BEST MANAGEMENT

PRACTICES FOR OPTIMIZED USE OF SOIL AND WATER IN AGRICULTURE

SHui

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AUTHORS.

***** Gómez, J.A.**

Institute for Sustainable Agriculture (IAS-CSIC), 14004 Córdoba, Spain.

***** Krasa, J.**

Faculty of Civil Engineering, Czech Technical University in Prague, Thakurova 7, 16629 Prague, Czech Republic.

***** Quinton, J.N.**

Centre for Sustainable Agriculture, Lancaster Environment Centre, Lancaster University, UK.

***** Klik, A.**

University of Agricultural Sciences Vienna (BOKU), Vienna, Austria.

***** Fereres, E.**

Department of Agronomy, University of Cordoba, 14014 Cordoba, Spain.

***** Intrigliolo, D.**

Centro de Edafología y Biología Aplicada del Segura (CEBAS-CSIC), P.O. Box 164, 30100, Murcia, Spain.

***** Chen, L.**

College of Soil and Water Conservation, Beijing forestry University, Beijing 100083, China.

***** Strauss, P.**

Institute for Land and Water Management, Federal Agency of Water Management, Pollnbergstraße 1, 3252 Petzenkirchen, Austria.

***** Yun, X.**

Faculty of Geographical Science, Beijing Normal University (BNU) Beijing 100875, China.

***** Dostal, T.**

Faculty of Civil Engineering, Czech Technical University in Prague, Thakurova 7, 16629 Prague, Czech Republic.

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ANNEXES.

PAGES

1.- OBJECTIVES.

This document provides a comprehensive review of Best Management Practices (BMPs) for optimized used soil and water in agricultural systems within the context of the SHui project. The main reasons for writing this document are:

1.- To give any reader, internal or external to the project, an overview of the technical description of available options of BMPs for optimizing soil and water use.

2.- To identify how BMPs are defined and requested in relation to large policy instruments, particularly the Common Agricultural Policy (CAP), to provide guidance on simulated scenario as well as on recommendations for improvement to policy stakeholders.

3.- To provide a common framework, within the project as well for external users, for the definition of BMPs using a standardize terminology.

4.- Help to identify, in cooperation with WPs1, 2 and 5 of the SHui project, a selected number of BMPs which could be fully evaluated and analyzed combining experimental information, simulation model analysis at field scale, and stakeholders feedback (WP5) at selected study regions.

These BMPs have been always reviewed in the context of the SHui project, which covers different agro-climatic regions across Europe and China and these agricultural systems are:

1- Rainfed tree crops.

2- Irrigated tree crops.

3- Cereal based rotations under rainfed conditions.

4- Cereal based rotations under irrigation.

Regarding use of water for irrigation, this document will also cover the use of low-quality water, including wastewater, and the use of recycled water for irrigation.

2. METHODOLOGY AND STRUCTURE.

2.1. Methodology.

This doument is based on a review of available literature, and it was carried out in three steps.

1.- A review of key available literature on BMPs according to standard manuals, and international reference sites, complemented with consultation to experts on specific subjects within SHui.

2.- A bibliographic review of key documentation related to major policy instruments regarding compulsory or voluntary implementation of BMPs in agricultural areas in Europe and China. Among these instruments are the Common Agricultural Policy, hereafter CAP, at EU level (for current period and incoming one) and the National special program of 13th five-year plan for comprehensive control of soil erosion for slope arable land.

3.- This has been complemented with a detailed revision of the national regulations of Good Agricultural and Environmental Conditions (GAECs) at national level among EU countries in 2019 regarding the BMPs mentioned in this document.

2.2 Document structure.

This document is structured to allow independent reading of the technical sections, therefore each section has its own bibliography. References are selective, ideally freely available, to provide the reader with an entry point to the wider literature.

All the readers should start from section 3.1 Summary of BMPs which is a master table listing all the BMPs practices covered in this document. This table has hyperlinks which take the reader directly to the expanded definition of specific BMPs and also to the Good Agricultural and Environmental Conditions (GAECs) of the current and incoming CAP.

Section 3.2. contains a detailed definition of each BMPs with examples and links to technical documentation and case studies.

Section 4. provides a summary of national definitions of different BMPs across the different EU countries, within the context of CAP implementation as indicated in the GAECs.

Section 5 provides a summary of the different ways to simulate scenarios for specific BMPs by the erosion and hydrologic models evaluated in SHui, which include many of the models more frequently used. It indicates the way in which these models can reproduce the effects of the different BMPs on soil and water conservation, noting also when are not capable to simulate that effect. It can be useful to anyone that needs an overview of the capabilities, and limitations, of these simulation models to appraise effect of BMPs on specific elements of soil and water conservation plans.
Finally **Annex 1** provides a summary of terms and definitions of key elements of the CAP in relation of sustainable use of soil and water, and **Annex 2** a concise introduction of major policy instruments for sustainable use of soil and water in agricultural areas in China.

3. DEFINITION AND CLASSIFICATION OF BEST MANAGEMENT PRACTICES (BMPs) FOR SOIL AND WATER CONSERVATION IN AGRICULTURAL AREAS.

3.1 Summary of BMPs for soil and water conservation.

Table 3.1.1. Summary BMPs for soil and water conservation. GAEC, Good Agricultural and Environmental Conditions.

#	BMP	Definition, link to section	Main purpose	Additional impacts	CAP GAEC, as Table A.2.
1	Terraces.	Modification of terrain to reduce slope and facilitate traffic.	Erosion control, water conservation.	Improvement of soil and water quality.	GAEC 7, GAEC 6
2	Contour planting of tree and vine crops.	Planting of perennial vegetation following the contour lines of the slope.	Erosion control.	Water conservation.	GAEC 7, GAEC 6
3	Maintenance of landscape elements.	Maintenance of non-productive natural or artificial landscape elements.	Improvement of biodiversity.	Improvement of landscape values.	GAEC 9, partially GAEC 6 and GAEC 4
4	Cover crops in tree crops.	Use of vegetation in the lanes avoiding bare soil.	Erosion control.	Improvement soil quality and biodiversity.	GAEC 7, GAEC 6
5	Mulching in tree crops.	Covering of the soil in the lanes using mulching material.	Erosion control.	Improvement soil quality and biodiversity.	GAEC 7, GAEC 6
6	Contour farming.	Tilling following the contour lines of the terrain.	Erosion control.	Water conservation.	GAEC 7, GAEC 6
7	Vegetated barriers.	Stablished vegetation barriers obstructing the flow of runoff.	Control offsite contamination.	Erosion control.	GAEC 4, GAEC 9, partially GAEC 6 and GAEC 7
8	Gully control structures.	Restoration of gullies present and the field.	Erosion control.	Control offsite contamination improvement of biodiversity and landscape values.	GAEC 7, GAEC 4, GAEC 6
9	Conservation Agriculture.	Reduction of soil disturbance through minimization of tillage.	Erosion control.	Control offsite contamination, improvement of biodiversity.	GAEC 7, GAEC 6
10	Cover crops for annual crops.	Cover crops intercropped, in time or space, with annual crops.	Erosion control.	Improvement of soil quality, reduction of offsite contamination.	GAEC 4, GAEC 7, GAEC 6
11	Agroforestry.	Integration of trees for forest production with crops and/or livestock.	Diversification of farm products.	Improvement of soil quality and biodiversity, reduction of erosion and offsite contamination.	GAEC 6, GAEC 4, GAEC 7
12	Water harvesting.	Techniques aimed to concentrate and stored surface or subsurface runoff for crop use.	Water conservation.	Improvement of water quality.	None
13	Deficit irrigation.	Use of limited available water for irrigation in best period for optimizing yield.	Water conservation.		None
14	Water reuse.	Reuse of water used for prior activities.	Water conservation.		None
15	Increasing soil water holding capacity.	Modifying soil properties for better infiltration of water and increasing soil water storage capacity.	Soil conservation.	Water conservation.	GAEC 4, GAEC 7, GAEC 6

Go back to section 2.2. Document structure.

3.2. Expanded definition of BMPs.

3.2.1. Terraces

3.2.1.1. Description.

Terraces are earthen embankments established across the dominant slope portioning the field in uniform and parallel segments. When properly designed the terraces have a major impact on soil and water conservation. There are many types of terraces (see Figure 3.2.1.1.) with the best option and specific layout depending on the features that appear in Table 3.2.1.1.

Table 3.2.1.1. Major features conditioning terrace types and layout.

#	Feature
1	Field topography.
2	Climate (rainfall, wind).
3	Soil type.
4	Tillage and cropping systems.
5	Cost of construction.
6	Accessibility to heavy equipment.

Terraces are important for the reasons summarized in Table 3.2.1.2., although their specific impact depends on the edaphoclimatic conditions, type of terraces and particularly appropriate design and maintenance.

Table 3.2.1.2. Main functions of terraces.

#	Feature
1	Slow runoff velocity and decrease peak flow.
2	Reduce erosion reducing slope length and steepness .
3	Promote soil water storage increasing infiltration and reducing runoff.
4	Reduce wind erosion increasing soil moisture and increasing surface roughness.

Terraces are one of the most effective techniques to enhance soil and water conservation, particularly on very steep slopes. However, their high construction and maintenance cost is one of the major obstacles for their implementation, been restricted to situations where its high cost is justified by rural development reasons (e.g. Figure 3.2.1.6.) or high value of the crop (e.g. Figure 3.2.1.9.). Currently and particularly in the context of CAP in Europe, there is a focus on the maintenance of existing terraces (particular traditional ones with stone walls, e.g. Figure 3.2.1.7.).

3.2.1.2. Types of terraces.

The multiple types of these structures can be summarized in Figure 3.2.1.1. There are several classifications according to their alignment (Figure 3.2.1.2.), cross section (Figure 3.2.1.3a and b.), how they deal with the slope grade (Figure 3.2.1.4.) or outlet type (Figure 3.2.1.5.). Usually these structures are also combined with channels to redirect runoff water to an outlet at reduced velocities preventing erosion. Usually these outlets need to be designed for containing and delivering safely runoff flows corresponding to rainfall events with a 10 year return period for the area.

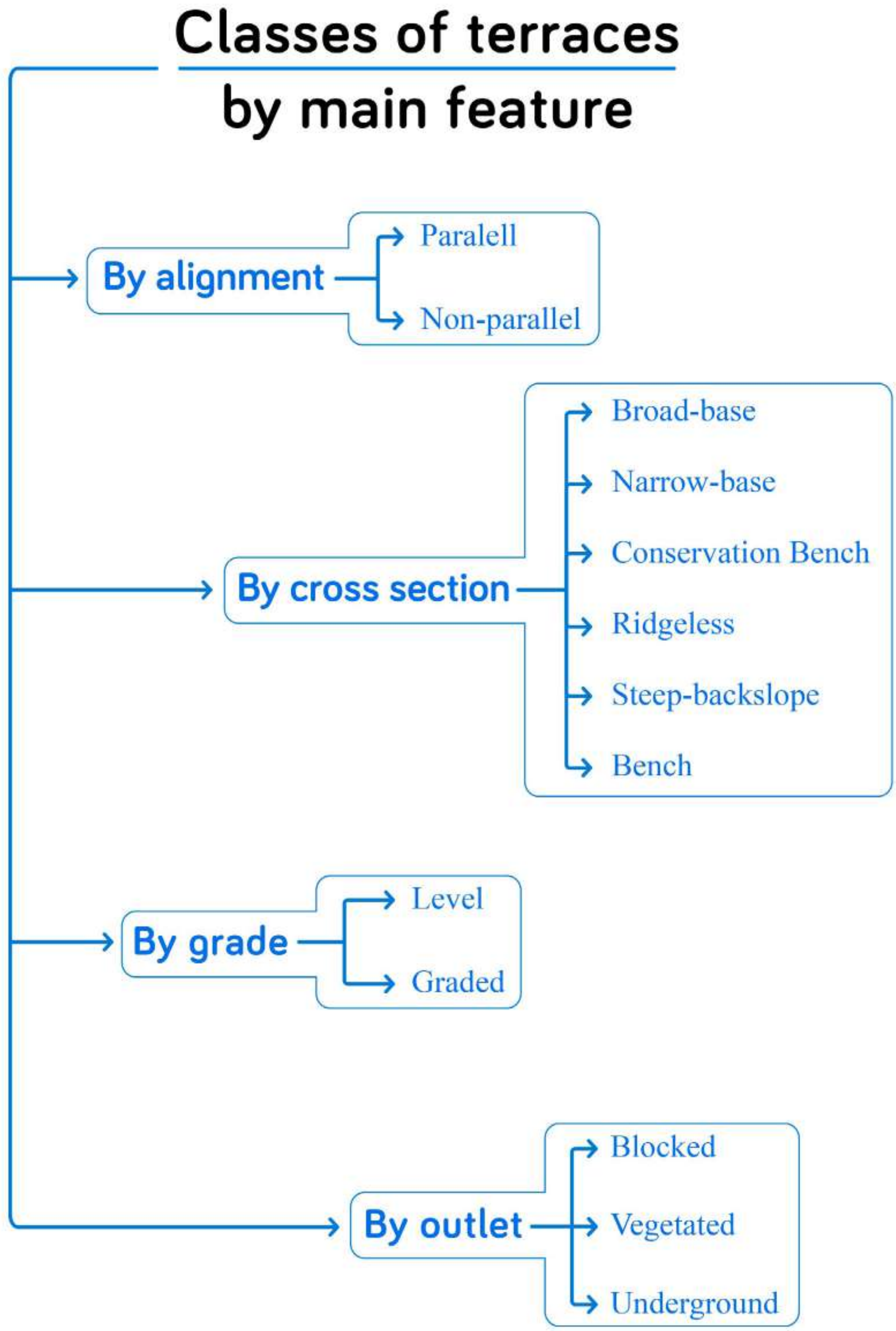


Figure 3.2.1.1. Type of terraces according to their design. Adapted from Blanco et al. (2008).

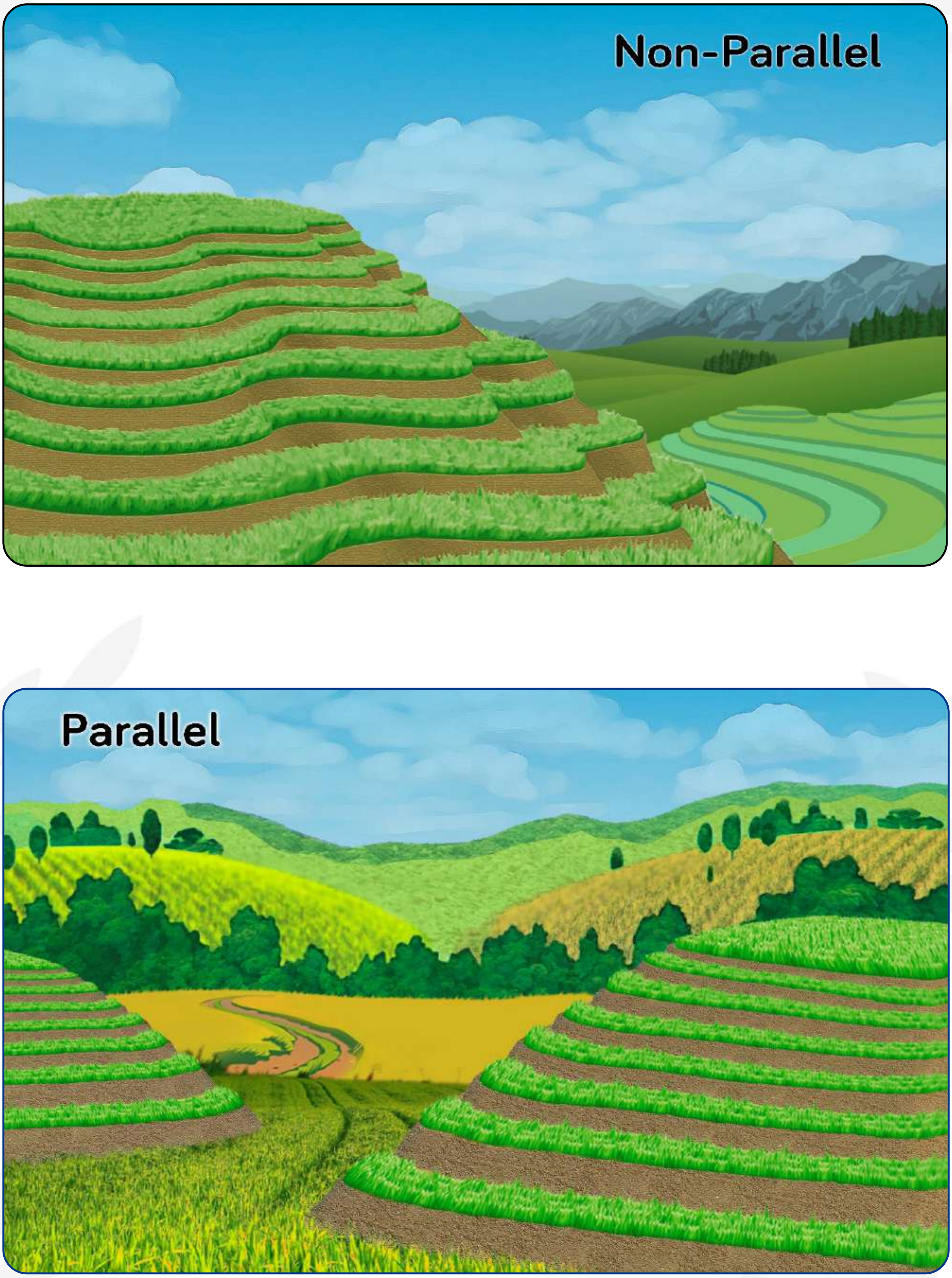


Figure 3.2.1.2. Comparison of terraces according to their alignment: non-parallel (following the contour lines), or parallel (straight).

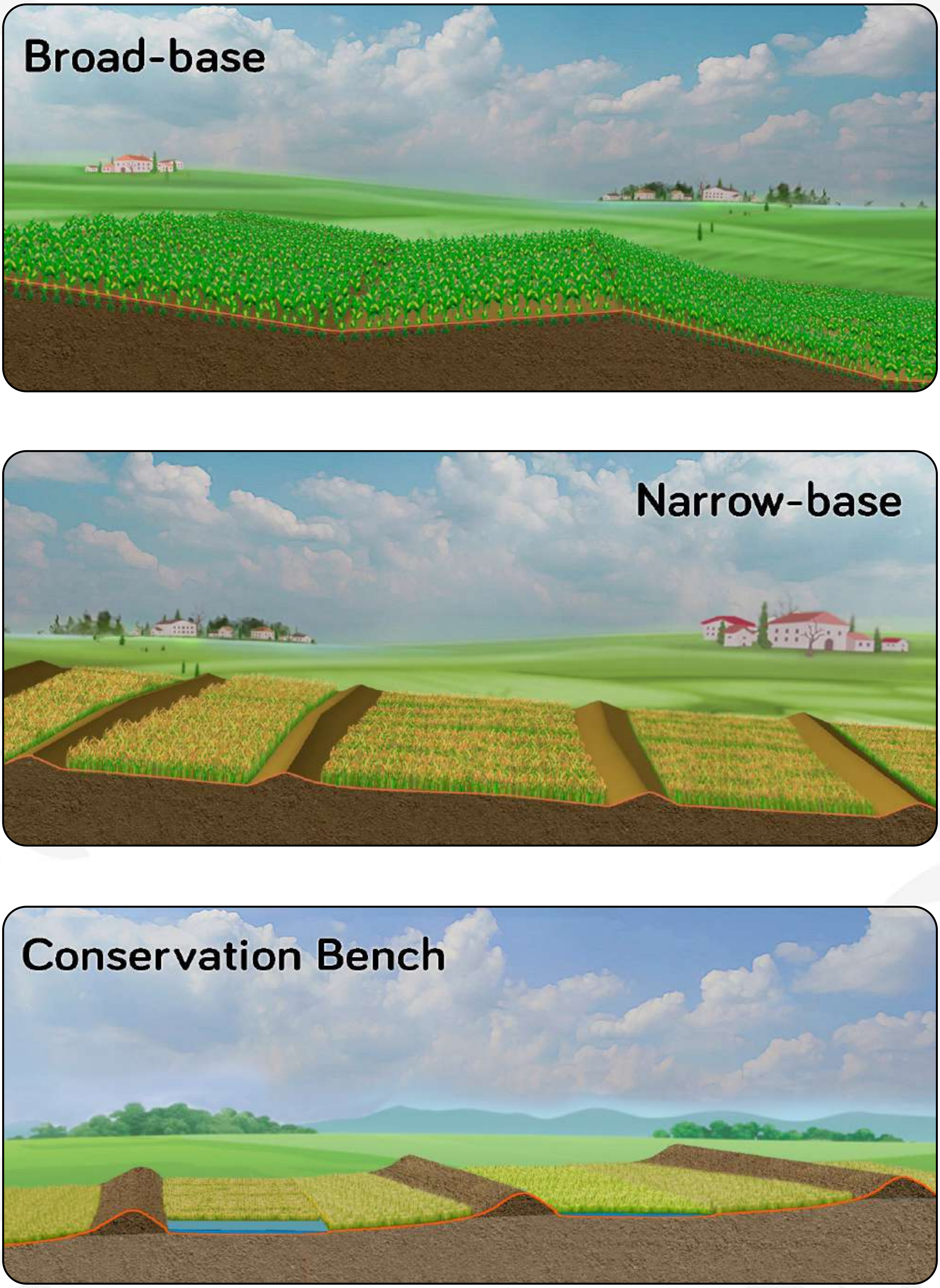


Figure 3.2.1.3a. Comparison of terraces according to their cross-section: broad base, narrow based and conservation bench.

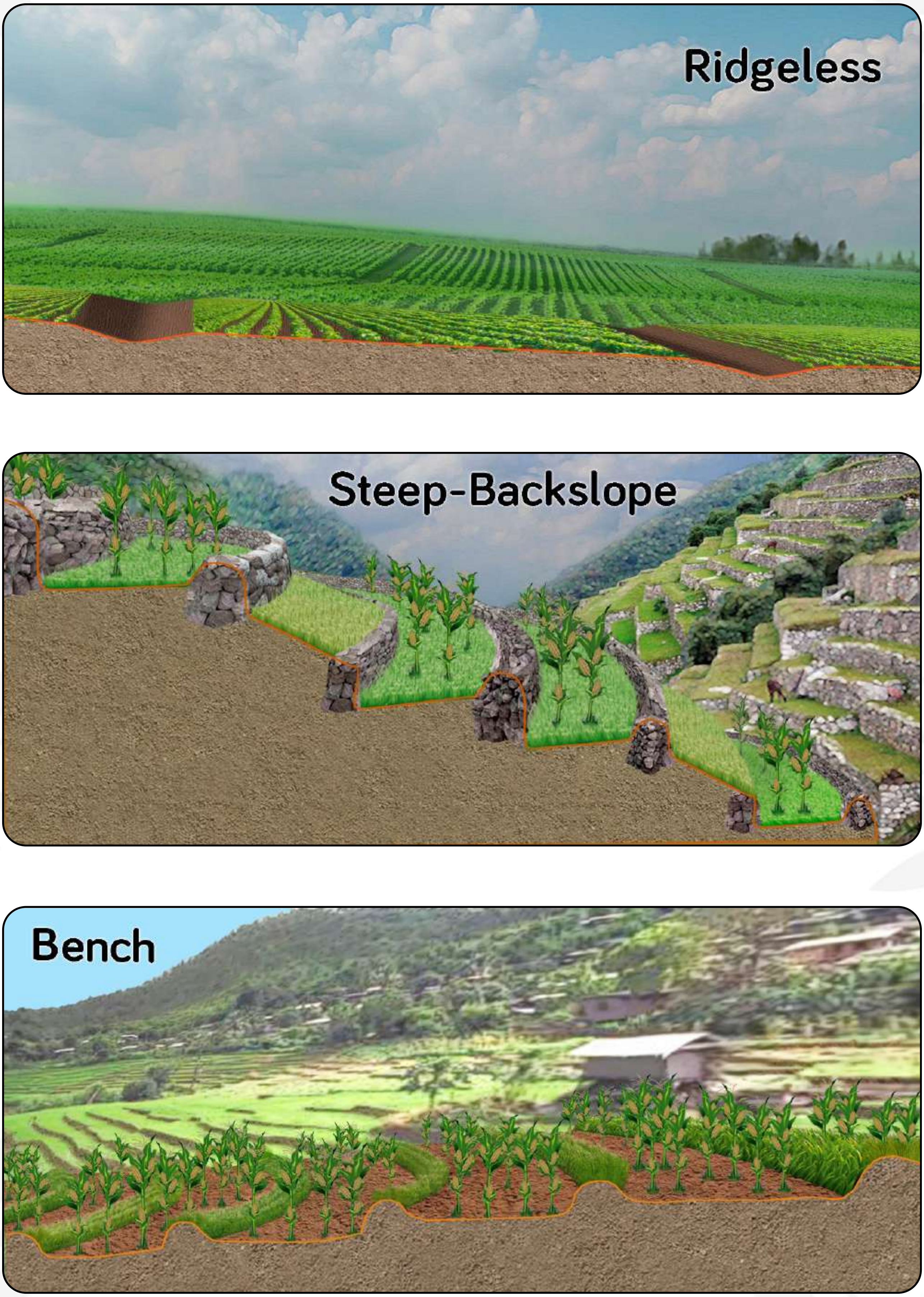


Figure 3.2.1.3b. Comparison of terraces according to their cross-section: without ridges, with steep back slope and bench terraces.

