Soil Moisture Retention and Soil Fertility Options for Agricultural and Degraded Lands

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Introduction

Land degradation is a common problem of farmers and herders in hills and mountain areas in the Hindu Kush-Himalayan region. Over time, people have used land resources haphazardly by either converting most marginal and sub-marginal lands including forests and natural grasslands in grazing lands and cultivated land, or by overexploiting the vegetation resources. In Afghanistan, about 11.2 million hectares (m ha) of land is affected by water erosion and 2.1 m ha by wind erosion (Lal 2004).

Soil erosion is regarded as a major threat to sustainable growth in agriculture and livestock production, and each year large amounts of top soil containing soil organic matter and nutrients are lost. Maintaining good soil structure and soil moisture and fertility are crucial for a good agricultural and natural resources base.

Rationale and Relevance

The application of soil and water conservation measures is important to:

- conserve moisture in the soil,
- increase organic matter content and bind nutrients,
- increase soil productivity, and
- increase biomass.

The climatic regions of Afghanistan are diverse; precipitation ranges from about 77 to 1,020 millimetre (mm) a year and average rainfall is 300 mm/year. This chapter presents potential options for soil and water conservation for three eco-regions, from lowland to mountains excluding extreme low land (Table 1).

Table 1: **Potentials of a variety of options in three eco-regions of Afghanistan**

Options	Lowland 900 – 1,300m	Upland 1,300 – 2,400m	Mountain Above 2,400m
Mulching			
Organic	H	M	M
Inorganic	M	M	M
Multiple cropping			
Sequential	H	M	L
Simultaneous	H	M	L
Conservation tillage			
Zero tillage	H	M	M
Min. tillage	H	M	M
Contour tillage	H	H	M
Surface Seeding	H	L	L
Compost			
Heap	H	M	L
Pit	H	M	H
Vermi	H	M	N
Black plastic	H	M	M
Green manuring	H	M	L
Hedgerow	H	M	L

Potential: H = high; M = medium; L = low; N - not possible

Available Technologies for Soil Moisture Retention

The following list suggests a few soil conservation measures to improve soil moisture status.

Mulching

Mulching is covering the soil surface by a layer of organic or inorganic material to create a favourable environment for plant growth (Figures 1a and b).

Benefits of mulching

- Mulch provides an insulating barrier between the soil and the air, thus moderating and stabilising soil temperature
- Conserves moisture in the soil through reduced evaporation and improves the soil's water holding capacity
- Protects seeds from being washed out

- Protects delicate plants from high soil temperature generated by intense sunlight
- Protects the surface from raindrop erosion by providing ground cover
- Suppresses weed growth, depending on mulch material
- If mulch materials are organic, adds organic matter to the soil, thereby increasing soil fertility
- The pH (acidity or alkalinity) level of the soil can be regulated depending on the selected mulch

Figure 1: **Plastic (a) and Organic (b) Mulching at Godavari Demonstration and Training Centre, ICIMOD**

Two main methods of mulching

- **Mulching around individual plants**: Apply 5 - 10 cm thick mulch around the plant. Leave 5 - 15 cm space around the plant. Outside this, the mulch should form a circle of about 75 cm radius.
- **Mulching to treat an entire area**: Mulch is laid across the slope to form a surface cover of 5 cm thickness. This type of temporary surface armouring is normally used to aid the establishment of grass seed.

Resource required

- **Inorganic mulch** which includes materials such as aluminium foil, plastic, stones, pebbles, brick chips, gravel, shredded rubber tyre, landscape fabric, and geo-fabric
- **Organic mulch** which includes rice and wheat straw (used in Herat), leaves (e.g. poplar, mulberry and juniperus, salix, alfaalfa), food leftovers, animal manure and compost; wood products (wood chips, chunk bark), and newspapers, if available in the region

Multiple cropping

Multiple cropping is a broad term for growing individual cropping in sequence mainly to improve soil fertility.

Benefits of multiple cropping
- Improves fertility and increases soil organic matter content
- Increases surface vegetation cover
- Improves infiltration and stability of soil structure, and
- Decreases soil erosion

The various multiple-cropping practices may be grouped into two broad categories: *sequential cropping* and *simultaneous cropping* (Figure 2).

Sequential cropping is further categorised into:
- crop rotation, and
- relay cropping.

Simultaneous cropping is categorised into:
- intercropping (Figures 3a and 3b)
  - Mixed
  - Row
  - Strip
  - Relay
- interculture, and
- adjacent cropping.

