Best Management Practices to mitigate risk of runoff

a quick start

TOPPS PROWADIS

Best Management Practices

to mitigate risk of runoff

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TOPPS – projects started 2005 with the 3 year funded project from Life and ECPA to reduce losses of Plant Protection Products (PPP) to water from point sources. TOPPS-eos (2010) evaluated technologies on their contribution to optimize the environmental friendliness of sprayers.

The follow up project TOPPS prowadis (2011 to 2014) is focussed on the reduction of diffuse sources. TOPPS – prowadis is funded by ECPA, involves 14 partners and is executed in 7 EU – countries.

TOPPS projects develop and recommend Best Management Practices (BMPs) with European experts and stakeholders. Intensive dissemination through information, training and demonstration is conducted in European countries to create awareness and help to implement better water protection.

TOPPS stands for: Train Operators to Promote Practices & Sustainability (www.TOPPS-life.org).

MITIGATION MEASURES TO REDUCE WATER POLLUTION WITH PLANT PROTECTION PRODUCTS FROM RUNOFF AND EROSION: TOPPS-PROWADIS PROJECT

The use of agro-chemicals for weed management in agricultural systems may represent a potential risk for the contamination of surface (e.g. wells, channels and torrents) and subsurface (e.g. groundwater) water bodies. This may lead to alterations in the equilibrium of aquatic ecosystems as well as a possible deterioration of the quality of water for human consumption.

The causes of water contamination may be due to point or diffuse sources. The former that may result from operations such as the filling, washing and emptying of machinery, have been previously evaluated within the Life project TOPPS and practical indications on their containment provided (www.topps-life.org). On the other hand, diffuse sources may result from superficial runoff caused by the transport of water on the soil surface and subsurface, and drift that occurs during the employment of these products in the field.

The european TOPPS-Prowadis project

TOPPS-Prowadis (acronym of Train Operators to Promote Practices and Sustainability - to protect water from diffuse sources) is a three-year project funded by the European Crop Protection Association (ECPA), that complements the project TOPPS dealing with point sources. The main objective of TOPPS-Prowadis is to develop Best Management Practices necessary to prevent the diffuse pollution of surface waters by Plant Protection Products. It also aims to favour the application of these guidelines through information, demonstration and training activities directed towards stakeholders and end-users at national and European levels. Project partners include research institutions from 7 EU countries (Italy, Spain, France, Belgium, Germany, Denmark and Poland).

The initial phase of the project will involve the gathering and evaluation of documentation regarding the phenomenon of diffuse pollution of water by plant protection products, the most common practices adopted in the farms to mitigate losses of such products to the environment, the studies carried out so far and current national legislation on this topic. In each partner country, a questionnaire will be presented to end-users in order to provide a detailed evaluation of the current situation in terms of sensibility towards and knowledge of the risk of contamination of waters by agrochemicals, the mitigation strategies currently adopted, and the management techniques and practices used on farms.

With reference to runoff, the development of diagnostic measures for the environmental, operative, pedoclimatic and topographic characteristics that may influence the transport and environmental fate of plant protection products, will allow for the definition of more effective technical, operative and agronomic measures for mitigating the risk of water contamination. These measures will represent the Best Management Practices defined by TOPPS-prowadis for the prevention of water pollution from runoff. Formation courses for end-users as well as demonstration sites will be organized for an effective dissemination of these practices.

This project will also provide for the identification of an area at watershed level in each partner country (Demonstration Catchment Areas), in which a detailed analysis of the potential risk of runoff and the most appropriate mitigation measures to adopt at farm level will be evaluated. For this, geographical and territorial information systems (GIS/TIS) will also be adopted. The activities that will be carried out in the Demonstration Catchment Areas will be disseminated among end-users through specific training sessions that will allow for the sharing of appropriate know-how in order to enable the transfer of these measures to other territories.

The outcomes of TOPPS-prowadis are perfectly in line with the objectives of the national Directive on the sustainable use of pesticides (Directive 128/2009), and will therefore provide an important contribution to improve the awareness of end-users towards this subject, and transfer know-how to end-users regarding the most appropriate mitigation strategies specific to the operative conditions present, to limit diffuse contamination of superficial water bodies.

RUNOFF

Types of runoff

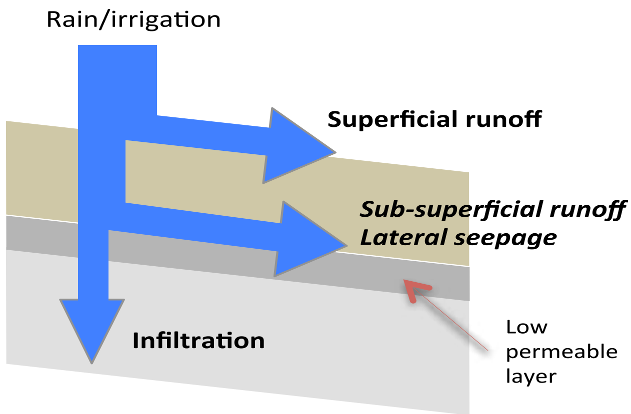
Runoff is the water movement over the soil surface and in the subsurface layers. Runoff cause transport of substances dissolved in the water and eroded soil particles. Runoff may thus transfer nutrients and pesticides to superficial water bodies, while erosion determine heavy transport of soil particles causing rills and gullies.

There are three types of runoff:

1) **Runoff by soil infiltration restrictions:** it occurs when the rain intensity excess the water infiltration capacity of a soil. This type of runoff is sometimes caused by presence of a low permeable layer formed on the soil surface (e.g. capping). A special case is the thawing of frozen soil, where an impermeable layer is present (the frozen soil), at the same time as excess water is being released. This can lead to both runoff and erosion.

2) **Runoff by soil water saturation:** it occurs when the soil is saturated with water. In this case, no additional water can infiltrate into the soil and excess water will exit the soil due to ponding in topsoil on an impermeable subsoil layer ("bucket is full"). Runoff by saturation is more a soil water capacity problem and occurs if total rainfall exceeds water-holding capacity.

3) **Concentrated flow runoff:** it occurs when water accumulates into small water streams due to structures related to the soil management (e.g. large fields, tramlines along slopes, etc.) or to the landscape (slope, talweg, soil characteristics). Concentrated flow is generally easily visible as it goes often along with erosion, a severe form of high intensity surface runoff. Erosion favours the transfer of soil particles with the runoff water and substances bound to soil.



General key factors determining the risk of pesticide transfer with water runoff

Runoff and the risk of pesticide transfer to the surface water bodies are affected by several factors. The most important are:

- **Connection to surface water:** the longer the distance of a sprayed field to surface water, the lower the risks of pesticides transfer with runoff / erosion. Also speed of runoff water which is leaving the fields towards water courses, and potential concentrated flow pathways (e.g. roads, talwegs, short cuts through pipes) need to be considered.
- **Soil characteristics:** soil properties influence infiltration of water and adsorption/dissipation of pesticide. Infiltration of water into the soil reduces or eliminates the runoff water and erosion risk at the source. The longer the pesticide is in direct contact with the soil (micro organisms in particular) the higher can be the potential degradation of the pesticide and therefore reduces the risk of transfer. Water movement in the deep soil layers is generally much slower than surface water flow.