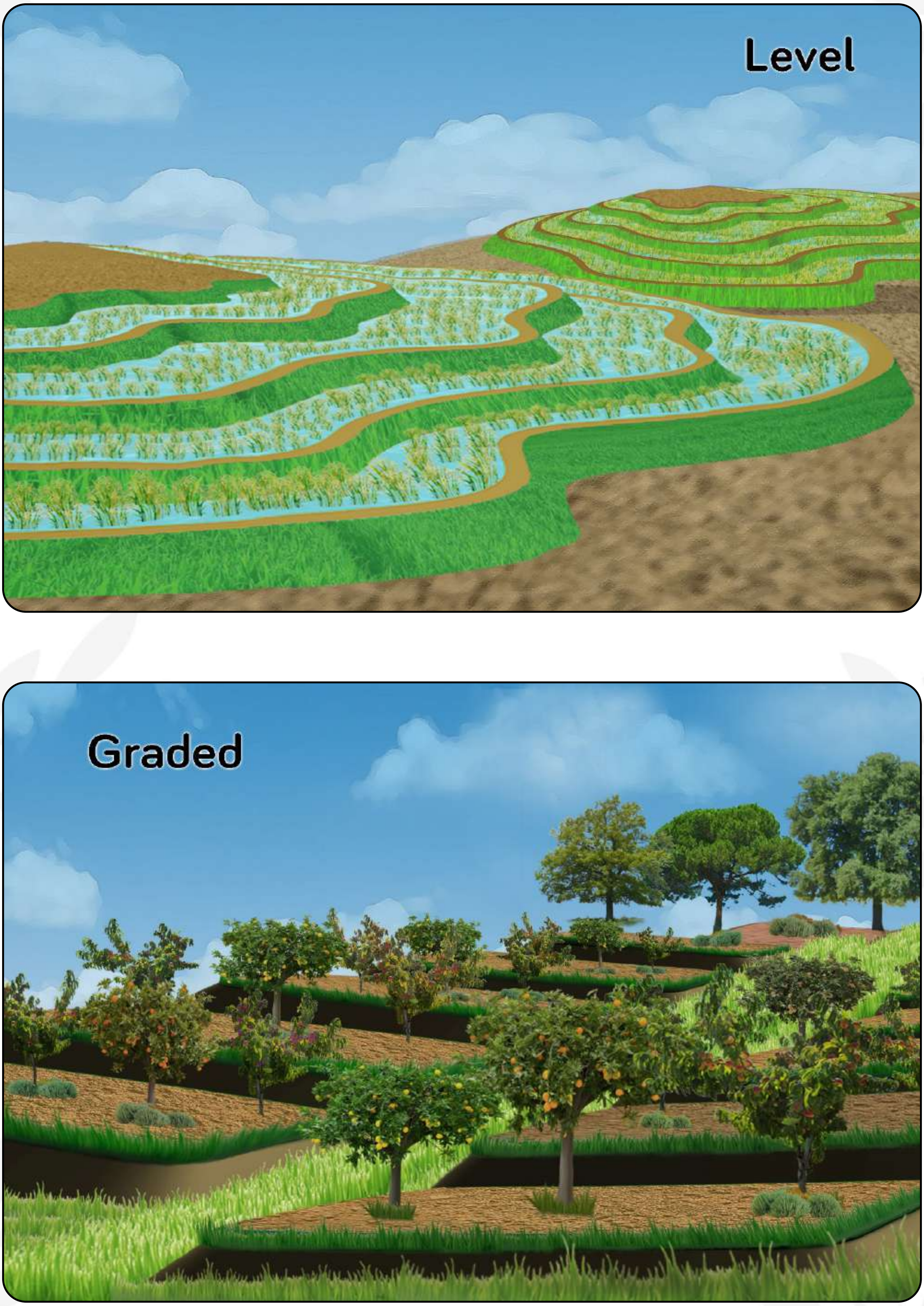


Figure 3.2.1.4. Comparison of terraces according to their grading: level vs. graded.

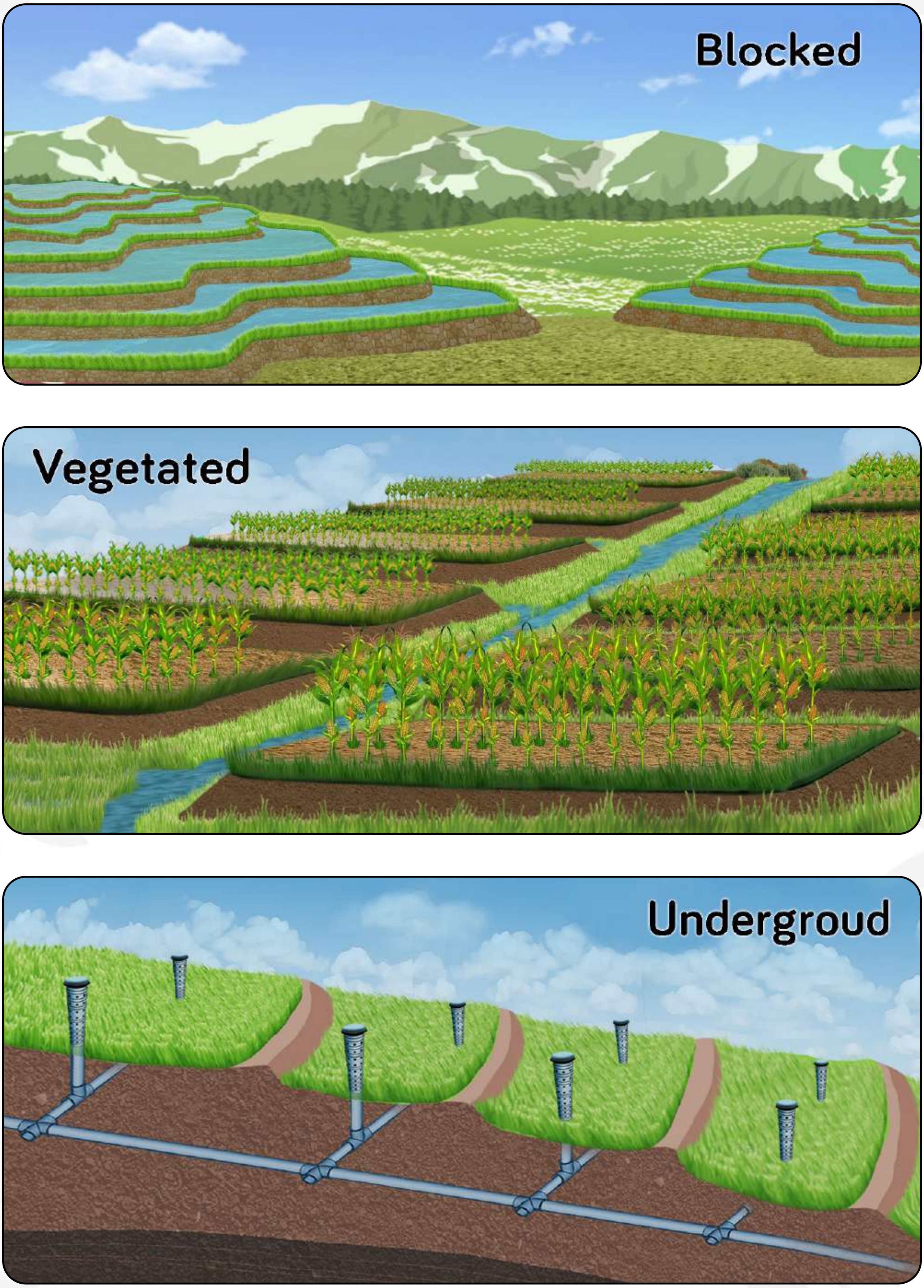


Figure 3.2.1.5. Comparison of terraces according to the outlet used: closed, vegetated channel or underground.

3.2.1.3. Images of different kind of terraces.

Figure 3.2.1.6. Broad base terraces in the black soil region of northeastern tern China (Photo L. Meng).

Figure 3.2.1.7. Traditional stone narrow base terrace with stone walls in Eastern Spain (Photo J.A. Gómez).

Figure 3.2.1.8. Stone bench terraces in the mountain area of north China (Photo L. Meng).

Figure 3.2.1.9. Narrow base terraces with vegetated lanes in Wachau valley (Austria) on vineyards (Photo P. Strauss).

Figure 3.2.1.10. Terraces in Central Bohemia (Grunta) used for wheat and potatoes (Photo T. Dostal).

Figure 3.2.1.11. Terraces in Southern China with different crops (Photo T. Dostal).

3.2.1.4. Selected References.

Blanco, J., Lal, R. 2008. Principles of Soil Conservation and Management. Springer.

Gómez et al. 2019. Criterios técnicos para el diseño y evaluación de cárcavas. Available in https://www.juntadeandalucia.es/servicios/publicaciones/detalle/79281.html In Spanish.

NRCS, 2011. National Resource Conservation Services Standards. Terraces Code 600. Available at https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1046935.pdf

WOCAT 2011. Vegetated earth-banked terraces (Spain). Available in https://qcat.wocat.net/es/wocat/technologies/view/technologies_4037/ Note that in WOCAT database there are several examples of terraces.

Return to Table 3.1.1.

3.2.2. Contour planting of trees and vines.

3.2.2.1. Description.

Contour planting consists of planting perennial vegetation like trees (e.g. vines, olives, almonds) or other perennial vegetation on the contour to impose that all the operations are made on direction perpendicular to the maximum slope. Its purpose is to reduce runoff and water erosion. The use of this contour planting practice implemented without terracing is not as effective as terracing because of the difficulty of keeping the tree lines perpendicular to the maximum slope, and the easiness of runoff to breach the tree lines. Nevertheless, it might be used as a partial alternative effective under certain conditions, see Table 3.2.2.1. It is usually implemented when the terrain has been terraced.

Table 3.2.2.1. Best conditions for use of contour planting.

Feature	Reason
Is most effective on slopes between 2 and 10 %.	Above 10% slope machine traffic is quite complicated and below 2% it is not usually necessary.
Fields that are cut by gullies or have strongly undulating topography are not well suited for this practice.	It is complicated to arrange plantings and orchard and gully erosion is not controlled.

This technique is most effective when combined with vegetative ground cover (cover crops) and the use of vegetated barriers on the contour. The main criteria for best implementation of this technique appear in Table 3.2.2.2.

Table 3.2.2.2. Main conditions for proper contour planting. Adapted from NRCS 2016.

#	Condition
1	Maximum row slope will be aligned as closely to the contour as feasible, but not to exceed 4% slope steepness in the direction of the trees (or 10% if permanent cover crop is provided).
2	On soils with slow to very slow infiltration rates establish a lane slope of not less than 0.2 percent to prevent waterlogging.
3	Avoid very long lanes, to prevent concentration of runoff. Shorten these lanes by running them into controlled outlets (e.g. grassed waterways) at regular intervals.
4	Always provide a controlled outlet for the runoff that accumulates in the alleys, see figure 3.2.1.5.

This BMP should be the always implemented when stablishing a new orchard to prevent water erosion in areas prone to this environmental threat.

3.2.2.2. Images of different kind of contoured planting.

Figure 3.2.2.1. Contoured olive orchard in Spain (Photo J.A. Gómez).

Figure 3.2.2.2. Contoured vineyard in NE Italy (Photo J.A. Gómez).

Figure 3.2.2.3. Contoured vineyard terraces in Samos, Greece (Photo T. Dostal).

3.2.2.3. Selected References.

NRCS, 2016 National Resource Conservation Services Standards. Contour orchard and other fruit areas. Code 330. Available at https://apps1.cdfa.ca.gov/EcosystemServices/docs/331ContourOrchardandotherPerenialCrops2016_STD.pdf

WOCAT 2011. Olive tree plantations with intercropping (Morocco). Available at: https://qcat.wocat.net/en/wocat/technologies/view/technologies_1112/
Note that in WOCAT database there are several examples of contouring.

Return to Table 3.1.1.

3.2.3. Landscape elements.

3.2.3.1. Description.

Landscape elements are non-productive areas of natural or artificial origin present in agricultural landscapes. They provide numerous benefits in term of the provision of ecosystems services not-related to yield. In the current orientation of the CAP these landscape elements usually fit into the category of 'Ecological Focus Area (EFA)' and have been recognized a major role in enhancing biodiversity (e.g. Biodiversa, 2017). This section covers elements presents in agricultural landscapes that are already present, but which have not been specifically implemented with a purpose already covered in a different section (e.g. vegetative barriers that will become hedgerows with time). Table 3.2.3.1. summarizes the major classes of landscape elements within this context.

Table 3.2.3.1. Major landscape elements within agricultural landscapes.

Element	Reason
Island forest.	Small forest creating an enclave of trees and shrubs in an agricultural landscape.
Hedgerows.	A line of different types of shrubs and small trees growing very close together, especially between fields or along the sides of roads in the countryside.
Tree line.	Line of trees of shrubs narrower than a hedgerow.
Isolated trees.	Single trees located in a homogeneous agricultural field.
Fallow land.	Land that is permanently left fallow.
Stone walls.	Walls, usually made of dry stone and of high aesthetic value used as field boundaries or retaining walls.
Traditional structures.	Other typical rural constructions such as isolated houses, wells, barns etc.

The positive effect of these elements depends usually of the amount, and type, of vegetation and the care and attention paid to them. For instance, they need to be maintained clean of aggressive weeds, mowed or pruned and cleaned regularly, and paying attention to accidental damage by cropping operations. For instance, avoid spraying them accidentally when applying agrochemical treatments in adjacent crops. Table 3.1.3.2. summarizes the expected impact of these elements assuming that these conditions are fulfilled.

Table 3.2.3.2. Impact of selected landscape elements on several ecosystem services. ++ means high impact, + moderate impact, o means negligible.
***means impact only if buffering a water stream from runoff from an agricultural area.**

Element	Enhancement of biodiversity	Erosion control	Offsite contamination	Landscape aesthetics
Island forest.	++	++	++/o *	++
Hedgerows.	++	++	++/o *	++
Tree line.	+	+	o	++
Isolated trees.	+	o	o	++
Fallow land.	+	++	++/o *	++
Stone walls.	+	++	+	++
Traditional structures.	+	o	o	++

3.2.3.2. Images of different kind of landscape elements.

Figure 3.2.3.1. Island forest in NE Italy (Photo J.A. Gómez).

Figure 3.2.3.2. Hedgerow separating two fields in S. Spain in a semiarid environment (Photo J. Mora).

Figure 3.2.3.3. Tree line in an access road in Southern Bohemia, Czech Republic (Photo T. Dostal).

Figure 3.2.3.4. Isolated tree in a fallow land in S. Spain (Photo J. Mora).

Figure 3.2.3.5. Vegetated fallow land in S. Spain (Photo J. Mora).

Figure 3.2.3.6. Stone wall in a terraced orchard in E. Spain (Photo J.A. Gómez).

Figure 3.2.3.7. Changes of landscape structure and encroachment of landscapes elements in Central Bohemia, 1953 vs. 2015. Photo https://kontaminace.cenia.cz/

Figure 3.2.3.8. Small forest island nearby a tradition house farm in S. Spain (Photo J. Mora).

3.2.3.3. Selected References.

Gómez et al. 2019. Criterios técnicos para el diseño y evaluación de cárcavas, revegetación para diversificación del paisaje, muros de contención, mejora ambiental de fuentes y abrevaderos y construcción de charcas artificiales. In Spanish. Available at: https://www.juntadeandalucia.es/servicios/publicaciones/detalle/79281.html

Biodiversa, 2017 Policy brief: The Common Agricultural Policy can strengthen biodiversity and ecosystem services by diversifying agricultural landscapes Available at https://www.biodiversa.org/1237

NRCS. 2011. National Resource Conservation Service. Hedgerow Planting. Code 422. Available at: https://efotg.sc.egov.usda.gov/references/public/NY/nyps422.pdf

WOCAT 2020. Pasture shelterbelts in the desert zone (Uzbekistan). Available at: https://qcat.wocat.net/en/wocat/technologies/view/technologies_1112 Note that in WOCAT database there are several examples of landscape elements.

[Return to Table 3.1.1.](#)

3.2.4. Cover crops under tree crops.

3.2.4.1. Description.

Cover crops grown under tree crops is a traditional technique, e.g. Worthen, 1948. In tree crops cover crops are used for several purposes including nutrient management, improvement of trafficability and soil properties, erosion control, and improvement of biodiversity. Cover crops are mainly regarded today as a water erosion control technique at hillslope scale, but it is important to acknowledge their role for improving soil properties, biodiversity and contributing to landscape value.
When approaching the use of cover crops as a BMP in tree crops we need to be aware of three major concepts.

1.- There are several strategies to implement this technique which are summarized in section 3.2.4.2.

2.- Their effectiveness depends in the ability of farmers to produce a well-established cover crop before the onset of heavy rainfalls. Therefore, choosing the cover crop option best adapted for the soil management objectives and soil, climate and cropping conditions is of paramount importance, see Table 3.2.4.1.

3.- The specific techniques and species used needs to be adapted to the soil management objectives, in this case soil conservation, and specific crop, climate and soil conditions. Some general guidelines can be found in Table 3.2.4.3. In climates with limited water availability, which cover some of the largest areas of tree crops cultivation worldwide, there is a trade-off between cover crop water use and water availability for the trees that needs to be managed in order to prevent negative effects on tree crop yield.

3.2.4.2. Types of cover crops according to extension and duration in the farm.

We can classify four major strategies for cover cropping. This section is written assuming that the cover crops are established in the alleys of the tree plantation where the area below the canopy was kept free of vegetation (by mechanical or chemical methods). This is the most common way of implementing cover crops in tree crops, although some farmers can also implement the cover crop in all the plot.

a) Permanent cover crop. In which the lanes are permanently covered during the whole year, although the vegetation can be dormant for part of the year due to drought or cold. This permanent cover crop can be established using perennial herbaceous vegetation, or annual herbaceous vegetation which self-seeds every year.

b) Temporary cover crop. Here farmers control the duration of the cover crop in the plantation. It is common in Mediterranean region, where cover crops grow during the rainy season, from fall to early spring, to be killed chemically or mechanically in early spring to prevent competition for soil water with the trees. Ideally, the cover crop should be killed once the seed for self-seeding for next year had been produced. However, since this is not always possible there are several strategies for producing seed for next year, including leaving a narrow (0.5 to 1 m) strip of cover crops untreated to complete the phenological cycle and produce seed. In many situations farmers help to spread this seed from the strip using agricultural implements (e.g. some tins, bars or rolling baskets).

c) Alternate cover crops. The cover crop is established in every other lane, with the other lane under different management, usually bare soil maintained by mechanical or chemical methods. The cover crop is alternated between the lanes in time, every one, two or three years.

d) Cover crop for green manure or soil fumigation. The objective here is to maximize production of cover crop biomass to incorporate it into the soil. This can act as a fertilizer (e.g. legumes for fixing nitrogen into the soil) or as a bio-fumigant (e.g. Sinapis alba derived glucosinolates to reduce inoculum of Verticillium dahliae in soils). The management of the cover crop is completely different to the strategies for a, b and c, with the management oriented to produce maximum biomass which is incorporated into the soil at the appropriate growth stage. This does not necessarily fit with the optimum timing for soil or water conservation.

Table 3.2.4.1. Types of cover crops according to the duration of the cover crop. ++ means high benefit, + moderate benefit, (leg) means benefit only if legumes are used. Alternate cover crops will provide an effect proportional to the number of lanes covered with the specific cover crop technique used. Adapted from Grant et al (2006).

Potential Benefit	Permanent cover crop (a)	Temporary cover crop (b)	Green manure (d)
Increaseof soil organic carbon.	+	+	++
Inc. of biological activity.	+	+	++
Nitrogen incorporation into soil.	+ (leg)	+ (leg)	+ + (leg)
Infiltration improvement.	++	+	+
Runoff/erosion reduction.	+++	++	+
Reduction of dust.	+	+	+
Reduction of soil compaction.	+	+	+
Weed control.	++	++	++
Reduce excess of soil water.	++	+	++
Improvement of trafficability.	++	+	+

Table 3.2.4.2. Incidence of potential risks associated with use of cover crops as compared to bare soil management. ncidence of potential risks associate to different types of cover crops. ++ means high risk, + moderate risk, o none or negligible risk. Alternate cover crops will provide an effect proportional to the number of lanes covered with the specific cover crop technique used. Adapted from Grant et al. (2006).

Potential RISK	Permanent cover crop (a)	Temporary cover crop (b)	Green manure (d)
Competition for soil water.	--	-	-
Increase of frost damage in Spring.	-	-	--
Interfere in eliminating some plagues.	-	-	-
Increase of rodents.	-	-	-
Interfere in chopping/withdrawing pruning residues.	o	-	-
Increase of nematodes.	--	o	o

3.2.4.3. Main types of vegetation and management options according to different objectives.

Depending on the main objective of the cover crops, different species may be selected. The objective also defines the major management options and decisions. Table 3.2.4.3. summarizes these decisions.

Table 3.2.4.3. Cover crop composition and some key questions and management decisions based on the main soil management objective.

Objective	Best type of cover	key questions?	Major management decisions
Enhancement of biodiversity, landscape.	Mix of plant with flowers.	What species to use to achieve a cover crop with staggered flowering periods and moderate costs.	How to control cover crop to maintain composition? When and how use mowing?.
Improvement of soil fertility.	Legumes or Legumes/grasses.	Species composition.	When to incorporate the cover crop? Soil preparation to maximize biomass production.
Erosion control.	Grasses.	Species with best adapted phenology to climate conditions? When to reseed?.	When to kill the cover crop if it is temporary one?.
Grazing.	Legumes or Legumes/grasses.	Species composition? When to reseed?.	Grazing density? time of the year when grazing is allowed?.
Trafficability.	Grasses.	Species composition? Time of seeding in relation to farm operations?.	When to control the cover crops, mechanical (mowing) or chemically?.

3.2.4.4. Images of cover crop examples in tree crops.

Figure 3.2.4.1. Permanent cover crops by annual grasses in an olive orchard on a degraded soil (Photo J.A. Gómez).

Figure 3.2.4.2. Temporary grassed cover crops in an almond plantation (Photo J.A. Gómez).

Figure 3.2.4.3. Vineyard with cover crops in Lower Austria (Photo T. Dostal).

Figure 3.2.4.4. Green manure cover crop in an olive orchard (Photo J.A. Gómez).

Figure 3.2.4.5. Cover crop mixes for biodiversity in an olive orchard (Photo J.A. Gómez).

Figure 3.2.4.6. Alternate cover crop in a vineyard in southern Moravia, Czech Republic (Photo T. Dostal).

3.2.4.5. Definitions of cover crops for tree crops in different countries.

A major source of misunderstanding when discussing cover crops, is that despite of being part of almost every country's scheme for agri-environmental measures, the definitions used for cover crops associated with subsidy payment can be quite different. The subsequent listing gives an overview about the requirements to receive subsidies for cover crop in different SHui countries as an example.

Country	Definitions
Austria Vines and Orchards.	**1.-** Cover crop is either an actively seeded plant or a plant existing from previous periods. **2.-** It must contain at least one cold resistant species. **3.-** Cover crops are not: a) organic mulches b) covers that are completely unsown, c) cereals, maize and mixed crops with more than 50% of cereal or maize, except in the case of oats or barley when used to establish permanent cover. Obligatory: Orchards: permanent cover required in all lanes except a maximum of 100 cm around stems. Vines: Slopes >= 25%: permanent required cover in all lanes, except a maximum of 80 cm around stems Slopes < 25%: cover required in all lanes between November 1st to April 30th (Variant A), or permanent cover of all lanes (Variant B) Soil management during the period of cover cropping is only allowed without destruction of cover (deep management for instance) The Austrian subsidy system – only obligatory measures
Czech Republic.	There are no restrictions neither obligatory rules within CAP and GAEC to implement permanent cover crops in vineyards, orchards or hop fields. Specific 5-year plans are allowed to obtain additional subsidies for implementation cover crops in wine lanes during implementation of new planting strategies.
Spain Olives.	Obligatory: To have a cover crop at least 1 m wide in the alleys, perpendicular to the direction of the maximum slopes. If this orientation is not possible, implement the cover crop in the direction of the alley. Recommended: To keep the cover crop during fall-winter, or in period of highest storm risk. Kill the cover crop in early Spring once the competition for soil water starts, using chemical or mechanical methods, or controlled sheep grazing. The cover crop residues should be left on the surface until next fall, when if necessary, a new cover crop can be seeded. Recommended: Seeding part of the orchard with legumes (in soil with N deficiency), grasses, mixes of grasses and legumes, crucifers or the species necessary to improve soil condition and provide habitat to birds.
Spain Vines.	Recommended: In areas where it is feasible, to have a cover crops or a mulch during fall-winter, or in periods of high storm risk. Eliminate the cover crop once competition for soil water starts. Recommended: If there is no risk for competition for soil water keep the cover crop as long as possible, limiting its growth by mowing or grazing. Complementing the cover crops with additional mulching material if necessary. Eliminate the cover crops with authorized chemical or mechanical methods, or by grazing by sheeps. Recommended: Establish a vegetated barrier around the farm perimeter using a cover crop band with a width equivalent to half of the planting space. Use legumes, grasses, mixes of grasses and legumes, crucifers best or the species necessary to improve soil condition and provide habitat to birds best adapted to the area.

Country	Definitions
Spain Citrus.	Recommended: Where feasible, keep a cover crop during fall-winter, or in period of high storm risk. Eliminate the cover crop in early Spring once the competition for soil water starts, using chemical or mechanical methods, or controlled sheep grazing. The cover crop residues should be left on the surface until next fall, when if necessary, a new cover crop can be seeded.
Spain Almonds.	Recommended: Where feasible, keep a cover crop during fall-winter, or in period of high storm risk. Eliminate the cover crop in early Spring once the competition for soil water starts, using chemical or mechanical methods, or controlled sheep grazing. The cover crop residues should be left on the surface until next fall, when if necessary, a new cover crop can be seeded. Recommended: seed part of the orchard with legumes (in soil with N deficiency), grasses, mixes of grasses and legumes, crucifers or the species necessary to improve soil condition and provide habitat to birds.
Spain Apples.	Recommended: Have a permanent cover crop (seeded or form natural vegetation) during the whole year. Recommended: In cold areas to maintain the soil bare at least during Spring to minimize frost risk. Recommended: In case of seeding a cover crop used the species most adapted to the to the soil type (legumes, grasses, mixes of grasses and legumes, crucifers). Recommended: use authorized methods for chemical or mechanical control of cover crops. Recommended: In addition to the cover crop in the lanes, keep not planted parts of the orchard with a cover crop to improve biodiversity.