(Details of each category can be found in Joshi, 2007.)

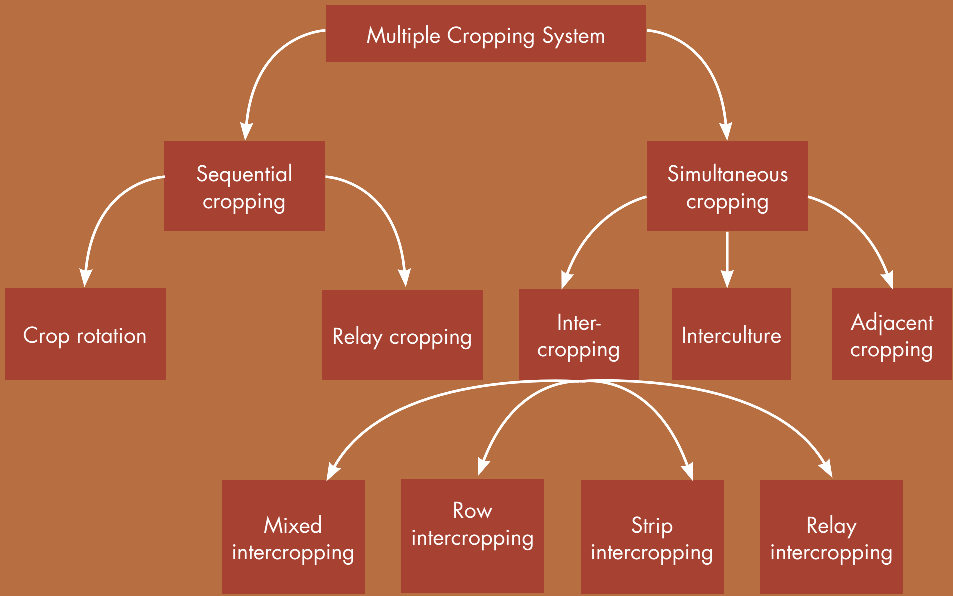
For example, in Herat, peach trees are intercropped with Alfaalfa, and sunflower with watermelon or sesame. In some areas in Badakhshan, Kabul, and Jalalabad, sequential cropping is done with different crops (e.g. cereal crops with vegetables or orchards).

Resource required
- Seeds and seedlings of different crops
- Technical support services

Conservation tillage

Conservation tillage is a method of cultivating crops with minimal soil disturbance to reduce fertile top soil loss to wind and water. When tillage is reduced, the stubble or plant residues are not completely incorporated; most or all remain on the top soil rather than being ploughed back or incorporated into

Figure 2: **A reflection tree of multiple cropping systems**



Source: Joshi 2007

Figure 3: **Intercropping (a) mixed intercropping of maize and soybean, and (b) row intercropping of maize and ginger.**

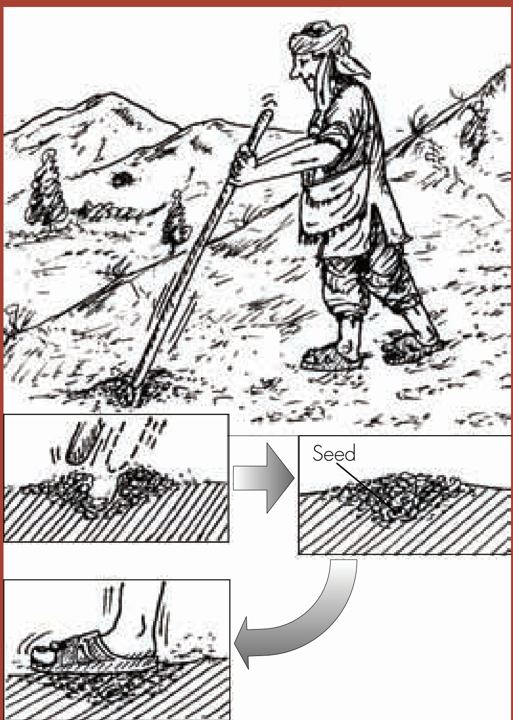
the soil. The new crop is planted into this stubble or small strips of tilled soil. Increased use of crop residue and organic matter in the soil under the conservation tillage system improves soil tilth and fertility after a few years of adoption.

Conservation tillage and sowing is performed after crop harvest. It results in timely planting but also conserves residual soil moisture. The field is not kept fallow under the conservation tillage system. If it is not possible to plant a major crop, a cover crop is sown during fallow period. Leguminous plants and grasses are the major cover crops. Every three to four years, one-time ploughing incorporates lime and fertiliser in the soil.

