

# Risque de sédimentation des réservoirs et mesures d'atténuation en faveur de la durabilité en Tunisie

## Activity No.: N-W-TN-2



Atelier de Consultation Nationale

18 Sep 2023, Hotel Golden Tulip El  
Mechtel, Tunis

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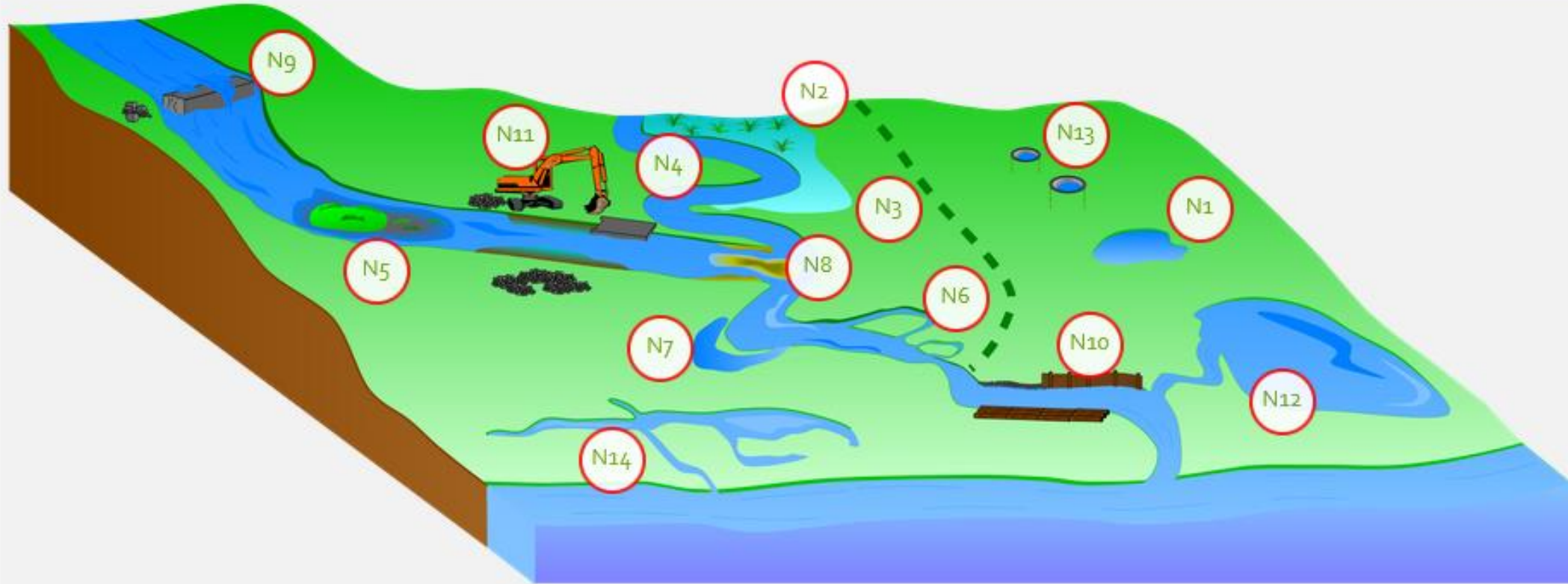


# Review of Natural Water Retention Measures in River Systems and Floodplains



**Water and  
Environment Support**  
in the ENI Southern Neighbourhood region

## Hydro morphology





# Review of Natural Water Retention Measures in River Systems and Floodplains



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## 1. Basins and Ponds

Definition: Both retention and detention basins





# Review of Natural Water Retention Measures in River Systems and Floodplains

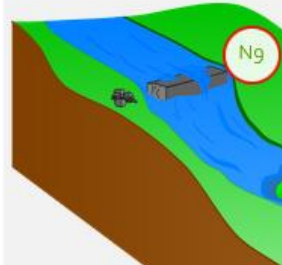
## 2. Wetland Restoration and Management

### Definition:

A wetland is an area of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres.

Wetland restoration and management can involve: technical, spatially large-scale measures (including the installation of ditches for rewetting or the cutback of dykes to enable flooding); technical small-scale measures such as clearing trees; changes in land-use and agricultural measures, such as adapting cultivation practices in wetland areas. They can improve the hydrological regime of degraded wetlands and generally enhance habitat quality. Creating artificial or constructed wetlands in urban areas can also contribute to flood attenuation, water quality improvement and habitat and landscape enhancement.

Hydro morphology



Wetlands are more  
former agricultural  
drained to increase





# Review of Natural Water Retention Measures in River Systems and Floodplains



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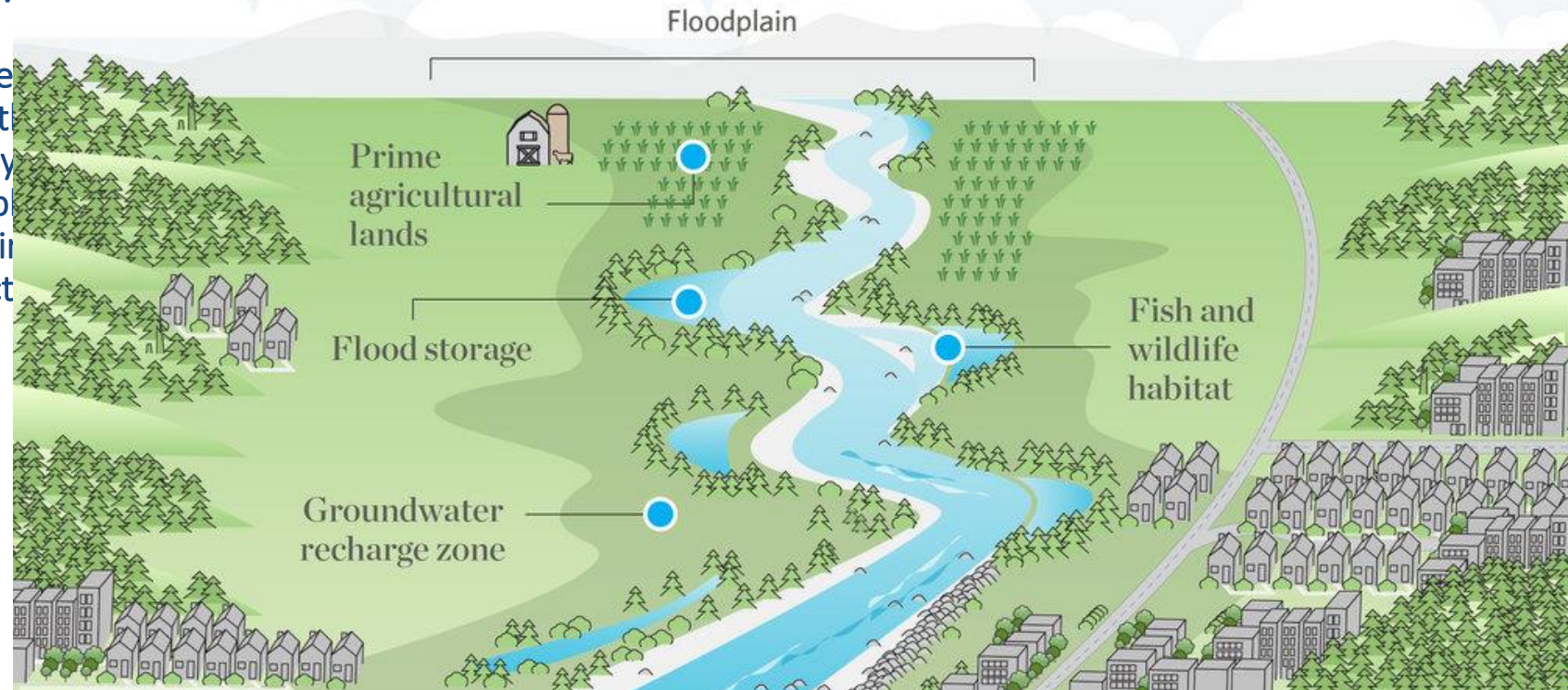
## 3. Floodplain Res

### Definition:

A floodplain is the area bordered by dikes, berms or other structures that provides space for the retention of floodwaters. Floodplain soils are generally very fertile, but have often been dried-out to be used for agriculture. Floodplains in many places have been separated from the river by dikes, berms or other structures that control the flow of the river. They often contain legacy sediments. Major flood protection is lost, due to land drainage, in river channelization. The objective is to restore their retention capacity and reconnecting them to the river.

A floodplain is an area of flat, low-lying land near rivers or coasts that has the potential to flood due to rain, tidal surges or other storm events.

When a river has room to roam within its floodplain it provides multiple benefits, making communities safer from flooding and helping both people and nature thrive.





# Review of Natural Water Retention Measures in River Systems and Floodplains



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## 4. Re-meandering

Definition:

A river meander is a U-form taken by the river, allowing it to decrease water velocity. In the past, rivers have been straightened by cutting off meanders. Many rivers in northern

channel speed of bed more cultivated meanders therefore river channel has a potential for newly habitats plants and



**Morava River**



# Review of Natural Water Retention Measures in River Systems and Floodplains (also in Urban Areas)



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## 5. Stream bed re-naturalization

### Definition:

Streambed (or riverbed) represents the floor of the river, including each riverbank. In the past, riverbeds were artificially reconstructed with concrete or big stones, therefore modifying flows and vegetation diversity. Those flood prevention or suppression practices for example. This is often done in rivers and often having effects on the river. Streambed re-naturalization consists of removing some concrete or inert construction from the riverbanks, then replacing them with natural materials in order to avoid these damages.



Kallang river , Singapore

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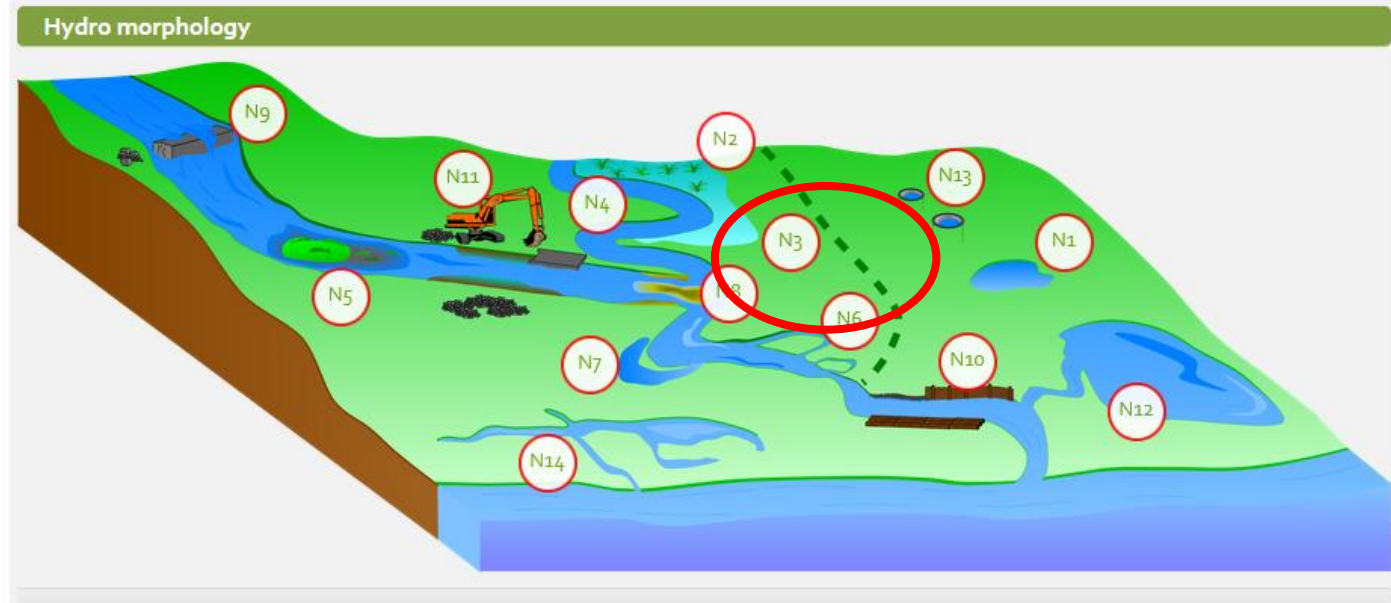
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## 6. Restoration and reconnection of seasonal streams

### Definition:

Seasonal streams or intermittent rivers are rivers for which surface water ceases to flow at some point in space and time. They comprise a large proportion of the global river network and are characterized by dynamic exchanges between terrestrial and aquatic habitats. These habitats support aquatic, semi-aquatic, and terrestrial biota. Seasonal streams provide essential ecosystem services to society, including flood control and irrigation.

Seasonal Streams are the vast majority of the streams in semi-arid areas, Therefore it is needless to distinguish between intermittent – ephemeral streams and perennial streams.





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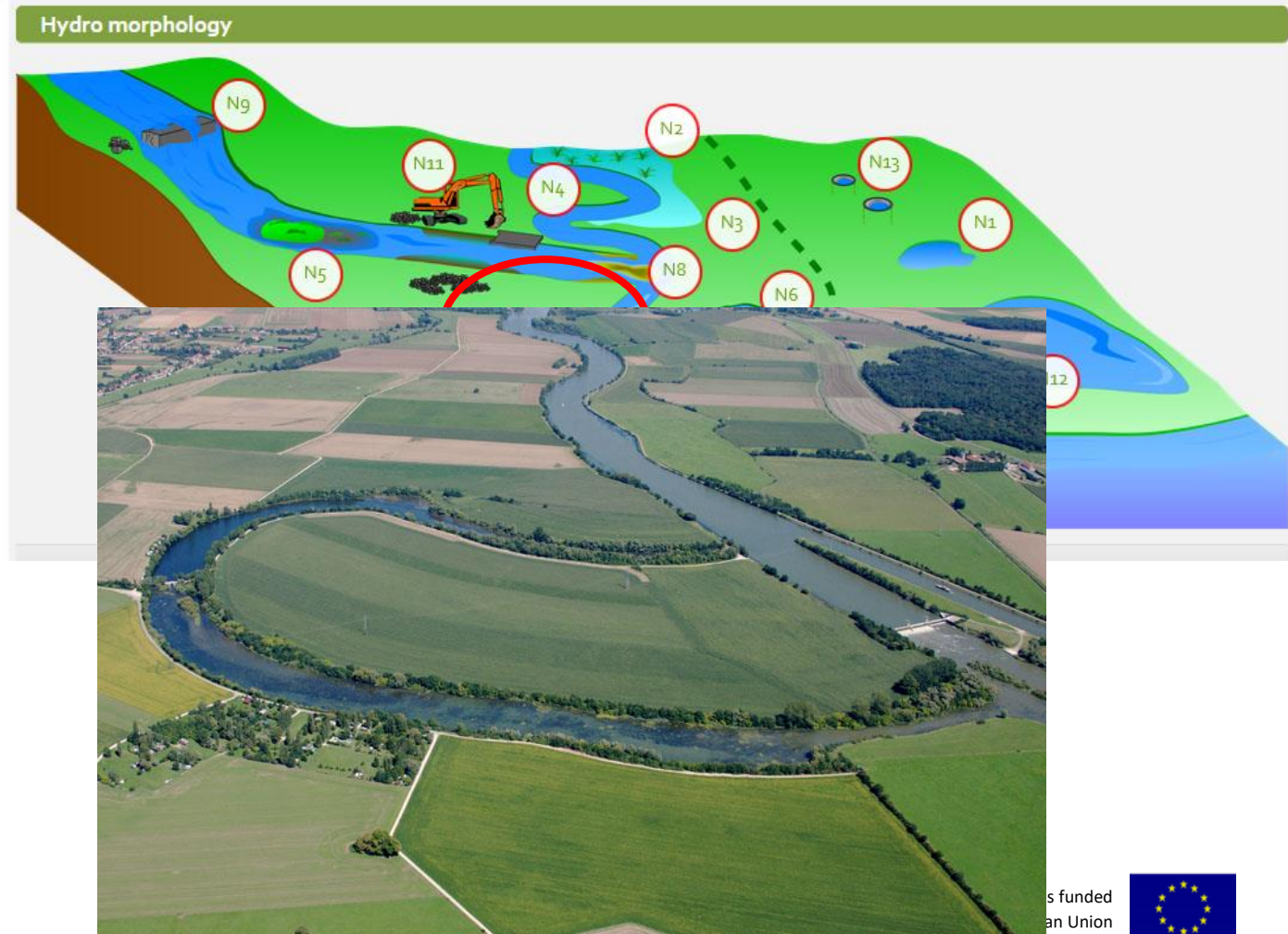
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## 7. Reconnection of oxbow lakes and similar features

### Definition:

An oxbow lake is an ancient meander that was cut off from the river, thus creating a small lake with a U form. Reconnecting it with the river consists in removing terrestrial lands between both water bodies, therefore favouring the overall functioning of the river by restoring lateral connectivity, diversifying flows and cleaning the river section of the present oxbow for a better water retention during floods.