DIAGNOSIS

- **Weather pattern and climatic conditions (intensity, frequency):** representative weather patterns (rain events) need to be defined to propose and prepare for appropriate mitigation measures.
- **Shape and length of the slope:** fields with steep and long slopes are more prone to runoff and erosion. Big fields may require a division of their size by in field buffers or bunds to reduce the risk of water accumulations (concentrated flow), which favour erosion.
- **Soil cover**: if soils are covered by vegetation (grassland, meadows) the risk of runoff and erosion is low, while arable crops in their early development stage leave the soil highly exposed to the rain causing a higher risk of runoff and erosion.
- **Characteristics of pesticides:** the risk of pesticide transfer to water bodies for runoff is mainly linked to the persistence of the product and its characteristics of solubility and adsorption, affecting its mobility in the soil.

Runoff risk mitigation

Mitigation of runoff risk can be obtained through selection and implementation of specific **mitigation measures** according to types of runoff and level of risk associated to it. After a careful preliminary analysis of the runoff risk, is possible to define the most appropriate measures to the specific context in which operate.

Analysis of risk of runoff is performed through an accurate **diagnosis** of factors influencing runoff and erosion. This diagnosis should be carried out both on a regional scale (diagnosis at catchment level) both on a single plot (diagnosis at the field level). The catchment scale approach is essential as runoff is a phenomenon that can lead to consequences also at great distance compared to the area in which it is generated. In addition, mitigation measures are fully effective only if applied at territorial level.

A. CATCHMENT DIAGNOSIS

Diagnosis at catchment level consists of identification of water flow at catchment scale mainly using cartographic information. To develop this diagnosis, collection of all available territorial information such us field map, water network, soil map, slope, climatic characteristics and adopted soil management and cropping practices is required. Main information necessary to determine the risk of runoff are:

- Water network.
- Field map and field size.
- Soil map (soil texture, depth of soil).
- Slope of the land from Digital Terrain Model.
- Weather data (rain pattern, rain events, statistics).
- Soil water holding capacity, if available.
- Permeability of the topsoil, if available.

The acquired set of geographical information should be analyzed by using GIS software in order to develop a map of transfer risk containing the classification of soil units according to the risk of runoff and erosion. In order to validate these information and assess effective risk of runoff and erosion, a field diagnosis is required.

B. FIELD DIAGNOSIS

Field diagnosis consists of validation, at field scale, of information obtained from catchment diagnosis, including soil and hydrographical characteristics. This diagnosis, to be performed by field survey to the examined area, also allows to collect any missing information (e.g. presence and efficacy of adopted mitigation measures, crops) and to identify specific risk situations (signs of runoff and erosion). In particular, some factors need to be considered to determine the water pathways in the fields and to apply dashboard for assessing runoff risk:

- Proximity of field to the water bodies (adjacent, not adjacent).
- Soil water holding capacity (estimable in field from soil texture).
- Slope of the land (using DTM or estimation in field).
- Permeability of the topsoil (estimable in field from soil texture).
- Discrete subsurface restriction (presence of plough pan or other infiltration restrictions).
- Landscape situation (shape of the valley, tile drainage).
- Transfer of runoff to downhill fields or water body.
- Signs of concentrated runoff in the field.
- Presence of concentrated runoff in: wheel tracks, in field corner and in field access area.
- Presence of moderately concentrated runoff in: rills, talweg.
- Presence of strongly concentrated runoff in: gully not in talweg or gully in talweg.
- Hydromorphic characteristic of soil: hydromorphic or not hydromorphic.
- Soil infiltration capacity in buffer: high or low.
- Signs of capping on soil surface.
- Presence of infrastructures: drainage systems, buffer zones, retention structures, talweg.
- Soil management and cropping practices: crop, soil covering, crop rotation and distribution, intensity of tillage and surface roughness.

Field methods and decision tree techniques have been developed to reduce complexity and to support correct decision-making. The dashboards are intended to support the diagnosis process and should help to determine the risk level for runoff in a specific field. Three decision levels need to be addressed to define the runoff risk levels: Very low/Negligible risk (green), low risk (yellow), medium risk (orange) and high risk (red).

In the BMP part, scenarios are described for the different situations that are linked to the determined risk levels. These scenarios are described in this document in general and may need to be adapted to the local situation (farming practices, climatic conditions and other factors). Depending on the local situation the farm adviser will propose mitigation measures listed in the Mitigation measures section addressing the different mitigation efficiency needs.

Three dashboards have been developed according to type of runoff:

- **Assessment of runoff risk due to infiltration restrictions - DASHBOARD 1**
- **Assessment of runoff risk due to saturation excess - DASHBOARD 2**
- **Assessment of runoff risk due to concentrated flow - DASHBOARD 3**

It is recommended to always use both dashboard 1 and dashboard 2 in the field, because both runoff types can in principal be relevant. Dashboard 3 need to be applied only with traces of concentrated flow in the field.

Combination of diagnosis and mitigation measures adapted to the specific risk conditions, defines the set of best management practices to mitigate risk of runoff in a given context.

With aim to support diagnosis operation in field, examples of fieldforms were attached to this document in the ANNEX section. In particular, are reported:

Annex 1 - **Fieldform SURVEY**, checklist of information necessary to apply dashboards.

Annex 2 - **Fieldform WHC**, to estimate Water Holding Capacity (WHC) from soil texture.

Annex 3 - **Fieldform TEXTURE**, to estimate soil texture by feel analysis.

Dashboard to assess the risk for runoff due to infiltration restrictions - DASHBOARD 1

Step 1 – Proximity of Field to Water Body		Step 2 - Slope of the Land	Step 3 – Permeability of the Topsoil		
			High	Medium	Low
	Adjacent	Steep (>5%)	I3	I4	I7
		Medium (2-5%)	I2	I3	I6
		Shallow (<2%)	I1	I2	I5
	Not Adjacent	***Step 4 – Transfer Likelihood*** Diagnose likelihood of runoff transfering downhill to the next field and then to surface water	Downhill Transfer Unlikely		T1
			Transfer Likely but not to Surface Water		T2
			Transfer Likely to Surface Water		T3

Risk level: Very low Low Medium High

Scenarios: T = Transfer; I = Infiltration restriction.

Permeability assessment

Low permeability: capping soil or clayey and loamy soils (>30% clay , < 30% sand) or swelling clay – (> 25% clay). Medium permeability: non capping soil and other soil structures. High permeability: non capping soil and sandy and sandy loam soil < 20% clay, > 65% sand or loamy and silt soils (sand +silt > 65%) good aggregate structures and high organic matter > 3% or non-swelling clays (< 25% clay).

Runoff for infiltration restrictions (DASHBOARD 1): BMP for risk mitigation

T1: Maintain good agricultural practices on field to minimize runoff and erosion.

T2: Maintain good agricultural practices on field to minimize runoff and erosion and in case of large amount of runoff: stop at source to avoid fast infiltration in downhill plot (ground water protection). If runoff transfer to downhill plot is not acceptable, treat plot as if adjacent to water.

T3: Stop runoff at source using in-field measures and/or edge-of-field buffers or ensure water infiltration in downhill plot by suitable measures (buffers, retention structures). In case of large amount of runoff: stop at source to avoid fast infiltration in downhill plot (ground water protection).

