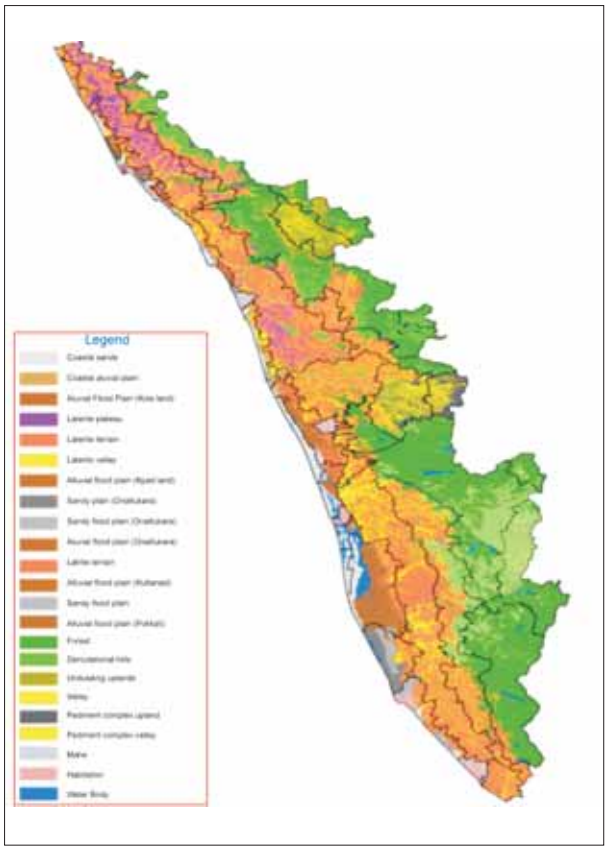
2. Soil and Water Productivity

Land degradation, groundwater imbalances, impaired soil health and contamination of food chain and environmental pollution are major problems today. Recent climate change impacts on agriculture further compounded the situation. Characterization, conservation and efficient utilization/management of the natural resources are essential to ensure food, nutritional and environmental security in the emerging context and work is progressing in that direction.

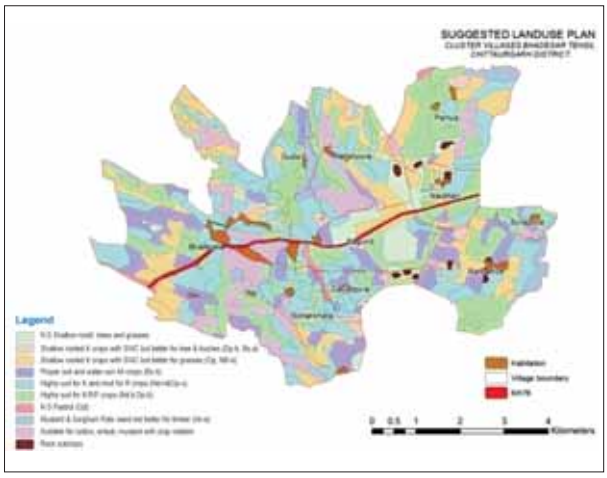
Soil resource inventory and management

Agro-ecological sub-units of Kerala mapped: To bring out the variability of land, soil and hydrology, agro-ecological subunits of Kerala were delineated. The maps highlight the potentials and problems of agro-eco units of each district, so that the same can be used as a base for planning agriculture and allied sectors.



Agro-ecological subunits of Kerala

Farm-level land use planning: A cadastral level (1:4000 scale) survey of 10 villages in Bhadesar tehsil of Chittaurgarh district of Rajasthan was undertaken along with remote sensing data (IRS-LISSS IU/P6) to suggest suitable crops in the region. Thematic maps for soil site characteristics, fertility and crop suitability maps