In some cases old oxbow lakes are dried and transformed into forest plantations, pastures, meadows or other semi-natural areas. Reconnection could be challenged by the need for land use change. An ox-bow lake, even if disconnected, can accumulate surface runoff from adjacent lands. However, its reconnection to riverbed, therefore increasing the river length, can largely increase its capacity in this aspect.



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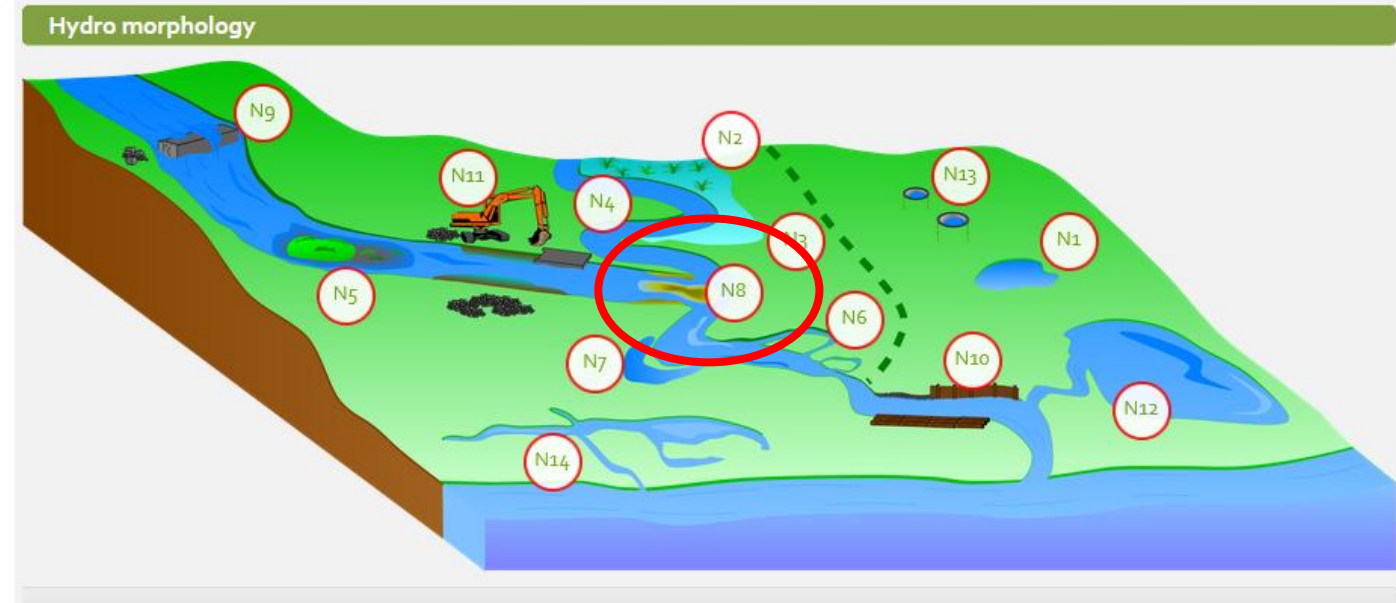
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## 8. Riverbed material renaturalization

### Definition:

Riverbed material represents the sediment eroded upstream, transported by the river and deposited on the river floor. It can be composed of coarse and/or fine material. Its renaturalization consists in recovering the nature-like structure and composition of the bed load, in particular the equilibrium between coarse and fine sediment.

In case of a dam upstream, gravel transport diminishes and river incision commences. Spawning fields for fish is also diminishing.





# Review of Natural Water Retention Measures in River Systems and Floodplains



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## 9. Removal of dams and other longitudinal barriers

### Definition:

Dams and other transversal barriers are obstacles crossing the river section and causing discontinuities for sediment transport and fauna. Removing them consists in destroying all obstacles, restoring the slope and the longitudinal profile of the river, therefore allowing re-establishment of fluvial dynamics, as well as sedimentary and ecological continuity.

The review of the case studies shows that this measure is applied predominantly for small and medium sized rivers. In the case of bigger sized rivers, appropriate management of the dam can re-establish part of the functions targeted by this measure without removing the dam. The renewal of energy production, as well as the multi functionality of dams is also an argument that can prevent the measure to be taken.



Brives dam, Loire River, France



# Review of Natural Water Retention Measures in River Systems and Floodplains



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## 10. Natural bank stabilization

### Definition:

Riverbank represents both natural and artificial terrain following the river flow. In the past, lots of artificial banks were built with concrete or other types of retention walls, therefore limiting rivers' natural movements, leading to degradation of the river, increased water flow velocity, increased erosion and decreased biodiversity. River bank renaturalisation consists

of several components, thus revealing the need to allow the bank to be stabilized naturally. Nature-based solutions are preferable, but civil engineering solutions are still strong hydrological constraints.





# Review of Natural Water Retention Measures in River Systems and Floodplains

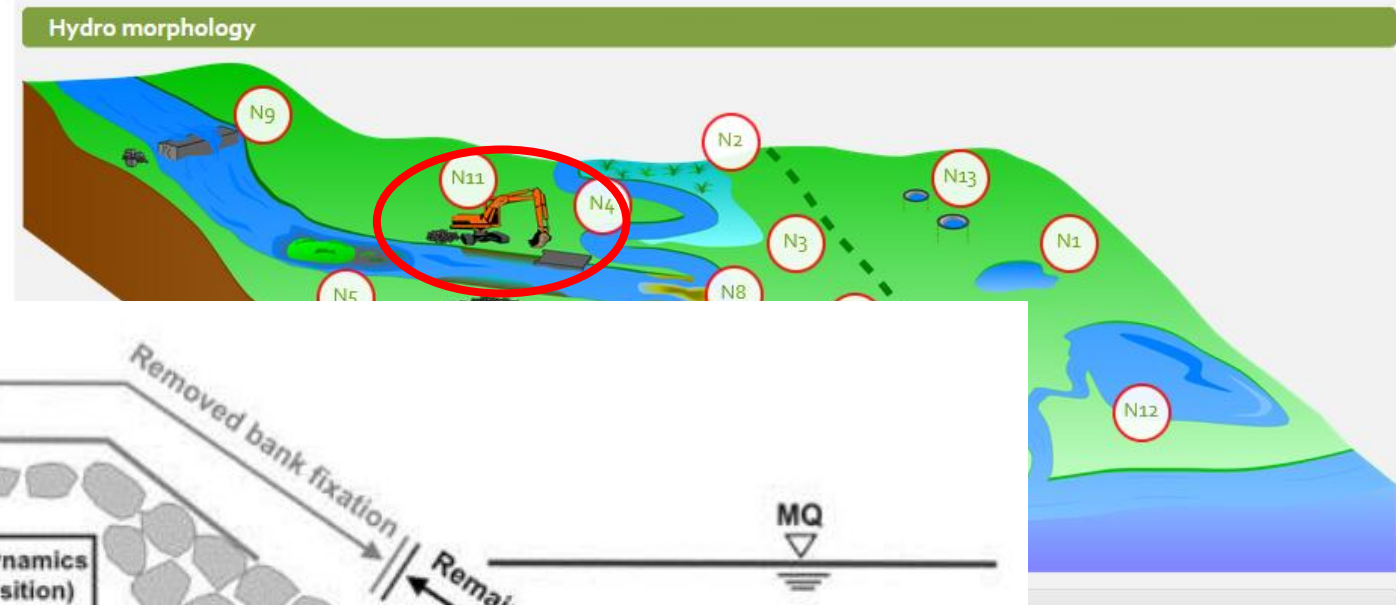
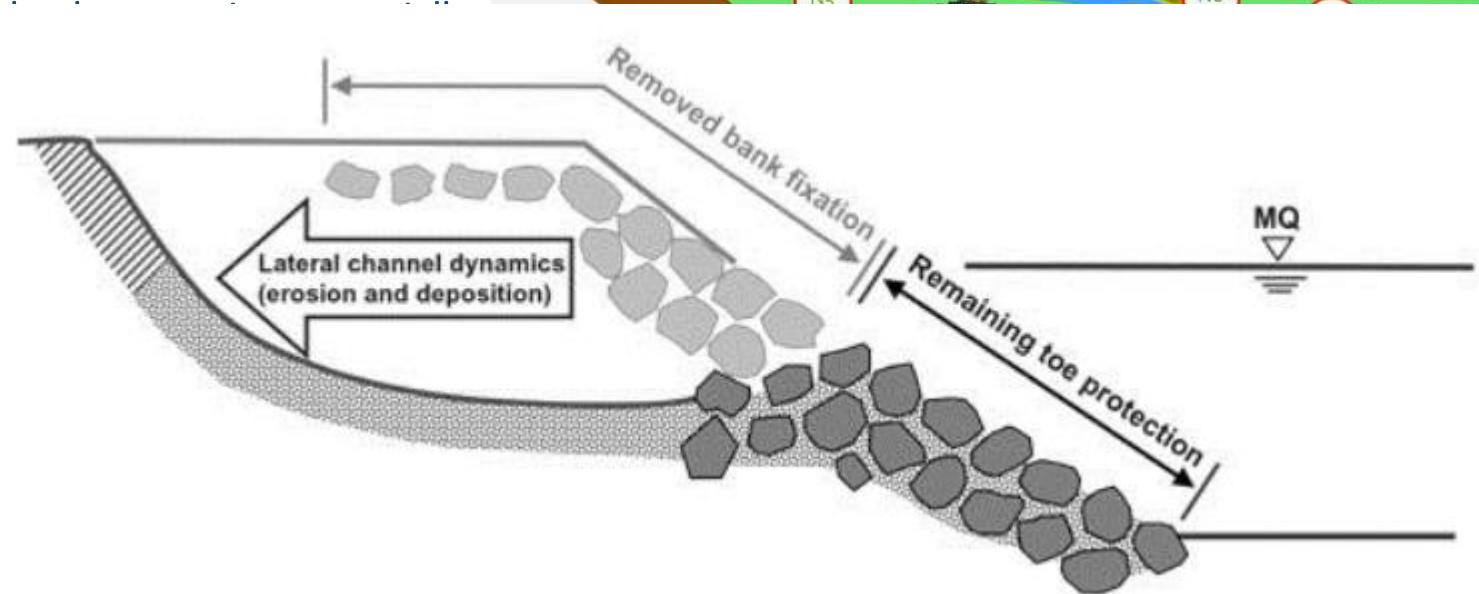


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## 11. Elimination of riverbank protection

### Definition:

A riverbank protection is an “hard” or “soft” construction providing bank fixation but also an obstacle for the lateral connection of the river. Eliminating it consists in removing some parts of the inert ones, in order to enhance river, diversify flows (depth, habitats, but also cap floods) prerequisite for many other measures or widening, as well as initiate lateral dynamics.



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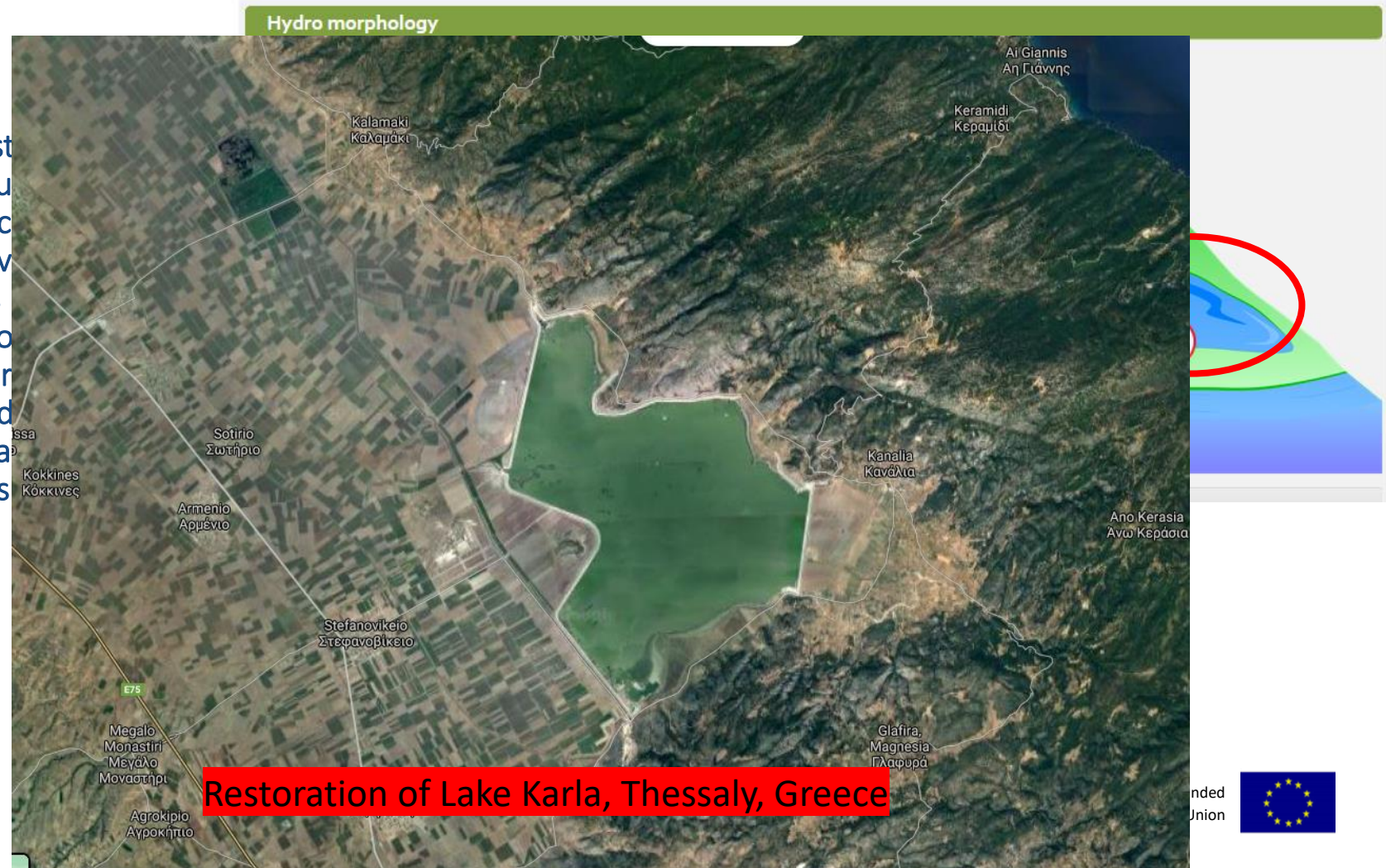


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## 12. Lake Restoration

### Definition:

A Lake is a water retention facility. It can store water (for flood control) and provide water for many purposes (water supply, irrigation, fisheries, tourism, etc). A lake also serves as a sink for carbon storage and provides habitats for numerous species of plants and animals, including waders. In the past, lakes have so often been drained to free the land for agriculture purposes. Lake restoration simply not been maintained and have silted up. Lake restoration consists in enhancing their structure and function where they have been drained in former times.