Benefits of conservation tillage

- Minimum soil disturbance, thus a significant reduction in soil erosion is noted
- Soil surface cover of at least 30% from crop residue conserves soil moisture, adds organic matter to the soil, and suppresses weeds
- Enhances agricultural productivity by improving soil fertility through biological processes
- Single pass bullock/tractor reduces operational costs of planting compared to multiple pass primary and secondary tillage before sowing
- A continuous no-till system increases small soil clumps or soil particle aggregation, making it easier for plants to establish roots
- Improved soil tilth also minimises compaction; compaction is also reduced by reducing trips across the field

Figure 4: **A dibble stick**



Conservation tillage methods

1. Zero tillage

   Under the zero tillage system, soil is opened through a narrow slit or small pit to place seeds and fertiliser and then covered. This tillage system includes dibbling using a dibble stick, sowing with a zab seeder, and use of a zero till drill (Figure 4).

2. Minimum Tillage

   Minimum tillage by depth. Under the conventional tillage system, several passes of tillage till the soil more than 10 cm deep. A minimum till drill is used which tills the soil of 2-4 cm deep, drops the seed, covers and presses the soil by a roller simultaneously in a single pass.

Minimum tillage by tillage area. In the conventional tillage system, the whole land is ploughed, whereas under the minimum tillage by area system, only a part of the land along the contour is ploughed, and a seed bed prepared instead of ploughing an entire plot.

Strip tillage. In strip tillage only a narrow strip is tilled and seeds are sown along the strip. In between strips the land is not tilled at all. A strip till drill also performs strip tillage.

3. Contour tillage

Tillage is performed across slopes along contours, and plants are planted along the contours. Contour tillage enhances infiltration and reduces runoff and soil loss. It also reduces variation in tillage depth and speed, and consequently reduces erosion from tillage (Lobb et. al 2000).

4. Surface seeding

Surface seeding is adopted for wheat crops after rice harvest if there is high soil moisture content. (Clearly visible footprints while walking on the field indicate high moisture content). The wheat seeds are mixed with cow dung and kept for 24 hours, then broadcasted in a field without tillage at late afternoon hours or at sunset. The seeds are mixed with cow dung to facilitate germination and prevent birds from eating them.

Surface seeding can also be practiced in rangeland areas as practiced in Afghanistan.

Resources required

Special plough equipment manual or mechanical and seeds

Available Technologies for Soil Fertility Improvement

The following list suggests a few measures for improving soil fertility.

Improved compost and farmyard manure

Compost and farmyard manure are used mostly to supplement soil nutrients in rural mountain areas. Crop residues, animal waste, leaf litter, solid wastes, oil cakes, and other wastes are used to make compost. Proper composting and storing is important for efficient use in maintaining soil nutrients. For example, in Herat, heap composting has been applied and marketed.

A starter for the decomposition process can be sprinkled over each layer of 50 cm of plant material such as ripe compost from the previous batch, forest soil, or even a small amount of animal dung, urine, wood ash, lime, urea, or effective microorganisms (EM).

Turn and mix the compost every 30-50 days, depending on the mix and the outside temperature for better aeration. Pipes can also be stuck into it. The compost must remain moist at all times to avoid slowing down decomposition and should be protected from direct sunlight, rainfall, and runoff to reduce the loss of nutrients.

Heaping or collecting the material in a pit helps the compost to reach the temperature needed (700°C) to destroy pests and weeds. A heap is made above-ground either plain or with different types of outer wall. Sealing the heap with mud or plastic helps to maintain moisture (see Box 2). (SSMP and ICIMOD, 2008)

Compost pit with roof

Once the compost is well decomposed and has an earthy smell, it can be applied directly to the soil or stored for later application. In Herat, marketing compost generates farm income.

Box 1: **Vermi-composting**

A special type of earthworm (*Eisenia foetida*) can speed up the composting process. Earthworms (*Eisenia foetida*) add casting, making the compost a high quality product.

- Add earthworms to the collection of animal and plant waste of succulent nature.
- No additives and no turning are required.
- Protect the vermi-compost from the elements (sun and rain).

Earthworm (*Eisenia foetida*)

Box 2: **Black plastic covered compost – an example of the heap method**

In the Jhikhu Khola watershed in Nepal, a traditional compost heap is covered with a piece of black plastic. This protects the nutrients from leaching during rainy days and provides a favourable environment for the growth of microbes (increased temperature and decreased evaporation loss). The approach is based on the principle of passive aeration, removing the black plastic from the compost heap for a certain period each day and covering it again.

