Towards climate-smart sustainable management of agricultural soils

SCALE

Managing Sediment Connectivity in Agricultural Landscapes for reducing water Erosion impacts

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Catalogue of catchments to develop mitigation plans with appraisal of erosion problems

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Abstract

This report provides a catalogue of 14 agricultural catchments from 8 European countries with different types of erosion problems that have been identified in need of implementing mitigation measures against on-site and off-site impacts of water erosion. This set of catchments has been selected by the SCALE project partners based on previous research and it is a representative sample of the variety of agricultural catchments present in the EU.

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1 Introduction

Work package 5 (Mitigation measures and decision support framework for stakeholders) is one of the six work packages in which the SCALE project is organised in. First objective defined for work package 5 (WP5) is the identification of catchments in need for implementing mitigation measures against on-site and off-site impacts of water erosion. The Task 1 of WP5, entitled 'Baseline identification/categorization of catchment according to need of mitigation', aims to obtain this first objective, and this report compiles part of the results obtained in this task.

This report focuses on:

- The selection of a set of agricultural catchments across Europe, representative of different climates and land uses, with high needs of mitigation measures to reduce on-site problems (as soil loss) as well as off-site damages like sediment delivery to watercourses or infrastructure damages, and
- The description of the erosion problems identified in the selected catchments considering connectivity issues

2 Data collection

The main information for this report was obtained by use of a questionnaire sent out to the SCALE project partners, who selected catchments from their countries based on their experience and previous research.

The questionnaire was firstly available online via a survey system, but also a Word version of the questionnaire was distributed to the partners that did not complete the online form.

The questionnaire included the following questions related to the focus of this report:

1. Name of the SCALE project partner institution
2. Catchment basic information:
    a. Name of the catchment
    b. Country
    c. Region/Province
    d. Extension
    e. Coordinates
    f. Availability of vector file of catchment boundaries
3. Basic description of the catchment properties (topography, geology, soils, land uses, main crops, human population, …)
4. Description of erosion problems in arable lands
5. Description of main connectivity issues
6. Do modelling exercises of soil erosion in the catchment exist?

The information of CORINE Land Cover 2018 version 2020 corresponding to the selected catchments has been considered to evaluate in a homogeneous way the representativeness of the selected agricultural catchments within the European agriculture.

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3 Catalogue of catchments

3.1 Catchments selected to develop mitigation plans

Thanks to the collaboration of the SCALE project partners 14 catchments from 8 countries in Europe has been included in the catalogue of catchments (Table 1). Selected catchments are well distributed across Europe from North (Latitude 60.47 N) to South (Latitude 37.48 N) and from East (Longitude 23.74 E) to West (Longitude 4.66 W) (Figure 1).

Table 1. Basic information of the selected catchments.

Name	Country	Region / Province	Extension	Coordinates		Model applied*
Göllersbach	Austria	Lower Austria	449 km^2	16.1208 E	48.4965 N	R, MF
HOAL	Austria	Lower Austria	0.66 km^2	15.1569 E	48.1450 N	R, W/S, MF
Maarkebeek	Belgium	Flanders / East Flanders	30.4 km^2	3.6569 E	50.8023 N	W/S, R
Molenbeek	Belgium	Flanders / Limburg	50.1 km^2	5.1266 E	50.7477 N	W/S, R
Hesselbaek	Denmark	Northern Jutland	24 km^2	10.1522 E	57.5172 N	W/S
Varbro	Denmark	Northern Jutland	20 km^2	10.0747 E	57.5014 N	W/S
Aurajoki	Finland	Southwest Finland	147 km^2	22.3602 E	60.4752 N	R+IC+SD
Mustionjoki	Finland	Uusimaa	116 km^2	23.7403 E	60.1221 N	R+IC+SD
Roujan	France	Occitanie	0.92 km^2	3.3066 E	43.5062 N	MH
Capriggine	Italy	Tuscany / Pisa	33.3 km^2	10.9057 E	43.4717 N	R
Cavalcanti	Italy	Tuscany / Pisa	0.80 km^2	10.8623 E	43.4671 N	R
Frattina	Italy	Sicily	52.5 km^2	13.3302 E	37.8949 N	-
Bystra	Poland	Lublin	17.1 km^2	22.1977 E	51.2803 N	S
Barriga	Spain	Andalucia / Cordoba	300 km^2	4.6632 W	37.4821 N	R