# Review of Natural Water Retention Measures in River Systems and Floodplains



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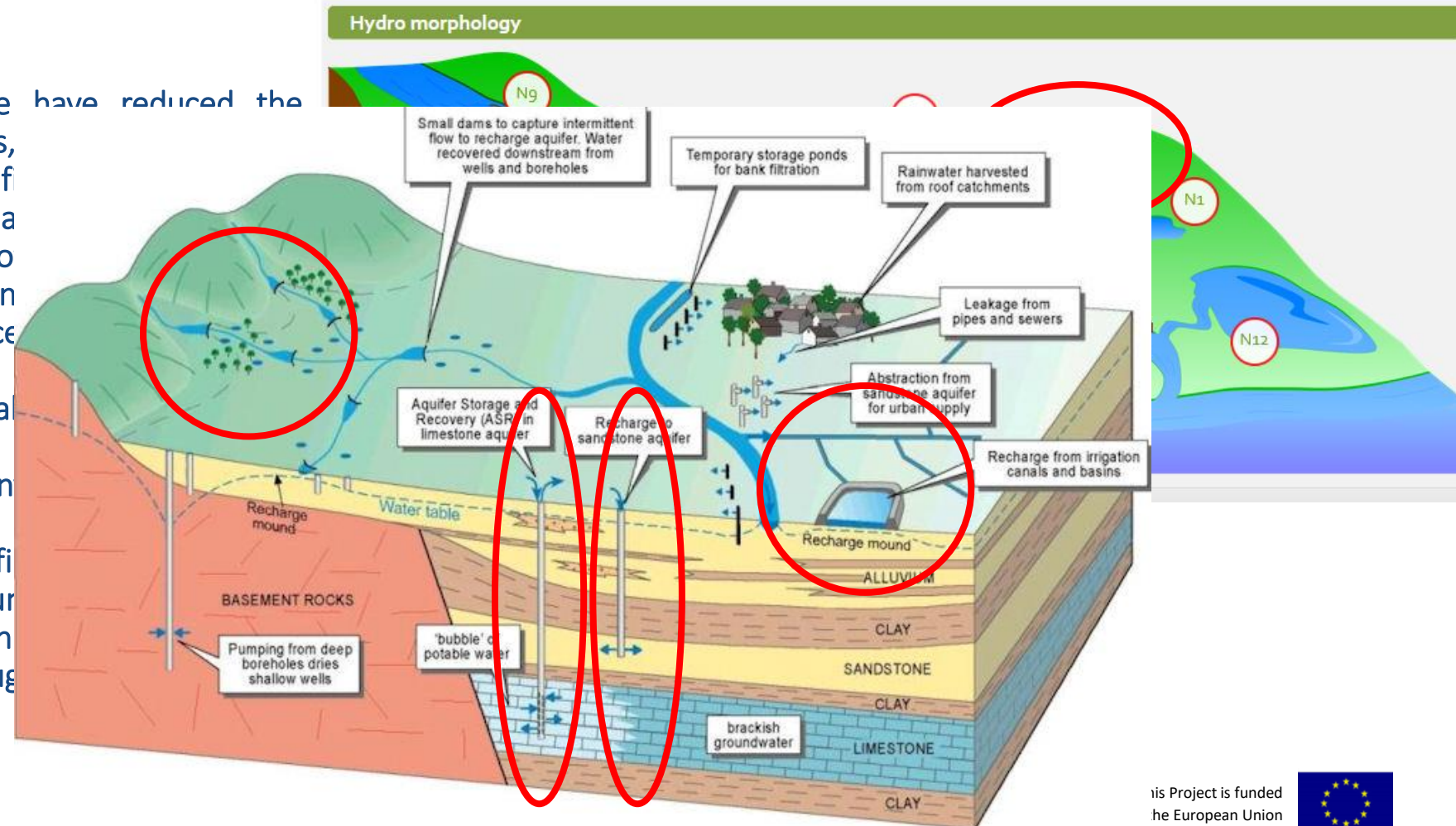
## 14. Artificial Groundwater Recharge

### Definition:

Previous modifications of the landscape have reduced the infiltration capacity of many European soils, rate at which precipitation is able to infiltrate groundwater aquifers. Restoration of natural groundwater enables a lowering of run-off land, and enhances the condition of groundwater availability. The natural cleaning process of infiltration can improve water quality.

Mechanisms to restore or enhance natural infiltration include:

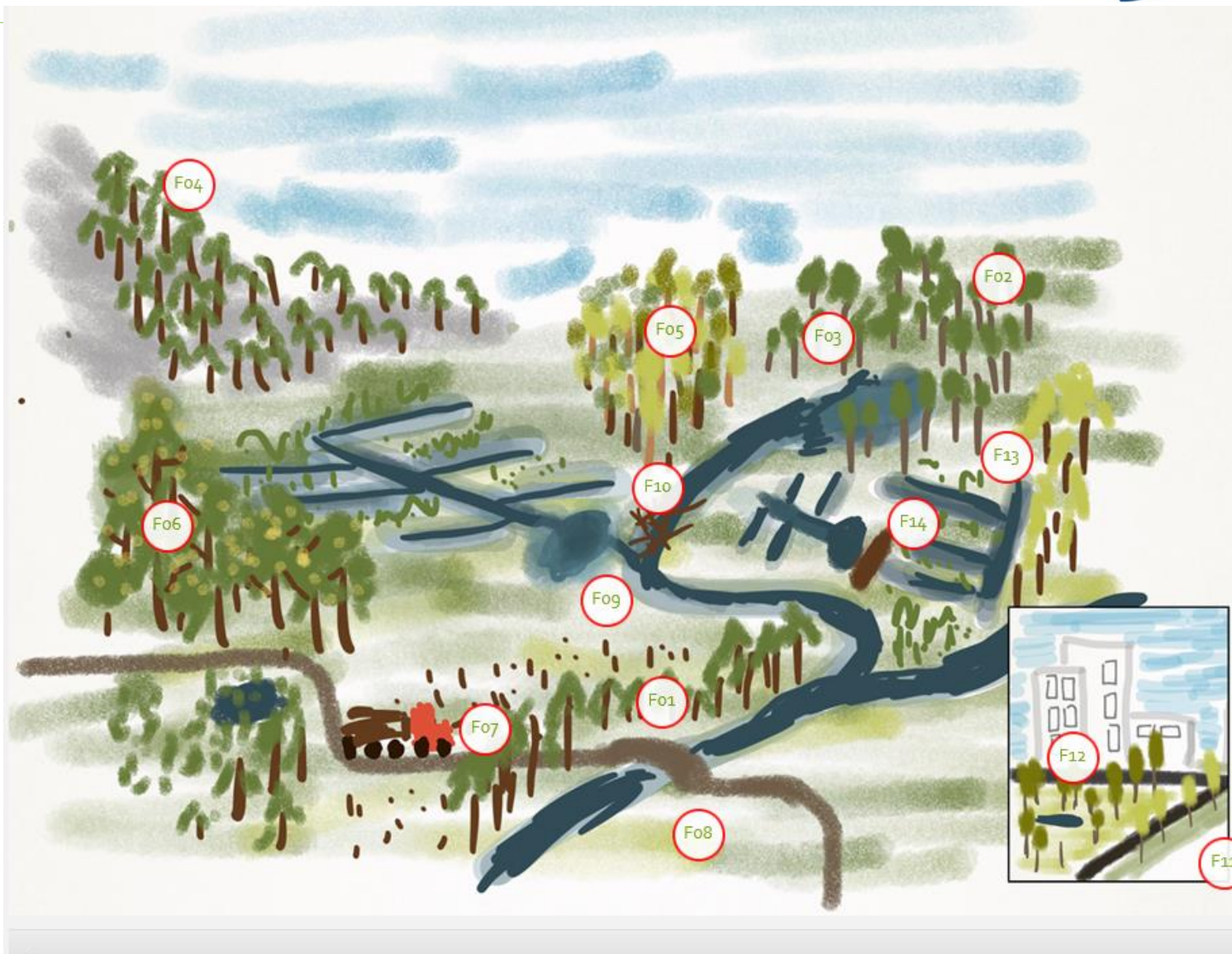
- (i) surface structures to facilitate/augment infiltration (e.g. soakaways and infiltration basins);
- (ii) subsurface indirect recharge – infiltration enhanced through wells drilled within the unsaturated zone;
- (iii) subsurface direct recharge – infiltration into groundwater aquifer is accomplished through saturated zone.



# Review of Natural Water Retention Measures in Forests



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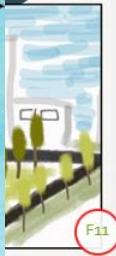
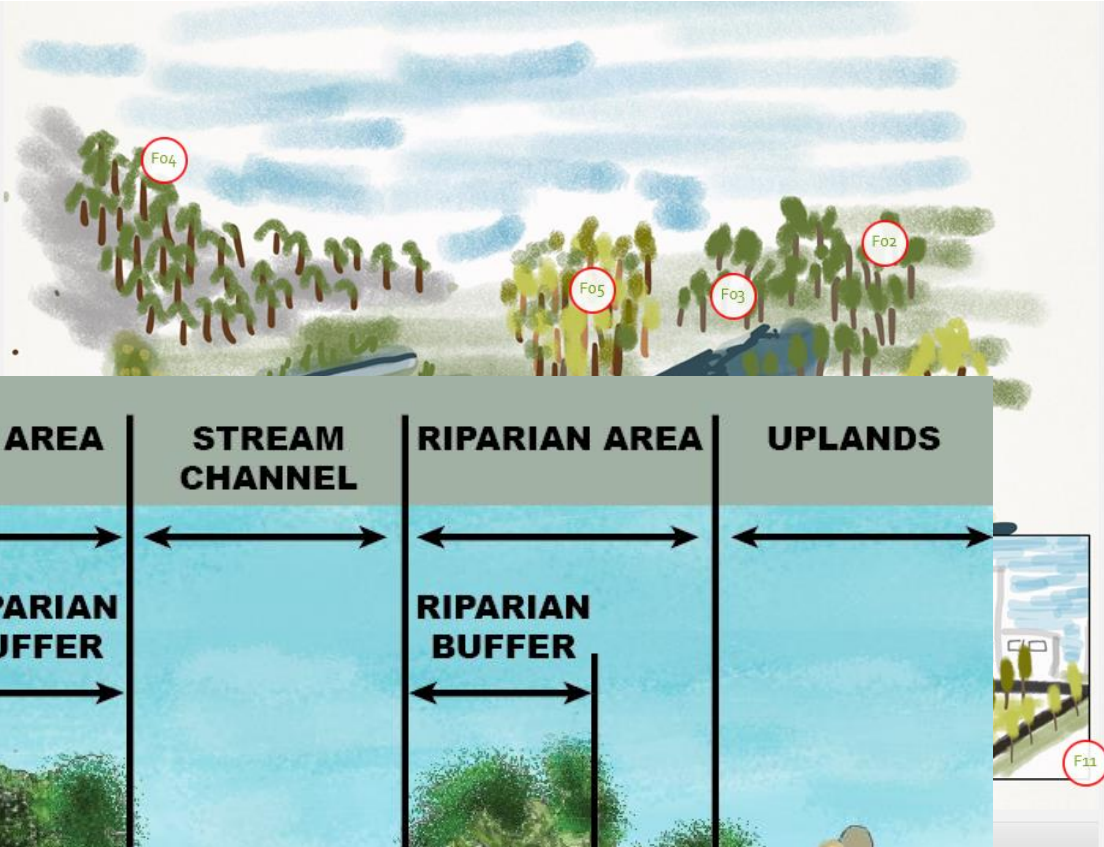
# Review of Natural Water Retention Measures in Forest Lands



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# Review of Natural Water Retention Measures in Forest Lands



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## 3. Maintenance of forest cover in headwater areas

### Definition:

Headwaters are the source areas for rivers and streams, crucial for sustaining the structure, function, productivity and complexity of downstream ecosystems. They are vital to hydrologic cycling as they are one of the main areas where precipitation contributes to surface and groundwater. Headwaters are typically less intensively used than downstream areas. In many headwater areas, extensive agriculture, forests or other semi-natural land cover types predominate. Forests in headwater areas have a beneficial role for water quantity and quality. Creating or maintaining forest cover in

headwater catchments is a key objective of the EU Water Framework Directive. In New York, Istanbul and Stockholm, the loss of forests for drinking water supply has reduced infiltration capacity than slowly releasing rainfall. Headwater catchments can contribute to reducing the risk associated with landslides and drought. In dry areas may lead to reduced