Layered compost heap with black plastic cover

Using this method, compost decomposes in 45-50 days compared to about 4-6 months without a plastic sheet. Black plastic is light, easy to use and handle, and durable (thickness ~ 800 micron) and consumes less time and labour than the standard method.

Bio-fertiliser

Bio-fertilisers refer to living organisms which augment plant nutrient supply one way or another. Bio-fertilisers improve fertility of the land using biological wastes, hence the term. Biological wastes do not contain chemicals detrimental to the living soil. Bio-fertilisers also convert atmospheric nitrogen into ammonia by fixing biological nitrogen in the root nodules of legumes with the help of a group of bacteria called Rhizobia. Fodder, pasture, grain and leguminous trees fix 80-500 kg of nitrogen/hectare/year from the atmosphere and are the most intensively used bio-fertilisers.

In Afghanistan, use of bio-fertilisers are not yet in practice and may be useful to explore.

Resource

Motsara, M.R., Bhattacharyya P., Beena Srivastava (1995). *Biofertliser Technology, Marketing and Usage - A Sourcebook-cum-Glossary*. New Delhi: Fertiliser Development and Consultation Organisation

Bio-pesticides

Insect repellent plant species such as *Artemia vulgaris* (Dari – Darmanh–Drownah), can be used to make bio-pesticides. Application of chemical pesticides is increasingly associated with ill effects to human health and the environment, whereas bio-pesticides are safer and more environmentally friendly. Their use is therefore gaining popularity.

To make bio-pesticides

1. Chop or mince insect repellent plant species such as *Artemia vulgaris* into small pieces and mix it with fresh cow dung and fresh cow urine in a plastic drum.
2. Add small amounts of yeast and salt for quick fermentation. Stir the mixture for five minutes regularly for a period of one week, then stir only once a week for four to five weeks.
3. After the fifth week, filter the mixture by squeezing in a plain cloth to collect the concentrated bio-pesticide solutions. Dilute the concentrated solution in water at the ratio of one to ten (1:10), one part bio-pesticide, 10 parts water before applying to the plants.

Aside from *Artemia vulgaris* many other insect repellent species can be used.

Green manure

Green manuring is the incorporation of fresh leaves, twigs, succulent stems and other plant tissues into the soil.

There are two types of green manure:
- seasonal crops, and
- perennial trees or shrubs
  – leguminous
  – non-leguminous

Green manure grows fast, is easy to plant and cultivate, and produces large quantities of biomass in a short time. Leguminous green manure can fix nitrogen and concentrate phosphorous so that decomposition is supplied to growing plants. The proportion of biomass should be higher in leaves than in woody materials. In Afghanistan, Alfaalfa (Dari – Sabest or Rashghah, Pashto – Shpashtey), Artemisia, and chickpeas are used for green manuring.

Benefits of green manuring
- Increases organic matter and plant nutrients in the soil
- Helps in conserving soil nutrients by reducing leaching
- Improves soil structure by improving organic matter content
- Deep-rooted green manure plants bring up nutrients from deep soils, which is generally not available for shallow rooted cereal crops
- Contributes plant nutrients to succeeding crops through its residual effect

Methods of green manuring
There are two common methods:
- *In situ production of biomass*. This is growing green manure crops on the same piece of land using biomass produced to supply nutrients to the next crops. After attaining sufficient green biomass, the green manure crops are chopped into small pieces and mixed into the soil by ploughing using animal drawn tools (local plough) or tractors.
- *Biomass transfer* or green manure crops are grown on other fields after harvest. The green biomass is transported to the fields and incorporated into the soil.

Resources required
Green biomass and manual or mechanical plough equipment

Contour hedgerows

Contour hedgerows intercropping is a soil conservation technique that reduces soil and wind erosion and improves the soil environment. The technology involves planting nitrogen fixing plants or other multi-purpose tree species along the contour lines of sloping land. The plants for hedgerows are selected according to need – whether for fuel or fodder – as for their soil conservation attributes or qualities. Planting local hedgerows or tree species is practical and applicable for the terrain and dry climate of Afghanistan.

