Niki Evelpidou · Tomás de Figueiredo (editors)

Soil Protection in Sloping Mediterranean Agri-Environments
Lectures and exercises

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Soil Conservation Measures: classification and description

T. de Figueiredo & F. Fonseca

Instituto Politécnico de Bragança (IPB/ESAB), CIMO – Mountain Research Centre, Bragança, Portugal

SOIL CONSERVATION MEASURES: WHY AND WHAT FOR?

The aim of Soil Conservation

Before going into the detail of Soil Conservation Measures, some preliminary questions must be considered, for sake of clarity either in formal terms or in the substantial ones, which, actually, justify the extent and in-depth approach to such topic.

As Morgan (2005) states:

"The aim of soil conservation is to reduce erosion to a level at which the maximum sustainable level of agricultural production, grazing or recreational activity can be obtained from an area of land without unacceptable environmental damage." (Morgan, 2005:152).

The core elements of his statement deserve ttentive consideration and they are:

- reduce soil erosion

  Not prevent (as soil erosion is a natural phenomenon it is not a matter of stopping it)
- to a [certain conditioned] level

  Soil loss tolerance (a central operational concept in soil conservation, addressed to later)
- obtain maximum activity output

  Resources are to be explored (as resource means a good valued by its potential or actual use).
- in a sustainable way

  Resources are not to be exhausted (as the need of such goods keeps existing and sometimes even increases).
- without unacceptable environmental damage

  Impacts kept controlled (again the sustainability issue, not only but also).

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Soil Loss Tolerance

Soil loss tolerance is a central operational concept in Soil Conservation. It defines the limit up to which soil loss rate is acceptable for the systems under consideration and the conditions set above (productivity, sustainability, and minimal environmental impact).

In theory, soil loss rate should be at most equal to soil formation rate, in order to ensure that the balance of particles is never negative in a certain placed and through time. The problems in defining soil formation rate are, however, manifold. Conceptual and practical discussions may be undertaken when addressing to the rates that should better represent soil formation rate: rate of weathering, rate of weathering front progress, rate of soil deepening (singly or combined).

Discussions apart, referenced values of soil formation rates ranges from 0.01 to 7.7mm equivalent soil depth per year. An average value of 0.1mm y-1 can be assumed and this approximately corresponds to 1t ha-1 y-1.

In practice, maximum permissible soil loss rate that maintains soil productivity in the medium to long term also depends on the possibility to increase soil depth and keep soil productivity at acceptable level through agricultural practices. As so, soil loss tolerance may vary and experience recommends (T is soil loss tolerance):

- Deep soils, developed on unconsolidated parent material – T = 11t ha-1 y-1 (10 is better!)
- Shallow soils, over hard parent material – T = 2t ha-1 y-1

The two thresholds mentioned (2 and 10t ha-1 y-1) are helpful to define classes of actual erosion risk. In fact, below the latter, all soils, shallower or deeper, are losing soil at an acceptable rate, meaning that erosion risk is low. Above the former, even the deeper soils are losing material at a rate higher than acceptable and, therefore, there is a severe erosion risk threatening soil. Between the two, erosion risk may be considered globally moderate, because for shallower soils it is high but for the deeper ones it is low.

PRINCIPLES OF SOIL CONSERVATION

What Soil Conservation measures should be

Application of soil conservation is a very practical issue and, performed under a variety of situations, not always easily or entirely seized. As so, or because of this, some basic principles must be considered in order to allow the intended purposes to be successfully attained, in any practical condition. Selection of soil conservation measures should then be a very locally oriented procedure, but always performed in respect of a certain set of principles.

Hence, soil conservation measures should be:

- adequate
  Focused on the problem(s) and process (es) identified
- effective
  Able to control the problem as predicted
- integrated
  Part of the activity regular practices
- feasible
  Account for local labour and economic conditions
- accepted
  Perceived as an improvement

The two first fall under the technical side of soil conservation whereas the remainders are part on the socio-economic approach to the problem. This means that, even though soil conservation should start as a technical matter, and this is the scope of the lecture, in no way social and economical issue should be kept apart from the solution when dealing with soil conservation implementation.

As soil conservation measures should be adequate and effective, and because soil erosion is the problem to be tackled, processes involved have to be identified at first. It can be readily perceived that different measure address differently to different processes. Therefore, to meet adequacy and effectiveness required, selection of soil conservation measures has to carefully consider processes acting in the field. The survey of evidences and or rates of processes and their spatial distribution is obviously required, too.