In case of large amounts of runoff, stop it at source to avoid transfer to downhill plot (ground water protection).

T3: Frozen soil: Implement buffer zones (hedges, woodlands) and/or wetlands across the slope or alongside watercourses.

I1: Stop runoff at source using in-field measures and/or edge-of-field buffers or ensure water infiltration in downhill plot / area by suitable measures (buffers, retention structures). In case of large amount of runoff: stop at source to avoid fast infiltration in downhill plot (ground water protection).

I2: Reduce runoff at source using suitable in-field measures. If this is not possible, consider implementation of buffer zones (edge-of-field, in-field).

I3: Reduce runoff at source by using all suitable in-field measures. Furthermore, implement buffers (in-field, edge-of-field) or suitable measures at landscape level (e.g. talweg buffers, retention structure), especially for fields with spring crops, or when in-field measures not viable.

I4: Minimize risk for runoff and erosion with all viable in-field measures, edge-of-field buffers, and landscape measures (buffers, retention structures). Combine effective measures to achieve maximum mitigation.

I5: Reduce runoff at source by using all suitable in-field measures. Implement buffers (in-field, edge-of-field) or suitable measures at landscape level (e.g. talweg buffers, retention structure), especially for fields with spring crops, or when in-field measures not viable.

I6: Minimize risk for runoff and erosion with all viable in-field measures, edge-of-field buffers, and landscape measures (buffers, retention structures). Combine effective measures to achieve maximum mitigation.

I7: Minimize risk for runoff and erosion with all viable in-field measures, edge-of-field buffers, and landscape measures (buffers, retention structures). Combine effective measures to achieve maximum mitigation.

Dashboard to assess the risk for runoff due to saturation excess - DASHBOARD 2

Step 1 – Proximity of Field to Water Body		WHC *	***Step 2 – Landscape Situation***	***Step 3 – Discrete Subsurface Restriction***		
				None	Pan or Other	Pan + Other
	Adjacent	<120 mm	Valley Floor / Concave Slope	S3	S4	S4
			Upslope Concave / Straight Slope	S2	S3	S4
			Tile Drained	SD2	SD3	SD3
		>120 mm	Valley Floor / Concave Slope	S2	S3	S4
			Upslope Concave / Straight Slope	S1	S2	S4
			Tile Drained	SD1	SD2	SD3
	Not Adjacent	***Step 4 – Transfer Likelihood*** Diagnose likelihood of runoff transfering downhill to the next field and then to surface water		Downhill Transfer Unlikely	T1	
				Transfer Likely to Surface Water	T2	
				Transfer Likely but not to Surface Water	T3	

Risk level: Very low; Low; Medium; High

Scenarios: S = Soil saturation; T = Transfer; D = Artificial drainage.

*WHC = Water Holding Capacity

Runoff for saturation excess (DASHBOARD 2): BMP for risk mitigation

T1: Maintain good agricultural practices on field to minimize runoff and erosion.

T2: Maintain good agricultural practices on field to minimize runoff and erosion and in case of large amount of runoff: stop at source to avoid fast infiltration in downhill plot (ground water protection). If runoff transfer to downhill plot is not acceptable, treat plot as if adjacent to water.

T3: Stop runoff at source using in-field measures and/or edge-of-field buffers or ensure water infiltration in downhill plot by suitable measures (wetland; ponds), retention structures). In case of large amount of runoff: stop at source to avoid fast infiltration in downhill plot (ground water protection). In case of large amounts of runoff, stop it at source to avoid transfer to downhill plot (ground water protection).

S1: Maintain good agricultural practices on field to minimize runoff and erosion.

S2: Reduce runoff at source using suitable in-field measures. If this is not possible, consider implementation of buffer zones (edge-of-field, in-field). See D* for drainage risk and G** for groundwater risk.

S3: Reduce runoff at source by using all suitable in-field measures. Furthermore, implement buffers with willow (salix) hedges or suitable measures at landscape level (e.g. talweg buffers, retention structure), when in-field measures not viable. See D* for drainage risk and G** for goundwater risk.

S4: Minimize risk for runoff and erosion with all viable in-field measures, edge-of-field buffers (buffers with willow (salix) hedges), and landscape measures (buffers, wet meadow, retention structures, wetlands). Combine effective measures to achieve maximum effect. If valley bottom or floodplain, see G** for leaching risk to groundwater.

SD1: Maintain good agricultural practices on field to minimize runoff and erosion. Risk of transfer via drainage water: Avoid application of susceptible pesticides during drainflow season (late autumn to early spring) and on cracked soils (spring/summer). If possible, retain drainage water in artificial wetlands/ponds.

SD2: Reduce runoff at source using suitable in-field measures. If this is not possible, consider implementation of buffer zones (edge-of-field, in-field). See D* for drainage risk and G** for groundwater risk.

SD3: Reduce runoff at source by using all suitable in-field measures. Furthermore, implement buffers with willow (salix) hedges or suitable measures at landscape level (e.g. talweg buffers, retention structure), when in-field measures not viable. See D* for drainage risk and G** for goundwater risk.

D* = Risk of transfer via drainage water: Avoid application of susceptible pesticides during drainflow season (late autumn to early spring) and on cracked soils (spring/summer). If possible, retain drainage water in artificial wetlands/ponds.

G * = Risk of transfer to groundwater in alluvial floodplain. Follow product-specific advice to minimize inputs to vulnerable areas (shallow groundwater, sandy soils with low organic carbon).

Dashboard to assess the risk for runoff due to concentrated flow - DASHBOARD 3

<table>
<tr><td rowspan="11">Runoff generated in the audited field?</td><td>No</td><td colspan="2">Runoff coming from uphill area in the catchment</td><td>C1</td></tr>
<tr><td rowspan="10">Yes</td><td colspan="2">Runoff Concentrating in Wheel tracks</td><td>C2</td></tr>
<tr><td colspan="2">Runoff concentrating in corner</td><td>C3</td></tr>
<tr><td colspan="2">Runoff concentrating in field access area</td><td>C4</td></tr>
<tr><td rowspan="2">Runoff moderately concentrated in rills</td><td>No hydromorphic soil</td><td>C5</td></tr>
<tr><td>Hydromorphic soil</td><td>C6</td></tr>
<tr><td rowspan="2">Runoff moderately concentrated in talweg</td><td>No hydromorphic soil</td><td>C7</td></tr>
<tr><td>Hydromorphic soil</td><td>C8</td></tr>
<tr><td colspan="2">Runoff strongly concentrated - Gully not in talweg</td><td>C9</td></tr>
<tr><td rowspan="2">Runoff strongly concentrated Gully in talweg</td><td>High infiltration soil in buffers</td><td>C10</td></tr>
<tr><td>Low infiltration soil in buffer</td><td>C11</td></tr>
</table>

Risk level: High

Scenarios: C = Concentrated runoff.

Runoff for concentrated flow (DASHBOARD 3): BMP for risk mitigation

Presence of concentrated flows within the field identify a high risk of runoff and erosion, so it is always necessary to apply mitigation measures to reduce such risks. It is therefore considered, for all cases, a high risk of runoff.