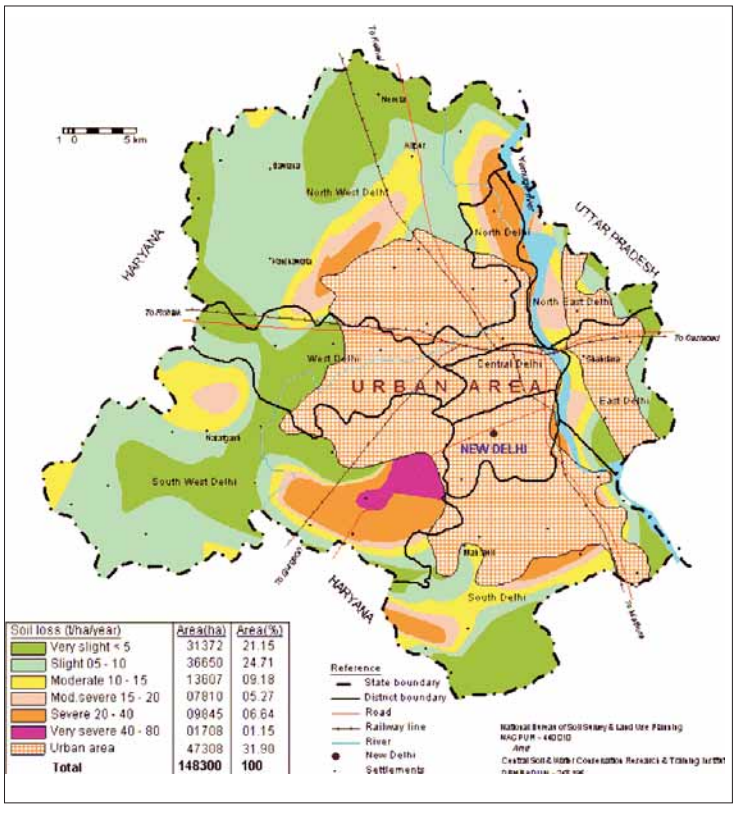


Suggested land use plan for cluster villages of Bhadesar tehsil

of the area were prepared to suggest alternative land use options.

Assessment of soil erosion in Delhi

GIS-based soil-erosion map of Delhi was generated using annual soil loss data. In Delhi, about 32% of the geographical area is within the limit of the New Delhi Municipal Committee (urban area), which was not assessed. Of the remaining non-urban area, 31% has very



Soil erosion map of Delhi

slight soil loss of < 5 tonnes/ha/year, and 36% area suffers from slight erosion in the range of 5–10 tonnes/ha/year. Only 19% of non-urban area has annual soil loss in the range of 15–45 tonnes/ha/year; these areas are concentrated in the pockets around Yamuna, Aravalli ridge-line in Tughlakabad, Mahipalpur and Mehrauli area, and contribute to more than one-half of total soil loss in Delhi state.

Integrated water management

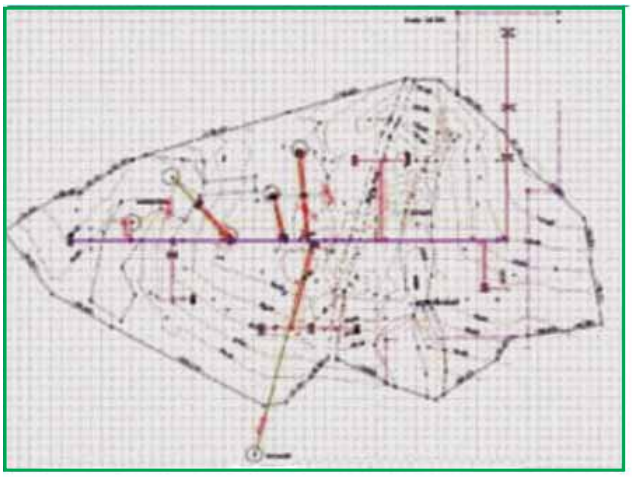
Enhancing water productivity through groundwater sharing: An innovative model of groundwater sharing was evolved in the Ranga Reddy district of Andhra Pradesh. An attempt was made for designing a pipeline network by pooling all bore wells in village Malkai Pet Thanda. This resulted in avoiding competitive digging by farmers, who do not own bore wells. Farmers were also encouraged to shift to irrigated dry crops in the village during *kharif* and *rabi*. About 18.21 ha under irrigated dry crops during *kharif* and 10.12 ha in *rabi* were brought under cultivation for the first time. The intervention helped in improving cropping intensity, water productivity and judicious use of groundwater. This successful model has attracted the attention of the NABARD and State Department of Rural Development, Andhra Pradesh are mainstreaming this practice.