Table 1. Soil conservation measures: effectiveness in controlling erosion processes

Practice		Rainsplash		Runoff	
	Specific	Detachment	Transport	Detachment	Transport
		Control of prcess			
Agronomic measures	Covering soil surface	strong	strong	strong	strong
	Incresing surface roughness	no	no	strong	strong
	Incresing depression storage	moderate	moderate	strong	strong
	Increasing infiltration	no	no	moderate	strong
	Fertilizers	moderate	moderate	moderate	strong
	Tillage	no	no	strong	strong
	Subsoiling, drainage	no	no	moderate	strong
Mechanical measures	Contouring, ridging	no	moderate	moderate	strong
	Terraces	no	moderate	moderate	strong
	Waterways	no	no	no	strong

(adapted from Morgan, 2005).

Classification of soil conservation measures

Soil conservation measures are of very different types. A fully consistent classification of measures is hard to reach and so, classification schemes may fail at some point to adequately accommodate any existing or newly designed measure.

One classification scheme commonly adopted, even though some variations may be found from author to author, considers the object and the material focus of measures of as a criterion.

- Soil Management

  Accounts for soil conservation measures addressing to improvements in soil resistance to erosion
- Vegetation (crop) management

  Accounts for soil conservation measures addressing to improvements in soil protection by vegetation cover
- Mechanical / Structural methods

  Accounts for soil conservation measures addressing to changes in topography and runoff paths

From the first to the last, there is an increase in implementation complexity, regarding the level of change in actual conditions and practices, as well as in the level of investment required to carry them on. From the first to the last, again, the number of processes controlled and the effectiveness of control achieved generally increases. This is due not only to the effectiveness each one of the measures per se, but results also of the imperative combination with other measures from more than one of the above categories. All together, the elements carried to discussion help explaining the recommendation of the first to almost any situation where erosion control is required, but a much more selective recommendation of the other, especially the structural methods, following increasingly severe erosion risk.

To illustrate this it can be said that conservational tillage methods should be a common practice in land under any erosion risk severity. On the contrary, only when erosion risk is very severe should structural measures be applied as terraces and these imply important changes in the landscape, I the land use model and in cultivation practices that normally come together with the implementation of other conservation measures, eg contour tillage. Furthermore, such change, and the investment required to perform it, can only be justified under conditions of very severe erosion risk.

A very schematic description of soil conservation measures is provided in the following sections, according the classification indicated above.

Soil management

Soil management measures account for improvements in soil intrinsic resistance to erosion. This can be achieved promoting structural stability or limiting structural degradation. The former focus in improving general structural conditions associated with biological activity and organic matter (organic fertilization), in increasing particle binding (stabilizers), in allowing moisture conditions that favour natural process of aggregation (drainage). The latter focus on tillage, as tillage is the main cause of soil disturbance in cultivated areas.

- Organic matter (Fertilization)

  Broadly fertilization or specifically organic matter management, through addition of residues or organic fertilizers to soil, enhances biological activity and improves soil structural condition.

- Tillage

  Tillage comprises practices and operations that are an integral part of the history of agriculture, since its very beginning. Traditional agricultural systems persistently included tillage as routine practice. Mechanization of tillage operations hugely increased degradation processes rates and extent. This, combined with the need for an efficient use of energy (due to the rise of energy cost), helped devising new tillage procedures and systems broadly labeled as conservation tillage. They are less disturbing for soil, they are cheaper as they are less energy consuming, they are more environmental-friendly, with no less crop productivity.

  Actual types of tillage systems are briefly described below:

  - Conventional tillage

    Traditional plowing is not considered a conservative soil management technique. It implies arable soil reversion as plow passes and, traditionally, this was performed more than once a year. Soil disturbance is highest among tillage systems and this, summed to the traffic of tractors and trailed implements in fields, outcomes serious structural degradation and compaction.

    In any case and in this one it is more than justified to carefully consider actual soil moisture at time of tillage. In fact, the friable cohesive sate of soil consistency is the best one for tillage.

  - Contour Tillage

    Contour tillage is the first step towards conservation tillage. It consists of tillage operation on contour, thus increasing surface roughness. This allows higher surface water detention during rainfalls, and so runoff and particle entrainment along the slope is reduced.

  - Conservation Tillage

    Some definitions help describing techniques under this heading.

    - Conservation agriculture

Crop residues are kept over ground, at least over 30% of the surface (where water erosion is major threat) or at an annual rate of 1100 kg ha-1 stubble (where wind erosion is the major threat).

- Minimum tillage

Tillage operations prior to seedling are performed with chisel, scarifier, etc. Weeds are controlled by tillage or by low environmental impact herbicide. In the former case, the soil is not entirely reverted and tillage is performed soon after harvest, in order to incorporate and trigger germination of seeds (weeds and prior crop), thus providing soil cover during inter-crop period.

