitrate pollution. Hooghly and Jalgaon district did not show any nitrate pollution in groundwater. The shallow and unconfined or semi-confined aquifers like dugged wells, open wells and hand pumps were more polluted than deep and confined aquifers in all the districts. In all districts higher nitrate was recorded in groundwater in areas under vegetables and orchards/plantation crops than rice-based/soybean-based cropping systems and other field crops.



Delineation of nitrate contaminated areas in West Godavari, Ferozepur, Coimbatore and Hoshangabad districts

Rapid composting through fungal bioinoculum: Microbial enriched composting technique using fungal bioinoculum such as *Aspergillus heteromorphus, A. terrus, A. flavus* and *Rhizomucor pusillus* was developed to accelerate the process of decomposition of organic waste such as wheat straw, soybean stalk, pigeonpea straw, cotton stalk, sugarcane trash and vegetables waste. These wastes were mixed with fresh cowdung in the ratio of 1: 0.2 (w/w) and starter nitrogen @ 0.5% on materials on dry-weight basis. Fungal bioinoculum was added to accelerate the process of decomposition at 5 and 30 days of decomposition @ 500 g mycelial mat/q materials on dry-weight basis.

After decomposition, addition of fungal bioinoculum helped in attaining early maturity indices for all the composts. Compost prepared from vegetable waste, pigeonpea straw, soybean straw and wheat straw with fungal bioinoculum decomposed faster and attained maturity in 120 days compared to uninoculated control (180 days), thus reducing the composting period from 6 months to 4 months. Cotton stalk and sugarcane trash, however, took some more maturity time to produce good quality compost.

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Water Management

Decision support software for shrimp aquaculture: Decision support software was developed to estimate the maximum allowable shrimp farming area based on the assessment of carrying capacity of particular water body. Based on the monthly estimates of nutrient loading from the shrimp farms and assimilation capacity for one year, area recommendations for shrimp aquaculture were made taking into consideration of Coastal Regulation Zone rules, Coastal Aquaculture Authority guidelines and supportive capacity of the ecosystem in Andhra Pradesh. This tool will help state governments and other regulatory organizations to regulate the level of shrimp farming activity for each receiving water body and in framing future guidelines and policies for sustainable development of shrimp farming.

Impact assessment of aquaculture on mangroves using remote sensing and GIS

Satellite images of Punnakayal mangroves, Tamil Nadu, were georeferenced to assess the impact of aquaculture development on mangroves. The land use maps indicated that no aquaculture farms are located around mangrove areas. GIS change detection analysis found that saltpans nearer to mangrove areas were the main reason for the degradation. The mangroves of 7.9 ha were converted to saltpan and 29.4 ha were degraded to scrub land. The soil and water analysis nearer to mangrove areas revealed that the electrical conductivity values (measure for salinity) in soil and water were more than 59 dS/m and 110 dS/m in soil and water samples, respectively. The high salinity observed in the vicinity of salt pans could be the reason for mangroves getting degraded into scrub land. The study indicated that aquaculture is not responsible for the mangrove degradation in Punnakayal area.

Development of diversified farming systems

As a part of diversified farming practice, the monoculture of the seaweed, *Hypnea valentiae,* was carried out by raft culture method at Navibunder, Gujarat. A maximum of 5.2-fold increase in yield was observed in 50 days during the post-monsoon period of December and January. The monoculture of *Hypnea musciformis* recorded a maximum of 6.2-fold increase in yield in 61 days during post-monsoon periods of January and February at Chorwad.

Molecular protocol to assess pollution effect: A molecular technique was developed for early and rapid detection of heavy metal pollution in open waters. The protocol could be used to assess the impact of pollution on freshwater fishes.

Assessment of inland fishery resources using remote sensing techniques: For the development of digital map of inland water bodies of the country using remote sensing satellite data, water bodies of 0.5 ha and above were identified and mapped for Punjab, Haryana and Orissa. The mapping of water bodies with area above 10 ha was completed in Madhya Pradesh. The ground-truthing was undertaken in 27 districts in Orissa and Uttar Pradesh for the verification of imageries with physical presence of the water bodies. Spatial and other information was attached with GIS format. Murugama (Sahara Jore) watershed in Purulia district of West Bengal was delineated and digitized for first, second and third order streams of the watershed.