C1: Prevent concentrated runoff at source uphill in catchment: Make runoff risk audit of the field where runoff is generated. In addition, buffers and retention structures may be needed to intercept any concentrated runoff downhill (see right-hand side of dashboard).

C2: Manage tramlines. Practice double sowing in headlines. Enlarge headlands.

C3: If soil is not hydromorphic: Implement buffer zones in corner of field. If soil is hydromorphic: Implement edge-of-field bunds; Construct retention ponds.

C4: Manage field access area.

C5: If buffer doesn't exist, implement edge-of-field buffer zones. If edge-of-field buffer exists, widen buffer, and/or implement fascines, hedges /hedgerows or retention structure. If possible, divide field with in-field buffer upslope.

C6: If buffer doesn't exist, Implement wide edge-of-field buffer zones (wet meadow). If edge-of-field buffer exists, widen buffer zone further (wet meadow) and/or implement wetland. If possible, divide field with in-field buffer upslope.

C7: If vegetated talweg buffer doesn't exist, do double sowing or establish vegetated talweg buffer (at the bottom), vegetated ditch or slow infiltration retention pond. If vegetated talweg buffer already exists, widen talweg buffer upslope, establish vegetated ditch or retention pond. If possible reduce slope length (strip cropping, in-field buffer) upslope where concentration of runoff starts.

C8: If no vegetated talweg buffer exists, implement vegetated talweg buffer or vegetated wetland downslope in talweg. If vegetated talweg buffer exists, widen talweg buffer (wet meadow) and/or construct artificial wetland as retention structure.

C9: Close gully. If edge-of-field buffer doesn't exist, implement buffer AND Implement fascines or retention structure. If edge-of-field buffer exists, implement fascines or retention structure.

C10: Close gully. If no buffer exists, implement vegetated talweg buffer. If talweg buffer exists, widen talweg buffer upslope and implement vegetated ditch or retention pond for slow infiltration.

C11: Close gully. If talweg buffer doesn`t exist, implement vegetated talweg buffer and /or Wetland or meadow. If talweg buffer exists, widen talweg buffer and implement with fascines, and/or implement wetland or meadow.

Mitigation measures

Mitigation measures to reduce risk of runoff are presented in this document by six categories:

- **A. Soil Management**
- **B. Cropping practice**
- **C. Vegetative Buffer Strips**
- **D. Retention and dispersion structures**
- **E. Correct PPP use**
- **F. Irrigation**

Before proposing and implementing mitigation measures always check that they are appropriate for the crop protection and tillage system of a farmer. Modifications of soil tillage or cropping practices should take into account all issues to be addressed: soil, climate, materials, technology, weeds, pests, crop yields, crop quality and commercial factors.

It should be noted that the mitigation measures included in this document were defined within TOPPS-Prowadis project aimed to have a general validity for the European countries. Some measures are unlikely to be adopted in all countries, but are reported for completeness.

A. SOIL MANAGEMENT

Soil management influence the water infiltration capacity of the soil, therefore it affects superficial and sub-superficial runoff. Aim of these measures is to keep the water in the field and to avoid runoff at the source, by breaking the soil compaction and increasing the soil porosity (water holding pores, aggregation).

Reduced tillage, crop rotations and cover crops are the three core practices in conservation agriculture.

1. Reduce tillage intensity

Allow to reduce runoff by acting on soil characteristics: improved pore continuity in the topsoil, increases crop residues left on the soil surface, reduces the slaking effect of raindrops on uncovered soil surfaces and increases the biological activity in the topsoil layer.

How to do

Change the tillage system: from ploughing to reduced-tillage or no-till; reduce energy of the machinery / tools working the soil; reduce number of passages and driving velocity.

2. Prepare rough seedbed

Rough seedbeds with clods increase the infiltration of water into the soil and can slow down the flow of the runoff water. The soil clods also avoid the "splash-effect" of the rain droplets, which can break the silty fine aggregates and reduce the infiltration capacity of the soil surface (capping).

How to do

Preserve coarse aggregates by reducing tillage to a minimum when preparing the seedbed and do not roll over after drilling.

3. Avoid surface soil compaction (capping, soil crusts)

Mainly soils with high silt content (> 30%) are prone to capping after rains. Soil crusts reduce the infiltration capacity of the soil and therefore represent a high-risk situation for runoff and erosion.

How to do

Improve topsoil aggregation and thus reduce the tendency of soils to crust by maintaining high organic matter content and reducing topsoil compaction. If the formation of crusts or capping layers cannot be avoided, the crusts need to be broken mechanically.

photo Francesco Vidotto

Also not compacted soil can lead to runoff for reduced infiltration caused by capping.

4. Avoid subsoil compaction

Subsoil compaction (e.g. plough pan) can be a barrier for water infiltration and a reason for subsurface runoff (lateral seepage or runoff by saturation).

How to do

Avoid ploughing or harvesting when the soil is too moist and use low-pressure tires or twin tires to prevent soil compaction. Subsurface compaction can be broken mechanically by ripping) or by growing plants with taproots.

photo Ellen Pauwelyn

Use of tires with a low imprint area may also cause the compaction of the soil at a certain depth, favoring runoff for boith reducted infiltration and saturation.

5. Manage/orient tramlines

Tramlines are crop free areas in the field, where the tractor drives to spray and to fertilize the crop. During a season, machines will travel on the tramlines several times, which can result in soil compaction. If the tramlines are oriented in the direction of the slope they work like channels for runoff water and soil erosion.

How to do

Alternate the orientation of tramlines after each cropping season (reduces hotspot compaction) and run it across the slope (avoid channel effect). This can be difficult to achieve, if there is more than one slope direction in the field or slope creates risk for machinery overturns. Reduce pressure in tires or use low-pressure and twin tires on machines.

photo Klaus Ghering

Tramlines created by machines may result in runoff for reducted infiltration as well as being preferential pathways for concentrated flows.

6. Create bunds in the field (contour bunding)

A bund is a barrier / small dam in the field which retains water in the field and slows down the water flow in order to allow more water infiltration. In row crops like potatoes, bunds between the ridges have shown good effects to mitigate runoff. Special machines are available, which make such bunds when preparing / maintaining the ridges. Bunds are especially important when the crop does not yet cover the soil surface completely, and mainly work in fields with slight slopes.

How to do

In field bunds should be made across the field slope and follow contour lines. The distance and height of bunds needs to be adapted to the expected water flow volume in the furrow.

MITIGATION MEASURES

7. Implement contour tilling

Contour tilling is a soil cultivation following the contour lines to redirect water flowing downhill. This creates rough surfaces acting as small bunds to slow down water flow and increase water infiltration.

How to do

Examine carefully the fields on their suitability for contour tilling (rather uniform slopes, not to steep) and machinery or equipment necessary to follow the contour lines during the farming operations (tractor with wheels vs. crawler, GPS systems).

B. CROPPING PRACTICES

Cropping practices can strongly reduce the risk of runoff and erosion by improving the soil structure and stability. The goals are to balance physical-chemical soil properties through crop rotation, crops with deep root systems, plant cover or organic matter cover to reduce rain splash erosion, reduce the field size and distribute crops in the catchment.