* **R**: RUSLE; **W/S**: WaTEM/SEDEM; **S**: SWAT; **MH**: MHYDAS; **MF**: MMF; **IC**: Index of Connectivity; **SD**: Sediment Delivery

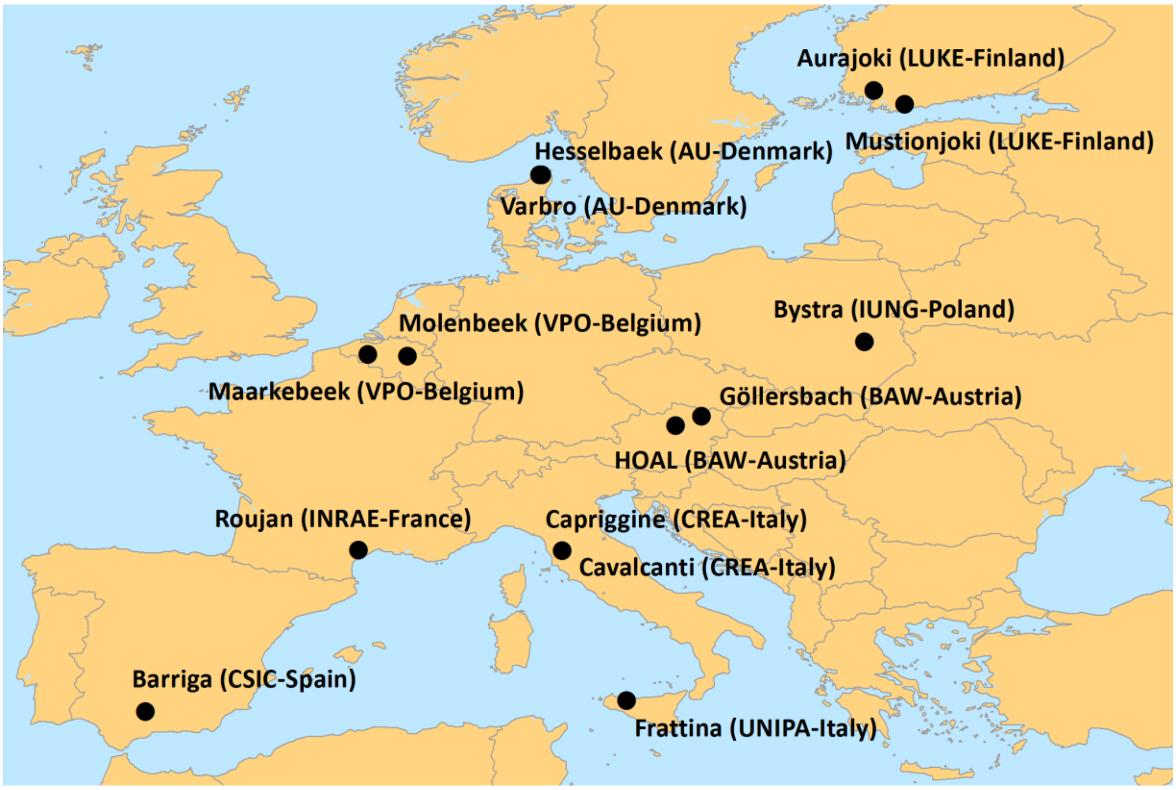

Figure 1. Spatial distribution of the selected catchments.

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3.2 Brief description of the catchments

This section of the report details some characteristics of the selected basins and describes the main erosion problems they present. The different types of water erosion described in the selected catchments are summarized in Table 2.