Economic analysis of farm ponds for water harvesting: The extent and determinants of viability were examined using data from 100 ponds in Anantapur district (Andhra Pradesh). Based on the changes in cropping pattern and yield gains attributed to introduction of ponds, additional returns generated in the plots where ponds were located were computed. The results showed that 14 out of 100 ponds generated additional returns of about ₹3,000 and 10 ponds more than ₹15,000. Majority of the ponds generated returns varying between ₹3,000 and ₹6,000. Assuming these returns would occur every year for a period of 15 years, the economic viability in terms of Net Present Value and benefit : cost ratio was calculated. The benefit:cost ratio varied between 2 and 4 in majority of the ponds.

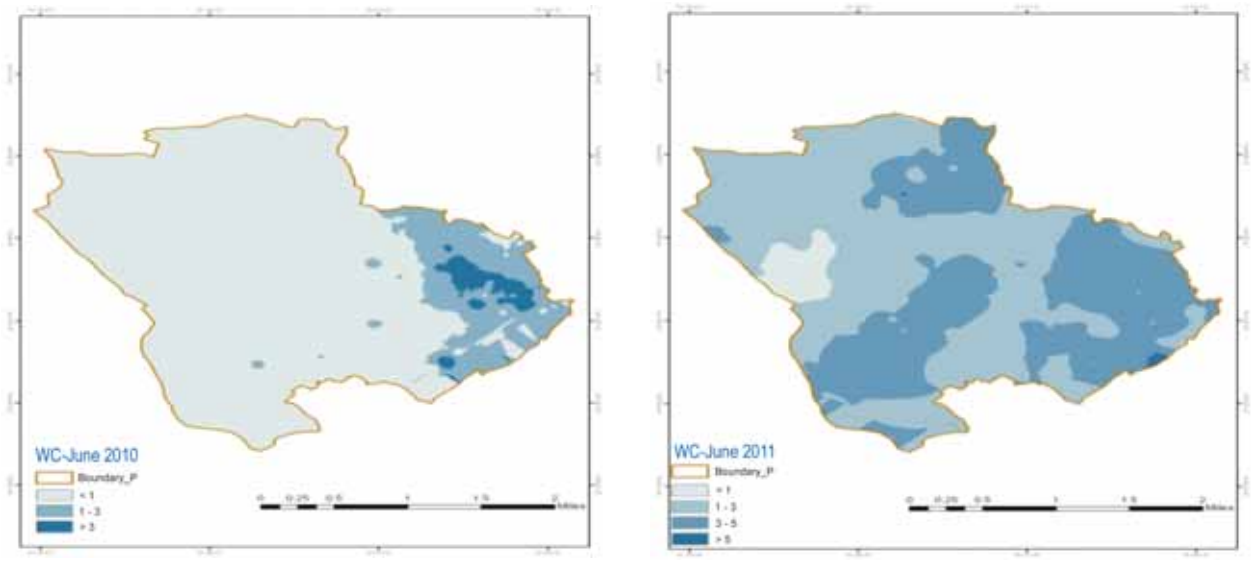
In order to examine the determinants of profitability, additional returns generated were regressed on independent variables, viz. size of the plot where the pond is located, size of the pond, change in cropping intensity (%), whether water is lifted to irrigate the crop, whether there is a bore well in the plot and number of fillings in the season. Four variables, size of plot, size of pond, change in cropping pattern and use of water for irrigation, showed significant positive effects on the profitability. Overall, it was found that larger plot size was more profitable.

Watershed management in drought-prone Bundelkhand region

Garhkundar-Dabar: Garhkundar-Dabar Watershed (Teekamgarh district) development project was initiated in October 2005 in a participatory mode. Soil- and water-conservation activities, crop diversification, agroforestry development and socioeconomic upliftment activities



Lay out of pipeline network (*top left*); pipeline network being laid (*left*) and *rabi* groundnut with sprinkler irrigation (*right*)



Depth of water column in open wells during June 2010 and June-2011

resulted in reduction of runoff and soil loss by 46% and 43%, respectively, compared to untreated (control) watershed. Peak discharge from treated watershed was delayed by 51 minutes, indicating more time for infiltration of rainfall. Cropping intensity increased to 161% and productivity of major crops increased from 20 to 60%. Increase in fodder availability, milk production and increase in buffalo population indicate overall watershed development. Flow of income increased by 250% and availability of fuel and fodder reduced drudgery of women and children.