8. Optimize crop rotation

Crop rotation is the succession of crops on the same field with the main goal of maintaining soil fertility and crop productivity over the years. The crop rotation influences largely the organic matter content in the soil which supports soil structure, soil aggregates, improve the soil water holding capacity and increases the microbiological activity and therefore the degradation and sorption of pesticides.

How to do

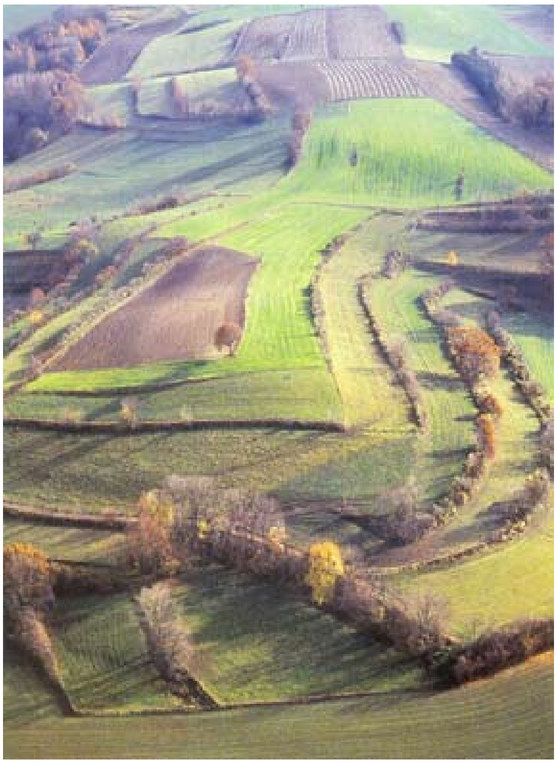
Alternate between crops providing a dense soil cover (e.g cereals, oilseed rape) on risky fields and periods, and leave organic residues after harvest on the field surface.

9. Implement strip cropping in field (across the slope)

Strip cropping in a large field can be seen as a measure to downsize the field by growing different crops on such a field. Strips of row crops e.g. potato, sugar beet, maize followed by a broadcast crop (e.g. winter cereals, oilseed rape or others) reduce water flow, increase infiltration and trap sediments. In semiarid areas a strip of fallow land sometimes follows a strip of a crop in order to collect and store water in the soil. The crop strips follow as much as possible the contour lines in the field and function as annual in field buffer strips.

How to do

Divide large fields vulnerable to runoff and erosions by planting different crops in strips along the contour lines. Requirements and restrictions are widely comparable with those mentioned under contour tilling.



Presence of different crops, arranged on plots oriented along the contour lines, disadvantage formation of runoff at source. Best results are obtained by using crop rotation in order to have a mosaic of plots with different vegetation covers.

10. Plant annual cover crops

Use of intermediate cover crop after harvest and before sowing a new commercial crop allow to reduce rainfall impact, increase soil organic matter, improve aggregate stability and splash resistance, and increase soil resistance to compaction.

How to do

Promote a fast and dense establishment of the cover crop and plant it across the slope. Sowing into a ripening crop or after harvest into the stubble. When destroying cover crops, leave vegetal residues on field to protect the soil.

11. Implement double sowing

When diffuse runoff is observed on a field, a strip with a higher plant density of a crop can reduce the volume of surface runoff water, without implementing a non-crop buffer strip (works like an annual crop buffer strip).

How to do

The double-sowing is done in a strip across the slope or in a talweg in addition to the first sowing process. The placement of the double-sowed strip follows in principle the same methodology as in-field vegetated buffer strips.

12. Establish perennial cover crops in plantations

Perennial cover crops protect and shade the soil, increase the soil porosity, slow down the water flow, increases the infiltration of water and traps runoff and erosion sediment.

How to do

Establish perennial cover crops between the crop rows and maintain the cover by mowing to control the height of the crop (10 to 15 cm). If cover crops cannot fully cover the soil surface bring in additional organic materials to cover the soil.


photo Francesco Vidotto

Cover crop in the vineyard allows to reduce runoff at source and to mitigate any water flow from uphill.

13. Enlarge headlands

Headland cultivated in a perpendicular direction to the rest of the field may serve as a cropped barrier for water running down slope.

How to do

Enlarge the headland if field has been diagnosed as having a higher runoff risk. Double sowing of the headland might be an option to further increase the mitigation effect of the headland (buffer strip).

C. VEGETATIVE BUFFER STRIPS

Vegetative buffers can be considered as infrastructure measures, established for several years, to provide infiltration areas for surface runoff water, to slow down surface runoff water through an appropriate vegetation, to provide habitats to increase biodiversity, to trap eroded sediment and reduce overall amount of water leaving the field. The main aim of vegetated buffer zones is to intercept runoff from cultivated plots upslope, therefore their positioning in the catchment is crucial.

Buffer zones should be preferentially located at sites near the origin of any diffuse runoff (ideally before any formation of concentrated runoff), in the upstream parts of the catchment, and sized basing on the water flow regime, the soil permeability and saturation, the slope and the slope length. The right positioning of the buffer in the catchment is usually more important for its efficiency to reduce runoff, than its width. A buffer aiming to stop primarily eroded soil particles can be smaller than one with the aim to intercept runoff water and its dissolved pollutants.

Schematic representation of a catchment and buffer zone positioning

(Source: CORPEN / IRSTERA Modified):

1: In-field buffer, used to break up a long slope inside a cultivated field.

2: Edge of field buffer zone, protecting a road (potential water pathway).

3: Edge of field buffer zone in down slope corner of a field, where water is concentrating.

4: Grassed talweg, to reduce concentrated water flow.

5: Large grassed buffer zone (i.e. meadow), used to intercept, disperse and infiltrate concentrated water flow exiting from the upslope talweg.

6: Riparian Buffer. Grassed buffer strip between edge of field and a surface water body, to intercept diffuse runoff from the upslope field.

For grassed buffers a regular mowing of the grass is necessary. The average height of the grass should be around 10 cm and the maximum height should not exceed 25 cm to maintain erect grass leaves. Soil compaction needs to be avoided, by limiting the traffic of machinery to the minimum possible.

14. Establish and maintain in-field buffer

In-field buffers can be very efficient as they can infiltrate runoff water in the soil coming from uphill areas, when the amount of runoff water is still relatively small.

How to do

Locate and size the buffers following as much as possible the contour lines in the field and positioning in a way that no concentrated flow develops (rather uniform slope/ no talweg). Shortcuts for water through buffers (e.g. via tramlines or tracks) should be avoided. In-field buffers can be set-up as grassed buffer or hedges, depending on desired additional functions that hedges may provide (wind shield, biodiversity, etc.).

15. Establish and maintain edge-of-field buffer

Edge-of-field buffers are located at the down slope end of a field, often separating a field from the next or from a road. The function of the buffer is to infiltrate runoff water in the soil and to trap sediments, before runoff water reaches a road or enters into a downhill field.

How to do

Locate the grassed buffers following the contour lines and preventing concentrated runoff. Avoid shortcuts for water through buffers (e.g. via tramlines or tracks) and provide a dense vegetation cover on the buffer.

photo Ellen Pauwelyn

Buffer strips at the edge of fields are designed to prevent transfer of runoff flow from plot to another one.