3.2.4.6. Selected References.

Grant, J. et al. 2006. Cover crops for walnut orchards. University of California. Publication 21627. Available at: https://anrcatalog.ucanr.edu/pdf/21627e.pdf

Gómez, J.A., et al. 2019. Jornadas sobre uso de cubiertas vegetales y otra vegetación para el control de la erosión y otros servicios ecosistémicos en cultivos leñosos. proyecto INTCOVER In Spanish. Available at: https://digital.csic.es/handle/10261/184360 (in Spanish).

Sbitri, M.O., et al. 2007. Production techniques in olive growing. Available at: https://www.internationaloliveoil.org/wp-content/uploads/2019/12/Olivicultura_eng.pdf

Worthen, E.L. 1948. Farm Soils. Wiley & Sons.

Sonderrichtlinie ÖPUL 2015. Sonderrichtlinie des Bundesministers für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft (BMLFUW) für das Österreichische Programm zur Förderung einer umweltgerechten, und den natürlichen Lebensraum schützenden Landwirtschaft. GZ BMLFUW-LE.1.1.8/0089-II/3/2014. Available at: https://www.bmlrt.gv.at/land/laendl_entwicklung/foerderinfo/sonderrichtlinien_auswahlkriterien/srl_oepul.html (In German).

Return to Table 3.1.1.

3.2.5. Mulching in tree crops.

3.2.5.1. Description.

Mulching under tree crops is the practice of using inert material for covering the lanes to protect the soil against erosion, improve soil quality and control weed growth. For cost, and environmental reasons, mulching is carried out using pruning residues from the trees, although in some situations pruning residues or straw are brought from other farms. Mulching is sometimes used to achieve an effective soil protection when planting an orchard or vineyard on very steep terrain while other techniques, for example cover crops or vegetated barriers are implemented. Mulching is also used as a substitute for, or complement to, cover crops, especially in arid and semiarid areas. There are many other mulching materials, see for instance NRCS (2011), but their costs normally restrict their use in orchards. In soils with a high stone content the stones may be used to cover the surface of the orchard soil and create a stone mulch. Although not recommended and now abandoned for environmental reasons, you can still find historic descriptions of mulching using plastic material in some crops e.g. pineapple fields.

The major advantages of mulching using pruning residues or straw are summarized in Table 3.2.5.1. Please note that to achieve an effective protection against sheet and rill erosion, or to reduce weed growth enough biomass to cover most of the ground during the rainy season is needed. In this respect residues from pruning material, which tend to decompose more slowly than residues from herbaceous plants, provide a more lasting cover. To be effective mulching material needs to be applied regularly to provide effective cover all year round. A reference figure for achieving effective mulching is 3.5-6 t ha-1 dry of biomass (e.g. straw or chopped pruning residues).

Table 3.2.5.1. Main benefits of mulching with organic materials.

#	Benefit
1	Control of water (sheet and rill) and wind erosion.
2	Increase of organic carbon and aggregate stability in the top (0-5 cm depth approximately) soil layer.
3	Reduces weed infestation.

Mulching might have occasionally negative side effects and it is important to take precautions to avoid these (Table 3.2.5.2).

Table 3.2.5.2. Precautions when using mulching in tree crops.

#	Caveat
1	Always check that there are not plant pathogens or diseases that can be spread or promoted if using a mulch.
2	Try to chop the pruning material to a size that facilitates uniform distribution in the farm and avoid propagation of plant pathogens and diseases.
3	Check the C:N ratio of your mulching material to correct for: a) temporal sequestration of soil N if C:N ratio is too high. b) avoid using mulching materials with high N content in areas connected to streams.
4	Check that there is no negative effect on protected flora and fauna (e.g. reptiles, ..).
5	Note that mulching will interfere with efforts to establish a cover crop. Take appropriate measures (e.g. spreading on alternate lanes) to avoid negative effects.

3.2.5.2. Images of different examples of mulching.

Figure 3.2.5.1. Lanes of an olive orchard mulched with chopped pruning residues in Spain (Photo J.A. Gómez).

Figure 3.2.5.2. Olive orchard mulched with cereal straw in Spain (Photo J.A. Gómez).

Figure 3.2.5.3. Mulch transported by rill flow in a very long slope (Photo J.A. Gómez).

Figure 3.2.5.4. Vineyard with mulched interrow in Hungary (Photo T. Dostal).

Figure 3.2.5.4. Mulch of non-chopped pruning residues in an olive orchard in S Italy (Photo J.A. Gómez).

3.2.5.3. Selected References.

NRCS, 2011. National Resource Conservation Services. Iowa Conservation Practice 484. Available at https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_006305.pdf

NRCS, 2018. Natural Resources Conservation Service. Conservation Mulching Code 484. https://efotg.sc.egov.usda.gov/references/Public/IN/484_Mulching.pdf

WOCAT 2013 Mulching (Kenya). Available in https://qcat.wocat.net/en/wocat/technologies/view/technologies_1318/ Note that in WOCAT database there are several examples of mulching.

[Return to Table 3.1.1.]

3.2.6. Contour farming.

3.2.6.1. Description.

Tilling following the contour can be implemented in depending on slope steepness, regularity of terrain and layout of the plantation. In orchards, whose trees form a hedgerow contour farming is only possible when the trees are planted on contour (see section 3.2.2.). The second, and major, limitation for contour farming is slope steepness: on steeper slope the use of machinery is restricted for the risk of turning over. On steep slopes contour cultivation is also less effective for reducing soil erosion. For contour farming many of the criteria described in section 3.2.2. contour planting also apply. Contour farming is most effective on moderate slopes on uniform terrain, see Table 3.2.6.1.

Table 3.2.6.1. Best conditions for use of contour farming.

Feature	Reason
Most effective on slopes between 2 and 10%.	Above 10% slope traffic is quite complicated and below 2% it is not usually necessary.
Fields that are cut by gullies or have strongly undulating topography are not well suited for this practice.	It is complicated to till following the contour and gully erosion is not controlled.

The effectiveness of this practice depends on maintaining ridges and furrows that can transport runoff water safely without overtopping or being eroded. For this reason, their effectiveness depends on the factors indicated in Table 3.2.6.2.

Table 3.2.6.2. Key factors defining effectiveness of contour farming.

Factor	Comment
Ridge height and spacing.	Large enough to accommodate expected runoff. Ridge height not less than 5 or 2.5 cm depending on ridge minimum spacing, more or less than 25 cm respectively.
Minimum row grade.	At less 0.2% to prevent waterlogging.
Maximum row grade.	2% of half of the critical slope steepness for rill erosion if this is small than 2%.
Maximum row length.	It is most effective on slopes between 30 to 120 m. Longer slopes tend to concentrate too much runoff to be safely delivered.
Row outlets.	The rows need to deliver runoff to an area protected against erosion by concentrated flow.

3.2.6.2. Images of different examples contour farming.

Figure 3.2.6.1. Spaced ridges on contour in S. Spain (Photo J.A. Gómez).

Figure 3.2.6.2. Reduced tillage on contour in a traditional olive orchard in S. Spain (Photo J.A. Gómez).

Figure 3.2.6.3. Contour shrubbery buffer strips in the black soil region of northeastern China (Photo L. Meng).

3.2.6.3. Selected References.

NRCS, 2007. National Resource Conservation Services. Natural Resources Conservation Service. Conservation Practice Standard Contour Farming #330. Available at https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_026017.pdf

Return to Table 3.1.1.

3.2.7. Vegetated barriers.

3.2.7.1. Description.

Vegetated barriers are vegetation strips located perpendicularly to the direction of overland flow whose main purpose is to trap sediment and agrochemicals transported by runoff, and so reducing sediment and agrochemical delivery from upslope areas to the fluvial system. Nevertheless, depending on their location in the landscape and their design their main purpose can differ. Figure 3.2.7.1 summarizes several types of vegetated barriers and recommendations for their minimum and maximum width. When vegetated barriers are located on the margins of water courses they are usually called buffer strips. Barriers being allocated annually on cropland and seeded by annual crops are covered in section of cover crops.

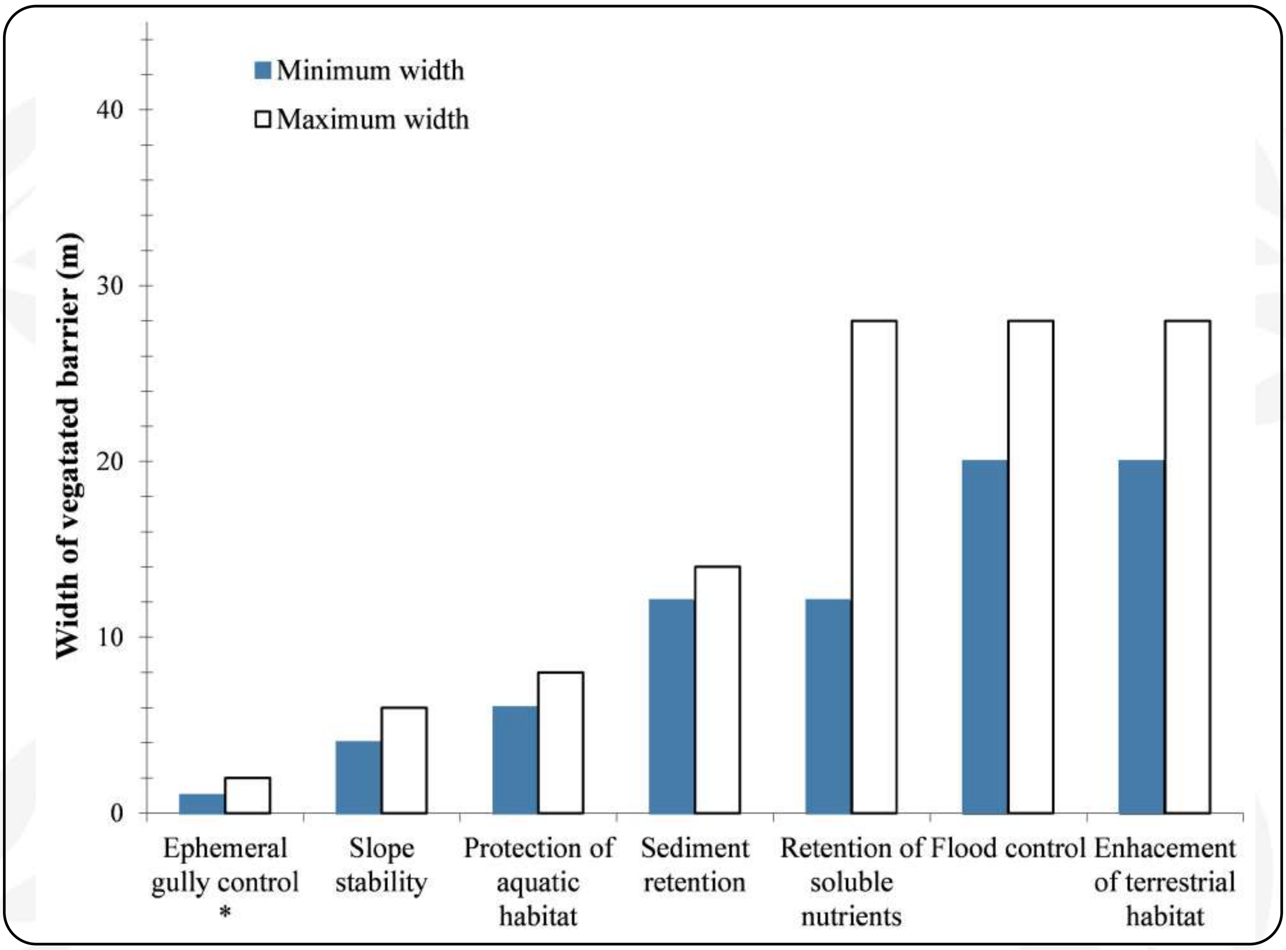


Figure 3.2.7.1. Recommended dimensions for vegetated barriers according to main function. (Adapted from Shultz et al. 2009, and NRCS, 2010). * Use at least two rows of vegetation.

The effectiveness of these barriers depends strongly on the ability of providing a dense and uniform obstacle to runoff flow by the vegetation. So, the recommendation of minimum plant density according the plant size and location according to the flow concentration (see Table 3.2.7.1) must always be considered. When used to prevent offsite contamination, the efficiency of these barriers is reduced very quickly if breached by rills that allow runoff to bypass the vegetation. For these reasons a careful management and soil preparation before implanting the barriers is necessary. Note also that there is usually sediment deposition in the upstream side of the barrier. This needs to be periodically removed to maintain the barrier effectiveness. In situations where large sediment deposition is expected is recommended to use taller plant species.

In most cases the species used in vegetative barriers are annual or perennial herbaceous plants well adapted to prosper in local conditions and of easily maintenance. In relation to species, it is very important to check that the ones used are not invasive plants and/or that they will not create a problem of severe weed infestation in adjacent agricultural fields. For several purposes, e.g. ephemeral gully erosion of improvement of habitats, shrubs and trees are also included in the vegetated barriers.

Table 3.2.7.1. Recommended plant stem density for vegetated barriers (Adapted from NRCS, 2010).

Stem diameter (cm)	Area of concentrated flow stems/m2	Other areas stems/m2
0.25	11000	5500
0.38	2200	1100
0.51	666	333
0.64	333	166
1.25	44	22
>2.54	11	11

3.2.7.2. Images of different examples of vegetated barriers.

Figure 3.2.7.1. Vegetated barrier for erosion control in a field margin (Photo NRCS).

Figure 3.2.7.2. Vegetation measures for gully control in the black soil region of northeastern China (Photo L. Meng).

Figure 3.2.7.3. Functioning of vegetated barriers in the Czech Republic (Photo J. Krasa).

Figure 3.2.7.4. Breaching of vegetated barriers during intensive events in the Czech Republic (Photo J. Krasa).

Figure 3.2.7.5. Failure of vegetated barrier (wheat) along a potato field (Photo T. Dostal).

3.2.7.3. Selected References.

Shultz, R.C., et al. 2009. Riparian and Upland Buffer Practices. In: H.E. "Gene" Garret (Ed.). North American Agroforestry. An Integrated Science and Practice. 2nd Ed. Amrican Society of Agronomy. Madison. Wisconsin.

NRCS, 2008. National Resource Conservation Services. Natural Resources Conservation Service. Conservation Practice Standard. Filter Strip Code 393. Available at https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1241319.pdf

NRCS, 2010. National Resource Conservation Services. Natural Resources Conservation Service. Conservation Practice Standard. Vegetative Barrier code 601. Available at https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_026353.pdf

WOCAT 2011. Terrace with Tree Barrier (Tayikistán) Available in https://qcat.wocat.net/es/wocat/technologies/view/technologies_1409/ Note that in WOCAT database there are several examples of barriers and strips.

Return to Table 3.1.1.

3.2.8. Gully erosion control techniques.

3.2.8.1. Description.

Gullies are incised areas where concentrated runoff flow has eroded the terrain creating an ephemeral stream. In addition to become a major source of sediment, gullies divide fields increasing costs of farm operations and creating risks for staff that have to cross them or work nearby. Gullies can be of many different sizes (see Figure 3.2.8.1) but they are usually classified as ephemeral or permanent gullies. Ephemeral gullies are those of small size (as a convention less than 0.3 m depth) and can be covered using equipment usually present at the farms (e.g. plough) while permanent gullies are of larger size and their control requires heavier equipment and specific techniques.

Figure 3.2.8.1. Comparison between ephemeral and permanent gullies (Photo J.A. Gómez).

3.2.8.2. Basic design principles.

In the context of agricultural areas where the limited investment capacity is major concern, the basic principles of gully restoration are aimed towards small works, mainly done with the available staff and equipment at the farm. These principles are summarized in Table 3.2.8.1., and the basic guidelines for the construction of gully control structures (mainly vegetated barriers in small gullies and check dams in large ones) appear in Table 3.2.8.2. They must be adapted to the specific climate, soil and crop conditions (see references at the end).

Table 3.2.8.1. Basic principles for gully erosion control.

#	Principle
1	Enhance infiltration in contributing catchment to reduce runoff flow.
2	Divert, if necessary and always in an area protected against concentrated flow, all or part of the runoff flowing to the gully head.
3	Stabilize the gully section against incision and widening using structural methods and vegetation.

Table 3.2.8.2. Basic guidelines for implementing gully control structures.

#	Guideline	Reason
1	Check dams not too high, <1.5 m if possible	They are safer to build and more stable. The system is more resilience if a single check dam fails.
2	Check dams properly space, see Figure 3.3.8.1	Prevent scoring between consecutive dams, and dissipates the stream energy.
3	Good structural design.	As well as being structurally stable, a spillway and toe protection should be included to prevent scouring the check dam base.
4	Complement with revegetation.	Revegetate with shrubs and herbaceous plants the gully boundaries to stabilize against erosion and mass movements.

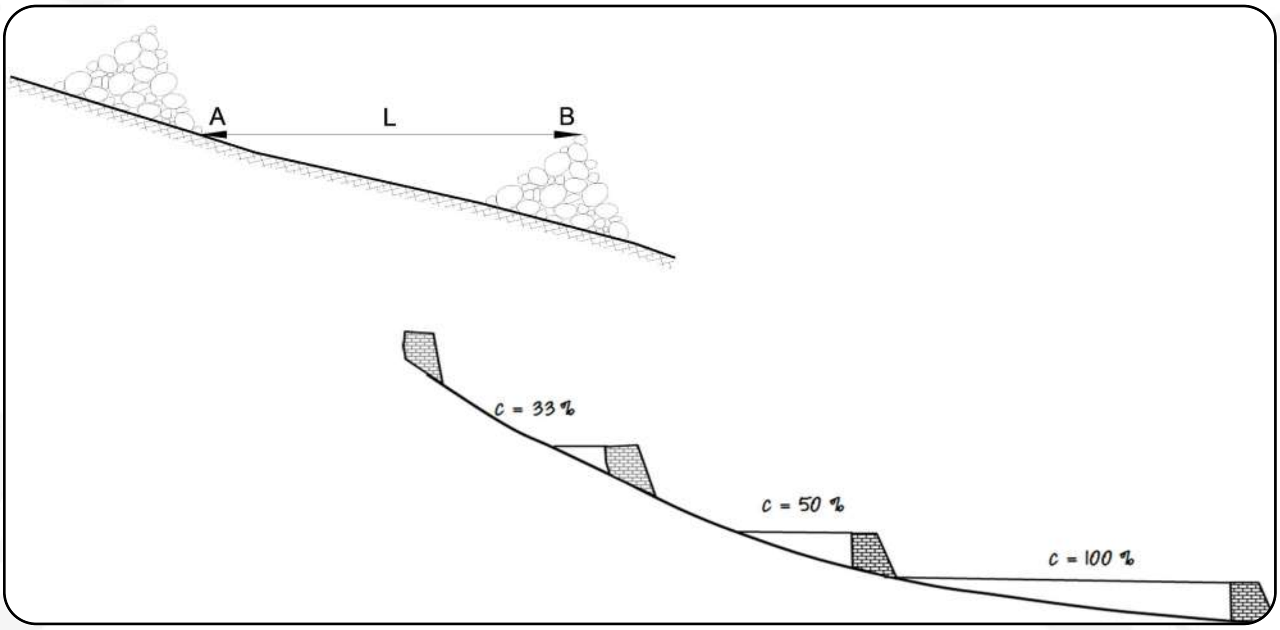


Figure 3.2.8.1. Different strategies from optimum check dam spacing, with a c=100% been the safest and most efficient. (from Gómez et al. 2019).

The actions to gully erosion control can be adapted according to the gully size (see Table 3.3.8.2).

Table 3.2.8.3. Conceptual classification of gullies according to size for implementation of restoring techniques.

Small gully dimensions and small contributing area.	
Main characteristics	**Suggested treatment**
Catchment area < 3ha, Depth <1 m Overland flow velocity <1.5 m sec-1	1- Cover and profiling of soil to form a wide channel. 2- Seeding of dense grass cover, see section 3.2.7. 3- If necessary include vegetated barriers.

Gullies of medium dimensions.	
Main characteristics	**Suggested treatment**
Catchment area > 3ha, Depth 1-2 m	1- Check dams. 2- Vegetated barriers in gully boundary.

Large or very large gullies.	
Main characteristics	**Suggested treatment**
Catchment area > 3ha, Depth > 2 m	1- Check dams. 2a- Vegetated barriers in gully boundary and gully walls if gully walls present geotechnical stability with revegetation. 2b- If gully sides are too steep or unstable consider terracing to provide geotechnical stability.

3.2.8.3. Examples of gully erosion control structures.

Tigure 3.2.8.1. Grassed waterway in Lower Austria (Photo T. Dostal).

Figure 3.2.8.2. Set of several check dams with different design in an olive orchard in Spain (Photo J.A. Gómez).

Figure 3.2.8.3. Stabilized ephemeral gully in Spain (Photo J.A. Gómez).

Figure 3.2.8.4. View of spillway and toe protection in small check dam (Photo J.A. Gómez).

Figure 3.2.8.5. Brick check dams for gully control in China (Photo L. Meng).

Figure 3.2.8.6. Combined soil conservation measures for a gully erosion control in a catchment in hilly regions of north-eastern China (Photo L. Meng).

Figure 3.2.8.7. Wicker waterway in the black soil region of north-eastern China (Photo L. Meng).

3.2.8.4. Selected References.

Gómez et al. 2019. Criterios técnicos para el diseño y evaluación de cárcavas. Available in https://www.juntadeandalucia.es/servicios/publicaciones/detalle/79281.html In Spanish.

NRCS, 2010. National Resource Conservation Services. Natural Resources Conservation Service. Technical Gullies and Their Control. Supplement 14P. Available at https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17826.wba

WOCAT 2011. Gully rehabilitation (Ethiopia) Available in https://qcat.wocat.net/es/wocat/technologies/view/technologies_1469/ Note that in WOCAT database there are several examples of gully erosion control and rehabilitation.

Return to Table 3.1.1.

3.2.9. Conservation Agriculture.

3.2.9.1. Description.

Reduction of the soil disturbance during agricultural management is a core concept in conservation agriculture (CA), which is based in three main principles see Table 3.2.9.1., and it is termed conservation tillage. Conservation tillage is part of practically all national agro-environmental schemes worldwide, as for instance in the regulations of the Common Agricultural Policy in the European Union.

This is mainly due to their potential effectiveness in reducing soil erosion and (partially also runoff) for arable land (Hösl et al., 2016; Strauss et al., 2003). This sections deals with different strategies of conservation tillage as applied to annual crops since another major part of CA techniques (e.g. cover crops are dealt for tree crops in section 3.2.4. and in annual crops in section 3.2.10.).

Table 3.2.9.1. Basic principles of conservation agriculture.

#	Principle
1	Minimalize mechanical soil disturbance appropriate to soil type.
2	Maximize permanent organic soil cover.
3	Include diversified crop rotations to minimize the need for external inputs.

When approaching the use of conservation tillage as BMP in annual crops we need to be aware of four major concepts, Table 3.2.9.2.

Table 3.2.9.2. Main concepts to understand conservation agriculture impact.

#	Concept
1	There are a number of different major strategies that are summarized in Table 3.3.9.3. Note that the same technique may be named differently in different countries which can creates confusion.
2	The major strategies have different effectiveness regarding soil protection and surface runoff reduction.
3	Their effectiveness depends on the ability of farmers to keep a sufficient ground cover after seeding.
4	Besides the major strategies for minimum tillage there exist a number of country specific specifications that are established within the particular agri-environmental schemes. These different approaches are also summarized below.

Table 3.2.9.3. Main conservation agriculture strategies.

#	Concept	Definition
1	Direct drill.	Seeding into undisturbed surface fully covered by residues of previous crops.
2	Reduced tillage.	Minimize primary and secondary tillage operations, reduce tillage operation depths and/or concentrate tillage in part of the field.
3	Mulch drill.	Minimized primary and secondary tillage operations, no turning of the soil, and concentrating operations only in the seeding row.
4	Strip tillage.	A variation of mulch drill in which non-inversion soil tillage is performed for the minimum possible area in the seeding row – it can be understood as the mid-point between direct drill and mulch drilling.
5	Ridge Tillage.	A system in which ridges are made and maintained annually with crops seeds on top of the ridges and residues cover permanently the ground in the furrows.

3.2.9.2. Implementation types for conservation tillage practices.

Direct Drill.

The major characteristic of direct drilling is to establish a soil cover before planting of the major cash crop. Seeding of the major cash crop will then be carried out without any further primary or secondary soil management. These techniques involve control of the green soil cover by either pesticide application (this is the normal approach in conventional agriculture) or some other form of biomass destruction, for instance application of a roller-crimper in organic farming systems. In the following season the crop is seeded into the residues of the previous crop, using a seeder that cut through the residues but without any further soil management.

Reduced tillage.

This may involve a large set of alternative primary and secondary tillage operations, but with the aim of using a reduced intensity of tillage. A typical approach to reduced tillage is to use a chiseling rather than a mouldboard plough.

Mulch drill.

Similar to direct drill mulching techniques, it also involves establishment of a soil cover before planting of the major cash crop. However, before seeding some sort of soil tillage is used to prepare seedbed, but without turning the soil. After soil preparation at least 30% of ground cover by either green or dead biomass is achieved. A large variety of management tools are available to prepare the soil surface for seeding, such as chisel plough, rotary hoe or rotary disc. The effectiveness of mulching against soil erosion and prevention of surface runoff largely depends on the number of passes with the tillage implement, the management depth per pass and the management tool that is used. This is because these are the factors that determine the amount of soil cover after this operations, as well as the degree of disturbance of soil structure.