Table 2. Types of water erosion identified in each catchment.

Erosion types	Göllersbach - Austria	HOAL - Austria	Maarkebeek - Belgium	Molenbeek - Belgium	Hesselbaek - Denmark	Varbro - Denmark	Aurajoki - Finland	Mustionjoki - Finland	Roujan - France	Capriggine - Italy	Cavalcanti - Italy	Frattina - Italy	Bystra - Poland	Barriga - Spain
Inter-rill erosion	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Rill erosion	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Gully erosion	√	√	√	√	–	–	–	–	–	√	√	√	√	√
Landslides	–	–	–	–	–	–	–	–	–	√	√	–	–	–
Calanchi	–	–	–	–	–	–	–	–	–	√	–	–	–	–
Suffusion	–	–	–	–	–	–	–	–	–	–	–	–	√	–
Subsurface flow	–	–	–	–	–	–	–	√	–	–	–	–	–	–

3.2.1 Göllersbach (Austria)

Rolling hills landscape, over predominantly loess deposits. Soils are loessy calcareous cambisols, and majority of land is occupied by cropland partly forested, all kind of crops (mostly grains, maize, sorghum, potato, rape and oil seeds, partly pumpkin, vegetables and miscellaneous crops). Significant evidence of erosion problems due to topography in combination with highly erodible loess soils. Most fields are not disconnected due to the absence of respective measures, partly buffer strips and hedges.

Figure 2. A landscape of Göllersbach catchment.

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3.2.2 HOAL (Austria)

Rolling hills landscape, over fluvial and loess deposits. Soils are predominantly cambisols, covered by extensive conventionally farmed cropland, with typical crop rotation for pig farms (grains, maize, sorghum, rape seed). There are on-site erosion problems due to unfavourable crop rotations in a highly erosive thalweg with respective off-site consequences for the stream. Highly connected parcels with thalweg favourable for overland flow and sediment delivery.

Figure 3. A landscape of HOAL catchment.

3.2.3 Maarkebeek (Belgium)

The catchment of the Maarkebeek belongs to the hilliest regions of Flanders, with an average slope ratio of 7.3%. The soil is sandy loam to loamy. In 2017, 76% of the area is arable land, of which 29% is pasture. 9% is covered with potatoes, 13% with corn. There is evidence of soil loss, gully erosion, production loss, muddy floods, and sediment delivery to the water system. Main connectivity issues are roads, ditches, sewage system, hedgerows, parcel borders, and land use.

Figure 4. A landscape of Maarkebeek catchment.

3.2.4 Molenbeek (Belgium)

The catchment of the Molenbeek belongs to the hilly regions of Flanders, with an average slope ratio of 4.1%. The soil is loamy. In 2017, 77% of the area is arable land, of which 8% is pasture. 9% is covered with potatoes, 14% with corn. This region is also known for its fruit cultivation, which accounts for about 10% of the area. On-field erosion problems are soil loss, gully erosion, and production loss. This region is known for its muddy floods, impacting infrastructure, ditches, and water courses. Over the last few decades, therefore, there has been an enormous effort in implementing erosion control measures. Although this catchment has the highest

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number of erosion control measures in Flanders (approximately 50% of the parcels is connected to a measure), the sediment loads in the water courses are still high. Main reason is the increased number of extreme rainfall events and higher intensity rainfall events. Main connectivity issues are roads, ditches, sewage system, hedgerows, parcel borders, and land use.

Figure 5. A landscape of Molenbeek catchment.

3.2.5 Hesselbaek (Denmark)

Gently rolling topography, over late glacial marine deposits in the North and glacial tills in the South of the catchment. Soils are Luvisols, Cambisols, and Podzols, predominately fine-sandy loamy sands. The landscape is characterized by mixed arable agriculture, and it is sparsely populated. Risk assessment predicts high erosion risk on the pronounced topography in the South of the catchment, while there are eroding slopes along water courses in the North. The stream network is relatively dense with rather narrow buffer zones adjacent to eroding land. Especially in the South, high sediment delivery is predicted to some 1st order streams.