16. Establish and maintain riparian buffer

Riparian buffer strips are buffer zones of managed or unmanaged vegetation situated alongside watercourses or ditches. These buffers reduce runoff by infiltrating water in the soil and trap sediment by reducing the water flow speed. Additionally, riparian buffer strips are efficient structure to stabilize the river banks, improve ecological conditions in streams, increase biodiversity and give contribute to ecosystem connectivity (green corridors in catchments) and catchment diversity.

How to do

Smaller ditches and streams (permanent or non-permanent) are often only protected by grassed buffer strips, while for larger streams and rivers woody vegetation becomes more important to achieve all protection goals. Locate and choose grassed buffers according to the mitigation objective. Use natural vegetation (non-invasive) adapted to the local condition and having stiff leaves to resist the water flow, and provide a dense vegetation cover. Do not fertilize, spray or use as a pathway for machinery.

photo Francesco Vidotto

Riparian buffer are located close to the river.

17. Establish and maintain talweg buffer

A talweg describes a situation where two different slopes come together to define a linear indention structure in a catchment (dry valley, hollow). These talwegs may collect water from adjacent slopes during rain events what may lead to concentrated (linear) water flow.

How to do

Establish vegetative buffers (i.e. meadows) in the talweg. Large talweg buffers and hedges are needed in situations where the runoff and erosion risk is high and average weather pattern result in big amounts of runoff water entering the talweg from upslope.

photo Francesco Vidotto

Talweg may lead often to concentrated runoff.

18. Establish and maintain hedges

Hedges alongside water bodies or as upslope catchment elements can provide a lot of benefits to the environment. They serve as efficient windbreaks, improve the microclimate, stabilize riverbanks, and provide habitat for wildlife. Hedges also have important agronomic functions like the infiltration of runoff water from the fields, trapping of soil particles from erosion and to intercept pollutants transferred by wind.

How to do

Hedges should be planted along the catchments contour lines on narrow grassed zones (minimum of 2 m), increasing its efficiency to reduce runoff compared with a hedge alone. The hedge should be planted in the middle of the grassed zone, rather than on one side of it. Carefully prepare the soil to allow root development of the selected bush/tree species, select regional and robust bush/tree species to achieve a vital and resilient hedge and cut it back regularly, particularly in the first years

.

photo Francesco Vidotto

Hedges at the edge of a field few years after plantation.

19. Maintain woodlands

Woodlands are efficient to achieve infiltration of runoff water from fields, trapping of soil particles from erosion and to intercept pollutants transferred by wind. They also provide additional benefits to the environment: serve as efficient windbreaks, improve the microclimate, stabilize river banks and provide habitat for wildlife.

How to do

Ideally, woodlands should be established on steep slopes or the downslope areas in catchments near streams. Shortcuts for water through woodlands via paths or roads in downslope direction should be avoided, if possible.

20. Manage field access areas

Field access areas are potential water pathways where concentrated water flow may start to form, especially in the down slope position of a field.

How to do

Use gravel or coarse stones to fortify the direct machinery travel tracks. Thereafter sow a robust grass species, which is deep rooting, sediment tolerant and traffic resistant. Smooth and recessed wheel tracks on the access area should be avoided, as these will serve as water channels for runoff from the field.

photo Francesco Vidotto

Access areas may be potential water pathways and favour concentrated runoff. This is often associated with significant erosion in declivous areas.

D. RETENTION AND DISPERSION STRUCTURES

Retention and dispersion structures are constructed in the catchment to reduce and slow down the concentrated flow runoff, to disperse and promote water infiltration in the soil and to limit water entering in a down slope field.

21. Establish or maintain vegetative ditches

Vegetated ditches are created to capture, evaporate and infiltrate runoff (or drainage) water and retain eroded sediment, in order to protect downstream areas.

How to do

Sizing vegetated ditches to capture the runoff water and eroded sediment of at least the typical runoff event on site. Limit or slow down exchange between vegetated ditches and groundwater, establish local species (non-invasive) adapted to irregular inundation and remove sediments to maintain the water retention capacity at an adequate level.

22. Establish or maintain retention ponds and artificial wetlands

Retention structures are created to protect downstream areas by retaining runoff water and transported sediments (concentrated flow), as well as water discharged from artificially drained areas, by supporting infiltration and evaporation.

How to do

Sizing wetlands to capture the runoff water and eroded sediment of at least the typical runoff event on site. Limit exchange between artificial wetlands and groundwater and develop some kind of natural vegetation. Optimize residence time of the water detained in the retention structure by using e.g. weirs or barriers within the structure.

23. Establish or maintain edge of field bunding

Edge of field bunding is a small embankment or dam of soil at the lower edges of the field to keep runoff and erosion, which works by halting the movement of runoff and its sediment load, which enables water infiltration and sediment deposition.

How to do

Dig the soil up on the outer edge of the field and pile it up as bund with a breadth of 30-50 cm and to the required height and distance up the field edges. Size the heights and distances of the bunds according to the estimated volume of runoff.

24. Implement dispersive constructions

Dispersive constructions are artificial structures, including fascines and mini-dams, of logs/branches/stones, erected to disperse concentrated surface runoff, to disperse and slow down the water flow, to limit erosion and capture transported sediments.

How to do

Fascines are constructed from bundles of branches between wooden logs, and are established across the slope to cut off pathways of concentrated runoff water. They are permeable to water, but slow down its flow considerably, disperse the water and thereby leading to sedimentation of eroded soil. Mini-dams consist of stones and wooden logs, and are established at the mouth of the streamlets and are constructed on the entire section of the streamlet by connecting the wooden logs with the riverbed and the banks.

photo Ellen Pauwelyn

Fascines properly positioned may be valid dispersion structures able to maintain their high effectiveness for many years.

E. CORRECT PPP USE

PPP registration addresses risks associated with applications of the PPP in relation to environmental and human safety aspects. Related to water protection, these PPP evaluations may result in regulatory requirements listed on product labels to mitigate predicted exposure concentrations in surface water following drift, runoff and / or drainage events. Correct use of PPP include also regular checks and precise calibration of the spray equipment.

25. Optimize PPP application timing

Key points need to be considered to reduce risk of water contamination from pesticide use: do not apply products when significant rainfall is forecasted, do not apply PPPs on saturated soils or fields where the water is flowing from drains, reduce the number of applications and the amount of applied PPPs to the necessary minimum.

How to do

Indicate or mark field areas, where application restrictions need to be respected according to your PPP selections, study PPP label carefully if application timing requirements in relation to rainfall exist, check weather forecast (the first rain event after application is the most critical one) and check soil water saturation levels.

26. Optimize seasonal PPP application timing

To reduce risk of water contamination, study PPP label carefully and select appropriate PPP according to the time window for application. If possible, apply pesticides outside of main groundwater recharge / drain flow season.

How to do

Indicate or mark field areas where application restrictions need to be respected according to your PPP selections. Limit spraying as far as possible late in autumn or early in spring, when soils are typically (almost) saturated with water or water flows from artificial drains.

27. Select appropriate crop protection products

Selection of the most suitable plant protection product, related to the local conditions, provides a key factor to reduce risk of water contamination.

How to do

Use of plant protection products characterized by high efficacy against specific target organisms to be controlled and a positive environmental profile (low-dose use, low solubility in water and limited persistence).