Domagor-Pahuj: This watershed (1,373 ha) project was initiated in a participatory mode in Jhansi district in 2009. Soil- and water-conservation activities, agroforestry (plantation of 15,000 seedlings of multipurpose tree species) and other activities resulted in alround development. Using geographical information system, it

Watershed management in Domagor- Pahuj

Rainwater harvesting in Domagor –Pahuj watershed

was estimated that following the implementation of the project, depth of water column during June was in the range of 1–3 m in 55% area against 13% before implementation.

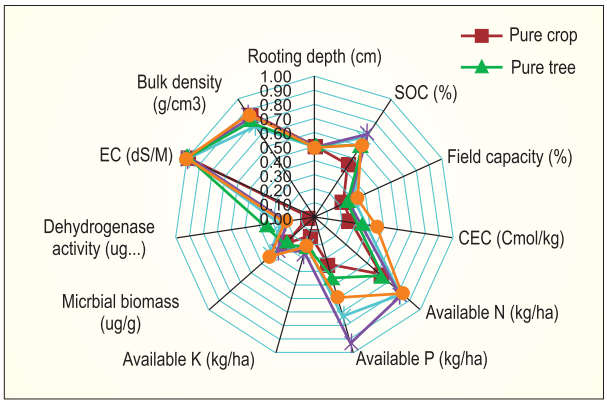
The results from the two experimental watersheds indicate that agroforestry with conservation measures provide drought-proofing with enhanced and sustained productivity and rural livelihoods.

Microbial bioremediation of wastewater with heavy metals: Wastewaters from industries contain high concentrations of heavy metals like Pb, Cd, Cr and Ni, which are toxic to living organisms even at low concentrations. To study the growth of efficient microbes on agro-waste materials for removal of heavy metals from aqueous solution, five fungi (*Trichoderma fasciculatum, Aspergillus niger, Aspergillus terreus, Trichoderma longibrachiatum, Aspergillus awamori*) and two bacteria (*Bacillus cereus* and *Bacillus* sp.) were grown on agro-waste materials. Fungal and bacterial growth was maximum on rice straw. The dead fungal biomass of *Aspergillus flavus* and *Aspergillus nidulans* packed in columns was able to remove substantial amounts of heavy metals such as Pb, Cd, Ni and Cr from aqueous solution. Six efficient fungal cultures, *Trichoderma fasciculatum, Aspergillus niger* var. *columnaris*, *Aspergillus niger*, *Aspergillus terreus* (MTCC9613), *Trichoderma longibrachiatum* and *Aspergillus flavus* developed for bioremediation have been deposited in the National Bureau of Agriculturally Important Microorganisms (NBAIM), Mau.

Integrated nutrient management

Maintaining soil organic carbon: Soil organic carbon (SOC) is a strong determinant of soil quality and agronomic productivity, especially in arid and semiarid tropics. The critical carbon (C) input required for maintaining SOC at the existing level was worked out for two agroecological settings using data from long-term experiments with chemical, organic and combined input use. The critical organic C input for maintaining SOC was 2.47 Mg/ha/year for Inceptisols under rice–lentil cropping system at Varanasi in the northern plain hot semi-arid ecosystem, and 1.12 Mg/ha/year for Alfisols under groundnut monocropping at Anantapur in the Deccan plateau hot arid ecosystem.

Soil-quality index for assessing soil health of agroforestry systems: To assess contribution of agroforestry in soil conservation, a soil-quality index (SQI) for assessing soil health of different agroforestry systems has been developed. For assessing soil quality, minimum data set of indicators comprising soil physical, chemical and biological properties was selected from



Radar plot of soil quality index and functional scores of soil health indicator for *Albizia procera* based agroforestry system

three agroforestry systems with *Albizia procera, Emblica officinalis* and *Hardwickia binata.*

Results from *A. procera*-based agroforestry system revealed that after 8 years of planting, maximum SQI was for the practice of zero pruning (0.566), closely followed by 50% pruning (0.552) and 70% pruning (0.548). Pure crop had minimum SQI (0.430). Radar diagram of functional scores indicated that soil biological activity was the most limiting indicator for all pruning treatments. Hence, canopy management through judicious pruning helps improving soil health.