Figure 6. A landscape of Hesselbaek catchment.

3.2.6 Varbro (Denmark)

Gently rolling topography, more pronounced than in the Hesselbaek catchment, over late glacial marine deposits and glacial tills, respectively, in the western and eastern part. Soils are Podzols and Alisols, predominately fine-sandy loamy sands. The landscape is characterized by mixed arable agriculture, and it is sparsely populated. In the Danish context, high soil loss rates by water erosion are modelled on much of the cropland. Relatively high sediment delivery is predicted to a dense stream network with rather narrow buffer zones adjacent to eroding land.

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Figure 7. A landscape of Varbro catchment.

3.2.7 Aurajoki (Finland)

The catchment is the lowest sub-catchment of a larger catchment, flat area with relatively steep riverbanks, mainly clay soil. More than a third of the total area are agricultural lands, where main crops are spring cereals and perennial grass type crops. At the basin outlet is located the second largest city of Finland (Turku). There are higher erosion rates particularly near streams and rivers. Off-site impacts are significant in the Finnish archipelago in the Baltic Sea because high-erosion areas are well-connected to water bodies. Fields are well drained with open ditches surrounding field parcels and artificial sub-surface drainage is a common practice. Sub-surface drainage act as an important sediment transport pathway from surface soil to ditches and surface waters. Erosion and sediment loading to waters are typically managed with winter-time vegetation cover, reduced tillage, and riparian buffer zones. The catchment had an experimental field with erosion measurements under different agricultural practices.

Figure 8. A landscape of Aurajoki catchment.

3.2.8 Mustionjoki (Finland)

The catchment is the lowest sub-catchment of a larger catchment, mildly undulating, that mainly present clay soils. It is a partially forested area where agriculture, mainly spring cereals and perennial grass type crops, represents a third of the total area. Undulating topography contributes to higher erosion rates. The river has highly endangered freshwater mussels (Margaritifera margaritifera) and agricultural erosion has been identified as one of the key problems for this species. Despite the high erosion areas not being close to water bodies the erosion loading to streams and the river is high. Fields are well drained with open ditches surrounding field parcels and artificial sub-surface drainage is a common practice. Sub-surface drainage act as an important sediment transport pathway from surface soil to ditches and surface

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waters. Erosion and sediment loading to waters are typically managed with winter-time vegetation cover, reduced tillage, and riparian buffer zones.

Figure 9. A landscape of Mustionjoki catchment.

3.2.9 Roujan (France)

The substratum of Roujan belongs mainly to the Miocene marine deposits. The bedrock of the catchment is composed of calcareous loose sandstone with centimetric laminations and intercalations of loamy clay material covered by lacustrine limestone. The soil types depend on the nature of the deposits and on the position within the slope, soils are mainly calcareous silty. Temporary and permanent shallow groundwaters are present along the hillslopes and in the bottom lands. Significant evidence of rill and inter-rill erosion causing field losses. The ditch network suppresses or restricts the lateral connectivity between fields with regard to surface runoff.

Figure 10. A landscape of Roujan catchment.

3.2.10 Capriggine (Italy)

The Capriggine watershed is a sub-basin of the Era River Basin. The lower part of the watershed is constituted by marine pliocenic sediments, mainly clayey and silty clay blue-gray locally with fossiliferous levels, while in the upper part of the main outcrops are clays with intercalations of sandstone and conglomeratic levels. There are common phenomena of mass and rill erosion favoured by tillage along the maximum slope direction. Previous studies indicate that inter-rill, rill and channel erosion processes are predominant on mass movements. Reduction in the number of smalls farms during last decades has led to the elimination of the pre-existing drainage system, stone walls or hedges, the latter also used to delimit farm boundaries. This contributes to the increase of the hydrologic connectivity and facilitates the

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sediment transport to the hydrographic network. On the other hand, the increase in construction of new road infrastructures and small artificial reservoirs for the storage of irrigation water, even at the level of single farm, contribute to the decrease of the hydrologic connectivity.