Strip tillage.
Can be envisioned as a mixture of direct drill and mulch drill management in which non-inversion tillage operations are restricted to a strip as narrow as possible in the seeding row and the rest of the field remains under no till conditions.

Ridge tillage.
In this system permanent ridges, 15 to 20 cm high, are made and maintained annually. On these ridges crops are seeded. Residues cover is maintained permanently on the furrows, and residues are regularly deposited on the top of the ridges during ridge formation and harvest.

3.2.9.2. Implementation types for conservation tillage practices.

Table 3.2.9.4. and Table 3.2.9.5. summarize the positive and negative impact of different conservation tillage on the provision of different ecosystem services when compared to conventional tillage.

Table 3.2.9.4. Impact on delivery of soil ecosystem services of different conservation tillage strategies. ++ means high impact, + moderate impact, o means negligible.

Potential Benefit	Direct drill	Reduced tillage	Mulch drill	Strip tillage	Ridge tillage
Increase of soil organic carbon.	++	+	++	++	+
Reduction of soil erosion.	++	+	++	++	++
Reduction of runoff.	+	o	+	+	+
Enhancement of soil quality.	+	o	+	+	+
Enhancement of biodiversity.	++	o	+	+	+
Reduction of off-site contamination.	++	+	++	++	++
Reduction of soil evaporation.	++	+	++	++	++

Table 3.2.9.5. Potential negative impacts of conservation tillage strategies. ++ means high probability, + moderate probability, o means negligible. Note this is an approximation to the probability of appearance of these negative impacts, and that they can only be addressed with studies at specific climate, soil, crop and management conditions.

Potential Benefit	Direct drill	Reduced tillage	Mulching	Strip tillage	Ridge tillage
Soil compaction.	++	o	+	++	+
Herbicide resistant weeds.	++	+	+	+	+
Reduced seedling germination due to slow soil warming.	++	o	+	+	+
Reduced crop yields	+	o	+	+	+
Increased chemical leaching.	+	o	o	+	o

3.2.9.4. Definitions of conservation agriculture in different countries.

A source of confusion is that despite that fact that CA is part of almost every country scheme for agri-environmental measures, the local definition of conservation agriculture operations may differ among countries. This list gives an overview about the requirements to receive subsidies for conservation tillage in three different SHui countries.

Country	Definitions	Subsidy Level
Austria.	* No differentiation between direct drill, mulch drill and strip tillage * farmer qualifies for subsidy when green cover has been established in previous year before 15 October. * Soil management of green cover not before 15 February. * Minimum of two different varieties for green cover * Maximum time between soil management and seeding is 4 weeks * No ploughing	60 €/ha for minimum tillage. 120 – 170 € for establishment of green cover.
Czech Republic.	Direct Payments represent the largest share of payouts determined for subsidies in agricultural sector. They are provided in accordance with rules of the EU Common Agricultural Policy (GAEC). Conservation agriculture is defined by very complex system of variable rules within GAEC, where different soil conservation techniques are recommended for different fields (based on slope, and soil risk assessment), and for different groups of crops. Crops are grouped as: conservative, normal, and risky (concerning soil erosion resistance). Single area payment scheme (SAPS) is major contributor (138 EUR/ha in 2020), and in many fields no conservative approach is needed to reach SAPS. Obligatory: GAEC 4 – over 4° mean field slope: stubble has to be left on field till spring seeding, or strip-till, or cover crop have to be seeded before September 20th and keeping cover crop till October 31st. Exception is manure application and tillage. GAEC 5 – erosion risky soils (SEO) over 2 ha area must apply conservation agriculture via extremely complicated list of measures for variable crops. Here are main techniques: Corn, potatoes, beets, broad beans, soybeans, sunflowers and sorghum prohibited; row crops are permitted when: direct seeded, contour seeded (up to 35 ha), strip-tilled, using permanent cover crops, using protection belts of winter cereals (above 6 ha areas); stone rows are installed during potato seeding (stone removal); under plowed (causing plow pan disturbance) when sugar beet is seeded; seeding winter cereals into 30% mulch cover; putting solid manure into the field during management process of any crop. Winter cereals without additional technique have to be split by protection belts (22 m width) after 220 m slope length. Each above listed measure is described by control parameters to be checked by subsidy provider (date of management, pre-conditions, minimum and maximum field size, surrounding crops, protection belt parameters and density, per-cent of area of the cover crop etc.). The system is complicated and redesigned regularly from year to year.	

Country	Definitions	Subsidy Level
Spain Winter cereals.	Recommended: Introduce where possible, and particularly in areas of especial erosion risk (ZERE) conservation tillage techniques. Recommended: Minimize tillage reducing the number of tillage passes, its depth, and adapting tillage to maintain soil OM content and structure, adapted to soil texture. Obligatory: If conventional tillage is used. a) Do not perform primary tillage on waterlogged or snow covered fields. b) In ZERE (areas of special regulation) areas respect additional restrictions that might impose the administration. c) In rainfed crops do not till between the harvest and the primary tillage date as determined by the regional ministry of agriculture, except when secondary crops are grown, e.g. sunflower. d) In fields with average slope greater than 10% do not perform soil inversion tillage in the direction of the maximum slope unless is authorized by the administration.	

3.2.9.5. Examples of conservation tillage alternatives.

Figure 3.2.9.1. Direct drilling on a cereal rotation in Lower Austria (Photo T. Dostal).

Figure 3.2.9.2. Corn in direct drilling in Austria (Photo Josef Rosner).

Figure 3.2.9.3. Strip tillage in Austria (Photo NÖ LK/Josef Wasner).

Figure 3.2.9.4. Cotton on ridge tillage (Photo J.A. Gómez).

3.2.9.6. Selected References.

Jones, C. et al. 2006. Conservation Agriculture in Europe. An approach to sustainable crop production by protecting soil and water?. SOWAP. Available at https://vtechworks.lib.vt.edu/bitstream/handle/10919/68481/4243_conservationagriculture.pdf?sequence=1

NRCS, 2017. National Resource Conservation Services. Conservation Practice Standard Residue and Tillage Management, No-till. Code 329. Available at https://efotg.sc.egov.usda.gov/references/public/NY/nyps329.pdf

WOCAT 2017. No tillage (Estonia) Available in https://qcat.wocat.net/es/wocat/technologies/view/technologies_3089/ Note that in WOCAT database there are several examples of no and minimum tillage.

Hösl, R. and Strauss, P. 2016: Conservation tillage practices in the alpine forelands of Austria – Are they effective? Catena 137, 44-51. https://www.sciencedirect.com/science/article/pii/S0341816215300916?via%3Dihub.

Strauss P., D. et al. 2003. How effective is mulching and minimum tillage to control runoff and soil loss. Proceedings of 5 Years of Assessment of Erosion, Ghent, 22-26 September 2003, 545-550. https://www.baw.at/service/publikationen.html?q=swoboda&author=&category=%2Fservice%2Fpublikationen.html&releaseYear=&language

Return to Table 3.1.1.

3.2.10. Cover crops for annual crops.

3.2.10.1. Description.

In the context of annual crops, cover crops are close-growing crops that provide soil protection, seeding protection and soil improvement between periods of normal crop production (Blanco and Lal, 2008). Cover cropping is an ancient practice (Worthen, 1948) whose purpose has changed with time, from animal fodder and green manure to their current use. Nowadays, is mostly a companion practice to conservation agriculture and agroforestry to protect soil erosion, and improving soil and water quality.

When approaching the use of cover crops as BMP in annual crops we need to be aware of three major concepts.

1- There are several strategies to implement this technique which are summarized in section 3.2.10.1.

2- Their effectiveness depends on the ability of farmers to implement a well stablished cover crops and the strategy taken, see also Table 3.2.10.1.

3- The specific techniques and species to be used need to be adapted to the objectives and specific crop, climate and soil conditions.

3.2.10.2. Types of cover crops according to their extension and location within the crop rotation.

a) Cover crops integrated as part of the rotation. These are crops grown in the whole field as part of the rotation between cash crops to improve soil quality and protect against erosion. They are usually legumes, a mixture of legumes and grasses, species with a deep rooting system to alleviate soil compaction, or others with biofumigation properties such as Sinapis. Examples of these cover crops are rye, clover, or vetch.

b) Strip cropping. Is the practice of growing crops in alternate strips of row crops or forage/grass. Strip cropping is usually integrated in rotations where strips are planted to a different crop each year. If properly managed they can be a very effective way of reducing erosion if implemented perpendicular to the slope.

There are other alternatives for intercropping that are more related to agroforestry principles of diversifying crops production and synergies among crops more than to soil and water conservation BMP, like intercropping, or relay cropping and are not going to be dealt with in this analysis.

Table 3.2.10.1. summarizes the major positive impacts of cover crops in field crops according to the type of cover crop.

Table 3.2.10.1. Appraisal of cover crop impact according to type of cover crop ++ means high impact, + moderate impact, leg means legume cover crop. Adapted from Blanco and Lal (2008).

Potential Benefit	Cover crop in the rotation	Strip cropping
Erosion control.	++	+ +
Improving soil properties.	++	+
Enhancing soil fertility.	+ (leg)	+ (leg)
Supressing weeds.	++	++
Increasing soil organic matter.	++	+
Recycling nutrients.	++	++
Preventing leaching of nutrients.	++	++
Improving water quality.	+	++

3.2.10.3. Images of different kind cover crops in field crops.

Figure 3.2.10.1. Corn intercropped with wheat in Slovenia (Photo T. Dostal).

3.2.10.2. Strip cropping in the Czech Republic (Photo J. Krasa).

3.2.10.3. Strip cropping in Austria (Photo P. Strauss).

3.2.10.4. Selected References.

Blanco, J., Lal, R. 2008. Principles of Soil Conservation and Management. Springer.

NRCS, 2014 National Resource Conservation Services Standards Cover Crop. Code 340. Available at: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1263176.pdf

WOCAT 2017. Root-oriented cover crops (Italia) Available at: https://qcat.wocat.net/es/wocat/technologies/view/technologies_1291/ Note that in WOCAT database there are several examples of cover crops.

Worthen, E.L. 1948. Farm Soils. Wiley & Sons.

Return to Table 3.1.1.

3.2.11. Agroforestry.

3.2.11.1. Description.

Agroforestry is a land management system that combines trees and/or shrubs with agricultural crops and livestock production on the same piece of land. In a broad sense, agroforestry incorporates many of the individual practices already discussed separately in this document (e.g. vegetated barriers), although the main goal of agroforestry is to develop more resilient and sustainable agricultural systems diversifying the uses and products produced in the same land. In the context of BMP for optimizing soil and water use in agricultural area, this section aims to provide a general overview of agroforestry and outline major aspects of some practices not discussed on other sections.

Table 3.2.11.1. summary of the major beneficial effects of agroforestry when properly implemented. Adapted from Blanco and Lal (2008).

#	Effect
1	Reduction of runoff and soil erosion.
2	Improvement of biodiversity.
3	Improvement of soil quality.
4	Carbon sequestration.

3.2.11.2. Agroforestry practices.

Agroforestry practices can be classified into five major classes, Table 3.2.11.2.

Table 3.2.11.2. Major classes. Adapted from Young (1997).

#	Practique
1	Alley cropping.
2	Forest farming.
3	Silvopasture.
4	Riparian forest buffer.
5	Windbreaks.

Alley cropping.

It consists of planting agricultural or horticultural crops in widely spaced alleys, between 10 to 25 m wide, between hedgerows of trees and of shrubs, usually 1 to 5 m wide. When done following the contour this practice is known as “contour hedgerows”. It is one of the most widely studied agroforestry practices in tropical and subtropical regions. Conceptually, this integrates aspects of BMPs already covered in this document, such as vegetated barriers (section 3.2.7.) or cover crops (3.2.4.), but with the emphasis that both the alley crop and the hedgerows are dedicated to agricultural production and benefit the diversification of farm production.

Forest farming.

It is an intensive system where tree and other plant species are grown for different purposes (wood, fruit trees, medicine, etc) and production is structured in different strata within the forest. An example might be wood trees at the upper levels and shade tolerant crops at the lower levels, such as banana.

Silvopasture.

A system that integrates trees and shrubs with forage (pasture or hay) and livestock operations. It differs from traditional forestry because the whole system: type and number of trees, seeding and management of pasture, and grazing density are designed and managed as an integral unit. An example is the Dehesa in the S. Iberian Peninsula where oaks are grown for their cork and acorns as well as providing shade to grazing livestock (sheep, cows, pigs), see Figure 3.3.11.3.

Riparian forest buffer.

An area adjacent to a stream, lake, or wetland containing trees, shrubs, and/or other perennial plants which is differently from the surrounding landscape, primarily to provide conservation benefits as vegetated barriers. In this respect it has been discussed in section 3.2.7. In the context of agroforestry, this protection purpose is combined including trees and shrubs that produce a harvestable crop.

Windbreaks.

As with riparian forest buffer, it is a vegetated barrier with the purpose of protecting the crop (against wind damage) combined with other wood, fiber, or food harvest.

3.2.11.3. Images of different of agroforestry practices.

Figure 3.2.11.1. Example alley cropping system consisting of pine trees and cotton (Photo S. Jose).

Figure 3.2.11.2. Example of forest farming, goldenseal cultivated beneath a tree canopy. (Photo K Trozzo).

Figure 3.2.11.3. Example of a Dehesa Silvo pastoral system in S. Spain (Photo J.A. Gómez).

Figure 3.2.11.4. Example of a windbreak supplemented with red-stemmed dogwood to a provide and additional source of income for landowners. (Photo USDA National Agroforestry Center).

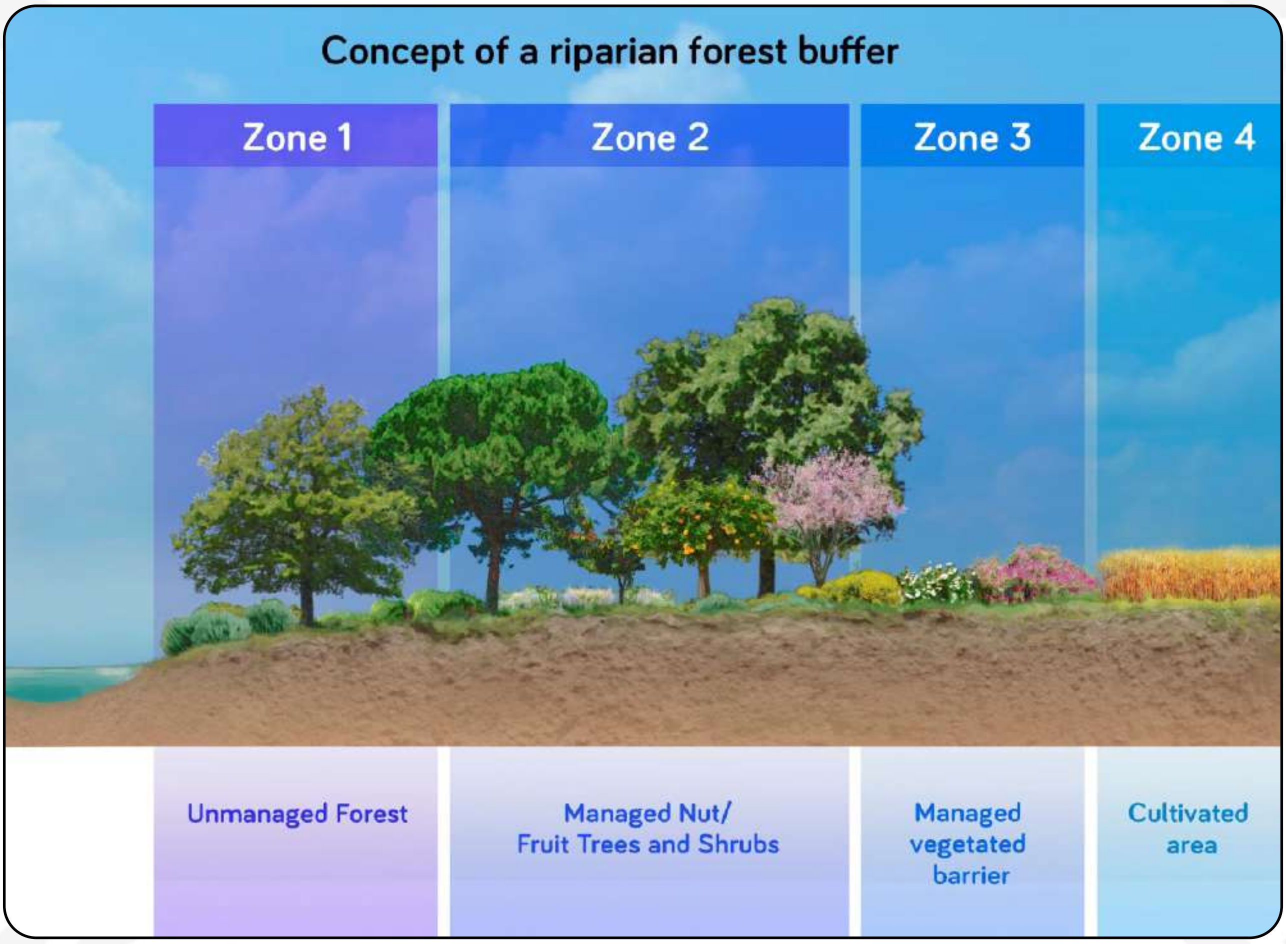


Figure 3.2.11.5. Concept of a riparian forest buffer.

3.2.11.4. Selected References.

Blanco, J., Lal, R. 2008. Principles of Soil Conservation and Management. Springer.

USDA, 2020. National Agroforestry Center. Available at: **https://www.fs.usda.gov/nac/practices/index.shtml**

WOCAT 2011. Orchard based agroforestry (Tayikistan) Available at: **https://qcat.wocat.net/es/wocat/technologies/view/technologies_1017/**

Note that in WOCAT database there are several examples of agroforestry.

Young, A. 1997. Agroforestry for Soil Management. 2nd Ed. CAB International. Wallingford UK.

Return to Table 3.1.1.

3.2.12. Water harvesting.

3.2.12.1. Description.

The aim of water harvesting is to collect runoff or groundwater from areas of surplus or where it is not used, store it, and make it available when and where there is water shortage. This results in an increase in water availability by either: (a) impeding and trapping surface runoff, and (b) maximizing water runoff storage or (c) trapping and harvesting sub-surface water (groundwater harvesting (Studer and Liniger, 2013). It is a technique that has been applied historically mainly in arid and semiarid areas. Table 3.2.12.6 classifies the main components of a water harvesting system.

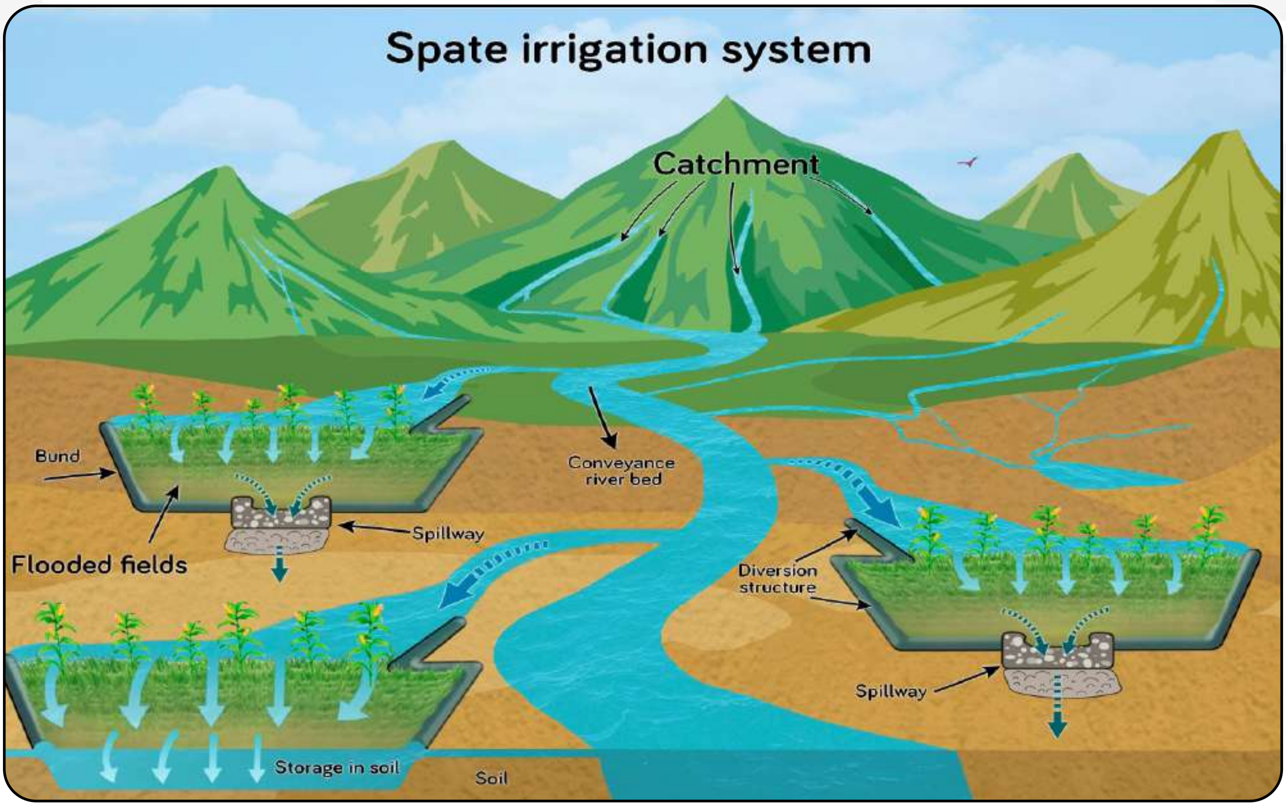
Table 3.2.12.1. Main components of a water harvesting system. Adapted from Studer and Liniger (2013).

Element	Definition
Catchment or collection area.	The area where rain in the form of surface or subsurface runoff is harvested.
Conveyance system.	The area and/or system through with runoff is transported to the cultivated fields or storage area, for example through grass waterways.
Storage systems.	The area where water is stored until used, e.g, retention pond, underground soil, cisterns.

Water harvesting systems can be classified into four large groups according to the design of these three basic elements. One group are those based on harvesting floodwater, in the fields or in the river bed, see Figure 3.2.12.1. A second strategy is based on storing runoff water of the catchment into the soil or in water storage facilities, see Figure 3.2.12.2. A third strategy, that can be implemented at farm scale is the harvesting of runoff water in micro-catchments within the plot, see Figures 3.2.12.3. and 3.2.12.4. Water harvesting strategies can also be applied at home scales for rooftop or courtyard harvesting, Figure 3.2.12.5.

These techniques can play a major role for optimizing water use in dry sub-humid, semiarid and arid areas storing excess runoff losses from ephemeral streams and large sporadic rainfall events, and/or concentrating runoff in specific areas of the field so insuring adequate water supply for crops in a fraction of the potentially cultivated area using the remaining area as a collection area. Many of them can have a positive impact on the reduction of soil erosion and improvement of water quality, particularly those applied at micro-catchment scale.

In other non arid or semi-arid climates, local flood control and technical soil erosion measures in cropland should consider using water harvesting techniques. Currently this is not always the case as many techniques divert surface runoff and drain it into permanent streams. With changing climate ditches, furrows sediment traps and retention ponds should be used as additional water sources for agriculture, in accordance to water harvesting principles.



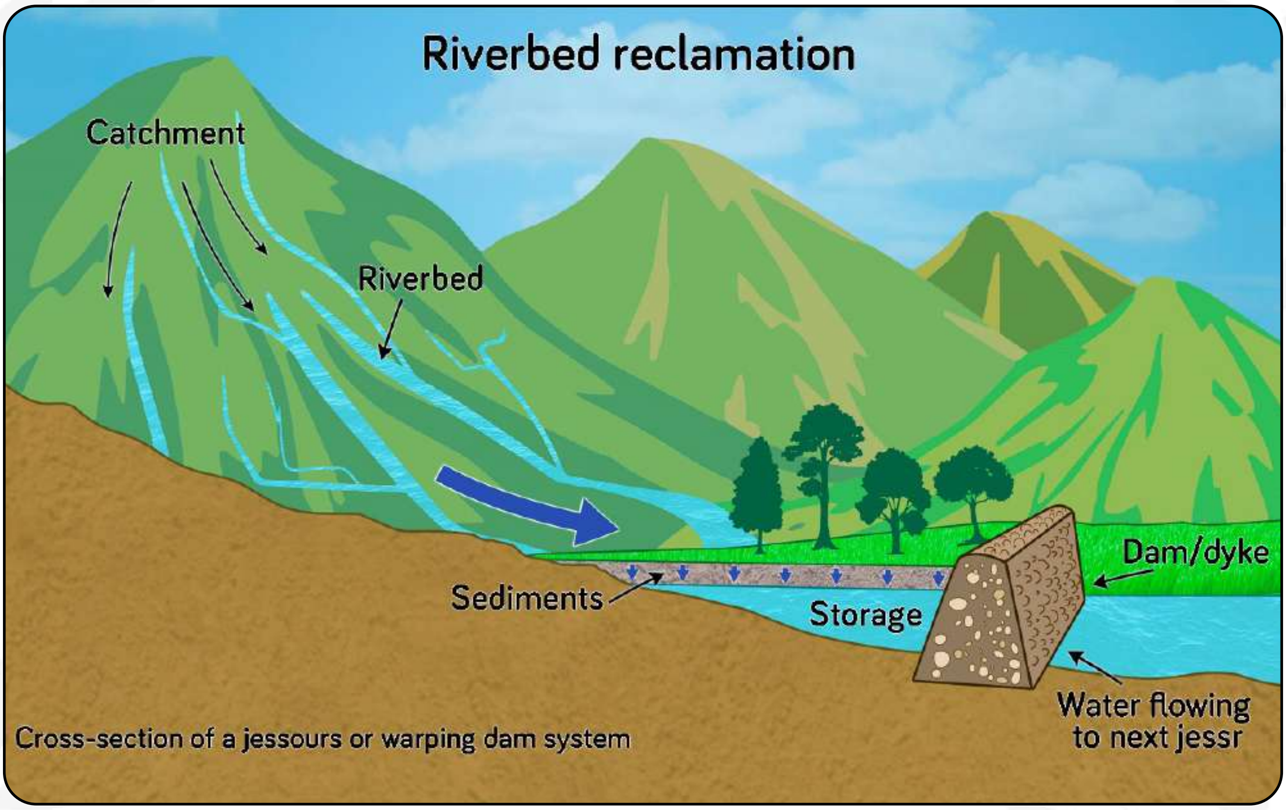


Figure 3.2.12.1. Strategies for harvesting floodwater. Diverting floodwater and spate irrigation, top. Riverbed reclamation to store water in the river bed, bottom. Adapted from Studer and Liniger (2013).

