**21.1 Strategies of Soil and Water Conservation**

The problems of soil and water conservation must be addressed through a concerted effort of soil stewardship and technological input. A prudent approach to soil and water conservation requires a holistic approach to solve practical problems that affect not only farmers but the entire society. An effective soil and water conservation

program is linked to political, social, and economic conditions of each region. Some of the strategies are the following:

1. Development of economic and conservation-effective practices to: (1) restore degraded soils, and (2) maintain and enhance the productivity of prime agricultural soils.

2. Identification and development of site-specific conservation practices based on local and regional biophysical, social, cultural, and political forces. There is no panacea, and no single practice fits all situations.

3. Establishment of pilot programs for on-farm demonstrations of improved soil and water conservation practices based on a multidisciplinary and farmer participatory approach in regions with resource-poor farmers (e.g., Africa, South Asia, South America) (Lal, 2007).

4. Establishment of programs that reward farmers for their commitment to soil stewardship as well as for the successful implementation of strategic conservation practices such as management of soil erosion, conservation of water in the root zone, reduction of soil compaction, alleviation of crusting and surface sealing, improvement in soil fertility, and installation of water ponds to harvest.

5. Installation of conservation-effective practices which keep the soil in place and reduce both the on-site and off-site effects of soil erosion. Conservation practices which minimize soil detachment and transport and reduce runoff rate and amount must be developed and refined. Erosion control practices trap sediment and chemicals at the downslope end of source areas or just above the water sources, while conservation practices keep the soil in place. Sediments deposited in the footslopes at the lower end of fields are considered a lost soil because it can neither be easily nor economically brought back to its original location.

6. Development of technologies to alleviate shortcomings of the conservation tillage systems (e.g., reduced tillage, no-till) such as low crop yields, excessive use of herbicides and fertilizers, stratification of soil organic C and nutrients near the soil surface, and interference of residue mulch with planting operations and soil warming.

7. Development of conservation practices which reduce both the water pollution and emission of greenhouse gases. Treatment of polluted water is expensive and degradation of water quality difficult to rectify. Thus, runoff of water and pollutants must be minimized by improving infiltration and water retention capacity of the soil.

8. Widespread adoption of soil conservation practices such as growing cover crops, planting of N-fixing trees, maintaining riparian buffers, establishing field borders, adopting strip cropping, using crop residue mulches, growing green manure crops, using agroforestry, and other biological measures in combination with mechanical structures (e.g., terraces).

9. Conversion of severely eroded soils to restorative land use such as perennial vegetation covers, and restoration of degraded and marginal soils through improvement in soil organic matter reserves and creation of a positive nutrient, C and elemental budget.

10. Refinement of the threshold levels of soil erosion or T values for each soil and region based on research data.

11. Increased emphasis on research and education along with the transfer of conservation effective technology to land managers and stake holders by strengthening networks and improving connectivity.

**Needs for additional basic and site-specific research include the following:**

1. Addressing site-specific priorities in soil and water conservation research.

2. Collecting on-farm data on water, wind and tillage erosion and their impacts on soil productivity with emphasis in developing countries.

3. Collating data on erosion impacts on crop yields under on-farm conditions. Credible data are needed to obtain reliable estimates of the magnitude of the problem for creating awareness of policymakers, farmers, and the general public about the negative impacts of erosion on food security and environmental quality.

4. Conducting basic research on soil erosion process particularly in transport and deposition processes in relation to soil C dynamics, climate change, and emissions.

in greenhouse gases. Greater understanding of soil erosion processes would lead to development of appropriate techniques of control and improvement in soil, air, and water resources.

5. Collating and synthesizing data on the performance of soil conservation practices and magnitude of soil erosion before and after adoption of control practices.

**21.2 Soil Conservation is a Multidisciplinary Issue**

Soil conservation is a wider and all encompassing problem than hitherto perceived. It is a discipline intrinsically linked to numerous disciplines in natural sciences (e.g.,geology, hydrology, climatology, engineering) and social sciences (e.g., economics,policy, human dimension). Thus, understanding processes of soil erosion requiresthe knowledge of basic principles of pedology, forestry, agronomy, climatology, sedimentology, hydrology, engineering structures, and other fields of soil-plantatmosphere relationships. Soil conservation does not only involve control of runoff and soil erosion but also comprises a wide range of management and practices including irrigation, application of amendments, fertilization, and drainage aimed at increasing and/or maintaining soil productivity. A successful program in soil conservation also requires active involvement of land owners, farmers, economists, social scientists, policymakers, and the general public. A greater interdisciplinary effort is necessary for developing soil conservation technology and adoption of these innovations at the local, regional, and national levels.

**21.3 Policy Imperatives**

Availability of funds for conducting research on soil and water conservation is dwindling. Government agencies and other institutions across the world must give a high priority to this issue and increase support to soil erosion research for generation of new technologies and strategies. Conservation policies must be directed to mitigating social costs and improving the economic conditions of farmers. Among the policies needed for soil and water conservation include the following:

1. Providing more funding for a strong enforcement of soil and water conservation programs.

2. Providing training and financial incentives for good soil stewardship.

3. Improving accessibility and providing more opportunities for education about the benefits of soil conservation and stewardship.

4. Giving technical and financial assistance for establishing soil conservation practices. 5. Emphasizing and prioritizing research and development of new technologies.