- Ridge / Strip tillage

No soil disturbance between previous harvest and new seedling, except nutrient injection on strips. Seeding equipment operates in weed cleared ridges, stubble being kept between plant rows. Ridges may be built up and seedbed prepared by several types of implements. Weeds are controlled by hoe-type implements or by low environmental impact total herbicide in prior to seedling or emergence.

- No tillage (direct-seedling)

No soil disturbance between previous harvest and new seedling, except nutrient injection on strips. Seeding equipment have specific implements that remove or cut stubble, open a rill in the soil surface and cover the seeds dropped in. Harvest must leave crop residues fairly distributed over ground. Weeds are controlled by low environmental impact total herbicide in prior to seedling or emergence. Exceptionally tillage may be performed for weed control. Better system for annual crops.

- Drainage

Drainage is important for soil conservation mainly for two reasons. Lowering soil moisture allows drier antecedent conditions when rainfalls occur and this may delay overland flow generation as higher soil water intake rates are possible. On the other hand, structural stability decreases as moisture increases (in the range of soil moisture addressed to here), increasing particle availability for entrainment.

- Soil stabilizers

These are substances or materials applied to soils in order to increase binding opportunity and strength among soil particles. Due to price and offer scarcity, their use is limited to small green areas and gardens.

Several types of soil stabilizers are found, such as: (i) Organic by-products; (ii) Polyvalent salts (gypsum); (iii) Synthetic polymers (polyacrilamide).

Actually, all but the last soil management conservation measures are or should be part of the regular practices in agricultural land, as appropriate agronomic measures.

Vegetation (crop) management

Vegetation or crop management measures account for improvements in soil surface protection by plant or plant residue cover. Protection provided by plant or residue cover reduces rainfall kinetic energy and thus the erosive power of raindrops hitting the surface. Vegetation intercepts rainfalls and, therefore, contributes to sharply increase actual water intake rate of soils because the rate at which effective rains reach the soil surface is much lower when compared with actual rainfall intensity. The former is generally such as to infrequently exceed soil infiltration rate. The probability of excess rainfall to be formed decreases as vegetation cover increases. If that happens, runoff is occurs and may flow along the slope. Again, crop or vegetation management contributes to protect soil from particle entrainment by overland flow and to limit erosive runoff generation or effects as it is the case of conce3ntrated runoff and gullying, respectively. In fact, stems, residues and surface roughness induced by the vegetation itself or by crop management operations, sharply reduce eha probability of occurrence of such processes. Moreover, indirect effects of practices concerning conservation crop management contribute to enhance soil intrinsic resistance to erosion, either through aggregate stability improvement or through infiltration rate increase.

In this section, the list of conservation measures considered under vegetation or crop management is simply indicated. Student is strongly encouraged to follow image descriptions presented in actual lecture and to find in literature recommended the literal description also provided during actual lecture. Morgan (2005) is the base reference.

An attempt to group measures according to the focus and context of their application is performed below:

- Measures strictly concerning cropland
    - Measures addressing to vegetation distribution in time and space
        - Rotation (the classic but also shifting cultivation, row-crop cultivation, grazing and forest land management)
        - Cover crops
        - Multiple cropping

- High density planting
- Strip-cropping (a specifically designed soil conservation measure)

  - Measures addressing to residue cover

    - Mulching

- Measures concerning degraded sites or marginal land

  - Revegetation (gullied areas, landslide scars, embankment and cut slopes, afforestation, pasture land, recreational areas

- Measures concerning integrated management areas

  - Agroforestry

Mechanical / Structural methods

Structural measures are meant to control runoff generation and distribution along slopes, and to minimize its erosive power or capability to transport soil particles. Normally structural conservation measures are limited in their application to areas where runoff and soil entrainment are likely to occur frequently and / or at high rates such that erosion damage, on- and off-site, is severe. More simply stated, structural measures should be applied to areas were severe erosion risk exists. Measures coping with specific problems such as severe and permanently gullied sites and steep cut slopes are also account for under the present heading.

In this section, as in the previous one, the list of conservation measures considered under structural measures is simply indicated. Student is strongly encouraged to follow image descriptions presented in actual lecture and to find in literature recommended the literal description also provided during actual lecture. Morgan (2005) is the base reference.

An attempt to group measures according to the focus and context of their application is performed below:

- Measures addressing to topographical reshape
  - Contour bunds
  - Terraces
- Measures concerning runoff control
  - Waterways
- Gullycontrol
- Slope stabilization (structures, geotextiles)

References

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