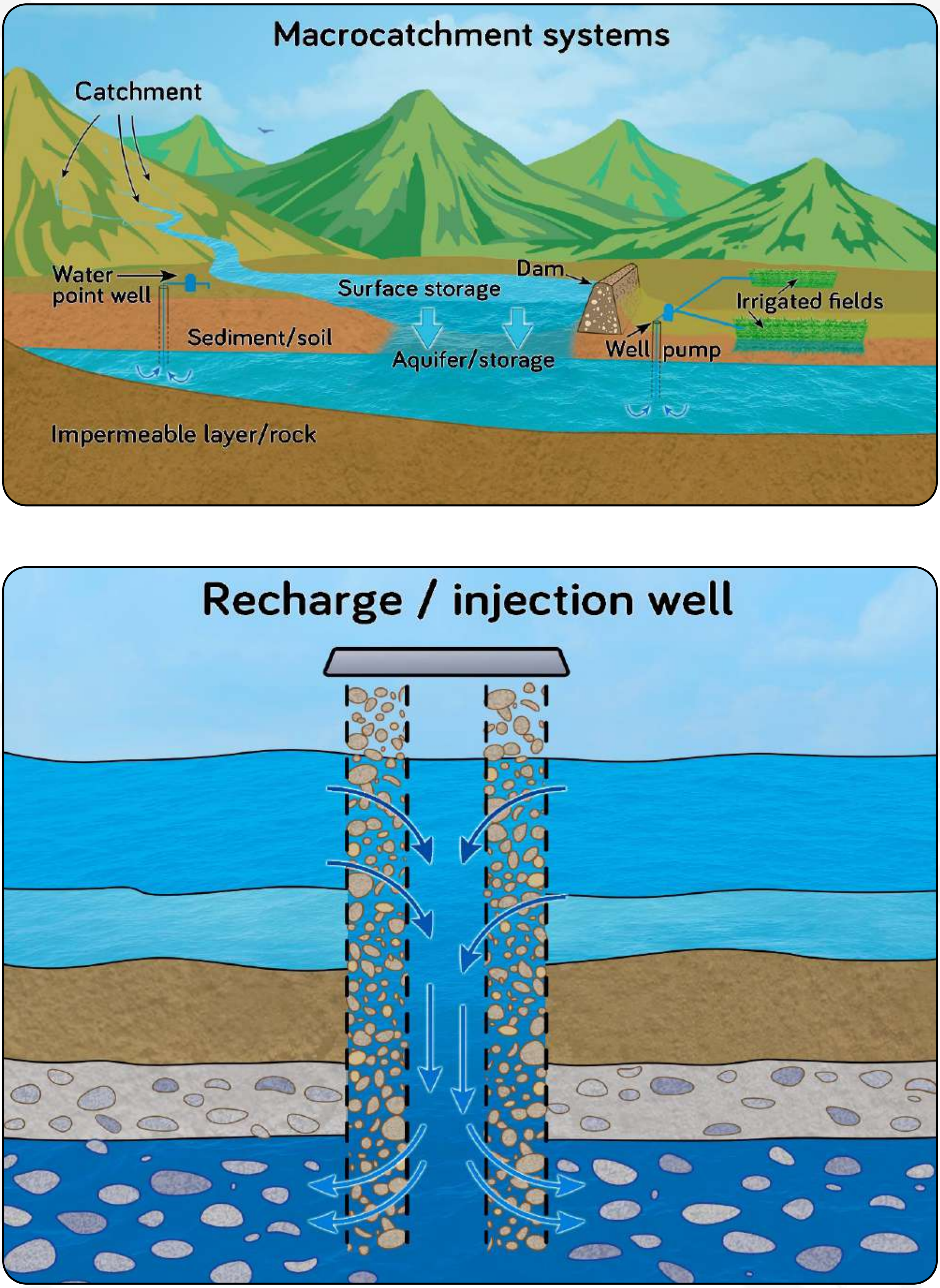


Figure 3.2.12.2. Strategies for harvesting runoff water from catchment at surface (top) or subsurface (bottom) structures. Adapted from Studer and Liniger (2013).

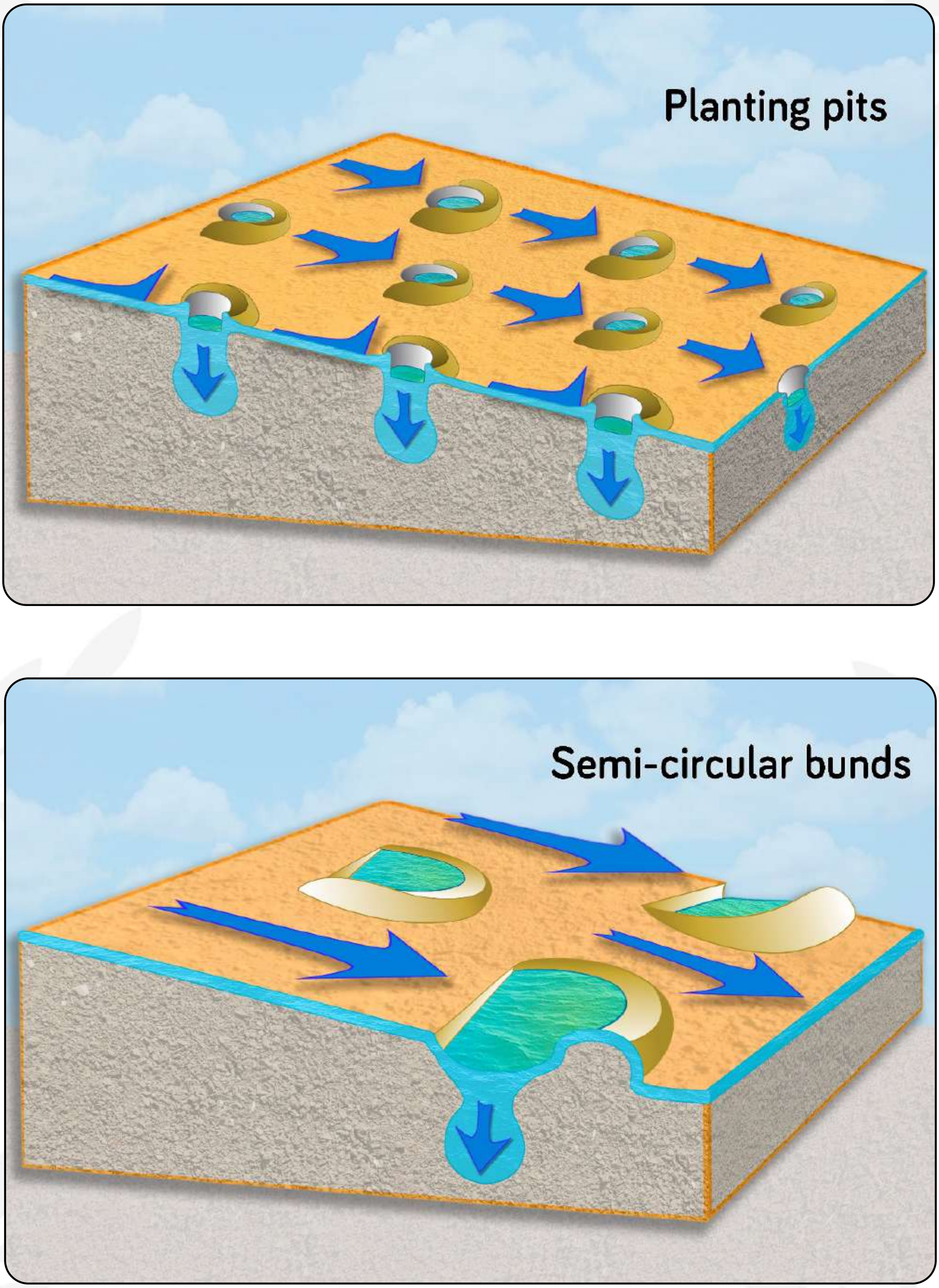


Figure 3.2.12.3. Strategies for micro-catchment runoff harvesting runoff water, using soil pits, top, or semi-circular bunds, bottom. Adapted from Studer and Liniger (2013).

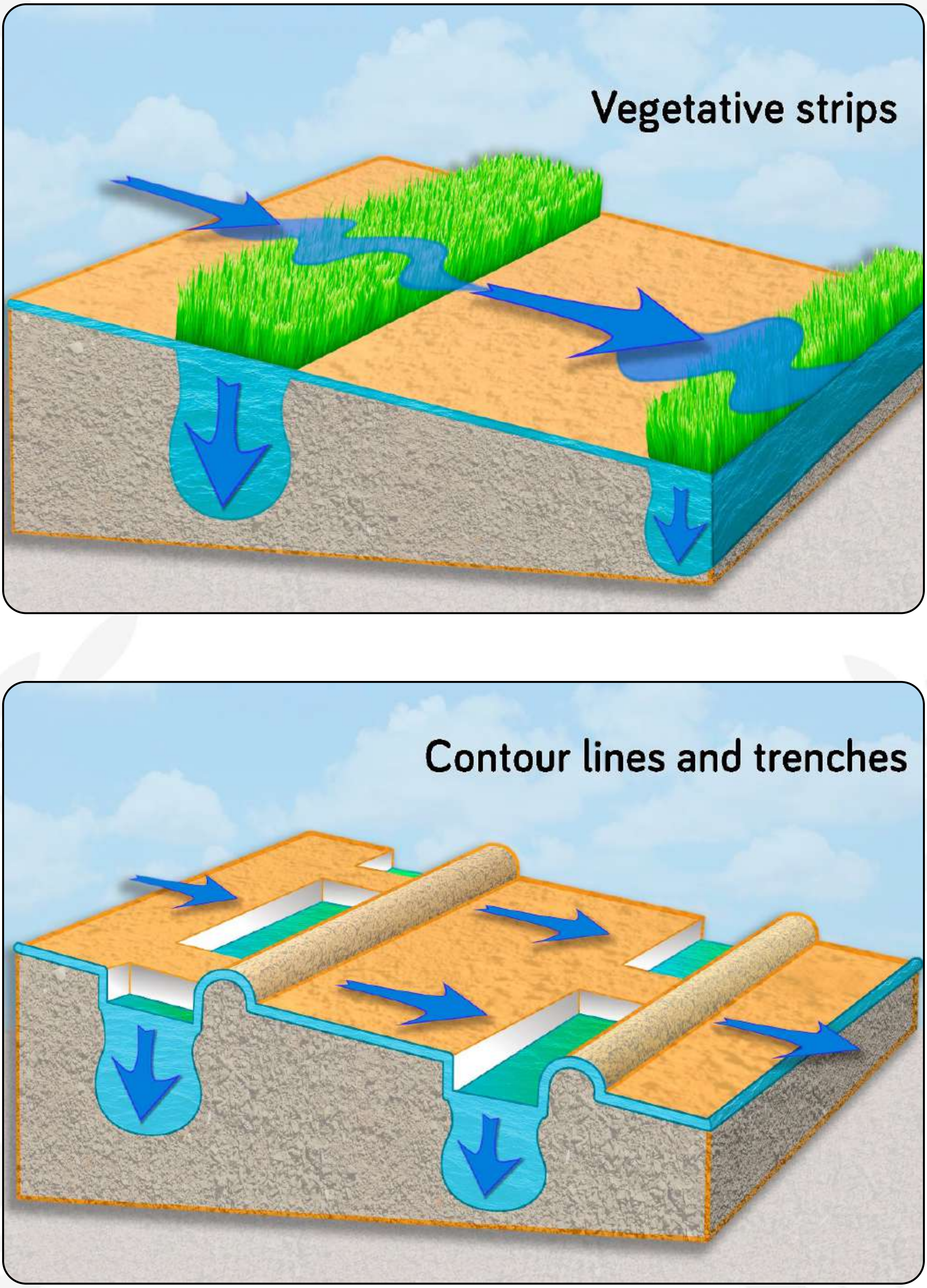
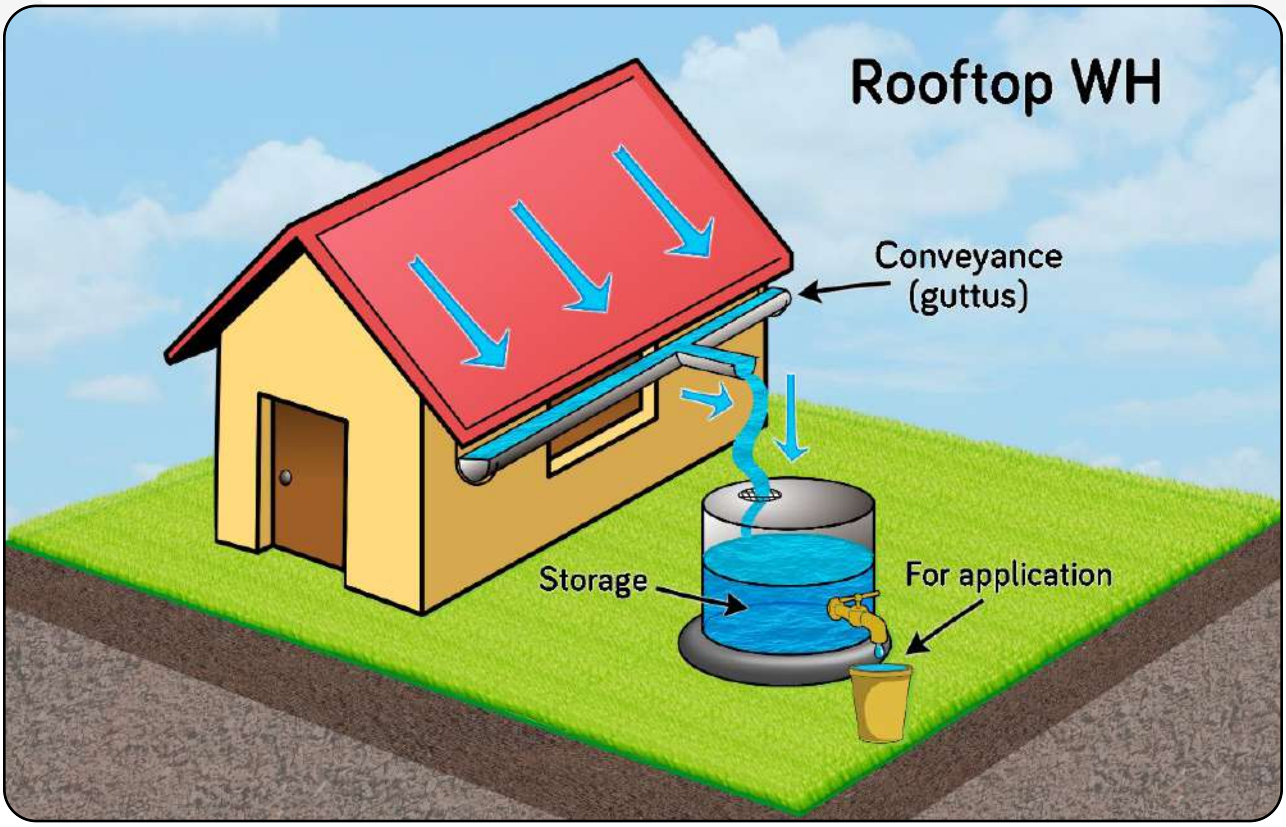


Figure 3.2.12.4. Strategies for micro-catchment runoff harvesting vegetative strips, top, or contour shoulders and trenches, bottom. Adapted from Studer and Liniger (2013).



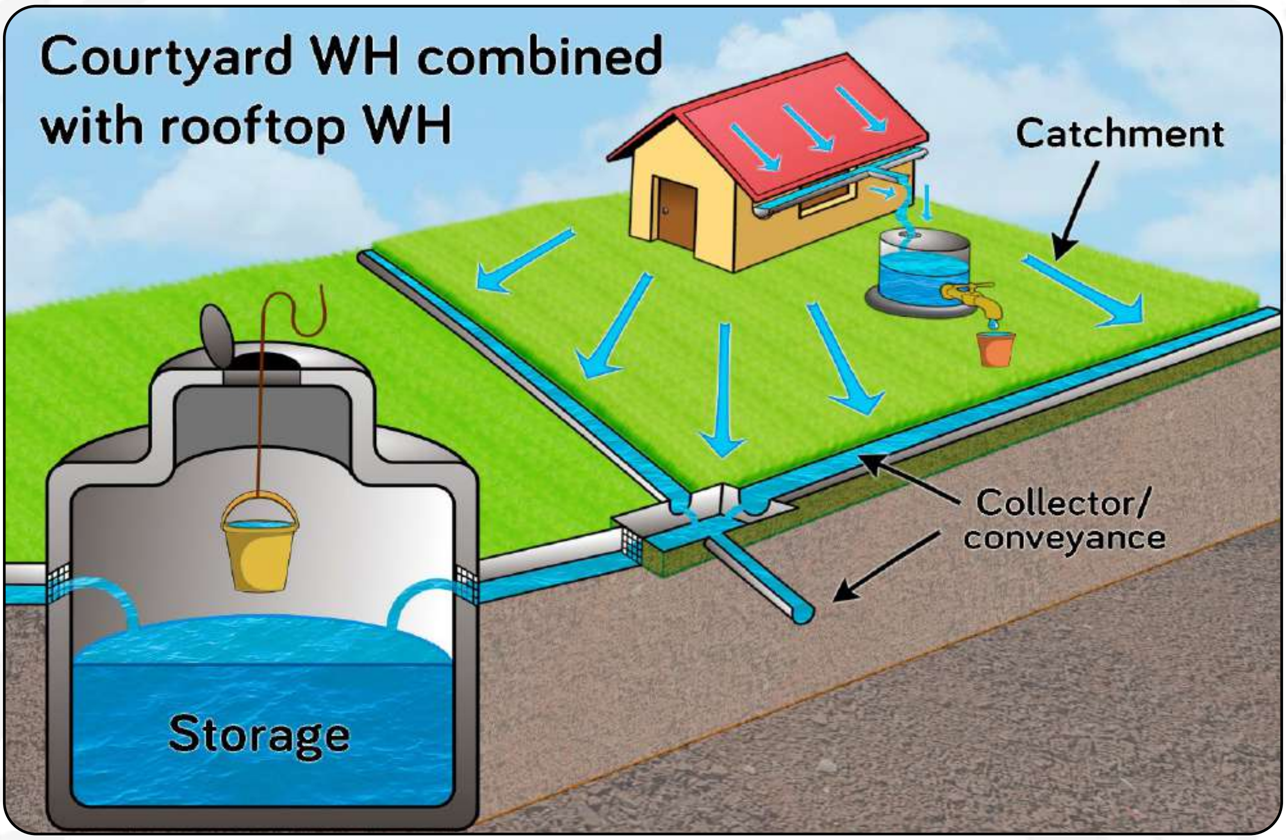


Figure 3.2.12.5. Strategies for runoff harvesting at rooftops, top, and courtyards, bottom. Adapted from Studer and Liniger (2013).

3.2.12.2. Images of different kind of water harvesting solutions.

Figure 3.2.12.6. Current picture of a runoff harvesting system based on the Nabatean system at Avdat (Photo J. Quinton).

Figure 3.2.12.7. Example of macro catchment water harvesting in an olive growing area in Tunisia, meskats. Contributing area (left) and storage area (right). (Photo M. Braham).

Figure 3.2.12.8. Illustration of micro-catchment to retain rainfall water in an orchard (Photo from Anser et al. 2014).

Figure 3.2.12.9. Water harvesting in a road ditch (Photo T. Dostal).

3.2.12.3. Selected References.

Anser, M. at al. 2014. Training manual on soil & water conservation technologies. Available at. https://www.researchgate.net/publication/307593381_TRAINING_MANUAL_ON_SOIL_WATER_CONSERVATION_TECHNOLOGIES

Critchley, W., Siegert, K. 1991. Manual for the Design and Construction of Water Harvesting Schemes for Plant Production. FAO. Available at:
https://www.samsamwater.com/library/Water_harvesting_-_Critchley.pdf

NRCS, 2010 National Resource Conservation Services Sediment basin. Code 350. Available at:
https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_025942.pdf

Studer, R.M., Liniger, H. 2013. Water Harvesting. Guidelines to Good Practice. CDE. Available at:
https://www.wocat.net/library/media/25/

WOCAT 2017. Micro-catchments for rainwater harvesting (Kenia). Available at:
https://qcat.wocat.net/es/wocat/technologies/view/technologies_2895/ Note that in WOCAT database there are several examples of water harvesting.

Return to Table 3.1.1.

3.2.13. Deficit irrigation.

3.2.13.1. Description.

Because of the costs associated with irrigation development, most irrigation systems are designed to apply sufficient water to meet crop needs (ETc). However, in cases where there is a structural deficit of water resources, for instance an increase of irrigated area without increasing water availability, or occasional shortages during a drought, deficit irrigation (DI) is used as an irrigation management technique that, by applying insufficient water causes crop transpiration to be below its maximum, unstressed value (Fereres and Villalobos, 2016). DI is a strategy to optimize the limited water supply and to cope with water shortages which may be temporary or permanent. In all cases DI requires a good understanding of the determination of crop water requirements, crop physiology and the yield response to water. The basic concept of DI is that, given that the reduction in yield for a given reduction in crop evapotranspiration (ET), ETc, will vary depending on the crop physiological stage (Figure 3.2.13.1). The reduced amount of water should be applied when the crop is least sensitive to water deficits.

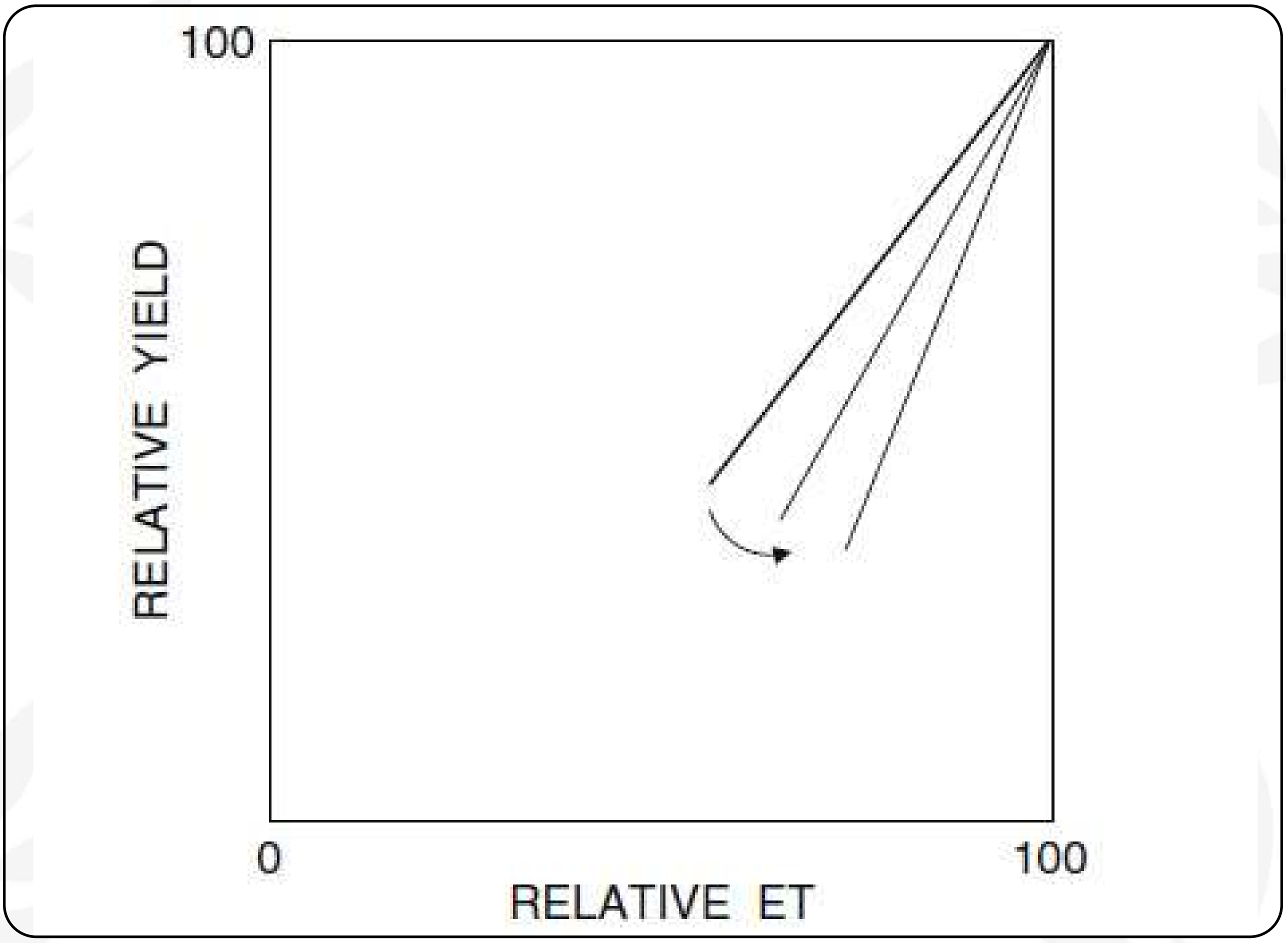


Figure 3.2.13.1. Response of crop yield to increasing deficit and application of this deficit to phenological periods of higher sensitivity to water stress (arrow direction). Source: Fereres and Villalobos (2016).