Benefits of contour hedgerows

- Controls erosion, maintains soil organic matter and physical properties, augments nitrogen fixation, and promotes efficient nutrient cycling
- Offers opportunities to synchronise the release of nutrients from leaf litter or 'green manure'
- Litter rebuilds soil structure, making soil less erodable and better able to absorb and hold water
- Creates a more favourable micro-climate for crops by shielding them from dry winds
- Hedgerows planted on slopes also anchor soil and form natural terraces, preventing the loss of precious top soil during heavy rains and the overflow of water
- Provides fruit, fodder, green manure, fuel wood, and cash incomes

Methods

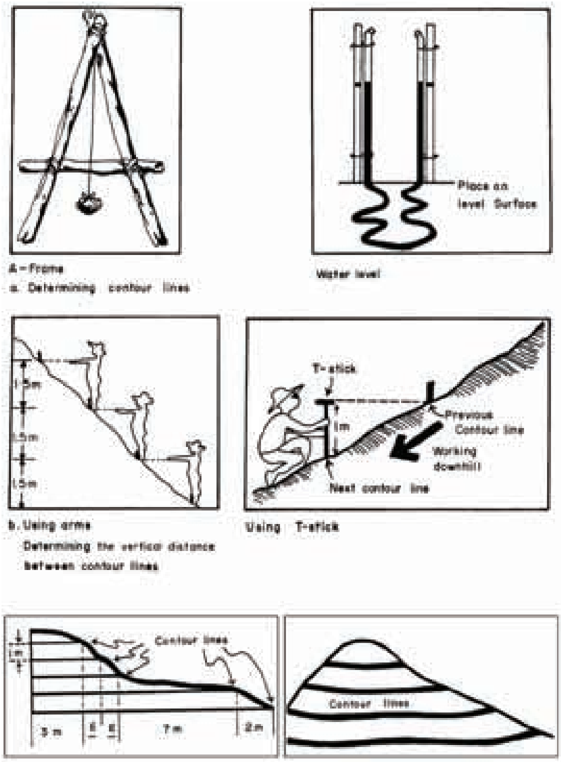
Setting up contour hedgerows (illustrated next page)

1. An A-frame is used to find the contour lines of the land. One person operates the A-frame and the second person marks the located contour line with wooden pegs. Begin marking contour lines near the highest point.

2. Space the contour line 2-6 metres apart. The closer the contour lines to each other, the less erosion occurs, but also the smaller the size of the plots in between. Therefore, the steeper the slope, the closer the contour hedgerows, and for gentle slope, widen the spacing of contour hedgerows. The distance between the double hedgerows varies from 30-60 cm. Plant-to-plant distance in each row should be about 10 cm.

3. For hedgerow species selection community participation is important (see Box 3) and the following site factors need to be taken into consideration:
   - mean annual precipitation and temperature
   - length and frequency of yearly drought
   - minimum and maximum temperature
   - incidence of frost
   - topography (elevation, aspect and slope percentage), and
   - soil pH, texture and depth.

   The promising species for hedgerow planting in Afghanistan are Alfaalfa (Dari – Sabest), Artemisa (Dari – Darmanh–Drownah), Mulberry (Pashto – Tuot), Agropyron (Dari – Alaf Gandomi), Artiplex (Dari – Shurak), and other locally available multipurpose shrubs and trees.



Step 1: How to make an A-frame (Partap & Watson 1994)

Step 2: How to locate contour lines using an A-Frame

Step 3: Preparing the contour lines

Step 4: Planting contour hedgerows with nitrogen fixing plants

Hedgerow species should have the following characteristics:

- Economic and livelihood value
- Rapid growth and biomass production
- Small bushy shrubs
- Deep rooting
- Good coppicing and re-sprouting ability
- Nitrogen fixing attributes
- Wide adaptability and stress tolerance
- Multi-purpose species

Resource required

- An A-frame, wooden pegs, and planting materials

Box 3: **Farmers' participation in making hedgerows**

Farmers' participation is a must for the successful development of hedgerows. Farming conditions vary greatly in mountain areas, so technologies such as hedgerows need to be adapted to local conditions.

Participatory Technology Development (PTD) is an effective approach to involve farmers actively in testing and modifying technologies, taking advantage of their local knowledge and expertise. Farmers and researchers decide together which options to try out, and what should be the evaluation criteria to make them more suitable, do-able, yet effective. This increases farmers' interest in the project, leading to easier and more successful implementation. The resulting technologies are more easily adopted and maintained by farmers.

In participatory hedgerow development in Nepal and India, farmers selected species that were more useful for their everyday needs and better adapted to their local environment, as well as reducing soil erosion and restoring soil fertility. They also changed the design of the hedgerows, including height and the distance between them.

Aryal et al. 2007

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