# Review of Natural Water Retention Measures in Forest Lands

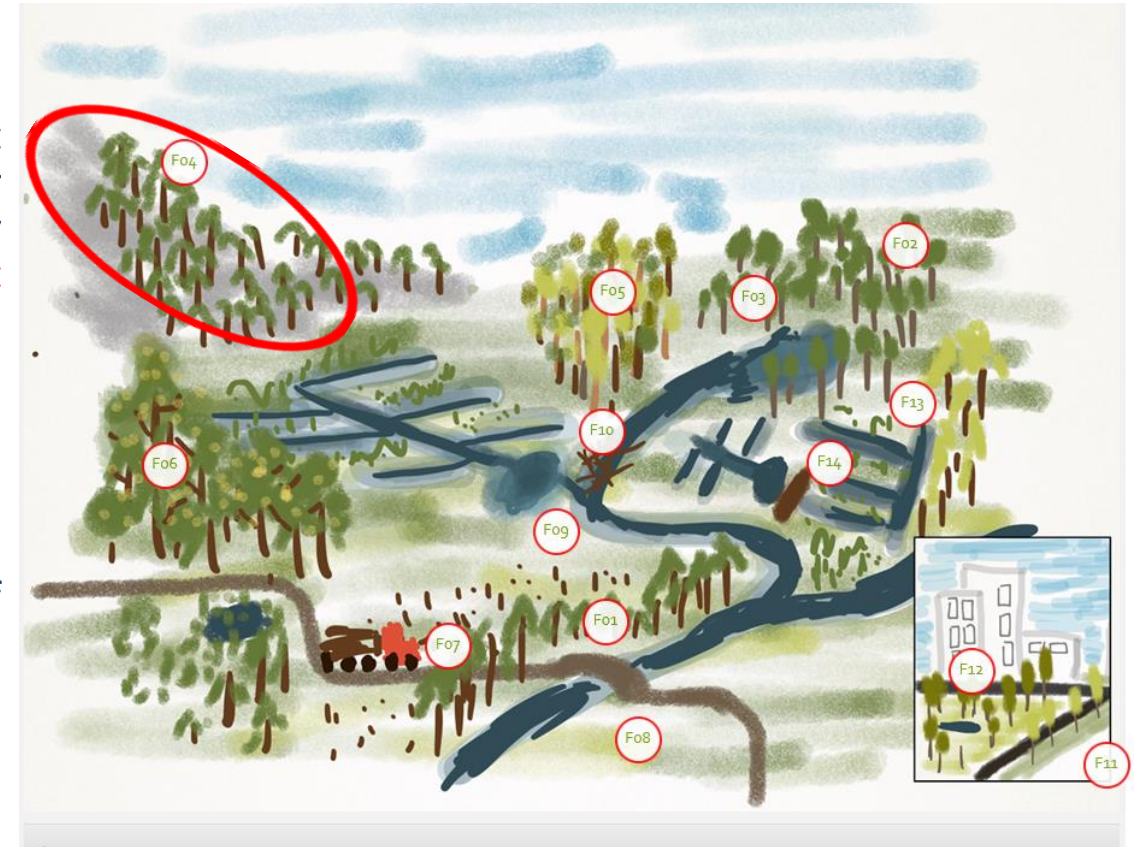


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## 4. Targeted planting for 'catching' precipitation

### Definition:

There is some evidence to suggest that loss of tree cover on Mediterranean hill slopes has altered weather patterns, which in turn have altered precipitation amount and timing. Modelling results suggest that Mediterranean precipitation regimes are very sensitive to variations in air temperature and moisture. Land use change and associated deforestation may have led to changes from an open monsoon-type regime with frequent summer storms over inland mountains to a regime dominated by closed vertical atmospheric recirculation where feedback mechanisms suppress storms over the coastal mountains and lead to increased summer time sea surface warming. This warming leads to torrential rains in autumn and winter. These rains can occur across the Mediterranean basin. This can be exacerbated by greenhouse heating associated with air pollutants. Targeted afforestation in some parts of the Mediterranean may be one means of combating drought and desertification. However, caution should be taken when choosing areas for afforestation to avoid possible adverse effects, as there is some evidence that afforestation in dry environments, especially in montane areas, may decrease water yield and cause water deficit in the downstream rivers. Local tree species should be used to reduce risks to



# Review of Natural Water Retention Measures in Forest Lands

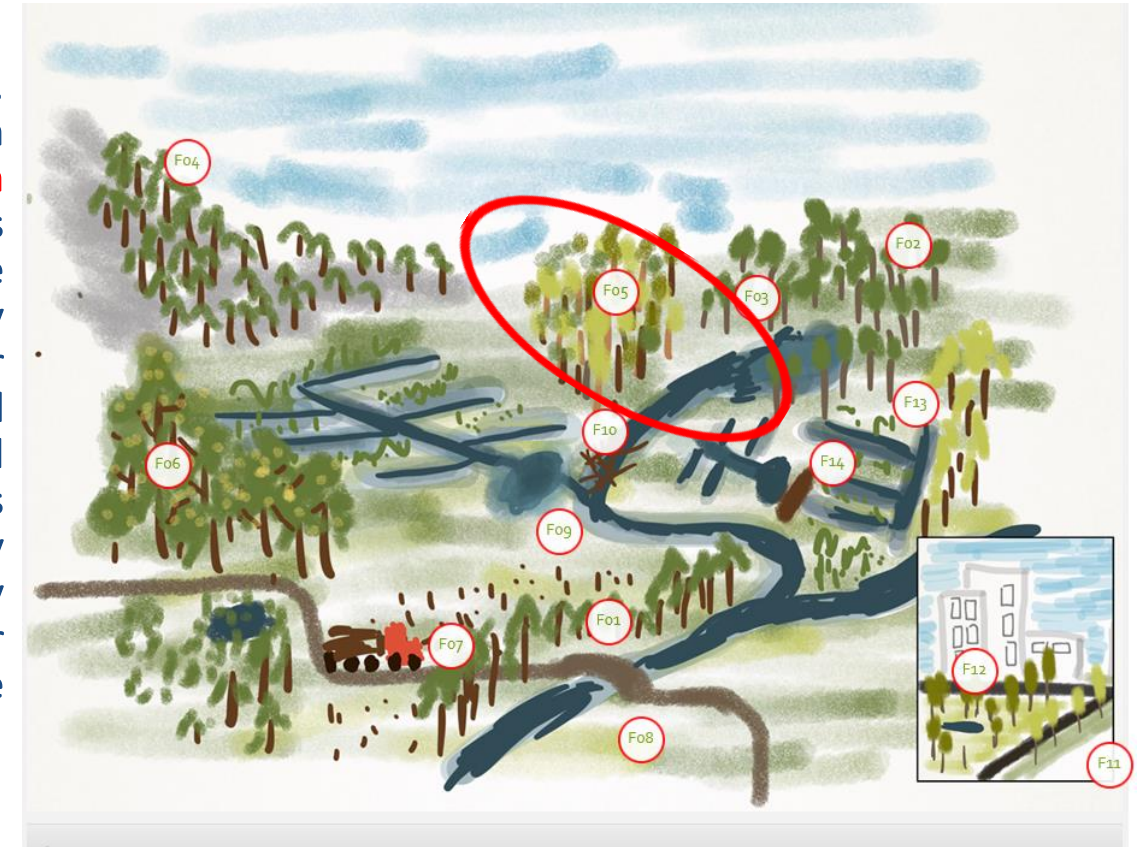


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## 5. Land use conversion

### Definition:

Land use conversion is a general term for large scale geographic change. Afforestation is one such land conversion in which trees are planted on previously non forested areas. **Afforestation may occur deliberately or through the abandonment of marginal agricultural land.** Depending on the tree species planted and the intensity of forest management, afforestation may have more or less environmental benefits. The NWRM related benefits include potentially enhanced evapotranspiration associated with growing forests and better water holding capacity associated with forest soils. The greatest environmental benefits are probably associated with planting of indigenous broadleaves and low intensity forestry. Plantation forestry with exotic species is likely to be less beneficial to the environment. It should be mentioned that afforestation in dry areas can cause or intensify water shortage. Even though afforestation may reduce available water supply at local scale, forest cover increases water supply regionally and globally, in particular through the intensification of the water cycle.





# Review of Natural Water Retention Measures in Forest Lands

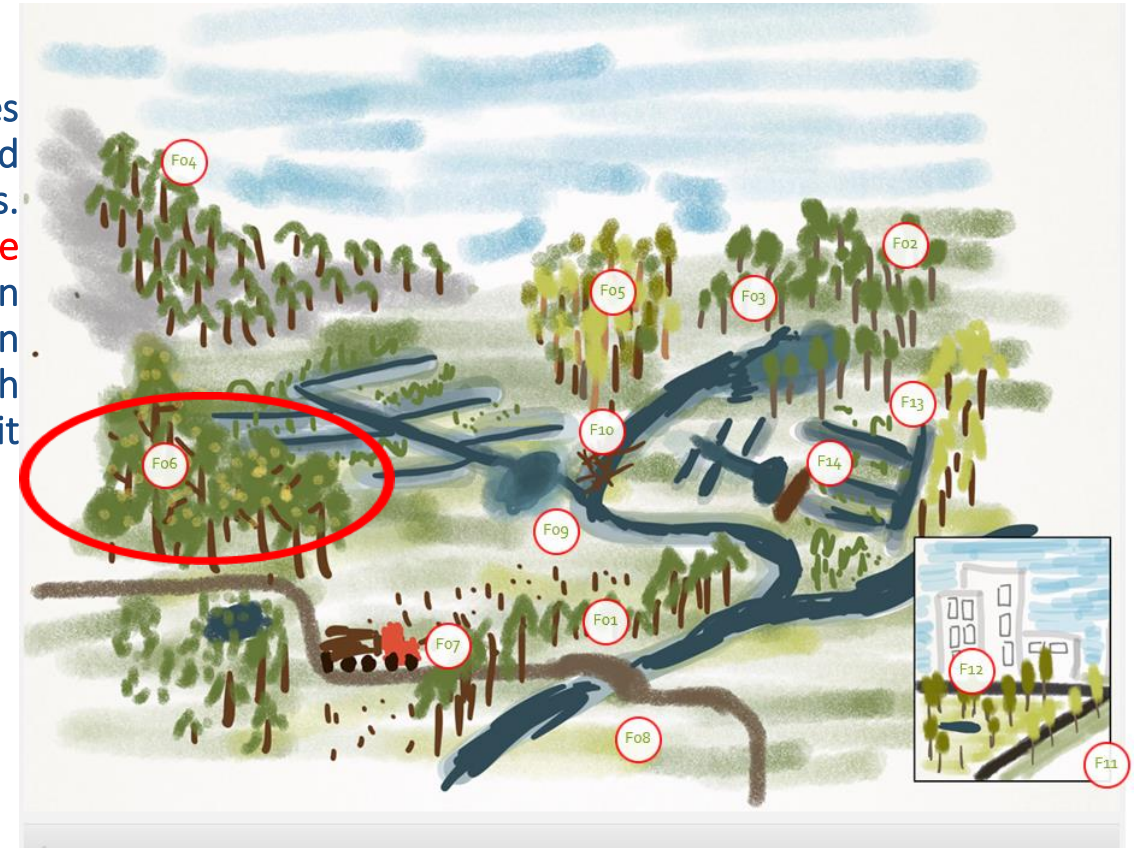


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## 6. Continuous cover forestry

### Definition:

Continuous cover forestry is a broad range of forest management practices which may have some beneficial hydrological effects. The main idea behind continuous cover forestry is a reduction in the number or size of clear-cuts. **Some definitions of continuous cover forestry state that no clear-cuts shall be larger than 0.25 ha.** Continuous cover forestry ensures that there is an uninterrupted tree canopy and that the soil surface is never exposed. An uninterrupted tree canopy will have higher interception than a site with discontinuous tree cover. Ensuring that soils are never exposed will limit sediment production.





# Review of Natural Water Retention Measures in Forest Lands



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## 7. 'Water sensitive' driving

Definition:

Off road driving has potentially severe negative consequences for runoff generation and water quality. Some of these damages can be minimized or mitigated if drivers of vehicles exercise a few simple precautions. Avoiding

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# Review of Natural Water Retention Measures in Forest Lands



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## 8. Appropriate design of roads and stream crossings

### Definition:

Forest access roads and other roads in rural areas often cross streams and other small watercourses. Design and material used in forest road building may have strong impact on erosion risk and water quality in streams. The

bridges or culverts used are often inappropriate and can lead to increased erosion and flooding. The design and material used in forest road building may have strong impact on erosion risk and water quality in streams. The bridges or culverts used are often inappropriate and can lead to increased erosion and flooding. The design and material used in forest road building may have strong impact on erosion risk and water quality in streams. The bridges or culverts used are often inappropriate and can lead to increased erosion and flooding.



**Inappropriate Culver Design (Before)**

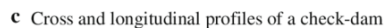
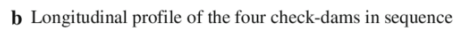
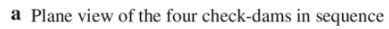


**Bridge Replacement (After)**





ponds (check dams)



b)



## 10. Coarse woody debris

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lead to form





# Review of Natural Water Retention Measures in Forest Lands (also in Urban Areas)

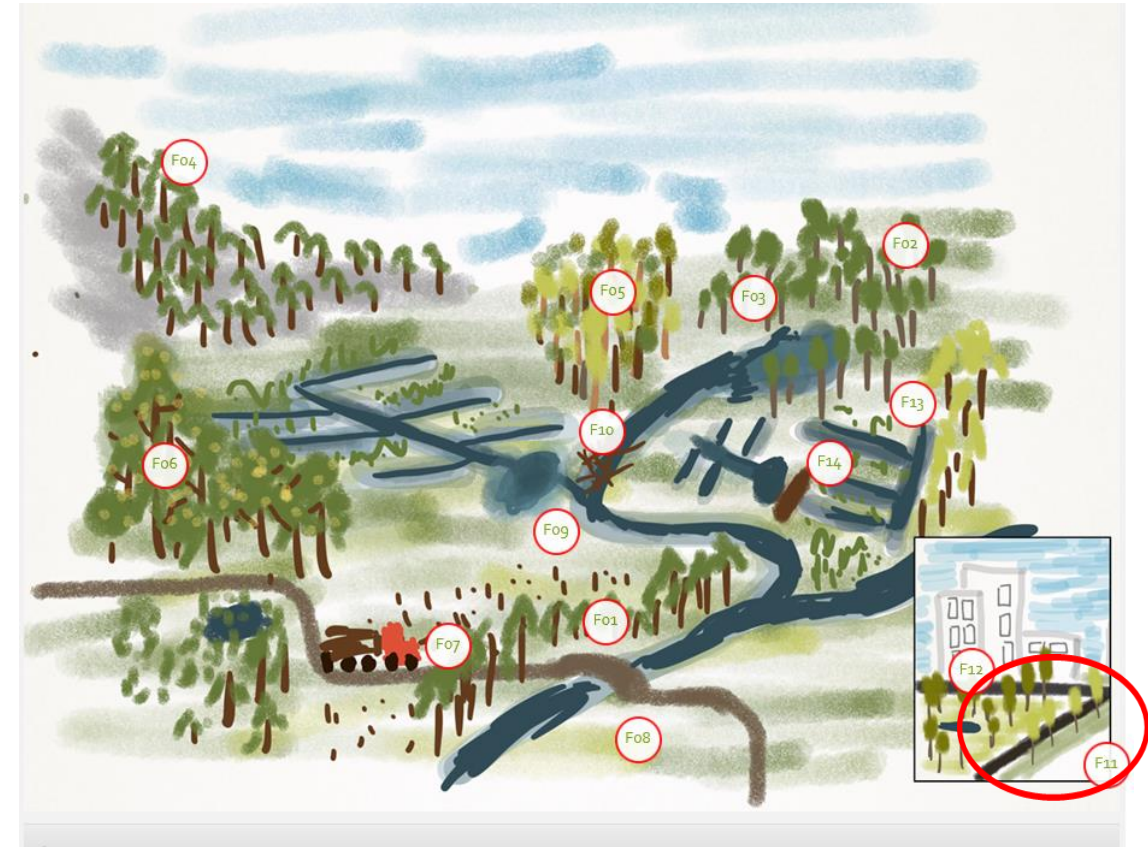


**Water and  
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## 11. Urban Forest Parks

### Definition:

Urban forest parks can deliver a broad range of hydrology-related and other ecosystem services. Forests in urban areas have great amenity value, can improve air quality, moderate local microclimates, improve urban biodiversity and contribute to climate change mitigation as well as having ancillary hydrological benefits. Forest soils often have greater infiltration capacity than other urban land cover and can be an important location for aquifer recharge.