There is a major distinction in DI between annual and tree crops. In both types of crops, proper implementation of DI relies on experimental information on specific crops and conditions. This information can be complemented with modelling analysis with crop simulation models, providing that they have been calibrated locally. In most annual crops the most sensitive stages to water deficits are those at which yield-determining processes occur (flowering, fruit set and fruit growth).
There is much less flexibility in tree crops as a opposed to field crops to respond to water shortage condition e.g. by reducing the planted area. Additionally, in tree crops the impact of DI in a given year will impact subsequent yields in future years. The response of tree crops yield to deficit irrigation is much more complex than that of annual crops, and their yield determining processes are less well understood. In tree crops, deficit irrigation is usually synonymous with Regulated Deficit Irrigation (RDI) in which the available irrigated water is distributed differently in different growing periods with the objective of concentrating the water deficits in the periods in which the tree crop is least sensitive to it (Figure 3.2.13.2). Thus, RDI is different to a sustained (or continuous) DI strategy in which a fraction of the water available for irrigation is distributed uniformly and proportionally to the crop ETc during the growing season. The DI approach, which distributes the available water uniformly, might result (depending on climate and soil conditions) in having water stress in some yield sensitive periods.

The formulation of a DI strategy as a BMP requires substantial knowledge of crop response and of the anticipated water availability. As a general rule, DI aims to concentrates the water resource in a way capable to provide 50-70% of ETc of the crop.

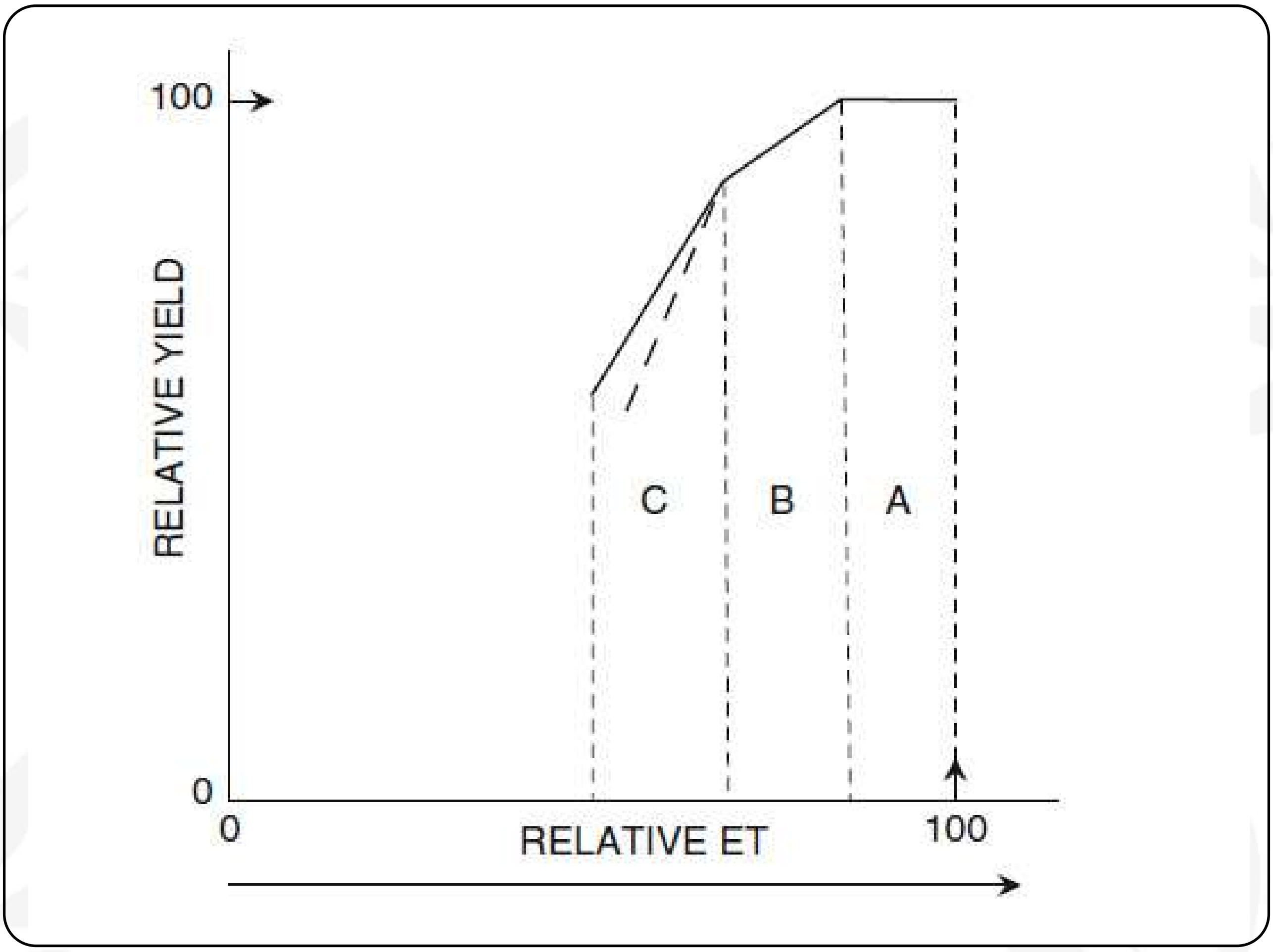


Figure 3.2.13.1. Response of tree crop yield to water stress in different phenological periods, from null (A) to very sensitive (C). Source: Fereres and Villalobos (2016).

3.2.13.2. Selected References.

Fereres, E., Soriano, M.A. 2007.Deficit irrigation for reducing agricultural water use J. Exp. Bot. 58, 147-158.

Fereres, E., Villalobos, F,J. 2016. Chapter 21 Deficit Irrigation,. In Principles of Agronomy for Sustainable Agriculture. Springer.

Steduto, P., Hsiao, T.C., Fereres, E., Raes, D. 2012. Crop yield response to water. Irrigation and Drainage Paper Nr. 66, FAO. Available at: **http://www.fao.org/3/i2800e/i2800e00.htm**

Return to Table 3.1.1.

3.2.14. Water reuse.

3.2.14.1. Description.

An emerging field for research, innovation and end-users application worldwide is the reuse for irrigation of water that comes from a previous use. Table 3.2.14.1 summarizes the major sources for this kind of water considered by most EU regulations. It is becoming of increasing interest in the EU (Alcalde-Sanz and Gawlik, 2017; BIO, 2015) as a strategy to increase available of water resources for several activities, among them agriculture. It is also of interest as it has the potential to reduce the contamination burden from wastewater, as well as the costs of treatment. In certain situations, it may also have a lower environmental impact than other alternative water supplies, such as water transfers or desalination. In many water-stressed areas, reusing water might be the only alternative for irrigation and to continue with a sustainable agriculture practice. In addition, depending on the origin, the water to be reused might be a source of nutrients for the plants implying that the external of use fertilizers could be reduced (Vivaldi et al. 2019).

Table 3.2.14.1. Major sources of reused water.
Adapted from Alcalde-Sanz and Gawlik (2017) and BIO (2015).

Source	Reason
Return flows.	Surface and subsurface runoff coming from irrigated areas upstream.
Treated urban wastewater.	Urban wastewater that is treated after collection, having been subject to secondary treatment at least.
Treated industrial wastewater.	Wastewater coming from food related industries.
Of mixed origins.	Mix of domestic and/or industrial rainwater with and/or runoff rain water.

The major concerns regarding water reuse for irrigation in agricultural areas are summarized in Table 3.2.14.2.

Table 3.2.14.2. Major concerns regarding reused water in irrigation Adapted from Alcalde-Sanz and Gawlik (2017) and BIO (2015).

#	Reason
Food security:	* Contamination of crops for animal or human use.
Environmental:	* Reduces flows in water courses below acceptable levels. * Reduction of aquifer recharge because of the increase in the consumptive water use in the whole basin. * Degradation of soil quality due to accumulation of toxic elements in the soil. * Soil salinization due to the high concentration of salts in the waste water. Loss of soil structure and sodification.

To prevent those risks, the reuse of water is subjected to different uses and controls according to their quality levels, as defined in the EU according to Table 3.2.14.3.

Table 3.2.14.3. Classes of reclaimed water quality. BOD5 Biochemical Oxygen Demand, TSS is total suspended solids, * According to Directive 91/271/EEC. Source Alcalde-Sanz and Gawlik (2017).

Reclaimed water quality class	Indicative technology target	E. coli (cfu/100 ml)	BOD5 (mg/l)	TSS (mg/l)	Turbidity (NTU)	Additional criteria for all
Class A	Secondary treatment, filtration, and disinfection (advanced water treatments).	≤ 10 or below detection limit.	≤ 10	≤ 10	≤ 5	
Class B	Secondary treatment, and disinfection.	≤ 100	*		-	Legionella spp.: ≤1,000 cfu/l when there is risk of aerosolization.
Class C	Secondary treatment, and disinfection.	≤ 1000			-	Intestinal nematodes (helminth eggs): ≤1 egg/l when irrigation of pastures or fodder for livestock.
Class D	Secondary treatment, and disinfection.	≤ 10000			-	

Table 3.2.14.4. Water quality and irrigation methods conditions for water reuse according to crop type. Source Alcalde-Sanz and Gawlik (2017).

Reclaimed water quality class	Indicative technology target	Irrigation method*
All food crops consumed raw and food crops whose edible portion is in direct contact the reclaimed water.	Class A	All methods allowed.
Food crops consumed raw where the edible part is above ground and not in direct contact the reclaimed water.	Class B Class C	All methods allowed. Drip irrigation only.
Processed food crop.	Class B Class C	All methods allowed. Drip irrigation only.
Non-food crops including crops to feed milk or meat producing animals.	Class B Class C	All methods allowed. Drip irrigation only.
Industry, energy and seeded crops.	Class D	All methods allowed.

3.2.14.2. Selected References

Alcalde-Sanz, L., Gawlik, B.M. 2017. JRC Science for Policy Report. Minimum quality requirements for water reuse in agricultural irrigation and aquifer recharge. Available at: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC109291/jrc109291_online_08022018.pdf

BIO by Deloitte. 2015. Optimising water reuse in the EU – Final report prepared for the European Commission (DG ENV), Part I. In collaboration with ICF and Cranfield University. https://ec.europa.eu/environment/water/blueprint/pdf/BIO_IA%20on%20water%20reuse_Final%20Part%20I.pdf

Vivaldi, G.A., Camposeo, S., Lopriore, G., Romero-Trigueros, C., Salcedo, F.P. 2019. Using saline reclaimed water on almond grown in Mediterranean conditions: Deficit irrigation strategies and salinity effects. Water Science and Technology: Water Supply, 19 (5), pp. 1413-1421. https://iwaponline.com/ws/article/19/5/1413/65497/Using-saline-reclaimed-water-on-almond-grown-in

WOCAT 2015. Water saving through reuse of return flow in paddy fields (Vietnam). https://qcat.wocat.net/es/wocat/technologies/view/technologies_1277/ Note that in WOCAT database there are several examples of water reuse.

Return to Table 3.1.1.

3.2.15. Measures to increase soil water holding capacity.

3.2.15.1. Description.

Water retention capacity (WRC) of agricultural soils is closely linked to soil structure, soil porosity and thus also to organic carbon content. Storage capacity within the topsoil is by far the largest available space within landscape – orders of magnitude greater than all other technical measures. For this reason, even a moderate increase in WRC might contribute significantly to improved soil water use by the crop.

Healthy soils, with high content of organic carbon and rich soil micro-fauna and flora usually generate good structure, indicated by high WRC, in the range of 115 to 265 mm of water to a soil depth of a meter in well-structured soils or 92 to 185 in structureless soils (William 1983). In addition they have high hydraulic conductivity and stable soil structure. However, too high a porosity can cause lowering of water holding capacity due to rapid water drainage. Highly porous soils also tend to have lower nutrient retention capacity.

The care of soil structure and overall soil health requires a continuous effort, based on:

* The minimization of soil compaction by mechanization;

* Soil management oriented towards high soil organic carbon content;

* Well-balanced nutrient content for soil micro-fauna and flora; and

* Optimization of vegetation cover at the field.

The potential impact of caring for soil structure is very high. For instance, an increment of soil porosity of 5 % within 0.4 m of top soil layer can provide up to additional 20 mm of water storage capacity, equating to 200 m3 per hectare.

This measure is effective for reduction of surface runoff, improvement of soil water balance for crops, and reduction of water erosion, Table 3.2.15.1

Table 3.2.15.1. Table Impact of soil structural managment.

Effect	Mechanism
Surface runoff reduction.	Due to better soil structure higher porosity and hydraulic conductivity, a higher proportion of rainfall event can be stored within soil profile reducing surface runoff.
Improvement of water balance.	Due to increase in infiltration during rainfall events and better soil storage more water is available to crops.
Soil erosion control.	Stable soil aggregates resist raindrop impact and overland flow reducing the availability of soil particles for transport. Additionally, surface runoff is significantly reduced due to higher porosity and hydraulic conductivity, reducing the potential for erosion.

3.2.15.2. Types of measures to increase soil water holding capacity.

Increasing soil organic matter content.

Organic matter in the soil is necessary for soil aggregation: key to a good soil structure. Organic matter alone is not sufficient, crucially it is the combination with soil fauna that transforms organic material into humus that leads to aggregate formation. To initiate and maintain aggregation, it is necessary to ensure that a sufficient amount of organic material is returned to the soil e.g. as crop residues. In addition proper nutrient balance in the soil, healthy soil fauna, and appropriate soil air, temperature and moisture conditions are also important for maintaining a god soil structure.

Compost applications.

Compost application has a positive effect on soil structure by introducing significant amounts of organic material helping to support soil life. The measure can be very effective, however, studies indicate that amount of compost necessary to be applied on soil surface to significantly improve soil properties are high (up to 150 t ha-1). These high application rates can be expensive for many crops, and also represent a technological challenge for processing and incorporating into the soil surface (Adunga, 2018, Koopmans and Bloem, 2018). Nevertheless, rates below the optimum can have a positive effect on priming soil fauna and soil conditions for establishing vegetation in degraded or very degraded soils. For these reason, the use of compost use should be considered, particularly on degraded soils where the soil ability for self-restoration might be limited.

Biochar application.

Biochar application has been developed and recommended for application in agriculture because of synergies of positive effects on soil quality, fertility and generally soil health and also carbon sequestration. However, although positive effects prevail, nutrients leaching, soil water repellency effects and other negative effects have also been documented. Its main limitation is related to the fact, that charcoal is produced by pyrolysis of biomass in no-oxygen environment. Therefore, amount available is not sufficient for massive application on agricultural land to improve their properties in large scale (Verheijen et al., 2009).

Crops residues.

Crop residues left on the soil surface after harvesting can help soil structure and protect the soil surface from raindrop impact and it is one of the pillars of conservation agriculture, see section 3.3.9.1. It is best to be combined with adequate support of other nutrients and, occasionally, mechanical cultivation, to initiate humus content increase. This measure is generally accepted as fulfilling Good Agricultural and Environmental Conditions (GAECs) regarding soil erosion control, as crops residues cover the soil surface and protect it against rain splash and runoff erosion.

3.2.15.2. Types of measures to increase soil water holding capacity.

Figure 3.2.15.1. Well -structured soil in Lower Austria (Photo T. Dostal).

Figure 3.2.15.2. Structure-less severely degrade soil showing the C horizon below (Photo J.A. Gómez).

Figure 3.2.15.2. Application of matured manure in various rates: 41, 25 and 5 t ha-1 (Photo Farm Advisory Service of Scotland).

3.2.15.4. Selected References.

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Return to Table 3.1.1.

4. COMPARISON OF BMPs RECOMMENDATIONS IN GOOD AGRICULTURAL ENVIRONMENTAL CONDITIONS OF THE CAP ACROSS THE EU.

4.1. Objectives and Methodology.

The purpose of this analysis is to provide a quantitative overview of how the BMPs are considered across the different EU member states within the CAP in relation to the sustainable use of soil and water. To do it so, we performed a full review of the national definition and conditions of the Good Agricultural Environmental Conditions (GAEC).

The specific objectives were:

1.- To evaluate the consistency among the recommendation of specific BMPs across countries for specific GAEC.

2.- To quantify the frequency of recommendation of specific BMPs.

Being made at the end of a CAP programming period (2014-2020), this comparison can provide an updated overview of different approaches to BMPs across the EU, identifying gaps and issues that might need to be worked on with different stakeholders.

This review was performed using database compiled by the European Commission Joint Research Center (JRC, 2020) of the definition at national level of the GAEC (Good Agricultural and Environmental Conditions) of the Common Agricultural Policy. We chose year 2019, using the English translation, which was the latest completed year for all the countries. For two countries (Belgium and United Kingdom) which included different GAECs in the database (Flanders and Wallonia; England, Wales and Scotland) each region was analysed and considered independently in the quantitative analysis. From this database we:

1.- Revised the conditions for all the GAEC and the 28 Member states (UK was included), identifying BMPs name it in the regulation as well as specific features that might be of interest to regulate implementation of these BMPs.

2.- Classified the BMPs and specific regulations in summary Tables and Figures to provide a quantitative analysis.

We performed this analysis only in those GAECS in which a relevant number of BMPs were named. For this reason, GAECS: "2 Compliance with water authorisation procedures"; "3 Protection of ground water against pollution"; and GAEC "6 Maintenance of soil organic matter", which does not make significant mention to BMPs, do not appear in this analysis.

4.2. Quantitative analysis

4.2.1. GAEC 1: Establishment of buffer strips along water courses.

The regulations regarding the implementation of buffer zones around the water courses was present in all the summary of national regulations with almost all the countries defining a minimum width (Figure 4.2.1.). The definition of buffer strips varied broadly among countries, with some countries defining only the prohibition of agricultural activities in this buffer zone (e.g. application of agrochemicals or tillage), while others went beyond and regulated nationally the detail of the vegetation cover in this buffer strips in terms of composition and management. Only 30% approximately, see Figure 4.2.1.1., of the countries regulated a variable minimum width according to different criteria (sometimes slopes, other location within more vulnerable areas). There is much less consensus in the definition of maximum extension of buffer zones, approximately 30% of the countries, with even less examples of consideration of national regulation of a maximum buffer width, Figure 4.2.1.1. There is also a different approach regarding the consideration of the buffer zone as an Ecological Focus Area (EFA), with buffer zones being considered as such in approximately 60% of the countries. There is also a large disparity in the range of maximum and minimum widths indicated by GAEC 1 across countries, Table 4.2.1.1., also the mean value for the minimum width median value been 5 m, a value just in the lower range of recommend widths to function adequately as a vegetated barrier see section 3.2.7.

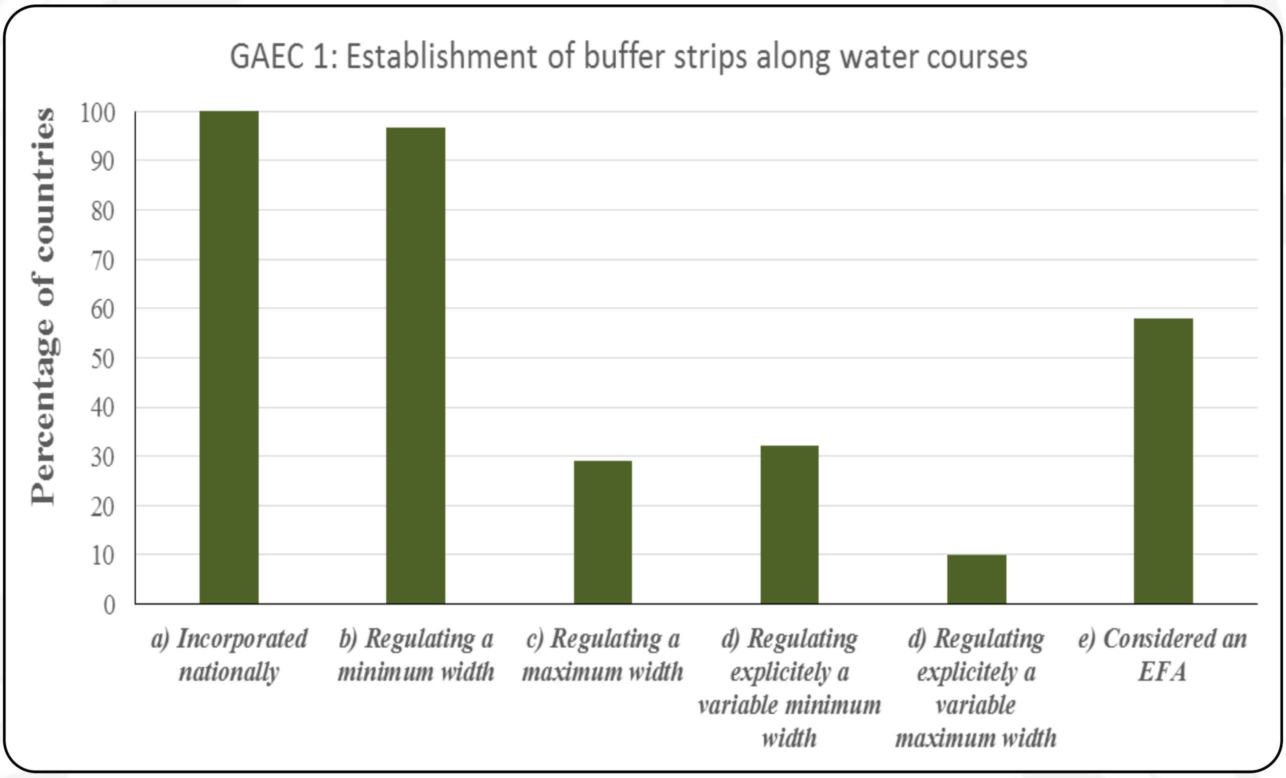

Figure 4.2.1.1. Summary of GAEC requirements for buffer strips along water courses. EFA is Ecological Focus Area.

Table 4.2.1.1. Summary of minimum and maximum buffer strip bands (m).

Minimum buffer width (m)		Maximum buffer width (m)	
Minimum	0.3	Minimum	10.0
Maximum	25.0	Maximum	300.0
Mean	5.6	Mean	62.5
Median	5.0	Median	35.5
Standard deviation	5.0	Standard deviation	88.0
CV %	89.3	CV %	140.8

4.2.2. GAEC 4: Minimum soil cover.

The criteria regarding the need to provide a minimum soil cover in agricultural areas varied across the EU members. So, while 40% imposed this as a general requirement, 60% of the countries required it only in part of the agricultural areas based on some criteria, Figure 4.2.2.1. 90 % of the countries defined the period in which this minimum soil cover must be provided, basically the rainy period, and it is also relevant to note how approximately 50% of the countries allowed the possibility of exceptions to this criterion, which are usually related to agronomic reasons like incorporation of soil amendments or reduction of risk of water stress during droughts.

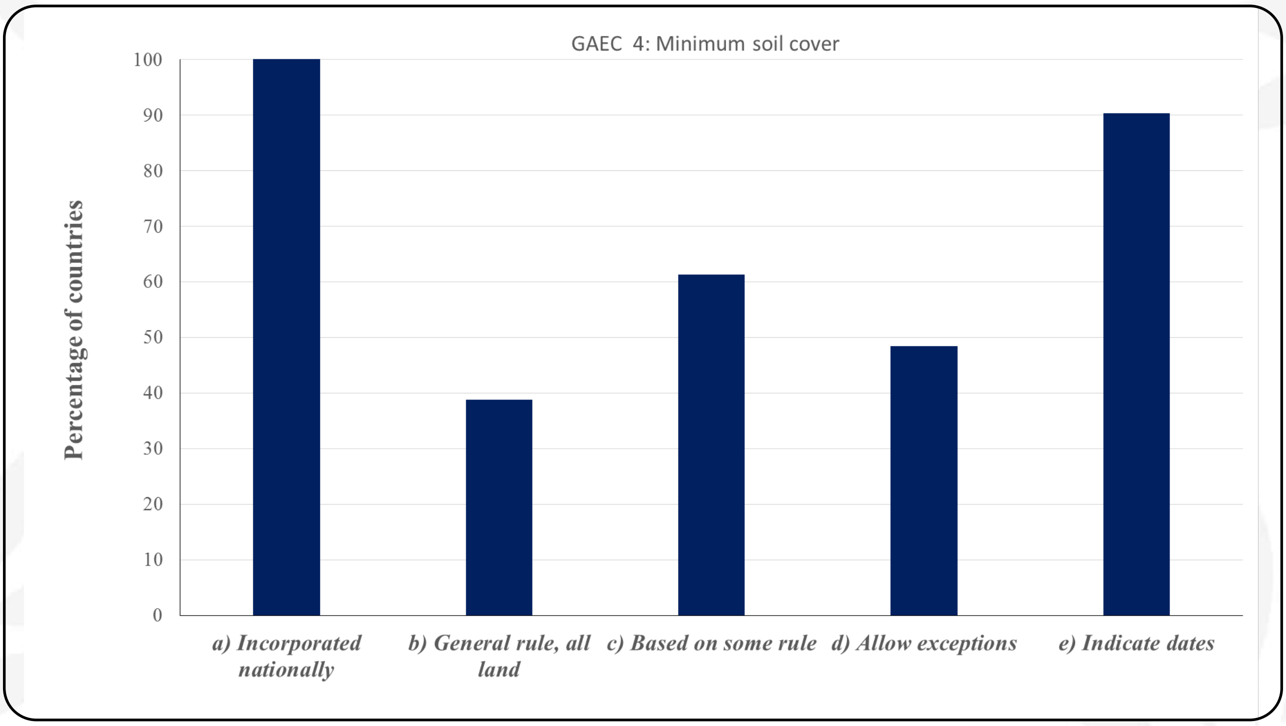

Figure 4.2.2.1. Summary of criteria for implementing GAEC 4.

