Soil and Water Conservation

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What Is Soil Conservation?

Soil conservation means a way of keeping everything in place, literally as well as in a more abstract sense of maintaining the functions of the soil in sustaining plant growth. Soil conservation practices involve managing soil erosion and its counterpart process of sedimentation, reducing its negative impacts and exploiting the new opportunities it creates. Young (1989) defined soil conservation as a combination of controlling erosion and maintaining soil fertility. In the past the focus has often been on trying to keep the soil at its place by plot-level activities only. Currently, the attention has switched to landscape level approaches where sedimentation is studied along with erosion, and the role of channels (footpaths, roads and streams) is included as well as the "filters" that restrict the overland flow of water and/or suspended sediment.

Why Bother With Soil Conservation?

Erosion concerns differ widely between human interest groups in the uplands and those who live downstream. Erosion is part of the long-term geological cycles of mountain formation and decline, occurs in any vegetation and is an essential part of soil development. Efforts to reduce erosion to zero in humanly used landscapes are doomed to failure, but perceptions of the optimum degree of soil conservation differ between interest groups (stakeholders).

Concerns on soil conservation for agriculturally used lands, especially those recently converted from forest, are usually based on a combination of:

1. On-site loss of land productivity,
2. Off-site concerns on water quantity (Annual water yield, peak (storm) flow, and dry season base flow)
3. Off-site concerns on water quality, as erosion leads to sedimentation on lowlands, siltation of lakes and reservoirs and/or the eutrophication of water.

Concerns b and c are mainly valued by lowland interest groups who perceive changes when natural (forest) vegetation is converted into agriculture, whereas aspect a is mainly an upland issue. The combination of those three concerns led to a widespread concept of erosion as the major contributor to loss of productivity of uplands as well as the cause of lowland problems with water quantity and quality.

Soil conservation measures will not address all concerns such as loss of land productivity (a), water quality (b) and water quantity (c) to the same degree. We have to differentiate between them in evaluating environmental impacts of land-use or land cover change and in considering options for maintenance of "forest functions" in agricultural landscapes.

Some Key Principles (Modified from FAO and IIRR 1995)

- The farm household should be the focus of every soil conservation program, as they take the daily decisions that shape the landscape; communal action at local level can be an important entry point for outside soil conservation programs.
- Farmers cannot ignore the short-term benefits of the land use decisions they make. Only those production strategies have a chance to be adopted that will provide a reasonable return on the labour and other resources a farmer has to invest. Conservation strategies or technologies that do not meet this criterion are doomed to fail.
- Lack of secure land tenure maybe a major cause of low farmer interest in environmental conservation. Improving tenure security may be the main intervention needed for farmers to adopt reasonable soil conserving technologies.
- Soil conservation programs have often led to "pseudo-adoption" if strong social pressure, subsidies or other government incentives (including tenure security) were used to support adoption of practices that required substantial labour and other resource investment.
- Loss of soil productivity is often much more important than the loss of the soil itself, as the soil on the move tends to be rich in organic matter and nutrients, relative to the remaining soil.

- Loss of soil productivity is not easy to assess, because impoverished zones of net erosion may be accompanied by enriched zones of net sedimentation and the farmer may decide to grow different crops in these two environments.
- In upland systems, plant yields are reduced more by a shortage or excess of soil moisture (especially for tuber crops) or nutrients rather than by soil losses per se. Therefore, there should be more emphasis on rainwater management, particularly water conservation, and integrated nutrient management and less on soil conservation. Agronomic process such as tillage and mulching that maintain infiltration rates are more useful than mechanical measures blocking the path of water flowing at the soil surface in preventing erosion and runoff.
- Erosion is a consequence of how land and its vegetation are managed, and is not itself the cause of soil degradation. Therefore prevention of land degradation is more important than attempting to develop a cure afterwards.
- Most past soil conservation programs focused more on land degradation than on the land user (the farm household), and used a top-down approach in "dissemination" and "extension" of "best-bet" practices. Top down programs have tended to focus primarily on the symptoms of erosion through subsidised terracing, promotion of hedgerow intercropping systems or other measures which have had mixed success when introduced by outside agencies, rather than through farmer-led adoption.
- Soil conservation programs that aim to reduce land degradation problems through treatment of causes, require a long term, bottom-up approach supporting farmers who generally have detailed knowledge of their farm, know a wide range of potential interventions (although they can still learn new ideas from experiences elsewhere) and choose between these interventions on the basis of the resources and pressures on the farm household.