Figure 11. A landscape of Capriggine catchment.

3.2.11 Cavalcanti (Italy)

The Cavalcanti catchment, near Volterra (Tuscany, Pisa province), is part of the Era River valley (Valdera) and includes part of the land belonging to the CREA S. Elisabetta Experimental Centre. As part of the Capriggine catchment, Cavalcanti catchment presents the same characteristics. There are common phenomena of mass and rill erosion favoured by tillage along the maximum slope direction. Elimination of the pre-existing drainage system, stone walls or hedges, contributes to the increase of the hydrologic connectivity and facilitates the sediment transport to the hydrographic network. Increase in construction of new road infrastructures and small artificial reservoirs for the storage of irrigation water, even at the level of single farm, contribute to the decrease of the hydrologic connectivity.

Figure 12. A landscape of Cavalcanti catchment.

3.2.12 Frattina (Italy)

The catchment is located in the central western area of Sicily (Italy). The landscape of the catchment shows the typical features of the central inland clay area of Sicily. The relief is characterized by undulating hilly morphologies in which flat areas appear at the base of moderately steep and steep slopes. The catchment is naturally characterized by water erosion that is worsened by anthropic activity. Arable lands are tilled according to the slope before the rainy season while the soils under tree orchards are tilled at the end of spring. In the last case

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the soil remains without a grass cover and prone to rainfall erosion at the beginning of the rainy season. Hydrological and sediment connectivity has been mainly affected by the construction of roads, land use change (conversion of pastures into arable land) and small reservoirs realized in the recent years.

Figure 13. A landscape of Frattina catchment.

3.2.13 Bystra (Poland)

Bystra catchment it is an upland catchment with loess soils. The landscape of the basin is hilly, mainly agricultural but with forest areas. In the agricultural lands there are significant evidence of heavy erosion caused by surface runoff, suffusion, and gullies.

Figure 14. A landscape of Bystra catchment.

3.2.14 Barriga (Spain)

The relief of the basin includes heights from 230 m, at the end of the stream, to 485 m, at the eastern limit of the basin. The geology is composed of clastic rocks with Calcarenites near to the town, and siliceous sandstones and white marls in the rest of the basin. The main erosion problems in this watershed are associated with olive groves, woody crop in which farmers avoid the presence of other species in the plot, which causes problems of rills and gullies. Most of the groves are associated with large watercourses (72%), there is a low number of physical boundaries, which may be because the current plots are caused by the segregation of large plots, so the connectivity between plots is high.

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Figure 15. A landscape of Barriga catchment.

4 Land uses within the selected catchments

The main characteristics of the catchments and the similarity among them have been summarised obtaining data from CORINE Land Cover 2018 version 2020 (Table 3; Figure 16).

Table 3. Frequency of land uses within the selected catchment according to CORINE Land Cover 2018.