Figure 4.2.1.2, groups the kind of criteria used by the 60% of countries not implementing this GAEC to all the agricultural land. Approximately 40% of these countries used slope steepness, with 10.5% as the median slope threshold value, although there was significant variability among countries, Table 4.2.2.1. Among the other criteria used by different countries the most frequent were those based on a land classification, often considering erosion risk, or the use of specific crops as the determining factor. Another criterion, used by only one or two countries, included the presence of erosion features in the field, or making the criterion regionally targeted.

Figure 4.2.2.3. shows the BMPs named in national GAEC 4 regulations. The most frequent one was the use of a cover crop in approximately 85% of the countries. This was followed in approximately 55% of the countries by the use of mulch or stubble of previous crop, or vegetation cover (other than the crop) present in the field during specified dates. Techniques related to conservation tillage , usually reduced tillage, with occasional mentions of buffer strips or retention measures are also mentioned in around 20% of the countries.

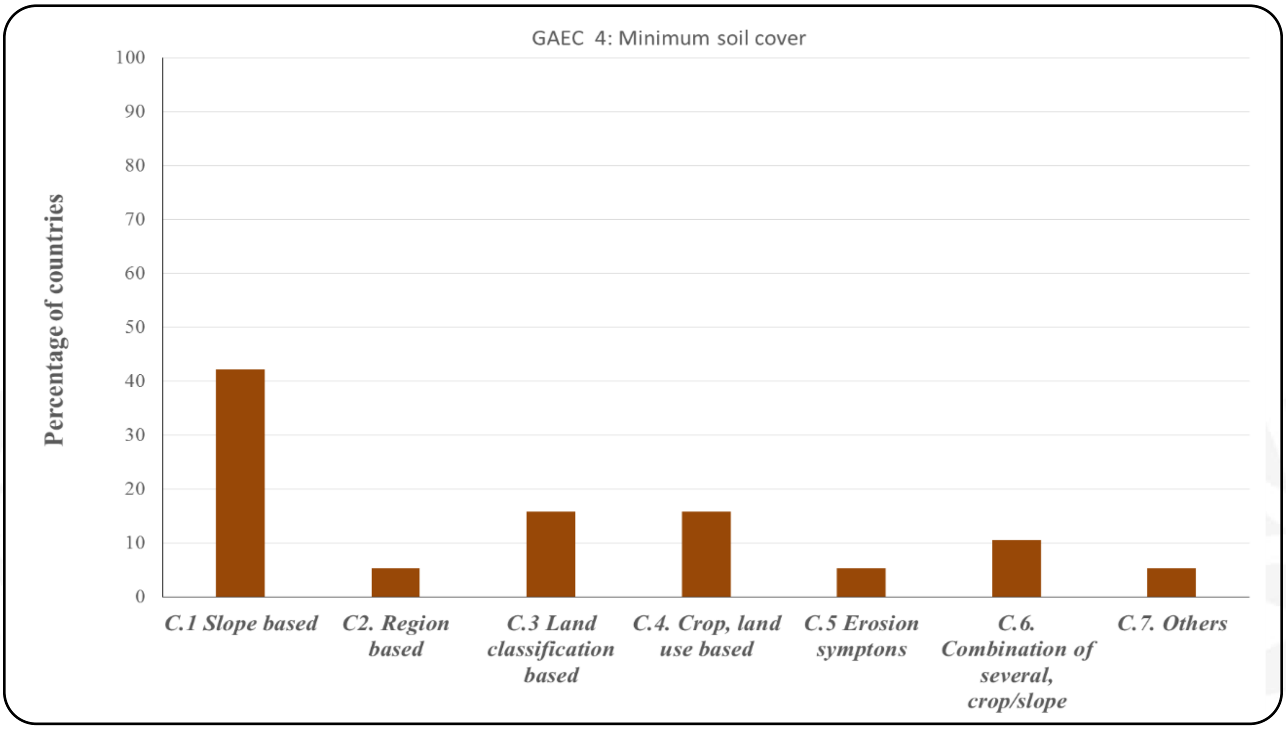

Figure 4.2.2.2. Criteria for defining area for implementing GAEC 4 in countries not applying it nationwide.

Slope criteria	%
Minimum	4.0
Maximum	20.0
Mean	11.4
Median	10.5
Standard deviation	4.1
CV %	35.9

Table 4.2.2.1. Summary of slope threshold when is used as criteria for GAEC 4.

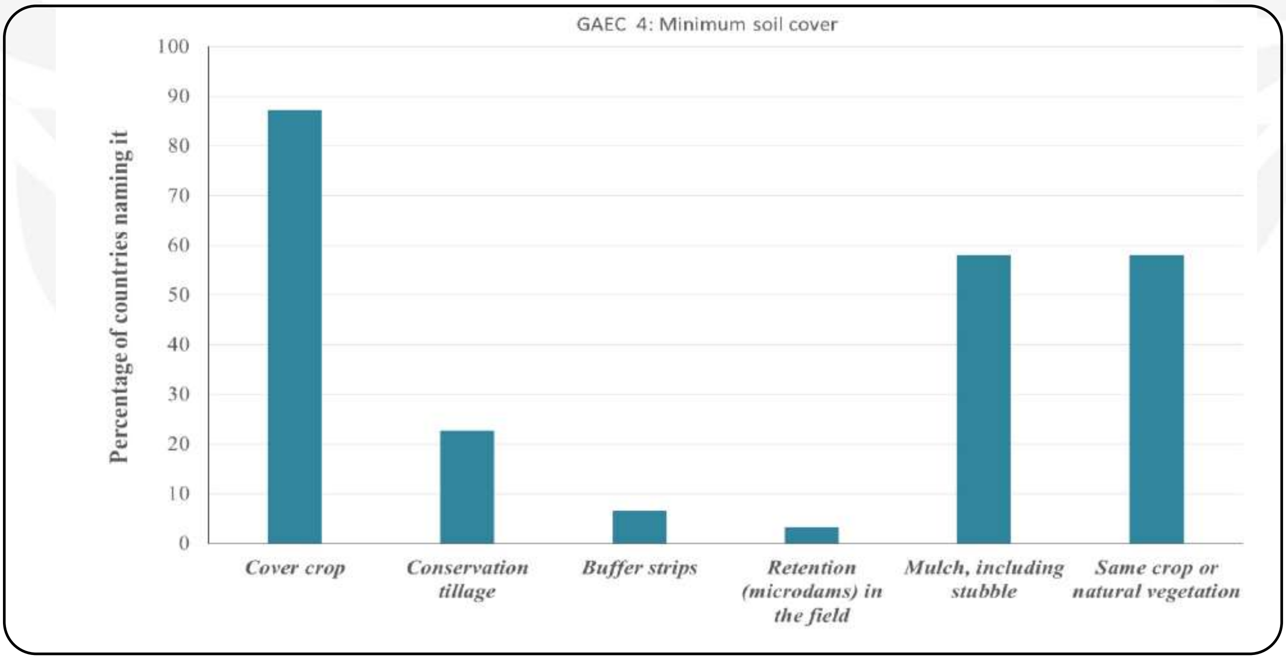

Figure 4.2.2.3. BMP named in national regulation for implementing GAEC 4.

4.2.3. GAEC 5: Minimum land management reflecting site specific conditions to limit erosion.

The criteria regarding the need to limit erosion incorporating appropriate measures based on specific conditions are summarized in Figure 4.2.3.1. Due to the nature of this GAEC requirement, which is a reactive measure to specific conditions, 80% of the countries required its implementation based on certain criteria, while 20% state it as a country wide requirement. The countries allowing exception are much less than for GAEC 4, again relating these exceptions to agronomic reasons.

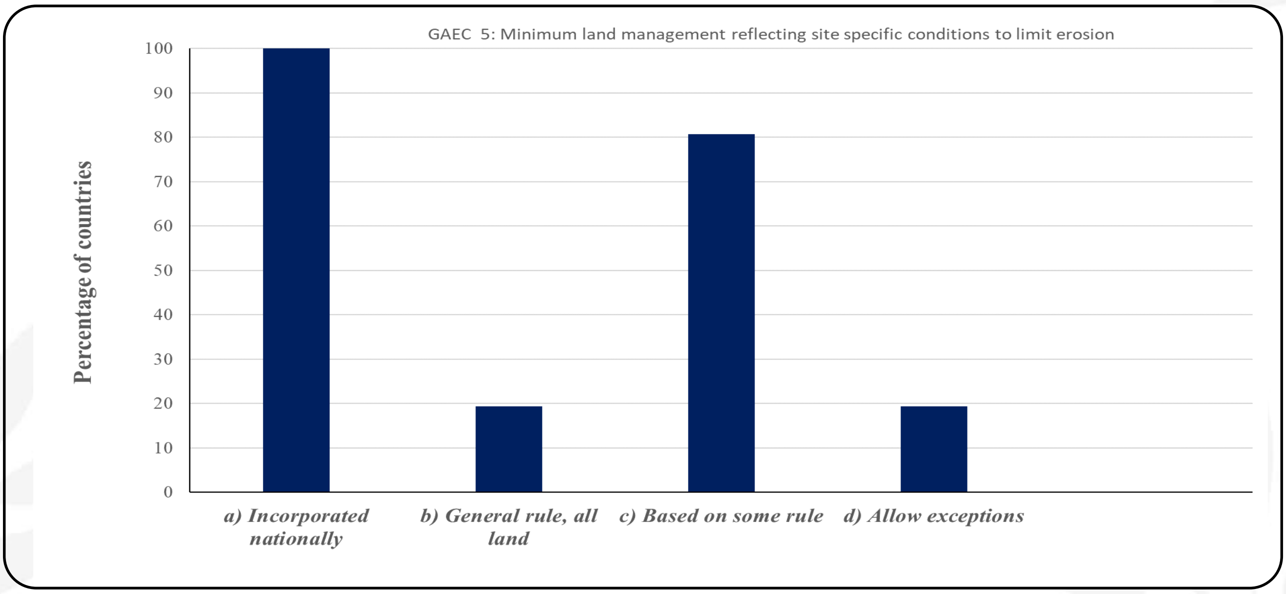

Figure 4.2.3.1. Summary of criteria for implementing GAEC 5.

Figure 4.3.1.2. groups the criteria used by the 80% of countries implementing GAEC 5 locally, reflecting the rules followed for GAEC 4 commented on above. The majority of the countries (60%) used slope alone, or combined with the kind of crop (5%). The slope value used as a threshold has a median value of 12.0%, but showed significant variability among countries (2 to 20%) see Table 4.2.3.1. Among the other rules used by different countries the most frequent were those based on a land classification, usually based on erosion risk, or the use of specific crops as the determining factor. There were other rules used by only one or two countries like the presence of erosion features in the field, indicating specific regions where this GAEC has to be implemented.

Figure 4.2.3.3. shows the percentage off countries naming BMPs in national GAEC 5 regulations. Contour cultivation and contour farming are the most named in 50 and 40 percent of national regulations. This is somewhat counterintuitive, since contour cultivation is sometimes recommended for a slope range in which its effectiveness is limited, see Table 3.2.6.1. After contour cultivation, cover crops (in annual or tree crops) in 35% of the countries, and mulch (including stubble of previous crop) in 30% of the countries, are the most common approaches mentioned. Other BMPs that feature in national regulations are buffer strips (used as vegetative barriers against erosion) in 26% of the countries, maintenance of terraces and natural elements that protect against erosion, and crop rotations appropriate to minimize leaving the bare and unprotected, which are found in 20% of the country regulations. The use of retention measures (micro-dams) is mentioned in only 10% of countries, while the explicit prohibition of working soils when frozen or waterlogged appears in 15% of the regulations.

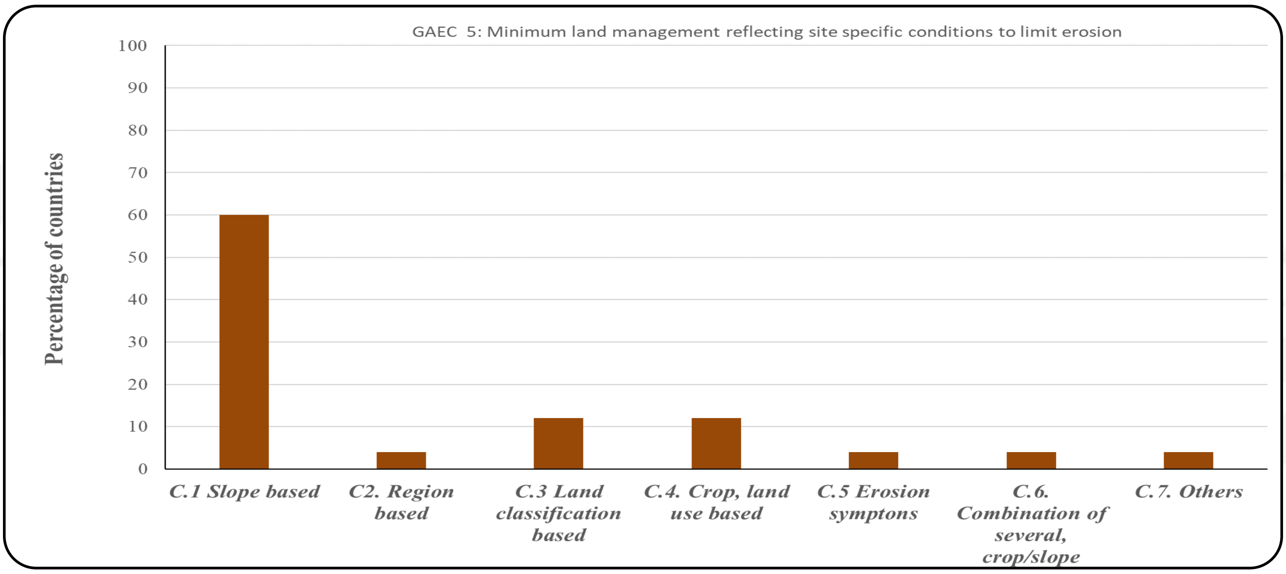

Figure 4.2.3.2. Criteria for defining area for implementing GAEC 5 in countries not applying it nationwide.

Table 4.2.3.1. Summary of slope threshold when is used as criteria for GAEC 5.

Slope criteria	%
Minimum	2.0
Maximum	20.0
Mean	13.2
Median	12.0
Standard deviation	4.6
CV %	35.1

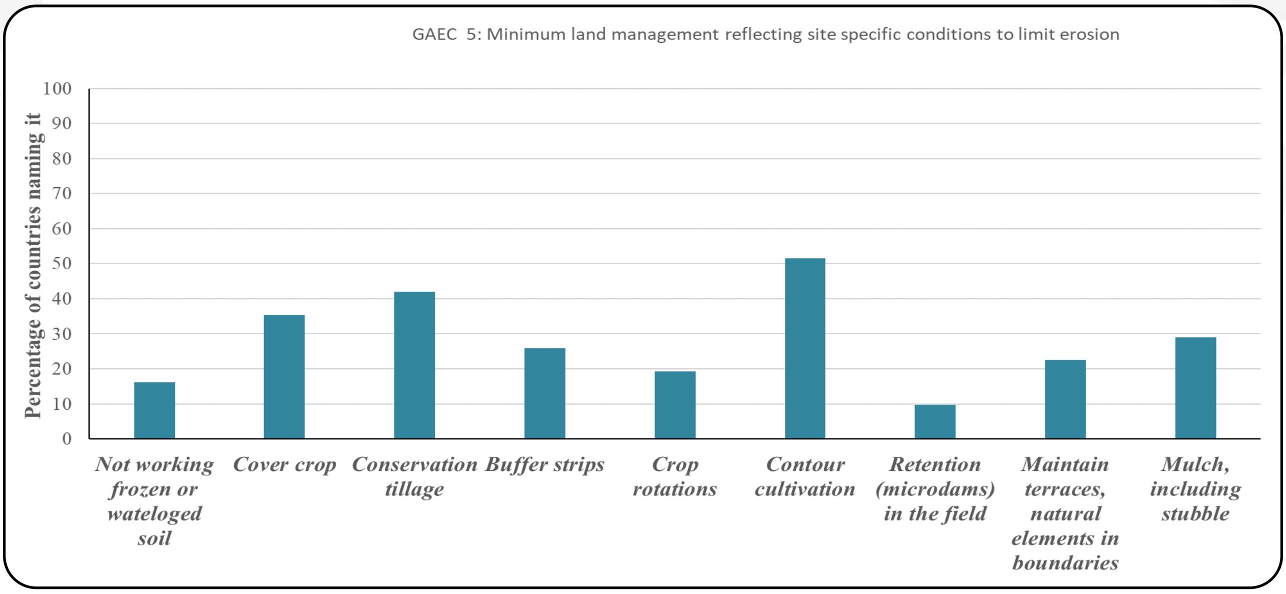

Figure 4.2.3.3. BMP named in national regulation for implementing GAEC 5.

4.2.4. GAEC 7: Retention of landscape features.

There are 12 different of classes of protected landscape features listed in GAEC 7, which are depicted in Figure 4.2.4.1. Unlike land management practices there application is more variable. Hedges, ponds, and trees (isolated, in line or in groups) are named in 50 % of the national regulations. In some countries trees are included within vegetation islands that are recognized as a different feature because they are linked to specific conditions on the vegetation type. Terraces, traditional stone walls, ditches, and natural or historical monuments are identified as elements to retain in 35-40% of the countries. Field margins and tree orchards are recognized as landscape elements in the regulations of a minority of countries. Among these elements some of them might have a role as BMPs for soil and water conservation and as such should be considered in an appraisal of conditions at field and landscape scale. Among the most relevant are: hedges, trees in lines and field margins (if vegetated) for their role as vegetated barriers against erosion (see section 3.2.7.); ponds for their role to store runoff and trap sediment (see section 3.2.12.); terraces and traditional stone walls (see section 3.2.1.); and ditches acting as measures to divert runoff excess (see section 3.2.12.).

Figure 4.2.4.2. shows the frequency in which these landscape features are accepted as an Ecological Focus Areas (EFA). Ecological Focus Area is defined as an area which a use and management oriented towards providing positive effects for biodiversity, and for soil, water and climate. Each country defines his own list of EFA that the farmers can implement. Some EFA implies devoting that area to a non-productive use, e.g. vegetated barriers, while other can be applied in a productive area (e.g. use of legumes that fix nitrogen) This is relevant since the minimum area devoted to EFA is linked to perception of CAP subsidies and it might act as an incentive for farmers to protect and improve these landscape features. It is apparent from Figure 4.2.4.2 the disparity in the approach to the use of EFA for these landscapes features across the EU. There is not a single landscape element that is systematically considered an EFA across the countries. Hedges, terraces and vegetation islands are those more frequently considered, in 60% of the countries. Tree related features, and traditional stone walls are the other landscape features more frequently considered EFA, around 50% of the countries.

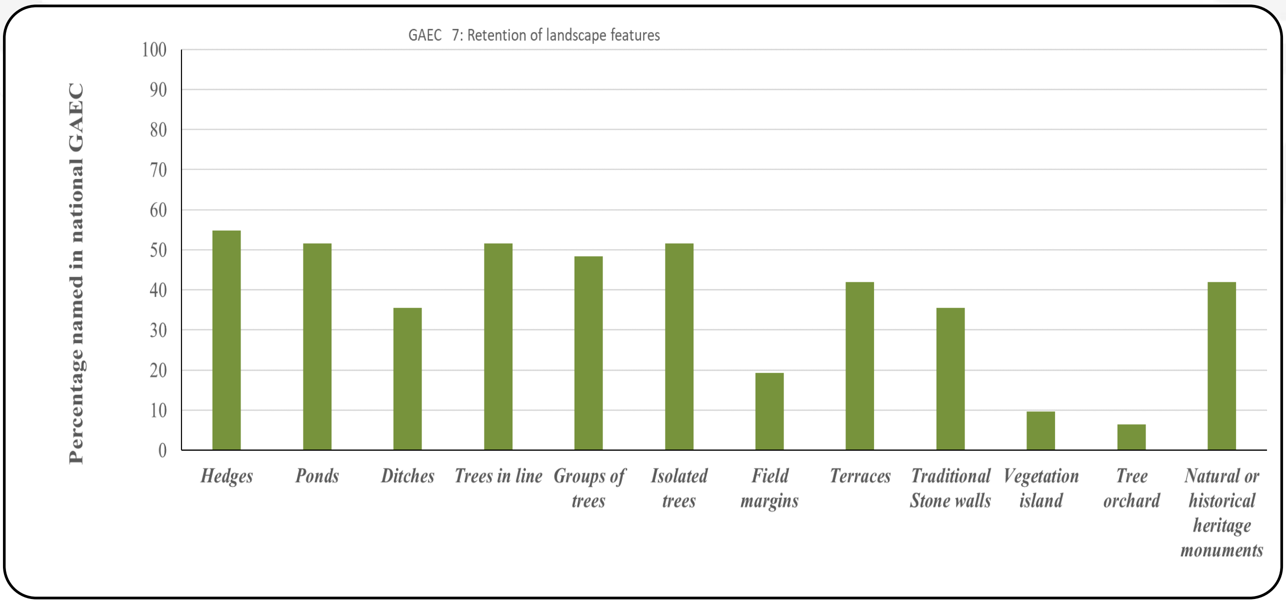

Figure 4.2.4.1. Proportion of landscape features considered in GAEC 7.

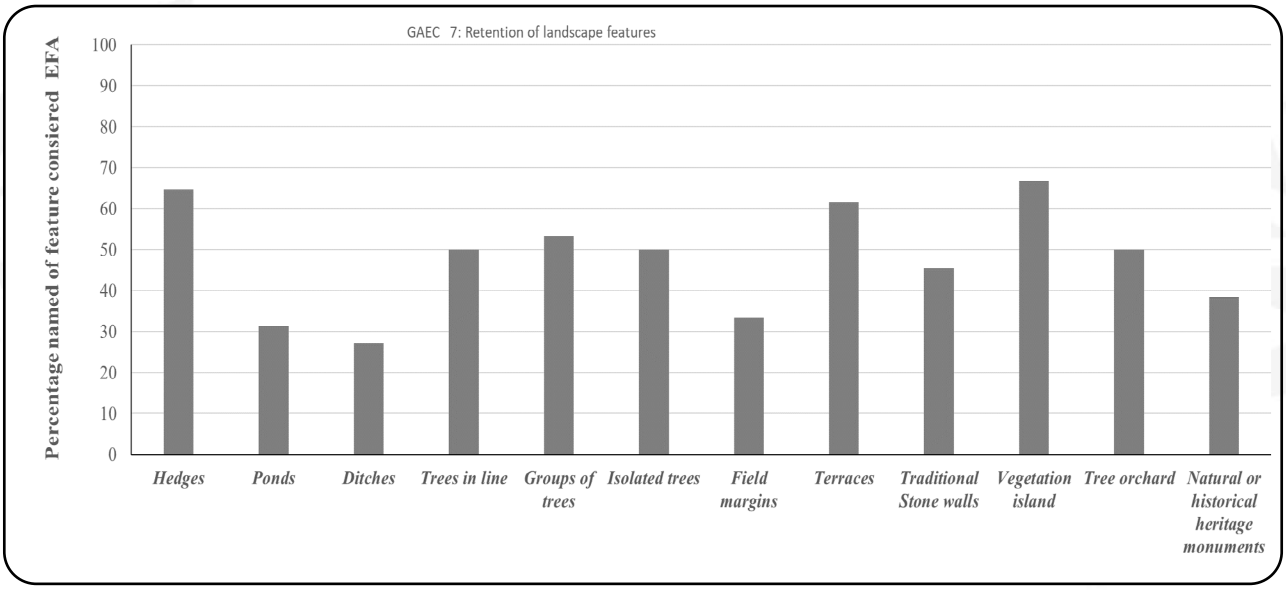

Figure 4.2.4.2. Proportion of landscape features considered as EFA, Ecological Focus Area. in GAEC 7.

4.3. Summary.

This analysis has identified the occurrence of BMPs in the national implementation of CAP related requirements related to soil and water through the GAECs. They demonstrate the similarities and disparities between countries, which has been noted by previous studies (Ecologic Institute 2017; Paleari, 2017, Turpin et al.,2017). The quantitative analysis described in this section allows identification of the most frequently named BMPs uses and criteria for their implementation. These results will be of interest for those carrying out regional model analysis of BMP effectiveness, as well as fostering critical discussion on how to improve incorporation of technical measures on improved soil and water use in the CAP.

4.4. References.

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Paleari, S. 2017. Is the European Union protecting soil? A critical analysis of Commnity environmental policy and law. Land Use Policy 163: 163-173.

Turpin, N. et al. 2017. An assessment of policies affecting Sustainable Soil management in Europa and selected member states. Land Use Policy 66: 241–249.

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5. APPRAISAL OF INCORPORATION OF BMPs TO BE EVALUATED THROUGH MODELLING IN REGIONAL ANALYSIS IN SHUI.

This section reflects the discussion of the hydrologic modelers group in relation to the feasibility of incorporating BMPs in regional analysis, through simulation models, for evaluating impact of different strategies on optimizing use of soil and water resources through improved agricultural practices. Although focused on the models and agricultural systems included in SHui, the information will be useful for similar studies facing the need to go through the process of converting specific BMPs into parameters and algorithms available on current models for simulating scenarios.

Tables 5.1.and 5.2 list, for the agricultural systems studied in Shui and the most relevant BMPs based on their effectiveness and presences in CAP requirements (section 4). Table 5.3. indicates suitability of five hydrologic/erosion models for modelling the effect of different BMPs. Table 5.4. lists the ways in which these models can incorporate the effect of the different BMPs.

Sections 5 provides a clear guideline to identify which models can reproduce the effect of an exhaustive list of BMPs, and the approach that they take to doing so. Combined with section 4, which provides an appraisal of the relevance of specific BMPs on CAP regulations, and section 3, which introduces the technical details for each BMP, this section provides an entry point for scenario simulation of the effect of specific BMPs on soil and water use.