Zinc delivery to plants through nano ZnO particles: A protocol was developed to coat seeds of maize, soybean, pigeonpea and okra with micron scale (<30 µm) and nano scale (<100 nm) ZnO powder @ 25 mg Zn/g of seed and @50 mg Zn/g of seed to supply the requisite Zn to plants. The germination test carried out with coated and uncoated seeds indicated better germination (93 to 100%) owing to ZnO coating compared to uncoated seeds (80%). Pot culture experiment conducted with coated seeds also revealed that the crop growth with ZnO coated seeds was similar to that observed with soluble Zn treatment applied as $ZnSO_4.7H_2O$ (2.5 ppm Zn). The advantage of seed coating with ZnO (both micron/nano scale) is that it does not exert any osmotic potential at the time of seed germination, thus, the total Zn requirement of the crop can be loaded on seeds.

Crop response to mixed biofertilizer formulations: In Vertisols of Maharashtra, chemical fertilizers to sweet sorghum up to 100% recommended dose of fertilizer (80:60:40 kg N, P_2O_5, K_2O/ha) along with dual inoculation of *Azospirillum* + *Gluconacetobacter* significantly increased green stalk (15.1%), millable cane (13.1%), grain (30.2%) and juice (30.2%) yields over the control. There was also significant improvement in juice quality (TSS, fermentable sugars) and nutrient uptake by crop.

Rhizobial (R33, R35) inoculation of soybean grown in Vertisols of Madhya Pradesh showed 17% increase in seed yield; PGPR strains (P3, P10, P25) increased it by 23%, and the combination of both by 28%. In chickpea, rhizobial strains (R40, R56, R58) revealed an average increase of 7.6% seed yield; PGPR strains (P3, P10, P25) by 9.7% and the combinations of both by 14.5%. In wheat, inoculation with three PGPR strains resulted in 26% higher seed yield.

Diversification of biofertilizers: The Plant Growth Promoting Rhizobacteria (PGPR) from cauliflower was identified by 16SrDNA analysis as *Bacillus pumilus.* Ten bacterial isolates associated with *Capsicum* in Himachal Pradesh were selected for PGP traits and antagonism against major fungal diseases—damping off (*Pythium* spp.), blight (*Phytophthora* spp.) and anthracnose fruit rot (*Colletotrichum* spp.). Field demonstrations involving application of *Bacillus pumilus* and 75% recommended doses of chemical fertilizer resulted in 30% increase in curd yield in cauliflower, besides saving 30 kg N and 20 kg P/ha.

Rose–A potential plant species for phytostabilization of chromium: A study was undertaken to examine response of rose to different levels (0, 25, 50, 100 and 200 mg/kg soil) of chromium and its possible use for remediation of soils contaminated with chromium. Rose grew well and tolerated up to 50 ppm. However, there was a reduction in the dry weight of roots and shoots. Cr decreased dry weight of roots by 18% at 25 ppm and 43% at 50 ppm. Partitioning of Cr revealed a higher concentration of Cr in roots (1985 µg/g on dry weight basis), followed by shoots (760 µg/g dry weight). Thus rose has a great potential to be used for phytostabilization of soils contaminated with moderate levels of Cr.

Rose, a potential plant species for phytostabilization of chromium

Utilization of inland saline waters: Shrimp farming technology developed for utilization of saline and sodic soil by Rohtak Centre of CIFE was validated. A production 1,280 kg/ha of *Penaeus monodon* with a net survival of 70% was obtained in 110 days culture duration at a stocking density of 10/m^2. In *Fenneropenaeus indicus,* cultured for the first time in such environment, an increase to an average size of 5 g/individual in two months was achieved. The technology can be easily applied for developing saline and sodic soils, thereby providing alternative means of livelihood and resource generation to affected farmers.

Water productivity enhancement through fish seed stocking: The water productivity of Mallaghatta reservoir in Karnataka was to 56 kg/ha/year with the stocking rate of 425 number of IMC/ha/year of catla : rohu : mrigal in the ratio of 4 : 3 : 3. During the reporting period the production of reservoir was 21.2 tonnes and the contribution of stocked species was 44.6% to the total catch. The average CPUE was 17.1 kg. ❑