# Review of Natural Water Retention Measures in Forest Lands (also in Urban Areas)

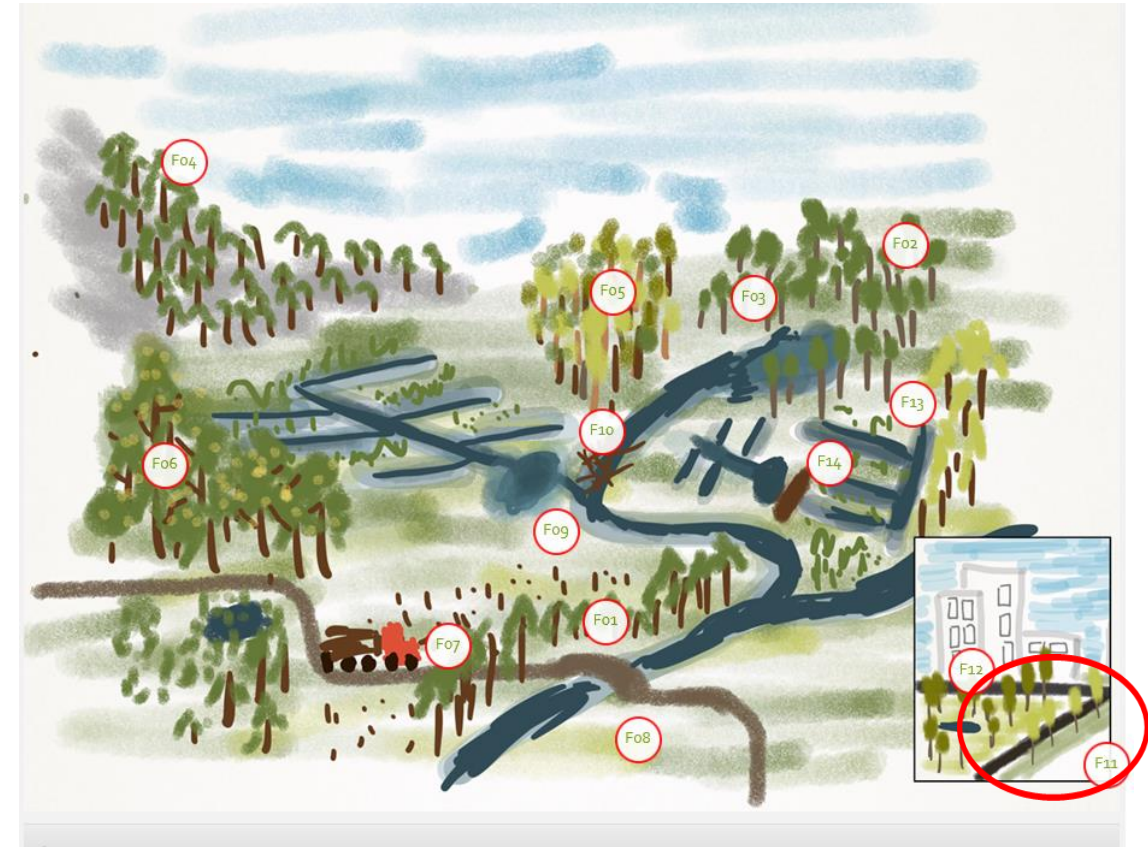


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## 12. Trees in Urban Areas

### Definition:

Trees in urban areas can have multiple benefits related to aesthetics, microclimate regulation and urban hydrology. Trees in urban areas can also be important biodiversity refuges and can contribute to reducing particulate air pollution. Trees intercept precipitation, reducing the amount of rainfall which must be processed by sewers and other water transporting infrastructure. The area around urban trees may also have greater infiltration capacity than the impermeable surfaces often found in urban areas. Trees also transpire, which dries the soil and gives greater capacity for rainfall storage.



# Review of Natural Water Retention Measures in Forest Lands

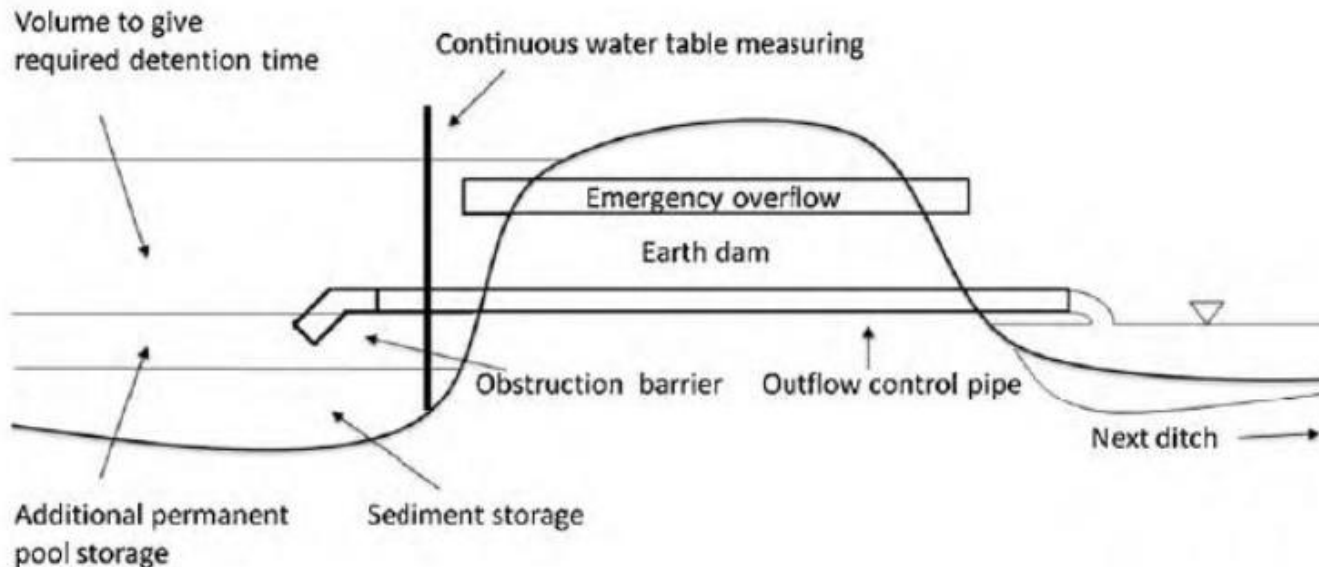


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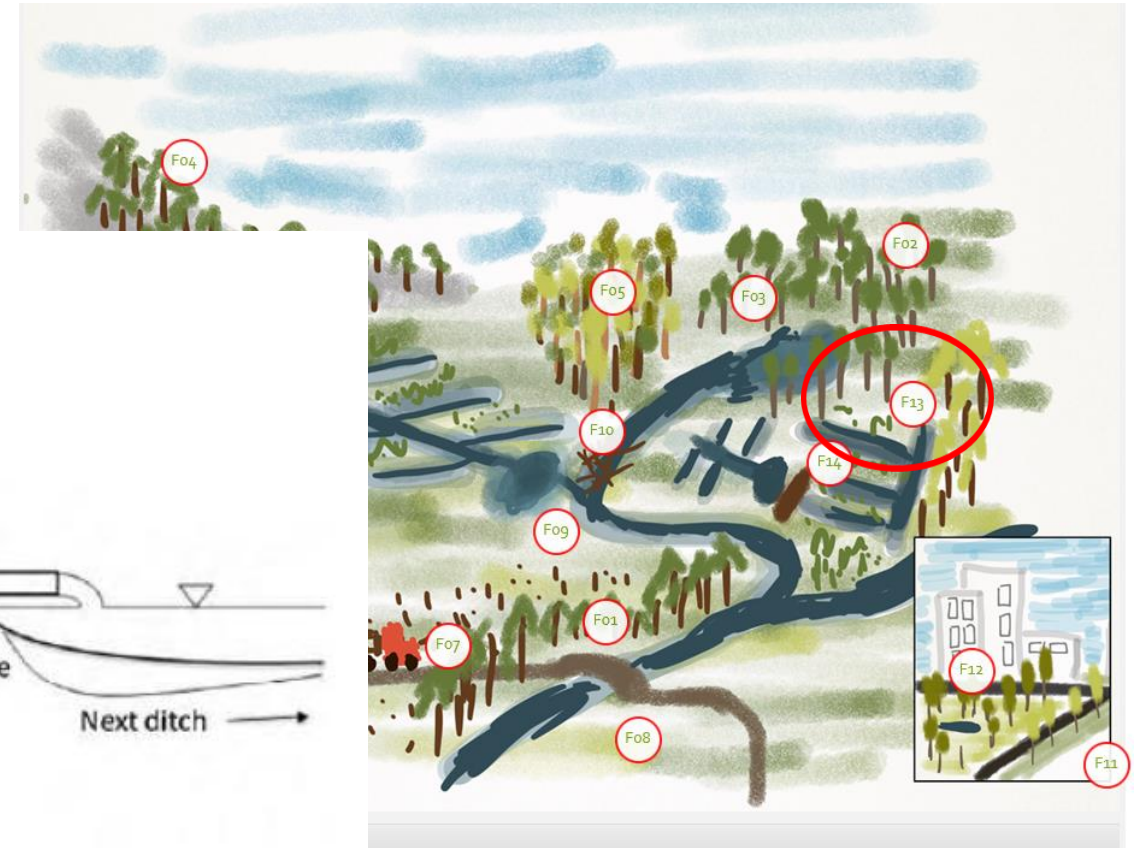
## 13. Peak flow Control Structures

Definition:

Peak flow control structures are designed to reduce flow velocities in networks of forest ditches. Peak flow control structures are engineered ponds designed to limit the rate at which water flows out of a ditch network. Because the structures slow water flow, they will contribute to sediment control and will have a limited detention period accumulated.



Schematic of peak flow control structure from Martilla et al. (2010)

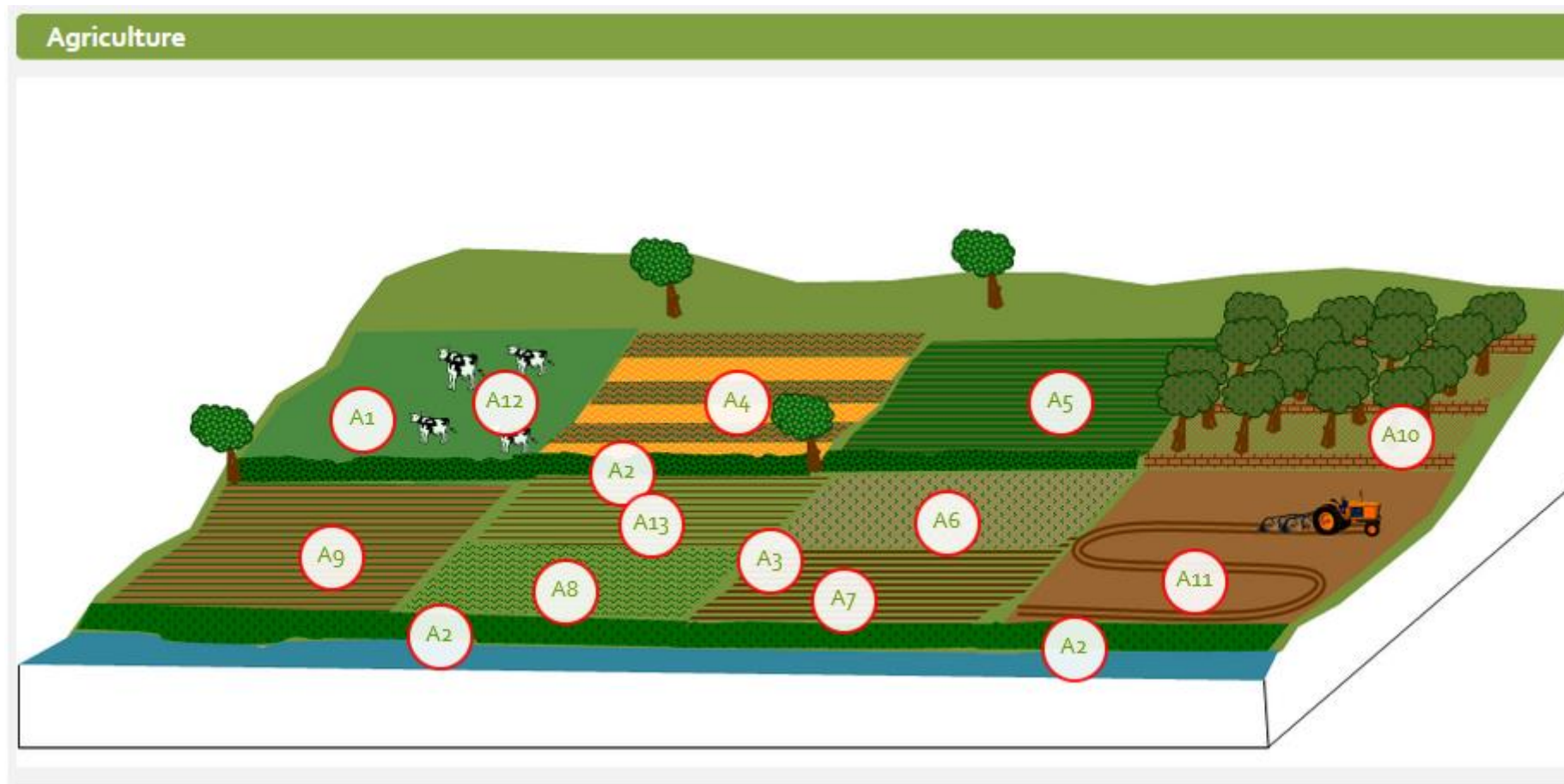




# Review of Natural Water Retention Measures in Agriculture



**Water and  
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# Review of Natural Water Retention Measures in Agriculture