Catchment	Non-irrigated arable land	Broad-leaved forest	Coniferous forest	Mixed forest	Vineyards	Olive groves	Complex cultivation patterns	Pastures	Transitional woodland-shrub	Natural grasslands	Water bodies	Sclerophyllous vegetation	Fruit trees and berry plantations	Inland marshes	Urban use and infrastructures*	Agriculture and natural veg.**
Aurajoki	27.2	0.0	25.1	4.3	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	28.6	14.0
Mustionjoki	24.9	2.2	24.0	26.7	0.0	0.0	0.0	0.0	4.7	0.0	2.2	0.0	0.0	0.0	5.4	10.0
Europe (+Turkey)	18.7	9.0	12.6	4.8	0.6	0.8	3.7	6.6	4.6	3.3	2.0	1.7	0.7	0.2	3.7	4.2
Capriggine	37.6	42.5	4.3	2.1	0.8	2.8	0.0	0.0	0.0	0.0	0.0	8.8	0.0	0.0	0.0	1.2
Göllersbach	58.7	16.0	0.0	11.3	1.6	0.0	2.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	6.1	3.5
Molenbeek	74.3	1.0	0.0	0.0	0.0	0.0	3.4	0.0	0.0	0.0	0.0	0.0	7.3	0.0	14.1	0.0
Hesselbaek	81.6	0.0	0.0	4.8	0.0	0.0	10.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6
Cavalcanti	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bystra	64.0	11.0	0.1	2.5	0.0	0.0	7.5	1.8	0.0	0.0	0.0	0.0	0.4	0.0	4.8	7.9
Frattina	75.2	11.4	0.0	0.0	1.9	0.0	0.0	0.0	0.0	3.3	0.0	2.6	0.0	0.0	0.5	5.0
Varbro	46.4	0.0	0.0	4.5	0.0	0.0	18.5	0.0	0.0	0.0	0.0	0.0	0.0	4.3	3.1	23.3
HOAL	63.5	0.0	0.0	0.0	0.0	0.0	36.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maarkebeek	41.9	2.3	0.0	0.7	0.0	0.0	27.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	12.3	8.9
Barriga	0.0	0.0	0.0	0.0	5.1	76.8	5.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.0	0.0
Roujan	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

* Urban use and infrastructures: 'Continuous urban fabric', 'Discontinuous urban fabric', 'Industrial and commercial units',' Road and rail networks and associated land', 'Port areas', 'Mineral extraction sites', 'Green urban areas', 'Sport and leisure facilities'.

** Agriculture and natural vegetation: 'Land principally occupied by agriculture, with significant areas of natural vegetation'

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From 43 land uses identified in the CORINE (excluding 'Sea and ocean' and 'No data'), 23 are present in the selected catchment. The data for no agricultural/natural vegetation were aggregated (urban, suburban, infrastructure and mining lands mainly) for the sake of clarity. The matrix land cover × catchment was submitted to a clustering scaling data by catchments. i.e., the algorithm was not applied to raw data but to the proportion of land cover within each catchment. Clustering algorithm was based on euclidean distance and with the complete linkage method. They were also included the whole CORINE data as a whole in order to have a global reference. CORINE covers all the European territory except Belarus, Russia and Ukraine but includes Turkey.

Results from clustering were represented in the heatmap of figure 16. The first obvious observation is the predominance of non-irrigated arable land in the selected catchments, however, details are interesting. The most differentiated group is formed by Barriga (Spain) and Roujan (France) catchments where olive trees and vineyards, respectively, are dominant. Then Aurajoki and Mustionjoki catchments clearly differentiate from other northern and central Europe catchments and from Italy also. This is due to the importance of mixed and coniferous forests in these Finnish catchments, but also to the less importance of non-irrigated arable lands.