6. Developing regulations or measures for the conversion of degraded croplands to a permanent vegetation cover.

7. Providing support for exchange of information among farmers, extensionists, and other institutions.

8. Supporting active and participatory research, extension, and training programs in developing countries with predominantly resource-poor farmers.

**21.18 Soil Management Techniques for Small Land Holders in Resource-Poor Regions**

Restoration of degraded soils and management of existing productive soils are high priorities particularly for small-land holders, which farm an average of 2 ha. Food insecurity from the decline in crop yields due to nutrient mining and nutrient depletion by soil erosion is a pressing concern in poor regions of the world such as is the case in Africa. Since expansion of cultivated area is not possible in most regions due to the scarcity of prime agricultural soils, food security must be improved by increasing the crop production per unit area. Principal challenges are to reduce soil erosion to permissible levels and to improve fertility of soils managed by resource poor farmers. Techniques of soil management for small farmers vary depending upon the ecosystem, topography, and climate. Various measures can be used for

managing soil erosion and improving soil fertility. Among these are (Mafongoya et al., 2006):

1. ***Terraces.*** These structures intercept, retain, slow, and divert runoff to safe outlets, reducing soil erosion and loss of nutrients. There are different types of terraces that can be used by mall farmers including conservation bench terraces, hillside ditches, orchard terraces, and intermittent and continuous terraces.

2. ***Rainfed ponds.*** Rainwater harvesting is a strategy to reduce soil erosion, store water for crops, and increase crop yields in sloping fields. During rainy seasons, runoff and rainwater can be harvested by constructing ponds. The stored water is used for irrigation and growing crops in dry seasons.

3. ***Inorganic fertilizers.*** Application of inorganic fertilizer at recommended rates and proper times increase efficiency of use while increasing crop yields. Efficient use and management of inorganic fertilizers can reduce environmental degradation. Costs of fertilizers must be reduced to allow accessibility and use. Applying 9 kg ha−1 of N can increase crop yields by as much as 50% if it is applied at the right time and place (ICRISAT, 2006). The effectiveness of fertilizers is a function of rainfall amount, type of crops, type of soil and tillage management.

4. ***Animal manure.*** Manuring is one of the oldest techniques to improve soil fertility. Quality and quantity of manure are often low in developing countries, depending on the type of animal and forage quality. The efficiency of the low quantity of animal manure produced can be improved by placing manure directly into the holes or furrows where plants will be grown as an alternative to broadcasting all over the field. As much as 60% of N and 10% of P can be lost during broadcasting and lack of proper management of manure (Mafongoya et al., 2006). This approach not only improves the efficiency of manure use but also reduces losses of manure-derived products through erosion, volatilization, and leaching. Manure management guidelines must be developed to reduce close contact of seeds with manure and rates of application.

5. ***Grain legumes.*** Incorporating grain legumes into traditional cropping systems is vital to improve soil fertility and N cycling. Grass and tree legumes when rotated or intercropped with row crops can be used as green manures. The biological nitrogen fixation by legumes contributes to soil with N and can reduce needs for using inorganic fertilizers. Growing legumes is an ecological and costeffective strategy to restore soil fertility. Economical benefits of rotating row crops with grasses or tree legumes must be determined as well as the guidelines of establishment and management developed.

6. ***Agroforestry practices***. Planting trees around and within croplands reduces soil water and wind erosion. Trees can also store N in soil through biological nitrogen fixation. Large-scale adoption of fertilizer trees is a potential solution to replenish N to nutrient-starved soils. *Sesbania, Tephrosia, Gliricidia, Leucaena Calliandra, Senna,* and *Flemingia* are some of the agroforestry species used for improving soil fertility in Africa ((Mafongoya et al., 2006). More aggressive expansion of agroforestry technology is needed as companion to grain legumes.

7. ***Integrated nutrient management practices***. Combining inorganic fertilizers and organic amendments is a better alternative to the use of either inorganic fertilizers or organic amendments (e.g., manure, compost) alone. The interaction of both nutrient sources reduces excessive use of inorganic fertilizers and improves nutrient-supplying capacity of organic amendments. An integrated approach of nutrient management involves the methods of application, timing, amount, and type of fertilizers in combination with grain legumes and agroforestry practices.

8. ***Tillage management***. No-till, reduced or minimum, mulch, and strip tillage are recommended tillage systems to restore degraded soils.

9. ***Residue management***. Residue return following harvest is important to maintain a protective cover and reduce wind and water erosion. Residue cover is insufficient in poor regions due to limited residue production and competing uses for residue. Returning crop residues and planting grass and legume trees can increase the amount of residue cover.

10. ***Conservation buffers***. Filter strips, grass barriers, riparian buffers, windbarriers, and field borders protect soil from erosion. Integration of grass barriers with food crops paralleling rows of crops reduce removal of sediment while buffers established at the lower end of fields reduced off-site transport of sediment.

11. ***Cropping systems***. Crop rotations, multi-cropping, strip cropping, contour farming, contour strip cropping, and cover cropping are strategies to conserve and water. Dense canopy and high-biomass producing crops intercept raindrops and protect the soil surface. Systematic arrangement of crops in strips, on the contour, and growing various but different crops per year reduce soil erosion.