What Soil Conservation Techniques Are Common?

A risk of accelerated erosion exists on cultivated land from the moment trees, bushes, grass and surface litter are removed. Erosion will be exacerbated by attempting to farm slopes that are too steep, cultivating up-and-down hill, continuous use of the land without any rotation of different crops, inadequate input of organic materials, compaction due to footpaths or heavy machinery used for tillage and removal of harvest products etc. Erosion control depends on good management, which implies establishing sufficient crop cover and selecting appropriate practices to maintain infiltration with or without soil tillage. Thus soil conservation relies strongly on agronomic methods in combination with a realistic soil management whilst mechanical measures play only a supporting role.

A range of well-illustrated examples can be found in FAO-IIRR, 1995. We just would like to highlight examples of those three main groups of soil conservation strategies that involve agroforestry:

Agronomic or biological measures utilise the role of vegetation in helping to minimise the erosion by increasing soil surface cover, surface roughness, surface depression storage and soil infiltration. Some examples are:

Strip cropping/alley cropping/hedgerow intercropping

Contour hedgerow systems using nitrogen fixing trees/shrubs have been widely promoted to minimise soil erosion, restore soil fertility, and improve crop productivity (Kang and Wilson 1987, Young 1997; Sanchez, 1995; Garrity, 1996, Friday KS, Drilling and Garrity, 1999). Hedgerows of trees or shrubs (usually double hedgerows) are grown at intervals of 4–6 m along the contours. The strips or alleys between the hedgerows are planted with food crops. The hedgerow trees are regularly pruned to minimise shading of food crops, the pruned biomass can be used as green manure or as mulch *in situ*, or as fodder. Through time, natural terraces can form at the base of the hedgerow trees, and thereby minimise soil erosion and surface run-off Terrace formation can be rapid if the soil is ploughed, but slower in no-till or manual tillage systems.

This technique has been recommended as a common feature of extension programs for sustainable agriculture in Asia. But this innovation has not been widely adopted outside of direct project intervention areas by upland farmers despite the positive results reported in a number of experimental and demonstration sites. The positive and negative ecological interactions between (hedgerow) trees and food crops are discussed more in detail in the Tree Crop Interaction lecture note (van Noordwijk and Hairiah, 2000). However, the major problem in practice the large amount of labour needed to prune and maintain woody hedgerows. ICRAF (1996) estimated that the amount of labour required to prune leguminous-tree hedgerows was about 31 days per hectare, or 124 days annual labour for four prunings in the Philippines. There is a need for simpler, less labour intensive but effective contour hedgerow systems.

One can state that on flat land hedgerow intercropping is not interesting because of the high level of labour input needed. On sloping land, the improvement of soil fertility, stabilising crop production, may in principle pay off the labour inputs, but real farmer interest probably requires that the soil fertility accumulated in the hedgerows be used for profitable trees, crops or fodder.

Improved fallow systems (IFS)

In the uplands, arable areas are planted with food crops for some years and then the land is fallowed for some time to allow the soil to rejuvenate. To shorten the fallow period, the area can be seeded with leguminous trees. Once the soil has been rejuvenated, the trees are cleared for crops. This can be considered as an improved version of the traditional shifting cultivation practice. More information on fallow management, which was initiated, tested, proved and developed by farmers can be found in the lecture note on Indigenous Fallow Management (IFM) (Burgers, Hairiah and Cairns, 2000).

Example: the native *Leucaena* is used in a fallow system in Naalad, Naga, Cebu (the Philippines). The trees are cut and the branches are piled along the contours to form a barrier structure known locally as *balabag*, which traps the eroding soil. Through time, natural terraces are gradually formed, thus stabilising the steep slopes. Other advantage of this system is the reduction of the amount of nitrogen (N_2) needed as fertiliser because of N-fixation by *Leucaena*. The pruned leaves and branches can be used as fodder.

Natural Vegetative Strips (NVS)

The use of natural vegetative strips (NVS) has proven to be an attractive alternative because they are so simple to establish and maintain. NVS are attractive as they mainly consist of no intervention. When land is ploughed along contour lines, certain strips of 40–50 cm wide are left unploughed, across the field on the contour. These strips are spaced at desired intervals down the slope and can be marked beforehand. The recommended practice for spacing contour buffer strips has been to place them at every one meter drop in elevation, but a wider spacing may be acceptable.