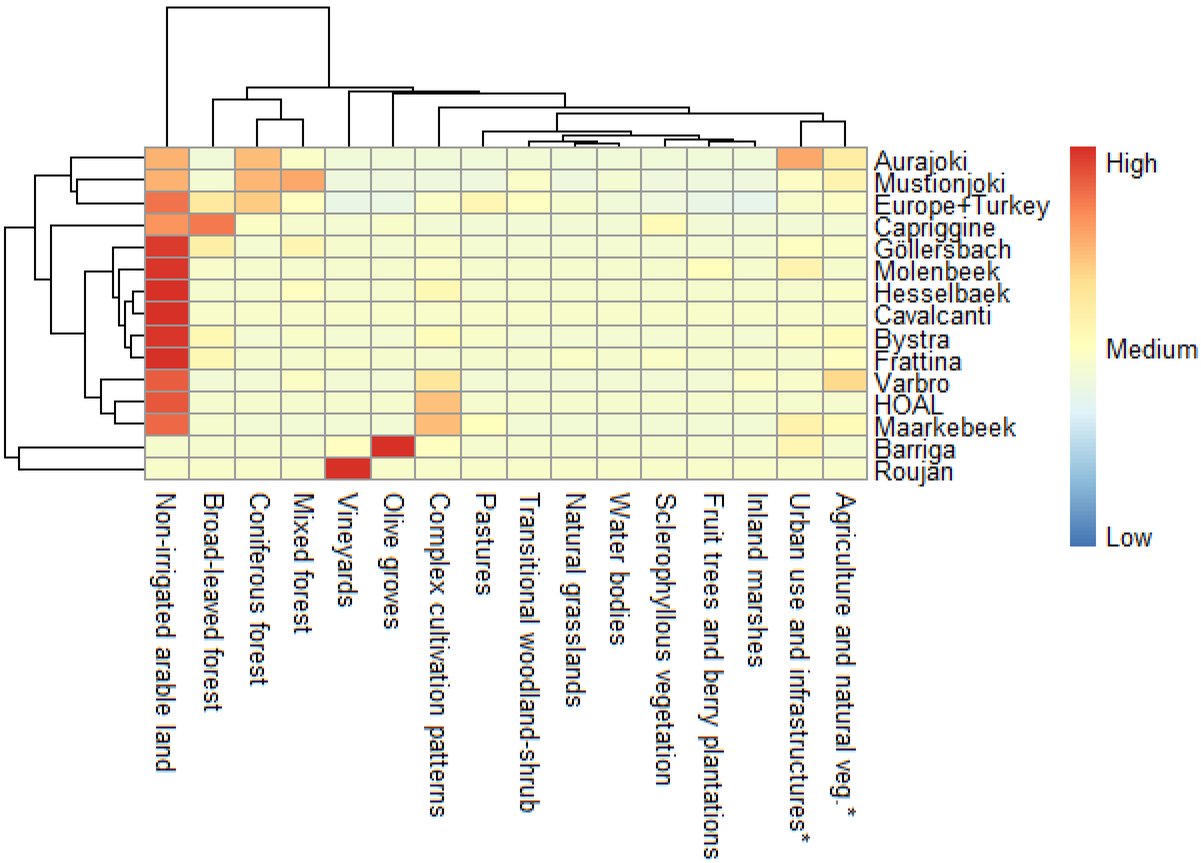

Figure 16. Heatmap of land uses within the selected catchment according to CORINE Land Cover 2018. (***Urban use and infrastructures**: 'Continuous urban fabric', 'Discontinuous urban fabric', 'Industrial and commercial units',' Road and rail networks and associated land', 'Port areas', 'Mineral extraction sites', 'Green urban areas', 'Sport and leisure facilities'. ***Agriculture and natural vegetation**: 'Land principally occupied by agriculture, with significant areas of natural vegetation')

The rest of catchments are similar in terms of land cover and differences between them are modest. This similarity is mainly driven by the dominance of arable land. Some nuances: Capriggine is characterized by importance of broad-leaved forests; HOAL and Maarkebeek by moderate abundance of complex cultivation patterns.

In terms of European representativity, it can be observed that 'Europe (+Turkey)' global values cluster with Aurajoki and Mustionjoki catchments. This is easily understandable as Europe and Turkey harbours extensive coniferous forests while the catchments selected in SCALE project are mainly cultivated land, except for these Finnish catchments.

5 Summary

This report presents an overview of 14 agricultural catchments selected by the SCALE project partners for implementing mitigation measures against on-site and off-site impacts of water erosion. Catchment selection has been based on the experience and previous research of project partners.

Selected catchments include a wide range of catchment sizes (from 0.66 km^2 to 449 km^2), they present different problems of water erosion and hydrological connectivity, different types of erosion models have been applied on them (RUSLE, WaTEM/SEDEM, SWAT, MHYDAS, Etc.), they are distributed throughout the European territory and, according to land uses, they include a wide variety of agricultural landscapes. In view of these characteristics, it can be affirmed that selected catchments for SCALE project form a representative sample of agricultural catchments in the EU.

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