F. IRRIGATION

The use of irrigation techniques and optimal water volumes, in relation to the crop requirements and the soil characteristics, is a key factor to prevent risk of runoff and water drainage.

28. Select irrigation technology

The irrigation systems are characterized by variations in water volumes used and by distinct differences of application. Flood irrigation requires the highest amount of water 800 -1200 m³/ ha, sprinkler irrigation uses about 300 -500 m³/ha.

How to do

Apply irrigation methods which allow to reduce water consumption while meeting the crop requirements: sprinkler, micro-sprinkler, drip irrigation.

photo Francesco Vidotto

Drop irrigation systems allow to use low quantity of water, avoiding runoff during the irrigation.

29. Optimize irrigation timing and rate

Key to reduce the risk of runoff is the correct irrigation management considering soil water content, soil water holding capacity and crop requirements in relation to evapo-transpiration.

How to do

Most important is to monitor, estimate and manage the correct amount of water needed by the crop. Key indicators are soil moisture content, soil moisture tension and consideration of possible rainfalls forecasted.

GLOSSARY

BMP	Best Management Practice: In the context of this document, recommendations and tools to prevent losses of PPP to water / sensitive areas.
Buffer strip	See buffer zone.
Buffer zone	Buffer zone is an untreated vegetated area designed and intended to prevent adjacent sensitive areas being contaminated from pesticides through spray drift and runoff.
Bund	A bund is a small dam to reduce water flow and to keep as much water as possible in the field to prevent runoff and to increase soil infiltration.
Capping soil	Soil compaction on the soil surface , especially on soils with high silt content (> 25%). Capping soils tend to be vulnerable to runoff and erosion.
Catchment	An area of land from which all surface run-off flows through a sequence of streams, rivers and, possibly, lakes to a particular point in a water course (normally a lake or a river confluence).
Cover crops	A crop grown between two main crops e.g. after harvest until new seeding. Purpose of the cover crop is to protect the soil structure (reduce splash effect from rain, shading effect) and to utilize water. Cover crops are efficient mitigation measures to reduce transfer of water soluble pollutants (PPPs and nutrients) to surface and ground water.
Crop rotation	Sequence of crops on a field or in a landscape. A wide crop rotation has many positive agronomic effects such as buffering the flow of water, reducing pest and weed pressure.
Cropping practice	General practice to grow crops in an area. Often a result of the main agricultural practices in an area (mainly determined by commercial, climatic, soil, and farm organization and other agronomic conditions).
Dashboard	Dashboard or decision tree provide aggregated key data, which allow the user to make fast and structured decisions without the need to know all details (e.g. dashboard in a car).
Decision tree	See dashboard.
Diffuse sources	Diffuse sources in the context of agricultural pollution can be defined as contamination which originates at field level and implies effects outside the target area. Often all agricultural pollution is reported as diffuse source pollution in general, which in our opinion does not capture important differences (e.g. pollution originating from activities on farm or farmyard) and therefore may lead to inconsistent recommendations for mitigation measures.
Ditch	Artificial channel for drainage or crop irrigation.

Drainage	Removal of excess water from the soil, either by a system of surface ditches, or by underground pipes if required by soil conditions and land contour. Drainage systems are installed to make land which stays wet for a long time suitable for agriculture production. Drain water will flow into a ditch or wetland.
Erosion	Erosion is the transfer of soil by water or wind.
Gully erosion	Extreme sign of erosion in a landscape. It is a steep and deep drainage channel built by surface water which is not flowing permanently.
Rill erosion	Rill erosion is the intermediate process between sheet and gully erosion. It results from concentration of sheet erosion into small, ephemeral concentrated flow paths that produces channels up to 30 cm deep.
Sheet erosion	Sheet erosion is a removal of soil particles in thin layers from an area of gently sloping land. Sheet erosion is commonly unnoticed by many, but can be responsible for extensive soil loss in both cultivated and non-cultivated environments.
Fascines	Fascines are mainly wooden structures (mostly from brush wood) intended to reduce water flow and to disperse the water.
Headland	Headland is an area of land at the edge of a field. Tillage or seeding direction is often across the main cropping direction in such a field. If not correctly managed, it may represent a preferential way of runoff.
Infiltration	Downward entry of water into the soil. Soil characteristics determine the amount of water, which can be kept in the field. Key criteria is the soil infiltration ability / capacity.
Lateral seepage	Lateral subsurface transfer of water e.g. forced by a layer of reduced permeability or impermeability.
Mulch	Materials from crop residues or cover crops on the soil surface which reduce rain splash effect, water flow on the surface and have a positive effect on water infiltration into soil.
Pesticide	According to EU legislation (Directive 2009/128/EC), 'pesticides' include Plant Protection Products (as defined in Regulation (EC) 1107/2009) and biocidal products (as defined in Directive 98/8/EC). In this document the term refers to Plan Protection Products only.
Point source	The term point source pollution is used in different ways. In the context of these BMPs point sources are entries of PPP to water originating directly from the full range of farmers' working processes: transport, storage, before spraying, after spraying, and remnant management.
PPP	Plant Protection Product: according to EU legislation (Regulation (EC) 1107/2009), PPPs are products consisting of or containing active substances, safeners or synergists, and intended for: (a) protecting plants or plant products against all harmful organisms or preventing the action of such organisms; (b) influencing the life processes of plants (as substances influencing their growth), other than as a nutrient; (c) preserving plant products; (d) destroying undesired plants or parts of plants; (e) checking or preventing undesired growth of plants.

Rain event	Rainfall from start to end. In the context of the BMPs the intensity (time and volume) of the rain event is important to generate runoff or erosion.
Retention structure	Retention structures are natural or artificial structures able to capture runoff water and sediments in the catchment.
Runoff	Surface runoff is the water flow that occurs when the soil is infiltrated to full capacity and excess water from rain, meltwater, or other sources flows over the land or infiltration restrictions (e.g. capping soils, plough pans or substrate) prevent water to infiltrate into the soil.
Concentrate runoff	Concentrated runoff is when surface water accumulates in rills or gullies in the field (e.g. in a talweg). Depending of the soil conditions concentration of runoff is the start for serious erosion problems.
Sheet runoff/sheet flow	Sheet runoff is water flowing downhill in thin sheets without concentration (e.g. rills).
Soil permeability	Soil permeability describes how much water can percolate on a certain area / time through the soil layer.
Soil texture	Soil texture describes the content of different particle sizes in a soil (sand, loam, clay).
Substrate	In the context with soil science the substrate is the bedrock, which produces the soil by alteration.
Talweg	A talweg is an abstract line that connects the lowest points in a river channel, or, in general, the lowest points where different slopes come together to build a valley. The term derives from the German word elements Tal (=valley), and Weg (=way).
Tillage	Tillage is a general term for soil cultivation. Traditionally tillage is linked to ploughing of the soil. Reduced or no tillage are cultivation techniques which do not disturb the soil structure as much as ploughing, which has a positive effect on the water infiltration capacity.
Tramlines	Tramlines are cropfree areas used for driving the tractor / machines in a field. Tramlines can be areas to concentrate water and additionally soil compaction may increase the risk of runoff / erosion.
Water body	In this document refers to "Body of surface water": a discrete and significant element of surface water such as a lake, a reservoir, a stream, river or canal, part of a stream, river or canal (Directive 2000/60/EC).
Wetland	See retention structures.