Soil management is concerned with ways of preparing the soil to promote dense vegetative growth and improve the soil structure so that it is more resistant to erosion. Some techniques included in this group are: minimum tillage, crop rotation (food/cover crops), manure, sub-soiling and drainage.

- Minimum tillage/zero tillage. In this system, simple farm equipment such as hoes and digging sticks are used to prepare land and plant food crops. Spraying herbicide kills weeds, and all plant residues (including weeds) are returned into the soil. Farmers in swidden systems traditionally are familiar with minimum tillage practices. While more intensive tillage generally increases porosity of the topsoil and reduced barriers to infiltration of the soil surface, it normally interrupts the continuity of the macro-pores in the soil and can reduce deep infiltration, especially if a plough-pan is formed. No till systems that are implemented on soils that have never been ploughed or compacted by the use of heavy machinery generally maintain the high infiltration rates of forest soils. Transitions from ploughing to minimum tillage systems often involve a number of years of reduced infiltration, before new continuous macro-pore system is re-established by the activity of earthworms and other soil engineers.
- Crop rotation is common practice for smallholder farmers in SE-Asia. It is a system with various crop species grown in sequence on the same plot. Example: maize grown at the first season and groundnuts in the second season. Groundnuts can replenish N (via N-fixation) which was extracted by maize. The different rooting pattern of different crop species planted may help on soil structure formation and improve water percolation. These cropping pattern can vary from year to year depending on market price or on soil/weather condition, but they are chosen for the same purposes: better soil physical and nutrient condition, interrupts life cycle of weed/pest/ plant disease.

Mechanical or physical methods can be viewed as an attempt to control the energy available for erosion (rain splash, runoff). These methods depend on manipulating the surface topography by installing terraces, ditches. Examples are:

Bench terraces consist of a series of alternating shelves and dykes and are used on sloping land up to 40% with relatively deep soils to retain water and control erosion. The dykes are vulnerable to erosion and are protected by a vegetation cover (e.g., *Cajanus cajan*, *Sesbania grandiflora*, *Sesbania sesban*, *Gliricidia sepium* or fruit trees such as banana (*Musa* spp.) and sometimes faced with stones or concrete. The plant spacing (6 x 6 m) of bigger fruit trees as mango (*Mangifera indica*), jackfruit (*Artocarpus heterophyllus*) etc., is generally too wide to be effective for dyke protection, but it increases economic revenue on those terraces. The terraces are normally constructed by cutting the soil to produce series of level steps or benches, which allow water to infiltrate slowly into the soil. Bench terraces are suitable mainly for irrigated rice-based cropping systems.

Soil traps (more commonly known as sediment traps) are structures constructed to harvest soil eroded from the upper slopes of the catchment. Common types of soil traps are check dams and trenches. They slow down the water flow and allow heavier soil particles to settle. It prevents widening and deepening of gullies and promotes the deposition of nutrient-rich, highly fertile sediments. Afterwards this area can be used for growing crops. The accumulated soil can also be returned to the field, but that is quite laborious.

The size of the check dam depends on the size of the drainage or gully to be protected. Check dams can be built of stakes (e.g., from *Gliricidia*), bamboo, loose rocks, logs or other locally available materials. They should be permeable, as they are meant to slow down the speed of the water to increase sedimentation. They are not meant to stop or divert the flow of the water.

A combination between agronomic measures and good soil management can influence both the detachment and transport phases of the erosion process, whereas mechanical methods are effective in controlling the transport phase but do little to prevent soil detachment.

Conclusion

To conclude with a word of caution: Most soil conservation measures require a lot of labour investment, while it is not always obvious who will benefit from it. Before an attempt is made to introduce soil conservation measures, some time should be spent to "read the landscapes." This means that some time should be spent on trying to answer the following questions, before any activity is undertaken:

- Is soil erosion a real problem? Who perceives soil erosion as a problem: the uplanders, the people downstream or other stakeholders?
- Are there any elements in the landscape, which are currently reducing soil erosion?
- If the different stakeholders see lack of soil conservation as a problem, how and to what extent will the person executing the soil conservation measures also benefit from his/her work? If the one who is supposed to carry out the job will not benefit in the short and long term, chances of failure are large.
- If soil erosion is seen as a downstream problem, then a discussion should be held between downstream and upstream stakeholders to find a reasonable solution, which could include compensation paid to farmers upstream to carry out soil conservation measures.
- If it is clear that those who will do the soil conservation also benefit from it, only then one can start thinking about different technical measures.

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