Go back to section 2.2. Document structure.

Table 5.1. List of most promising BMPs for soil conservation for scenario simulations. CBR is cereal based rotation, TC is tree crops, -R is rainfed and I is irrigated. * Cons. Till. specific conservation tillage strategies to be implemented.

Ag. system	Crop	Europe Humid climate	Semi-arid climate	China Humid climate	Semi-arid climate
CBR-R	Cereal rotation	Conservation tillage*	Conservation tillage*	Conservation tillage*	Conservation tillage*
CBR-R	Cereal rotation	Cover crops	Cover crops	Cover crops	Cover crops
CBR-R	Cereal rotation	Contour farming	Contour farming		
CBR-I	Cereal rotation	Conservation tillage*	Conservation tillage*	Conservation tillage*	Conservation tillage*
CBR-I	Cereal rotation	Cover crops	Cover crops	Cover crops	Cover crops
TC-R	Olives		Cover crops		
TC-R	Vines	Cover crops	Cover crops		
TC-I	Olives		Cover crops		
TC-R	Vines	Cover crops	Cover crops		

Table 5.2. List of most promising BMPs for water conservation for scenario simulations. CBR is cereal based rotation, TC is tree crops, -R is rainfed and I is irrigated.

Ag. system	Crop	Europe Humid climate	Semi-arid climate	China Humid climate	Semi-arid climate
CBR-R	Cereal rotation	Contour farming	Contour farming	Contour farming	Contour farming
CBR-R	Cereal rotation	Cover crops	Cover crops	Cover crops	Cover crops
CBR-R	Cereal rotation	Deficit Irrigation	Deficit Irrigation	Deficit Irrigation	Deficit Irrigation
CBR-I	Cereal rotation	Water reuse	Water reuse	Cover crops	Cover crops
TC-R	Olives	Micro water harvesting, mulching	Micro water harvesting, mulching		
TC-R	Vines	Micro water harvesting, mulching	Micro water harvesting, mulching		
TC-I	Olives	Deficit Irrigation	Deficit Irrigation		
TC-R	Vines	Deficit Irrigation, water reuse	Deficit Irrigation, water reuse		

Table 5.3. Feasibility of five hydrologic models to simulate effect of BMPs on soil and water conservation. D=directly (the model has a proper parameter/variable to simulate the effect). I= indirectly (effect can be approximated by mixing correlated parameters). N = the model cannot be used to for scenario assessment of this BMP. Models: SW = SWAT; MS = MIKE-SHE; WS = WATEM/SEDEM; C2 = CASE 2; CE = CSLE.

#	BMP type	Description	SW	MS	WS	C2	CE
1	Terraces.	Various width, decrease of slope, interruption of runoff.	D	D	D	D	D
2	Contour plating.	Increase of roughness in direction of slope, potentially redirecting of surface runoff.	D	D	D	D	D
3	Landscape elements.	Introducing various elements, various functions - not suitable for modelling.	N	N	N	N	N
4	Cover crops in tree crops.	Reduction of soil erosion, increase of surface roughness, higher infiltration.	I	I	D	I	I
5	Mulching in tree crops	Cover of soil surface by biomass.	I	I	D	I	I
6	Contour plowing.	Increasing infiltration, increasing surface roughness, initial step for contour planting.	I	I	D	I	I
7	Vegetated barriers.	Grass strips, reducing runoff velocity, increasing surface roughness.	I	I	D	I	I
8	Gully control structures.	Dams within gullies to stop sediment flux and induce siltation and stabilization.	N	N	N	N	N
9	Conservation agriculture.	Minimum tillage - minimum soil disturbance, altering soil management and crop rotation schemes.	I	I	D	D	N
10	Cover crops in annual crops.	Providing of permanent cover of soil between harvest and seeding.	I	I	D	D	N
11	Agroforestry.	Integration of tree for forest production with crops and/or livestock.	N	N	N	N	N
12	Water harvesting.	Techniques aimed to concentrate and stored surface or subsurface runoff for crop use.	N	N	N	N	N
13	Deficit irrigation.	Use of limited available water for irrigation in best period for yield.	D	D	N	N	N
14	Water reuse.	Reuse of water from previous activities - mostly treated waste water.	N	N	N	N	N
15	Increasing water holding capacity.	Influencing soil parameters and soil profile properties for better infiltration and water storage capability.	I	I	N	N	N
16	Crop rotation.	Changing crop rotation to decrease water deficit, due to lower water demand or more suitable temporary distribution of water demand by plants.	D	D	D	D	D
17	Technical measures - water diverting.	Usually ditches or hedges trapping sheet flow on sloped fields and diverting it to the side. Usually prevention of concentrated flow and gully erosion.	I	D	I	D	N
18	Technical measures - water retention.	Linear structures, strictly horizontally oriented, trapping surface flow on sloped fields to prevent concentrated flow. Water is infiltrated = harvested.	I	D	I	D	N
19	Retention reservoirs, related to water harvesting.	Retention small reservoirs, trapping and stopping water from surface runoff from fields - usually to prevent damages on infrastructure caused by concentrated flow.	I	D	I	D	N
20	Strip cropping, see cover crops for annual crops.	Contouring with strips of different crops (e.g. maize-wheat-maize).	D	I	D	D	I
21	Check dams, see gullies.	Small dams, trapping sediment transported downstream, reduce flood peak.	I	I	I	N	N
22	Fish-scale pits, see water retention.	change micro-topography with considerable sinks along the hillslope, trapping surface flow, increasing surface roughness, water harvesting.	N	N	N	N	N

Table 5.4. Strategy of hydrologic models to reproduce effect of BMPs on soil and water conservation indices. Appraisal of viability of parameter assessment: xxx = high; xx = moderate; x = low; none.

#	BMP type	Soil hydraulic conductivity	Slope modification	Organic carbon conten	Soil water holding capacity	retention capacity of catchment	Soil structure	Water harvesting for irrigation	Higher interception	Decrease of surface flow velocity	Infiltration due to surface roughness	Soil erosion conservation
1	Terraces.		XXX			XX						XXX
2	Contour plating.				X					XX	XX	
3	Landscape elements.											
4	Cover crops in tree crops.	X		XX	XX	XX	XX		XXX	XXX	XXX	XX
5	Mulching in tree crops.				X	X			XX			
6	Contour plowing.				X	X				XX	XX	X
7	Vegetated barriers.								X	X	X	XX
8	Gully control structures.											
9	Conservation agriculture.	XXX		XXX	XX	XX	XXX		XX	XX	XX	XX
10	Cover crops in annual crops.	X		XX	XX	X	X		XX			XXX
11	Agroforestry.											
12	Water harvesting.				X		X					
13	Deficit irrigation.											
14	Water reuse.											
15	Increasing water holding capacity.				XXX	X						
16	Crop rotation.	X										
17	Technical measures - water diverting.					XXX		X		XX		XXX
18	Technical measures - water retention.											
19	Retention reservoirs, related to water harvesting.					XXX						
20	Strip cropping.	X		X	XX	XX	X		X	XX	XX	XXX
21	Check dams.					X						XX
22	Fish-scale pits.					XX				XX	XXX	X

Annex 1: SOIL AND WATER BMP IN RELATION TO CURRENT AND INCOMING CAP.

A.1. Main Concepts used in the CAP.

A.1.1 Cross Compliance.

Source: EU:
https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/income-support/cross-compliance_en

Through cross-compliance, farmers are encouraged to comply with European Union (EU) standards for public, plant, and animal health and welfare. Cross-compliance plays a role in making European farming more sustainable. To receive EU income support, farmers must respect a set of basic rules. The interplay between this respect for rules and the support provided to farmers is called cross-compliance.

Rules farmers are expected to comply with include:

* **Statutory management requirements**, these apply to all farmers whether or not they receive support under the common agricultural policy (CAP).

* **Good agricultural and environmental conditions,** these apply only to farmers receiving support under the CAP.
Farmers violating EU law on environmental, public and animal health, animal welfare or land management will have their EU support reduced and may face other penalties.

Statutory management requirements (SMR).

All farmers, whether receiving CAP support or not, have to respect statutory management requirements (SMR). The SMR include EU rules on public, animal and plant health; animal welfare; and the environment. Regarding cropping these SMR are:
- *Public, animal and plant health* general food law (EU regulation 178/2002).
- Regulation on plant protection products (EU regulation 1107/2009).
- Environment.
- Nitrates directive (Council Directive 91/676/EEC).
- NATURA 2000 directive on wild birds (Directive 2009/147/EC).
- NATURA 2000 directive on natural habitats (Council Directive 92/43/EEC).

Good agricultural and environmental conditions (GAEC).

In addition to the statutory management requirements, farmers receiving CAP support have to respect EU standards on good agricultural and environmental condition of land (GAEC).

These standards are designed to:

1.- Prevent soil erosion by defining minimum soil cover and minimum land management practices.

2.- Maintain soil organic matter and soil structure.

3.- Maintain permanent grassland.

4.- Protect biodiversity and ensure the retention of landscape features for example, through a ban on cutting hedges and trees during the bird breeding and rearing season.

5.- Protect and manage water through the establishment of buffer strips along water courses, authorization on water for irrigation and protection of ground water from pollution.

There is a specific section on these GAECs below, A.1.3.

Penalties for non-compliance.

Under the cross-compliance system, farmers not respecting EU rules can see the following support reduced direct payments (decoupled or coupled) most rural development payments: area based payments including agri-environmental measures, areas with natural constraints, NATURA 2000 measures, afforestation measures, forest environmental payments, agroforestry, organic farming wine sector payments: restructuring and conversion of vineyards and green harvesting.

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A.1.2. Greening.

Source: EU:
https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/income-support/greening_en

The “green direct payment” (or “greening”) supports farmers who adopt or maintain farming practices that help meet environmental and climate goals. As applied in CAP for current period (2015-2020) EU countries must allocate 30% of their income support to “greening”.

The three actions farmers must put in place are:

Crop diversification: a greater variety of crops makes soil and ecosystems more resilient; maintaining **permanent grassland:** grassland supports carbon sequestration and protects biodiversity (habitats); **dedicate 5% of arable land to areas beneficial for biodiversity** in Ecological Focus Areas, for example trees, hedges or land left fallow that improves biodiversity and habitats.

Crop diversification.

Farms with more than 10 ha of arable land have to grow at least two crops, while at least three crops are required on farms with more than 30 ha. The main crop may not cover more than 75% of the land. There are exemptions to the rules, depending on the individual situation. For instance, farmers with a large proportion of grassland, which is in itself environmentally beneficial.

Maintenance of permanent grassland.

The ratio of permanent grassland to agricultural land is set by EU countries at national or regional level (with a 5% margin of flexibility). Moreover, EU countries designate areas of environmentally sensitive permanent grassland. Farmers cannot plough or convert permanent grassland in these areas.

Ecological focus areas.

Farmers with arable land exceeding 15 ha must ensure that at least 5% of their land is an Ecological Focus Area in order to safeguard and improve biodiversity on farms.

Exemptions.

The greening rules do not apply to farmers who opted for the small farmer’s scheme, for administrative and proportionality reasons.
Organic farmers automatically receive a greening payment for their farm, as they are considered to provide environmental benefits by the nature of their work.
Other exemptions may apply, depending on the individual situation of a farmer.

Alternatives to greening.

EU countries may allow farmers to meet one or more greening requirements through equivalent practices. Equivalent practices must be based on agri-environment schemes under EU countries' rural development programmes or national/regional certification schemes. Each EU country ensures that farmers using alternative practices do not benefit from both income support for mandatory greening and rural development funds.

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A.1.3. Good agricultural and environmental conditions (GAEC) as part of cross compliance.

Source: EU:
https://marswiki.jrc.ec.europa.eu/wikicap/index.php/Good_Agricultural_and_Environmental_Conditions_(GAEC)

The Good Agricultural and Environmental Conditions (GAECs) are defined in the framework of the so-called cross compliance. In order to ensure that all agricultural land, especially land which is no longer used for production purposes, is maintained in good agricultural and environmental conditions, Member States (MS) shall define minimum requirements on the basis of Annex II of Council Regulation (EC) No 1306/2013. Minimum GAECs requirements should be defined taking into account the specific characteristics of the areas concerned, including soil and climatic condition, existing farming systems, land use, crop rotation, farming practices and farm structures.

Minimum requirements can be defined at national or regional level. Member States shall not define minimum requirements which are established in Annex II. The implementation of the GAEC framework results in a high variety of minimum requirements throughout Europe and sometimes even within the MS when GAECs are defined at regional level.

Table A1: Good Agricultural and Environmental Conditions (GAECs) in current CAP extracted from Annex II of (EC) No 1306/2013.

Area	Main Issue	Requirements and Standards as defined in current CAP (2013-2020)
Environmental, climate change, good agricultural condition of land.	Water.	GAEC 1: Establishment of buffer strips along water courses. GAEC 2: Where use of water for irrigation is subject to authorisation, compliance with authorisation procedures. GAEC 3: Protection of ground water against pollution: prohibition of direct discharge into groundwater and measures to prevent indirect pollution of groundwater through discharge on the ground and percolation through the soil of dangerous substances, as listed in the Annex to Directive 80/68/EEC in its version in force on the last day of its validity, as far as it relates to agricultural activity.
	....	....
	Soil and carbon stock.	GAEC 4: Minimum soil cover. GAEC 5: Minimum land management reflecting site specific conditions to limit erosion. GAEC 6: Maintenance of soil organic matter level through appropriate practices including ban on burning arable stubbles, except for plant health reasons.
	Landscape, minimum level of maintenance.	GAEC 7: Retention of landscape features, including where appropriate, hedges, ponds, ditches, trees in line, in group or isolated, field margins and terraces, and including a ban on cutting hedges and trees during the bird breeding and rearing season and, as an option, measures for avoiding invasive plant species.

Table A2 extracted from available information in EC web site related to CAP.
https://ec.europa.eu/info/news/environmental-care-and-climate-change-objectives-future-cap-2019-jan-25_en

Table A2: Good Agricultural and Environmental Conditions (GAECs) as defined for future CAP period.

Area	Main Issue	Requirements and Standards as defined in future CAP (2021-2026)
Environmental, climate change, good agricultural condition of land.	Climate change.	GAEC 1: Permanent pastures. GAEC 2: Preservation of carbon rich soils such as peatlands and wetlands (new). GAEC 3: Maintenance of soil organic matter through ban on burning stubble.
	Water.	GAEC 4: Establishment of buffer strips along watercourses. GAEC 5: Compulsory use of the new Farm Sustainability Tool for Nutrients (New).
	Soil protection and quality.	GAEC 6: Minimum land management under tillage to reduce risk of soil degradation including on slopes. GAEC 7: No bare soil in most sensitive period. GAEC 8: Crop rotation (replaces crop diversification).
	Biodiversity and landscape.	GAEC 9: Maintenance of non-productive features and areas including a minimum share of agricultural area devoted to non-productive features or areas, retention of landscape features, a ban on cutting hedges and trees during the bird breeding and nesting season, and as an option, measures for avoiding invasive plant species (replaces Ecological Focus Areas). GAEC 10: Ban on converting or ploughing permanent grassland in Natura 2000 sites (New).

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A.1.4. The environmental objectives of the future CAP (2021-2026).

Source: EU:
https://ec.europa.eu/info/news/environmental-care-and-climate-change-objectives-future-cap-2019-jan-25_en

The green architecture.
Three of the nine future CAP objectives aim to enhance and improve our environmental and climate change actions and ambitions by:

1- Contributing to climate change mitigation and adaptation, as well as sustainable energy;
2- Fostering sustainable development and efficient management of natural resources such as water, soil and air; and
3- Contributing to the protection of biodiversity, enhanced ecosystem services and preservation of our habitats and landscapes.

Enhanced 'conditionality'.

Conditionality is an integral part of the future CAP framework and replaces 'greening' and cross-compliance of the current CAP. It sets the baseline for more ambitious and sustainable agricultural commitments through the adoption of good farming practices and standards by farmers. Conditionality links income support (and other area- and animal-based payments) to environment- and climate-friendly farming practices and standards known as '**Good Agricultural and Environmental Conditions' (GAECs) and Statutory Management Requirements (SMRs)**. These practices and standards aim to deliver a higher level of environmental and climate action. The GAECs set standards for mitigating and adapting to climate change; addressing water challenges; soil protection and quality; land management; and protection and quality of biodiversity. There are a total of 10 GAECs in the future CAP, an extra 3 new GAECs compared to the current CAP.

Climate change.

GAEC 1 – Permanent pastures.
GAEC 2 – Preservation of carbon rich soils such as peatlands and wetlands (new).
GAEC 3 – Maintenance of soil organic matter through ban on burning stubble.

Water.

GAEC 4 – Establishment of buffer strips along watercourses.
GAEC 5 – Compulsory use of the new Farm Sustainability Tool for Nutrients (new).

Soil protection and quality.

GAEC 6 – Minimum land management under tillage to reduce risk of soil degradation including on slopes.
GAEC 7 – No bare soil in most sensitive period.
GAEC 8 – crop rotation (replaces crop diversification).

Biodiversity and landscape.

GAEC 9 – Maintenance of non-productive features and areas including a minimum share of agricultural area devoted to non-productive features or areas, retention of landscape features, a ban on cutting hedges and trees during the bird breeding and nesting season, and as an option, measures for avoiding invasive plant species. (Replaces Ecological Focus Areas).

GAEC 10 – Ban on converting or ploughing permanent grassland in Natura 2000 sites (new).

The SMRs link the CAP to wider EU legislation that governs the environment, public health, animal health, plant health and animal welfare. The number of SMRs in the future CAP has increased and include requirements to respect obligations under the 'Conservation of natural habitats and of wild fauna and flora Directive'; 'Conservation of wild birds Directive'; 'Nitrates Directive'; and elements of both the 'Water Framework Directive'; and 'Sustainable Use of Pesticides Directive'.

Conditionality will be mandatory for both member states to implement and for those receiving direct payments to comply with. Member states will define a national standard for each of the EU-standards (GAECs and SMRs), detailing implementation, and tailoring them based on their specific local needs and characteristics (e.g. soil, climatic and farming conditions, land use, crop rotation, farming practices and farm structures). The environmental and climate delivery framework of the GAEC can be further enhanced by defining additional national standards. To encourage and reward member states who meet their environmental and climate performance targets the European Commission is offering a 5% performance bonus based on the country's allocated funding for 2017.

Eco-schemes.

The future CAP incorporates a new and innovative system, known as '**eco-schemes**', to increase national environmental and climate-care action based on local needs and circumstances. It is mandatory for member states to design and offer one or more eco-schemes. They are however voluntary for farmers to join. The eco-schemes involve an annual 'one-year-at-a-time' commitment making them flexible and attractive for farmers to continue in those schemes that worked best for them and ceasing those that did not. The eco-schemes present a unique opportunity for member states to heavily invest, incentivise, and reward their farmers for going beyond the mandatory and baseline requirements of conditionality and enhance environmental and climate performance based on local needs and conditions.

As the eco-schemes are funded from the national direct payment budget, member states can ensure the schemes accurately match the needs of their local environment and farmers. Payments are based on an annual payment per eligible hectare and could be offered as "top-up" to farmers' direct payments or as stand-alone schemes with payments based on income losses and extra costs incurred by farmers. The schemes could also include 'entry-level' schemes, which could be expanded and enhanced through ambitious rural development measures. Member states may design eco-schemes for agricultural practices such as enhanced management of permanent pastures and landscapes, nutrient management, food and nesting packages for pollinating species, agro-ecology and organic farming.

Agri-environment-climate measures (AECMs).

The AECMs of the future CAP are designed to ensure best environmental and climate practices under the Rural Development framework. They aim to restore, preserve and enhance ecosystems; promote resource efficiency; and move towards a low-carbon and climate-resilient economy. It is important to ensure the types of interventions put in place support specific national, regional, and local needs and, in certain cases, can build on those funded in the eco-schemes. AECM interventions could include: environmentally friendly production systems such as agroecology and agroforestry; forest environmental and climate services; forestry conservation and resilience based on native species; precision farming methods; organic farming; renewable energy and the bio-economy; animal welfare; and sustainable use and development of genetic resources.

As with the eco-schemes, the AECMs are mandatory for Member states to offer and design but are voluntary for farmers and beneficiaries to join. Member states will be required to commit at least 30% of their rural development budget to support environment and climate change action. Member states can enhance this spending by transferring up to 15% of their income support and market measures funding to the rural development one or by national co-financing. Payments are granted to those who voluntarily go beyond baselines mandatory standards to maximize actions for climate change, and protect water quality and availability, air quality, soil health, biodiversity, and ecosystem services.

New way of working.

The new Delivery Model of the future CAP is focused on Performance & Results. Member states will design their CAP Strategic Plan to achieve the EU common environmental and climate change objectives, setting quantified targets and taking specific local needs and conditions into consideration. The CAP Strategic Plan must be consistent with the EU-wide objectives, maintain commonality of the policy, and not distort or burden the single market. Consultation of national bodies, stakeholders, academia, the farming community, and citizens will help identify local environment and climate challenges and develop performance-based measures to address them. Once the plan meets the EU objectives and conditions, the European Commission will approve it.

A new annual monitoring and reviewing framework requires member states to monitor their progress against their targets, adjusting their plan where necessary, and submitting an annual Performance Report. The European Commission will review and make recommendations if necessary. For serious underperformance, the European Commission will suspend payments and work with the member state to help achieve the target. This new approach gives member states the freedom, flexibility, and responsibility to tailor and adapt their approach to local conditions and to show a greater level of ambition to care for the environment and climate.

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Annex 2: SOIL AND WATER BMP IN RELATION TO MAJOR CHINA POLICY INSTRUMENTS.

A.2.1. Conservation tillage action plan in black soil region of the northeastern China (2020-2025).

Source: The ministry of agriculture.
http://www.moa.gov.cn/gk/ghjh_1/202003/t20200318_6339304.htm

The "conservation tillage action plan in soil black region of the northeastern China (2020-2025)" was issued in 2020 by the ministry of agriculture and the ministry of finance. By 2025, more than 9 million ha of arable land will have adopted conservation practices including no-tillage and reduced-tillage to control soil erosion and improve soil qualities.

A.2.2. The pilot program of comprehensive control of soil erosion in black soil region of northeastern China.

Source: Shen, Bo, J. Fan, Q. Pan, L. Hui. Introduction on the pilot programme of comprehensive control of soil erosion in black soil region of northeastern China. Soil and water conservation of China, 2003, 11: 7-8 (published in Chinese).

The beginning of soil conservation in black soil region of the northeastern China was between 2003 and 2005 when a pilot project implementing comprehensive practices of soil erosion control was carried out in 8 river basins with area of 5583.21km2. The total investment was 195 million RMB. For sloping and arable lands The practices included terraces (5870.16 ha), contour ridge planting (39096.59 ha), ridge vegetation strips (23075.72 ha), close hillsides to facilitate afforestation (907.93 km²), and stone and vegetation check dams (13680) for gully control. Three different regions were classified into rolling hilly area, hilly area, and farming-pastoral transitional area for various practices. The dominant practices were ridge vegetation strips and contour ridge planting. These were distributed in arable lands with slopes of 8 to 15 degree and less than 8 degree for the rolling hilly area. Terraces were constructed in land with slopes between15 and 25 degrees. Hillsides for slope lands more than 25 degree were afforested, while wind brake forests, enclosed pasture of rotation grazing were used in the farming-pastoral transitional area.

A.2.3. Programs of comprehensive control of soil erosion in black soil region of Northeastern China.

Source: The ministry of agriculture.
http://nfb.mof.gov.cn/zhengwuxinxi/gongzuodongtai/201701/t20170110_2517626.html

Following the pilot program from 2003 to 2005, from 2008 to 2015 the programs of comprehensive practices for soil erosion control has been supported by the ministry of finance. The total investment was 120 million RMB, and was divided into several stages: learned lessons from the pilot project and the practices implemented in different regions including slope arable land conservation tillage and afforestation.

A.2.4. The Program of gully erosion control for arable land in black soil region of Northeastern China.

Source: The ministry of agriculture.
http://nfb.mof.gov.cn/zhengwuxinxi/gongzuodongtai/201712/t20171219_2781428.html

From 2017 to 2019, there was a focus on the gully control in sloping arable land. The investment was about 29 million RMB for controlling 976 large gullies including check dams, gully slope protection, and gully head protection combing both vegetation and engineering measures.

A.2.5. National pilot program of comprehensive control of soil erosion for sloping arable land.

Source: National development and reform commission, the ministry of water resources.
http://www.mwr.gov.cn/xw/sjzs/201702/t20170212_800196.html

In 2010, the national pilot program of comprehensive control of soil erosion for sloping arable land started covering 50 counties of 16 provinces through the country including terraces, water harvest pool, and irrigation and drainage ditches. During 2010-2012, a total of 98 million RMB was invested for terraces covering 44333 ha of sloping arable land in the southern hilly area of the black soil region in Northeastern China under the support of this program.

A.2.6. National special program of 13th five-year plan for comprehensive control of soil erosion for sloping arable land.

Source: National development and reform commission, the ministry of water resources.

http://www.mwr.gov.cn/xw/slyw/201703/t20170314_880871.html

The national special program of 13th five-year plan for comprehensive control of soil erosion for sloing arable land issued by national development and reform commission and the ministry of water resources. Soil and water conservation of China, 2017, 4: 14 (published in Chinese)

After the national pilot program during 2010-2012 the national special program of 13rd five-year plan for comprehensive control of soil erosion for sloping arable land was issued by both of national development and reform commission and the ministry of water resources. The objective was to build 327300 ha terraces arable lands covering 263 counties in 22 provinces including black soil region of Northeastern China by the end of year of 2020.

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BEST MANAGEMENT

PRACTICES FOR OPTIMIZED USE OF SOIL AND WATER IN AGRICULTURE

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