ANNEX

Annex 1 - FIELDFORM SURVEY

Checklist of information necessary to apply dashboards for assessing runoff risk

1	Proximity of field to the water body	Adjacent ☐	Not adjacent ☐	
2	Soil texture From soil map or estimation in field	Texture class ______		
3	Soil water holding capacity Estimable in field from soil texture by using table for WHC	<120mm ☐	>120mm ☐	
4	Slope of the land Using DTM or estimation in field	Low <2% ☐	Medium 2-5% ☐	High >5% ☐
5	Permeability of the topsoil Estimable in field from soil texture and presence of capping	Low ☐	Medium ☐	High ☐
6	Discrete subsurface restriction Presence of plough pan or other infiltration restrictions	None ☐	Pan or other ☐	Pan + other ☐
7	Landscape situation	Valley Floor / Concave Slope ☐	Upslope Concave / Straight Slope ☐	Tile Drained ☐
8	Transfer of runoff to downhill fields or water body	Downhill transfer unlikely ☐	Transfer likely but not to surface water ☐	Transfer likely to surface water ☐
9	Signs of any concentrated runoff in the field If No, ignore points from 10 to 14	Yes ☐	No ☐	
10	Presence of concentrated runoff in	Wheel tracks ☐	Field corner ☐	Field access area ☐
11	Presence of moderately concentrated runoff in	Rill ☐	Talweg ☐	
12	Presence of strongly concentrated runoff in	Gully not in talweg ☐	Gully in talweg ☐	
13	Hydromorphic characteristic of soil Verify presence of green/grey colours, iron/manganese concretions with redbrown and black colours, or low-permeability layer in the soil profile by using an auger.	Yes ☐	No ☐	
14	Soil infiltration capacity in buffer	High ☐	Low ☐	

Annex 2 - FIELDFORM WHC

Estimation of Water Holding Capacity (WHC) from soil texture

Texture		Density	Water holding capacity (mm of water per soil cm)
S	Sand	1.35	0.70
SL	Sandy loam	1.40	1.00
SC	Sandy clay	1.50	1.35
LlS	Light loamy sand	1.50	1.20
LS	loamy sand	1.45	1.45
LmS	Middle Loamy sand	1.45	1.60
LSC	Loam sandy clay	1.50	1.65
LCS	Loamy clay sand	1.45	1.75
Ll	light loam	1.45	1.30
Lm	Middle Loam	1.35	1.75
LC	Loamy clay	1.40	1.95
CS	Clay sand	1.55	1.70
C	Clay sand	1.45	1.75
CL	clay loam	1.40	1.80

Source: Service de Cartographie des Sols de l'Aisne

Example:

a) Determine soil texture: e.g. Sandy clay soil (SC)

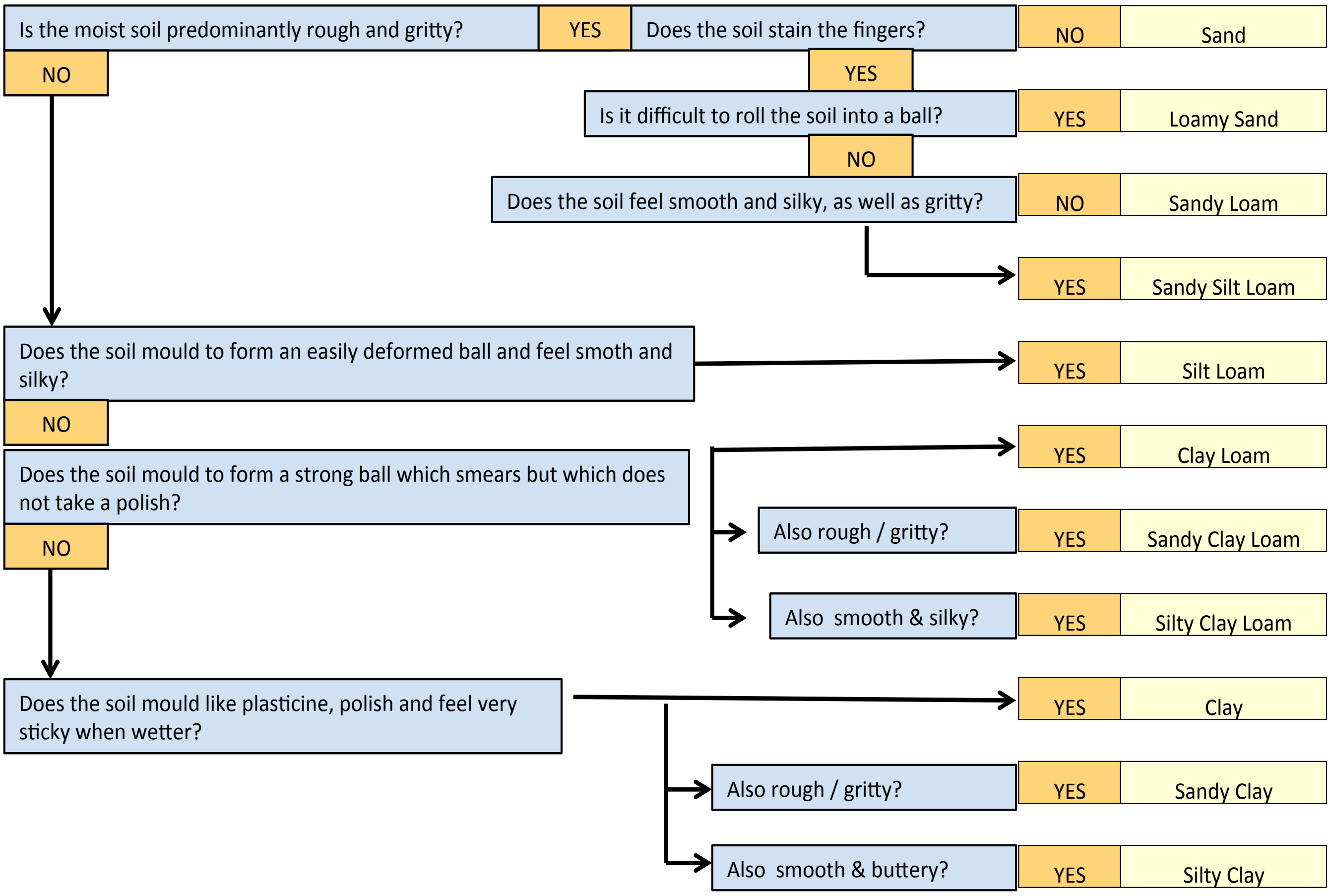
b) Determine soil depth: e.g. 100 cm

Water holding capacity estimate for Sandy clay soil (SC) = 1.35 mm per cm of soil

1.35 mm x 100 cm soil depth = 135 mm Water holding capacity

Annex 3 - FIELDFORM TEXTURE

Estimation of soil texture by feel analysis



Soil texture class can be determined in field by rubbing about 30 g of soil between fingers and thumb to estimate the sand particles by feeling the soil, and content of silt and clay by soil flexibility and stickiness.