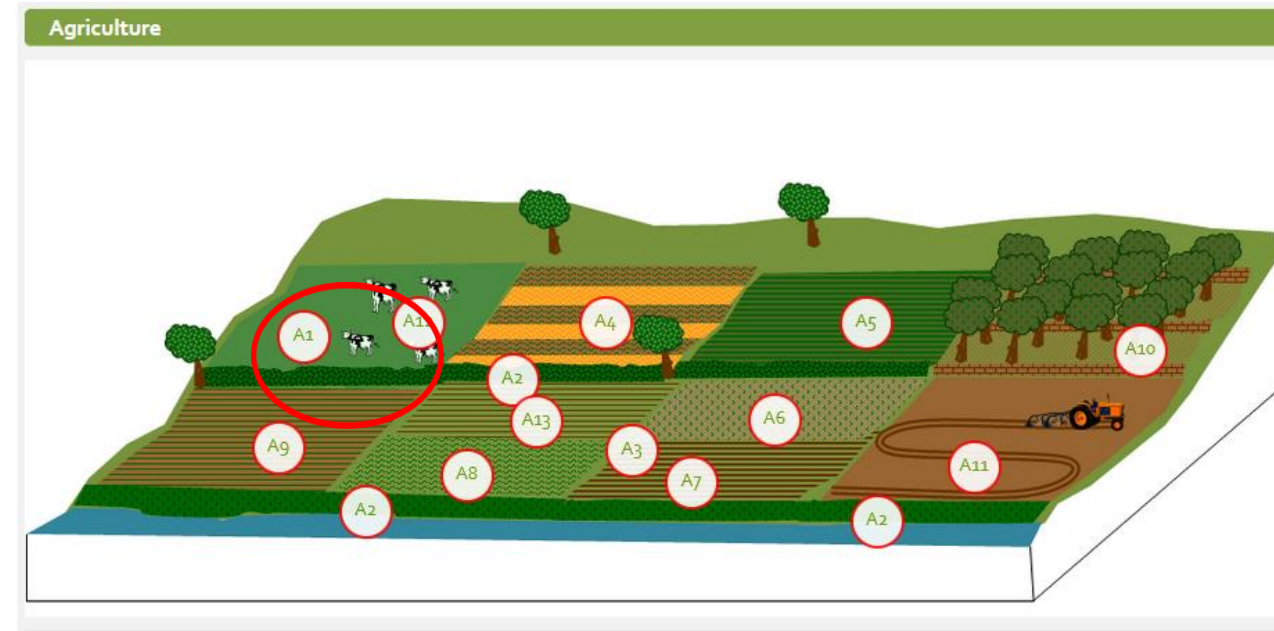
**Water and  
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## 1. Meadows and pastures

### Definition:

Meadows are areas or fields whose main vegetation is grass, or other non-woody plants, used for mowing and haying. Pastures are grassed or wooded areas, moorland or heathland, generally used for grazing. Due to their rooted soils and their permanent cover, meadows and pastures provide good conditions for the uptake and storage of water during temporary floods. They also protect water quality by trapping sediments and assimilating nutrients.

The measure offers the potential for temporary flood storage, increased water retention in the landscape and runoff attenuation. Soil cover is maintained at all times with rooted vegetation, this reduces the surface flow of water and allows greater infiltration to the soil. Rates of soil erosion are considerably lower than arable land with potential benefits for water quality.





# Review of Natural Water Retention Measures in Agriculture



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## 2. Buffer strips and hedges

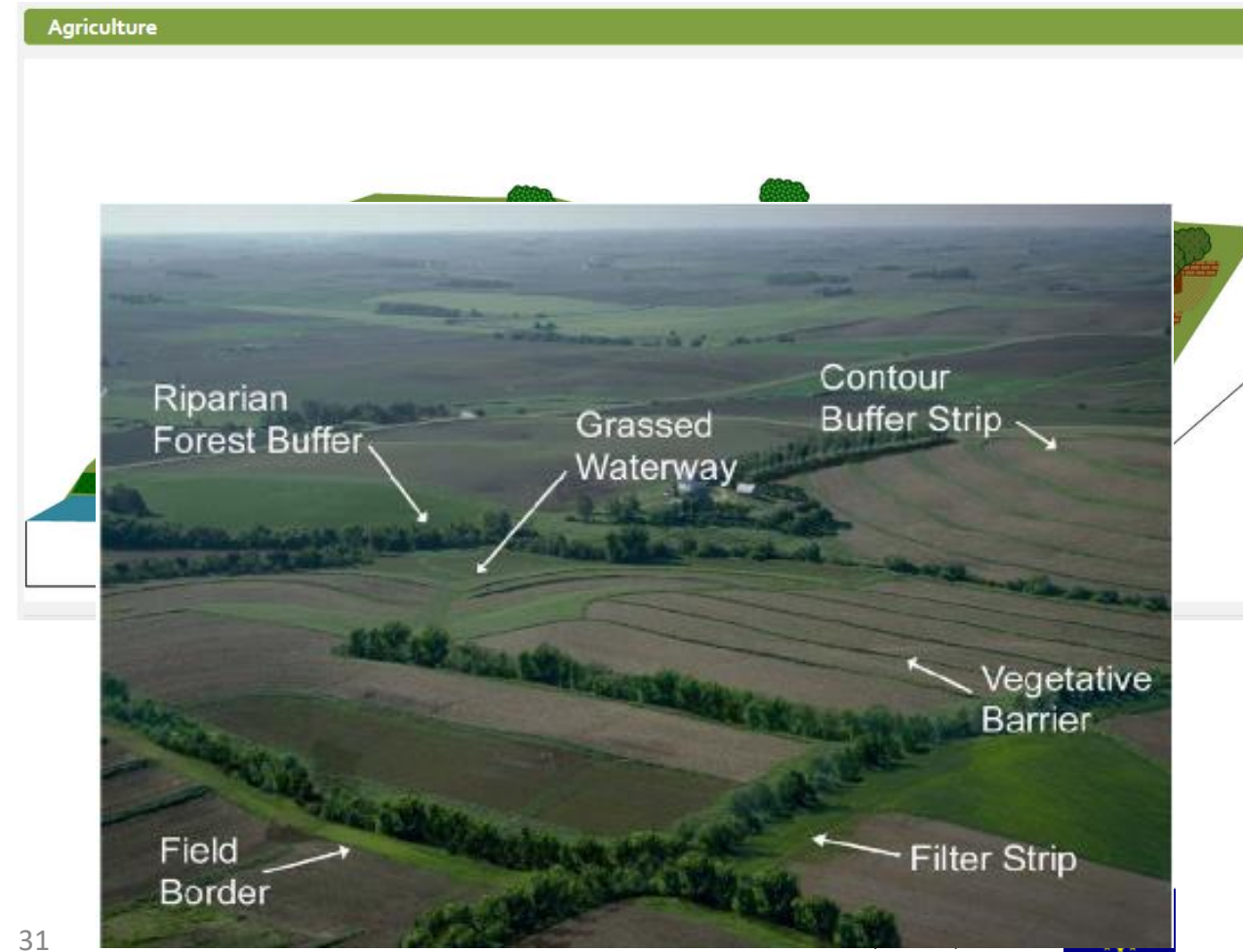
### Definition:

Buffer strips are areas of natural vegetation cover (grass, bushes or trees) at the margin of fields, arable land, transport infrastructures and water courses. They can have several different configurations of vegetation found on them varying from simply grass to combinations of grass, trees, and shrubs. Due to their permanent vegetation, buffer strips offer good conditions for effective water infiltration and slowing surface flow; they therefore promote the natural retention of water. They can also significantly reduce the amount of suspended solids, nitrates and phosphates originating from agricultural run-off. Buffer strips can be sited in riparian zones, or away from water bodies as field margins, headlands or within fields (e.g. beetle banks). Hedges across long, steep slopes may reduce soil erosion as they intercept and slow surface run-off water before it builds into damaging flow, particularly where there is a margin or buffer strip alongside.

Borin et al (2010) report on a study in Padova, Italy, in which a 6m wider buffer strip of trees and shrubs reduced runoff by 78% compared to no buffer strip, this was equivalent to a runoff depth of 231mm over 5 years.



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# Review of Natural Water Retention Measures in Agriculture



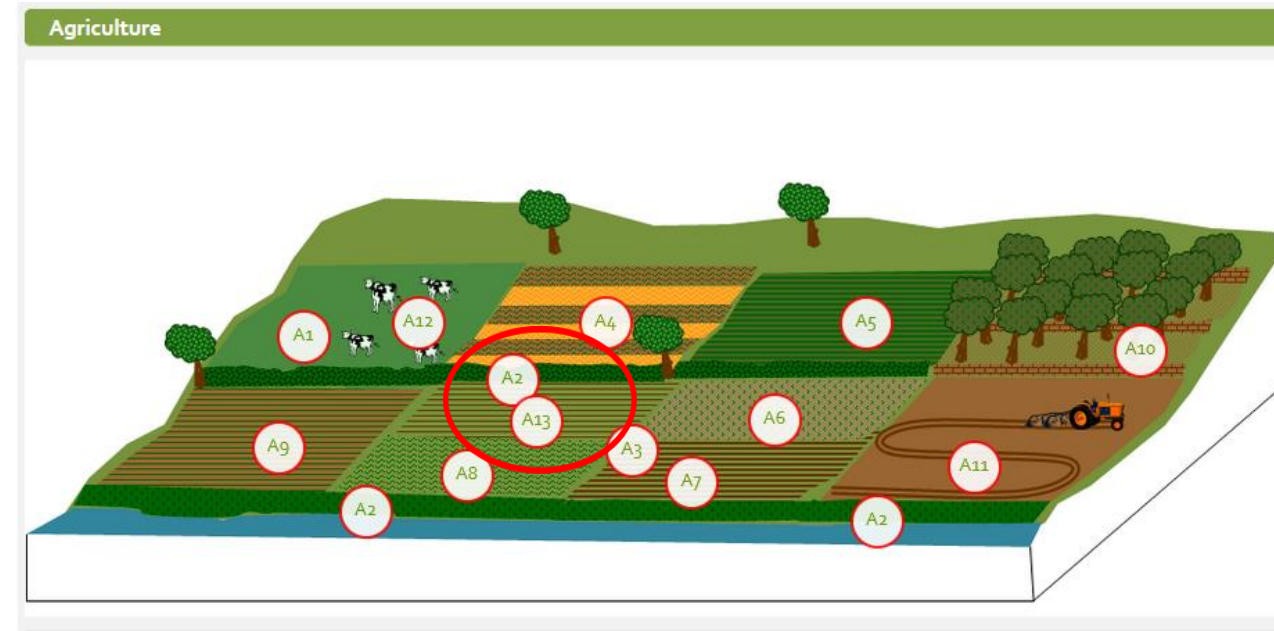
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## 3. Crop Rotation

Definition:

Crop rotation is the practice of growing a series of dissimilar/different types of crops in the same area in sequential seasons. Judiciously applied (i.e. selecting a suitable crop) crop rotation can improve soil structure and fertility by alternating deep-rooted and shallow-rooted plants. In turn this can reduce erosion and increase infiltration capacity, thereby reducing downstream flood risk. It gives various benefits to the soil. A traditional element of crop rotation is the replenishment of nitrogen through the use of green manure in sequence with cereals and other crops. Crop rotation also mitigates the build-up of pathogens and pests that often occurs when one species is continuously cropped.

Carefully designed crop rotations can reduce the period of time that soil is left bare or fallow. This may lead to increased infiltration and runoff reduction.



# Review of Natural Water Retention Measures in Agriculture



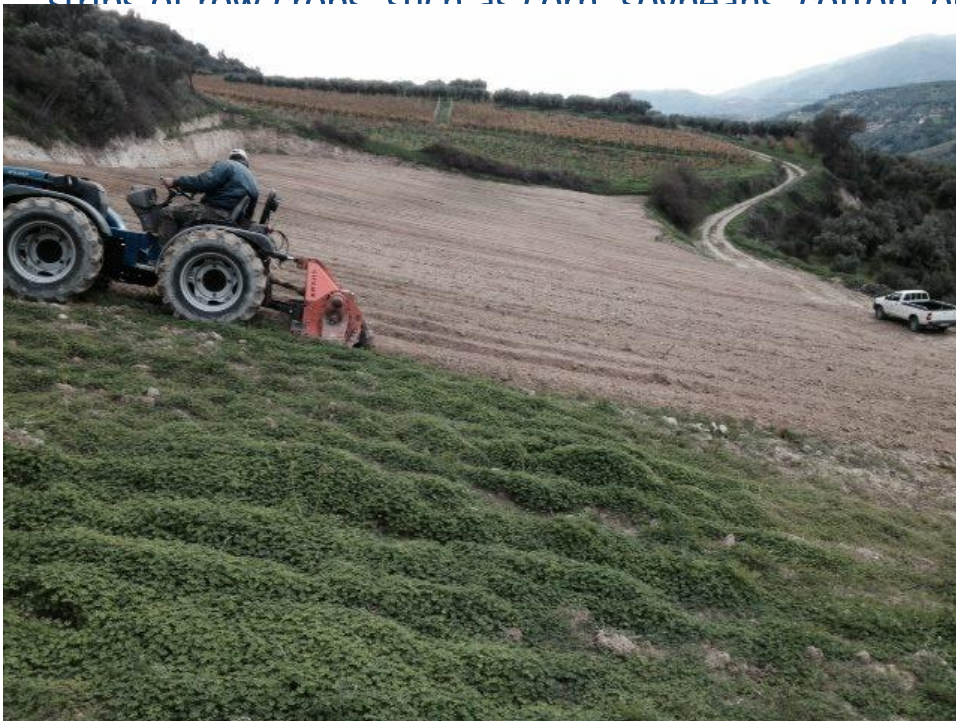
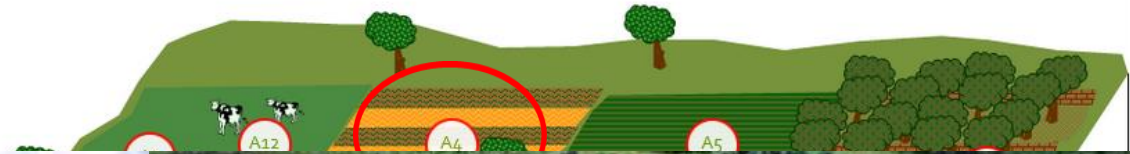
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## 4. Strip cropping along contours

### Definition:

Strip cropping is a method of farming used when a slope is too steep or too long, or otherwise, when one does not have an alternative method of preventing soil erosion. It alternates strips of closely sown crops such as hay, wheat, or other small grains with strips of row crops such as corn, soybeans, cotton, or sugar beets.

### Agriculture





# Review of Natural Water Retention Measures in Agriculture



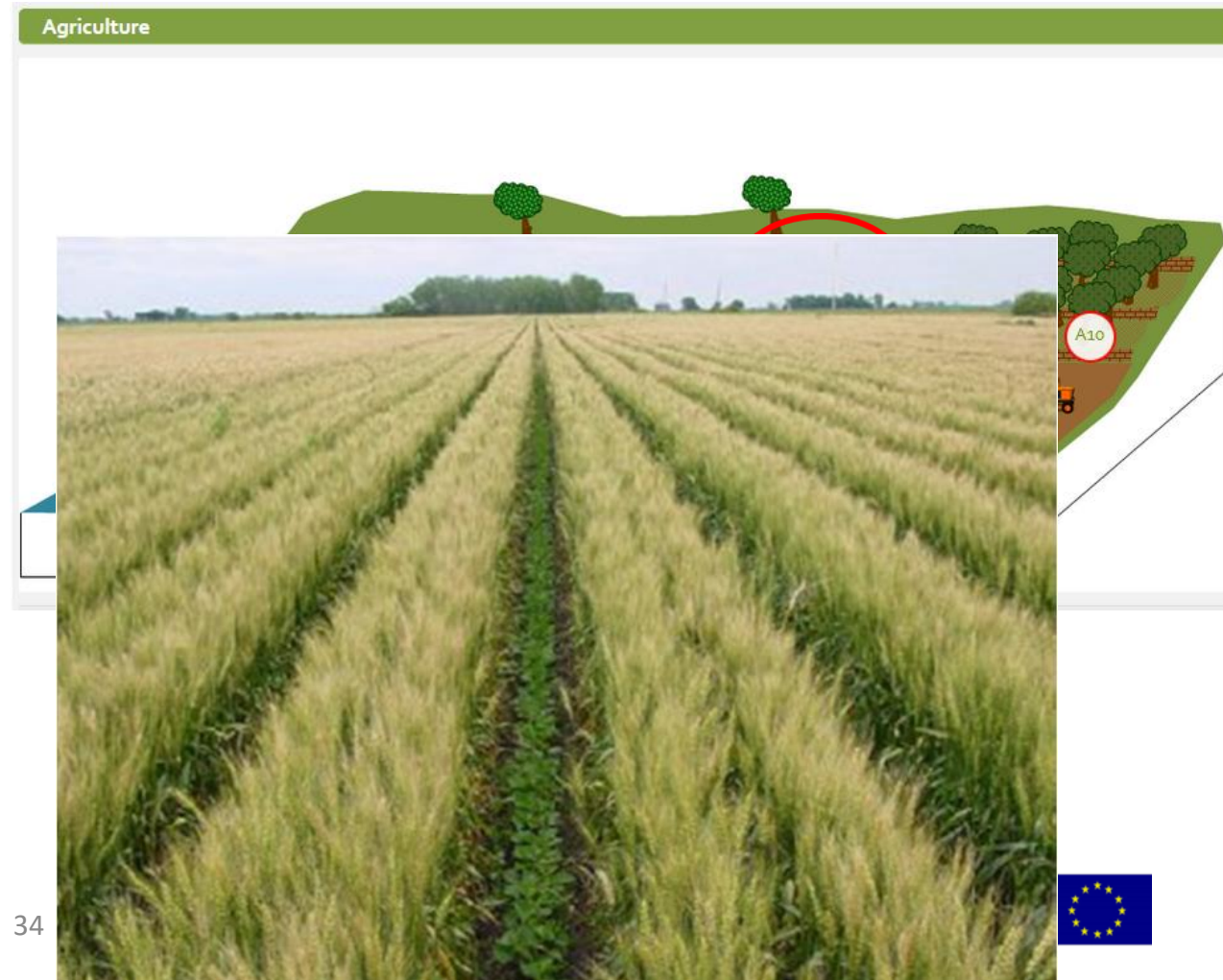
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## 5. Intercropping

### Definition:

Intercropping is the practice of growing two or more crops in proximity. The most common goal of intercropping is to produce a greater yield on a given piece of land by making use of resources that would otherwise not be utilized by a single crop. Examples of intercropping strategies are planting a deep-rooted crop with a shallow-rooted crop or planting a tall crop with a shorter crop that requires partial shade. Numerous types of intercropping, all of which vary the temporal and spatial mixture to some degree, have been identified: mixed intercropping, row cropping, relay cropping, etc.

By implementing cover crops where the soil is otherwise left bare (under other crops, between rows...) intercropping contributes to reduce runoff and increase water infiltration (Battany, 2000). For instance, experiments in the Sahel region showed that runoff decreased by 20-30% with sorghum-cowpea intercropping compared to sorghum sole crop and by 45-55% compared to cowpea monoculture (Zougmore, 2000).





# Review of Natural Water Retention Measures in Agriculture



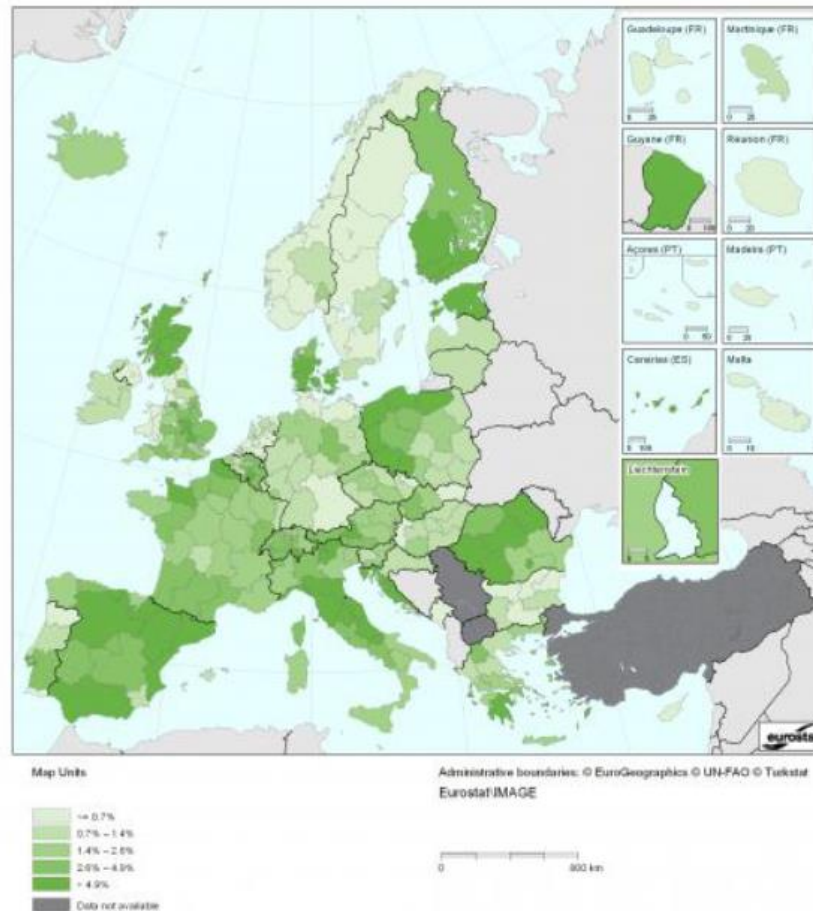
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## 6. No-Till Agriculture

Definition:

Tillage is a mechanical modification of the soil. Intensive tillage can disturb the soil structure, reduce its water retention capacity, lead to soil compaction and translocation of nutrients, and is called zero tillage or direct drilling. No-till is an agricultural system where the soil is not tilled, and the crop is sown directly into the soil. In agricultural regions it can benefit from no-tillage by making soils more resilient.

By implementing cover crops (under other crops, between rows), we can reduce runoff and increase soil water retention. For instance, experiments with sorghum cover crops decreased runoff by 20-30% compared to sorghum monoculture (Zhang et al., 2018).



Agriculture





# Review of Natural Water Retention Measures in Agriculture

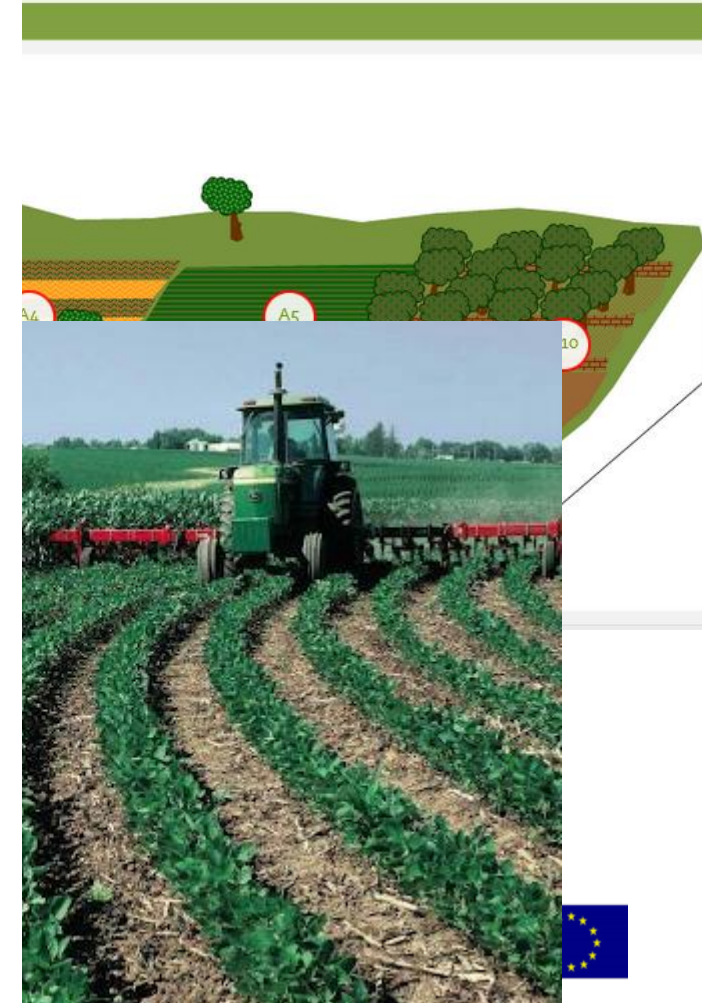
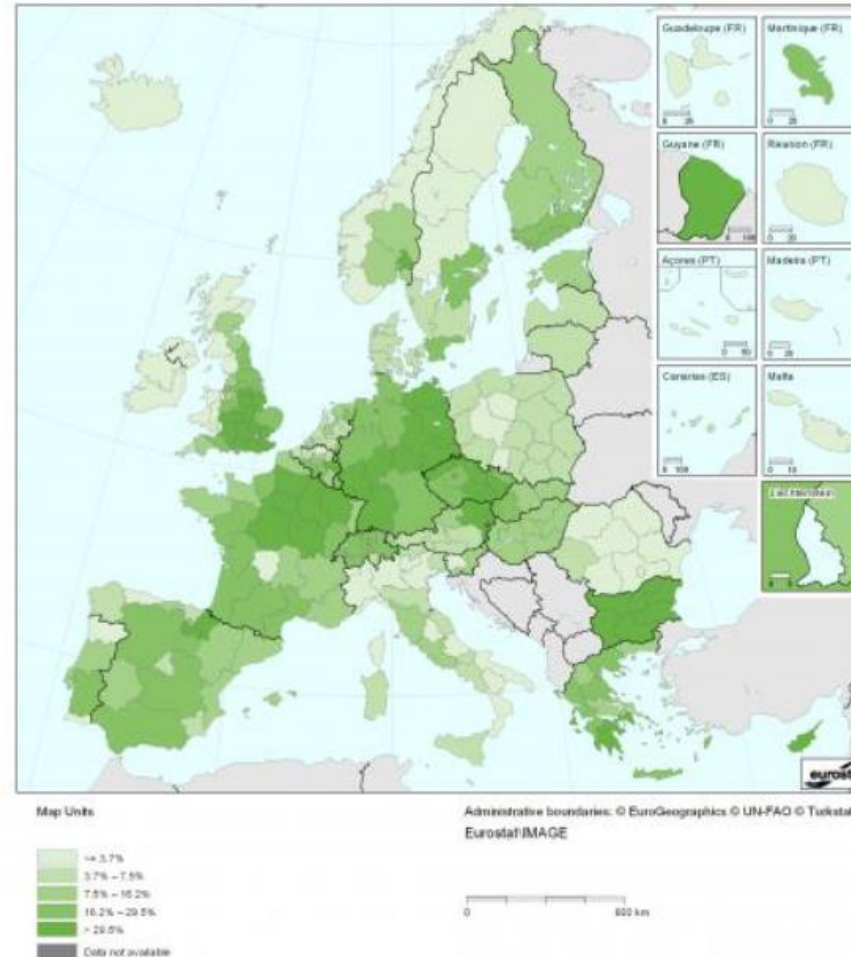


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## 7. Low-Till Agriculture

### Definition:

Low till agriculture, also known as conservation agriculture, applies to arable land. It consists of a combination of measures which leaves at least 30% of crop residue on the surface during the critical soil erosion period and some surface cover slows water movement, which reduces the erosion and potentially leads to greater infiltration.



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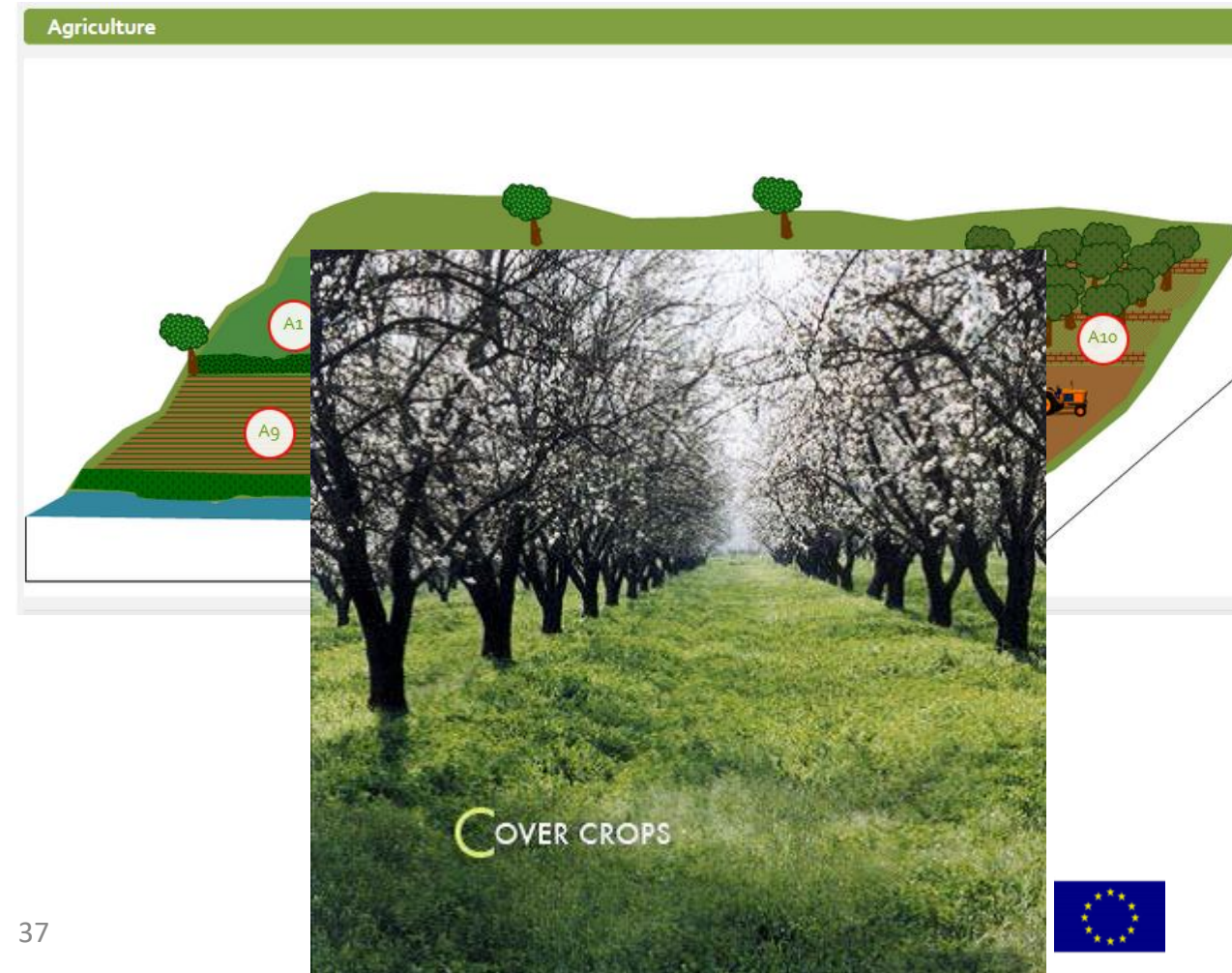


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## 8. Green cover

### Definition:

Green cover (including cover crops or catch crops) refers to crops planted in late summer or autumn, usually on arable land, to protect the soil, which would otherwise lie bare during the winter, against wind and water erosion. Green cover crops also improve the structure of the soil, diversify the cropping system, and mitigate the loss of soluble nutrients.





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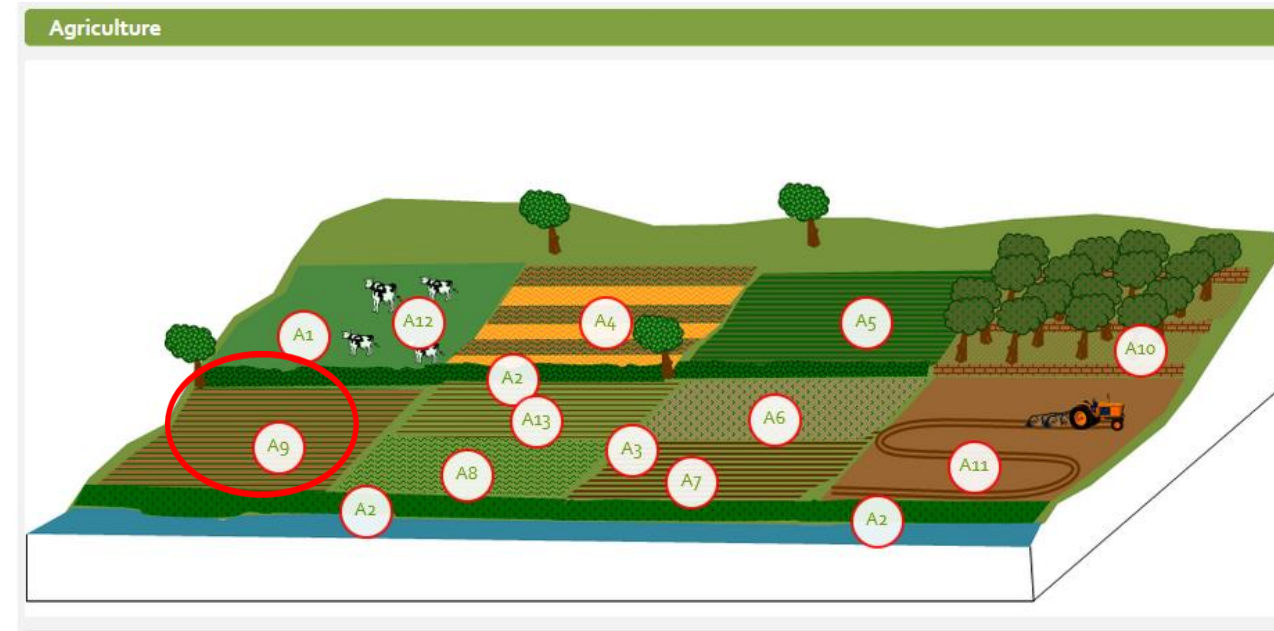


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## 9. Early Sowing

### Definition:

Early sowing refers to sowing up to six weeks before the normal sowing season. This allows for an earlier and quicker establishment of winter crops that can provide cover over winter and of a root network that leads to soil protection. The period in which the soil lies bare is shorter and, therefore, erosion and run-off are less significant and water infiltration is improved. Early sowing can also help to mitigate summer drought impacts on spring sown crops, in particular the extreme evapotranspiration rates of Mediterranean regions. However, early sown plants are frost sensitive; therefore farmers run the risk of losing the crops because of the low temperatures, not applicable in Israel. For both spring and winter crops, early sowing involves a number of trade-offs. For example, different pest and disease risks arise that might require changes in management.



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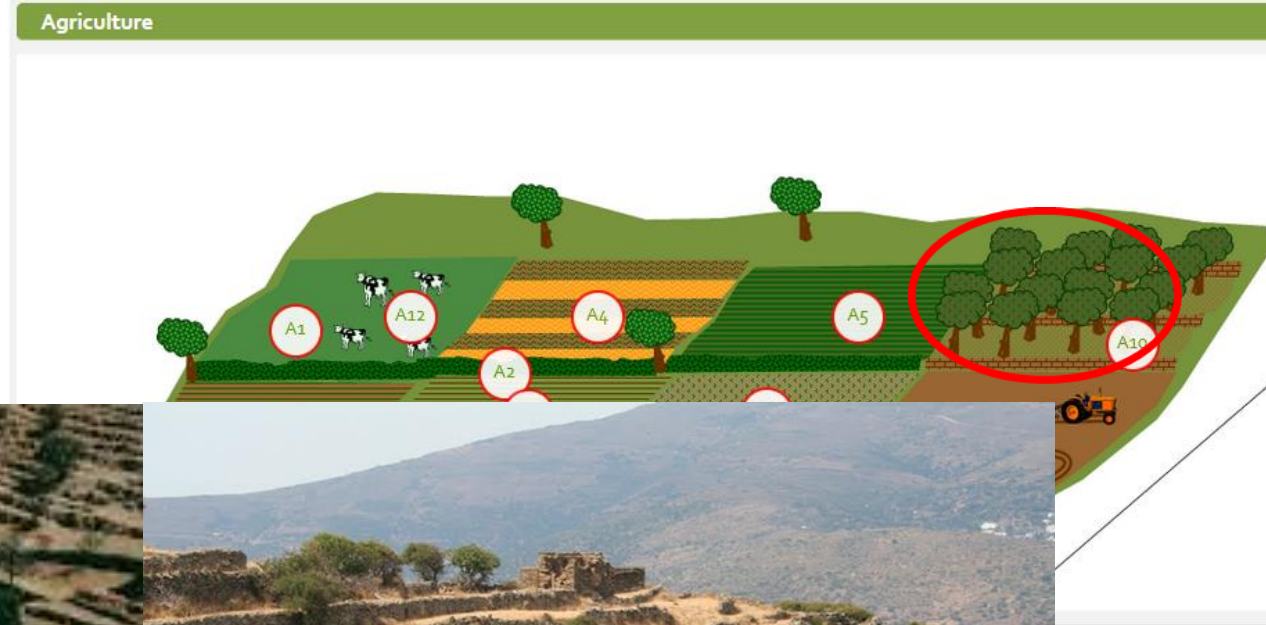
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## 10. Traditional Terracing

### Definition:

Traditional terraces consist of nearly level platforms built along contour lines of slopes, mostly sustained by stone walls, used for farming on hilly terrain. By reducing the effective slope of land, terracing can reduce erosion and surface run-off by slowing rainwater to a non-erosive velocity. This also increases the degree of infiltration and improves soil moisture. However, abandonment of traditional terracing can result in high levels of erosion and run-off due to the lack of maintenance of stone walls. Abandonment can

also change the nature of the landscape, which can be beneficial, for example, for biodiversity. However, abandonment can present a risk of soil erosion. This measure focuses on maintaining existing terraces, which involves less disturbance than creating new ones. As a significant levelling measure, it is highly labour-intensive. The focus of the measure is on maintenance rather than expansion.





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## 11. Controlled Traffic Farming

### Definition:

Controlled Traffic Farming (CTF) is a system which confines all machinery loads to the least possible area of permanent traffic lanes. Current farming systems allow machines to run at random over the land, compacting around 75% of the area within one season and at least the whole area by the second season. Soils don't recover quickly, taking as much as a few years. A proper CTF system on the other hand can reduce tracking to just 15% and this is always in the same place. CTF is a tool; it does not include a prescription for tillage although most growers adopting CTF use little or none because soil structure does not need to be repaired. The permanent traffic lanes are normally parallel to each other and this is the most efficient way of achieving CTF, but the definition does not preclude tracking at an angle. The permanent traffic lanes may be cropped or non-cropped depending on a wide range of variables and local constraints.



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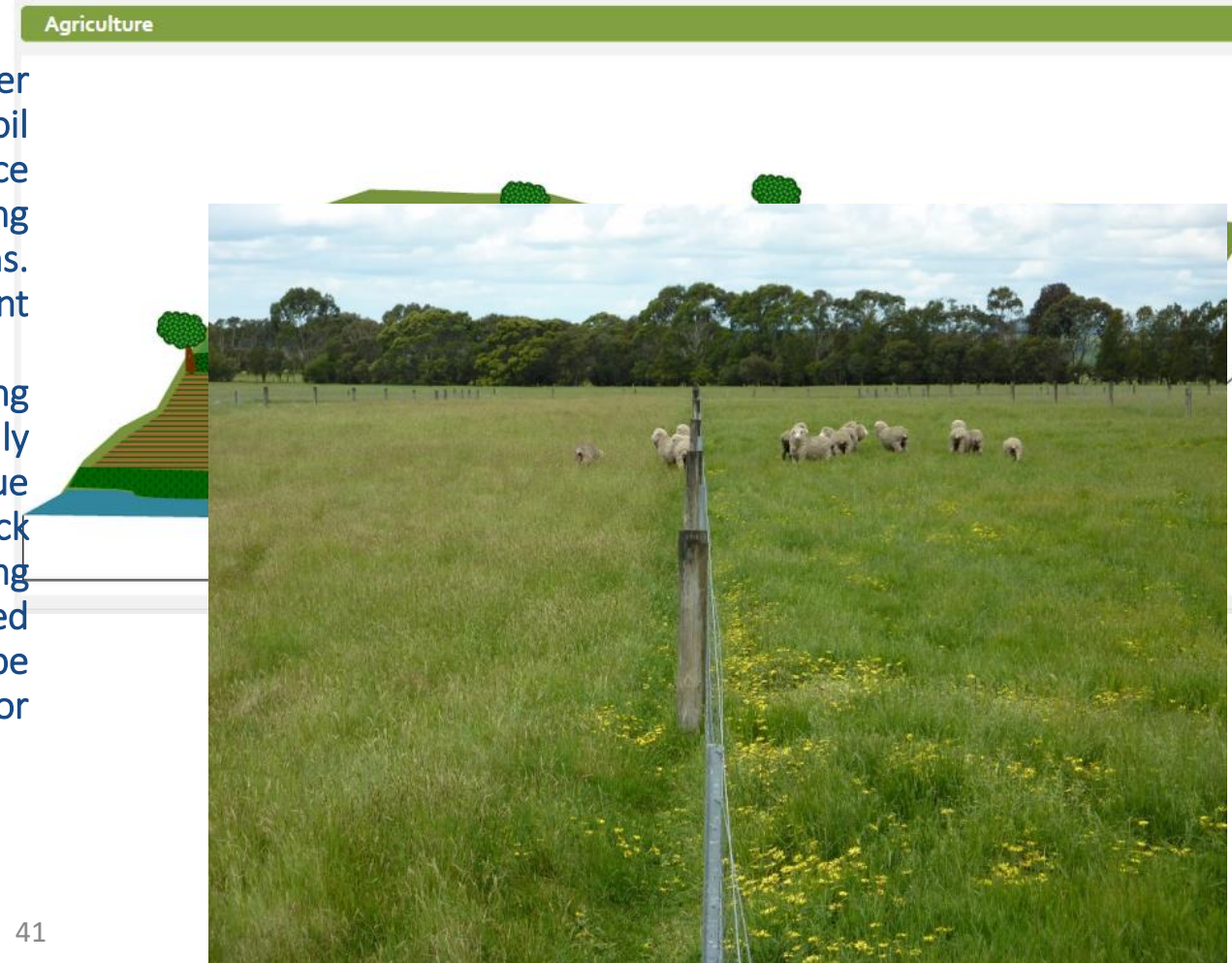
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## 12. Reduced Stocking Density

### Definition:

Livestock, particularly heavy species such as cattle, can have a number of damaging impacts on soil including compaction, destruction of soil structure (poaching) and loss of vegetation. These impacts can reduce infiltration of water into the soil, resulting in pooling and water logging with consequent impacts of denitrification and nitrous oxide emissions. Soil compaction will also increase the risk of run-off with consequent impacts on water quality and flood risks.

Reduced stocking density will limit soil compaction, thereby facilitating more rapid infiltration during precipitation events and potentially reducing peak flows and sediment runoff. There may also be issues due to management decisions which can increase risks due to livestock without changing stocking levels. For example increased out-wintering of cattle to avoid housing costs will exacerbate risks due to the increased vulnerability of soils during the winter months. The measure may be effectively achieved by moving grazing livestock from high risk areas or by increasing the use of housing.





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## 13. Mulching

Definition:

A mulch is a layer of material applied to the surface of an area of soil. Its purpose is any or all of the following:

- to conserve moisture reducing evapotranspiration
- to improve the fertility and health of the soil
- to reduce weed growth
- to enhance the visual appeal of the area

Mulching as NWRM is using grape pulp, shell nuts, green straw, dry grass, leaves etc. applied to bare soil, or a compost will be incorporated by worms and other organisms to improve crop production and in turn dramatically improve the







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Thank you for your attention!

