Directory of soil restoration strategies on TUdi across different soil degradation gradients across EU and China

Deliverable D3.1

14 June 2022

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TUdi

This project receives funding from the European Union's Horizon 2020 Research and Innovation action under grant agreement No 101000224.

Start of the project:	July 2021
Duration:	48 months
European coordinator:	Dr. José A. Gómez Institute for Sustainable Agriculture (IAS), Spanish National Research Council (CSIC)
Chinese coordinator:	Dr. Xiaoping Zhang Institute of Soil and Water Conservation (ISWC), Chinese Academy of Sciences
Deliverable title:	Directory of soil restoration strategies on TUdi across different soil degradation gradients across EU and China
Deliverable n°:	D3.1
Nature of the deliverable:	Report
Dissemination level:	Public
WP responsible:	WP3
Lead beneficiary:	Nick OSTLE (ULANC) and Zhiqiang WANG (BNU, China)

Citation: Hudek, C., Ostle, N., Quinton, J., Dodd, I., Liebhard, G., Tzvetanova, E., Wang, Z., Zumr, D., Dostál, T., Bakacsi, Zs., Pirko, B., Zavattaro, L., Pittarello, M., Gómez, J.A., Guzmán, G. (2022). Directory of soil degradation gradients and soil restoration studies across the TUdi project. Deliverable D3.1 EU Horizon 2020 TUdi Project, Grant Agreement No 101000224.

Due date of deliverable:	28 February 2022
Actual submission date:	14 June 2022

Deliverable status:

Version	Status	Date	Author(s)
1.0	Final	14 June 2022	Csilla Hudek, Nick Ostle, John Quinton, Ian Dodd, Gunther Liebhard, Ekatherina Tzvetanova, Zhiqiang Wang, David Zumr, Tomáš Dostál, Zsófia Bakacsi, Béla Piró, Laura Zavattaro, Marco Pittarello, José A. Gómez, Gema Guzmán

Table of contents

Preface

This report contains the result of a survey carried out on the long-term monitored farms and experimental sites (listed in D1.1) among the TUdi members' network. The site-specific soil degradation threats, degradation gradients and data on the impact of degradation threats on yield were recorded. A comprehensive dataset on the use of vegetation cover for soil restoration purposes was also collected. This report provides the basis for D3.2.

1 Introduction

This deliverable aims to identify degradation gradients, an index derived from soil related indicators, and to create a directory of degraded soil restoration experiments and long-term monitoring, established in different cropping systems (e.g., cereal, horticultural, tree crops and grasslands) across the TUdi partnership areas. In this context, soil degradation is defined as impaired soil properties and functioning, identified using a series of readily measured indicators (i.e. organic carbon, nitrogen, bulk density, water holding capacity, vegetation cover, biomass production) in line with those used by WP1 and WP2 in deliverable D1.1 (Bakacsi et al., 2022) and D2.1 (Krasa et al., 2022). In general, soil restoration techniques include conservation/regenerative agriculture, enhancement of biodiverse swards as well as management practices to reduce inputs and alleviate compaction/erosion. Deliverable 1.1. provides site specific information across TUdi partnership areas, on farming systems (conventional, integrated, organic, etc.), management practices such as tillage and fertilization methods, water supply and plant protection but information only covers the absence or presence of additional crop cover used. Therefore, to bridge the knowledge gap on existing soil bio-engineering tools used in soil restoration technique, this deliverable aimed to focus on gathering comprehensive information on the use of vegetation e.g., cover crops, swards, mulch, for soil restoration purposes.
The present deliverable contains information provided by the TUdi partners on the experimental and monitored farm studies, and a database of soil degradation gradients using an index derived from soil related indicators and the detailed nature of the restoration strategy implemented with particular focus on using vegetation as a soil bio-engineering tool. This task was performed in co-ordination with the TUdi national partners in cooperation with wider stakeholders and in close liaison with WP1 and WP2. This activity provided a list of restoration sites and degradation gradients for use in TUdi research that can be shared with the wider community and stakeholders.

2 Methodology

This deliverable builds on information and results collected and presented by WP1 and WP2 partners in D1.1 and D2.1 on soil degradation, farming systems, tillage methods and the presence or absent of crop cover. This information allowed us to narrow down the main soil degradation threats listed both by farmers in the WP2 questionnaire and observed on the long-term experimental sites in the WP1 questionnaire. Taking into consideration the results of both WP1 and WP2 questionnaires, we developed an additional questionnaire to collect information on degradation threats and their statuses, their effects on productivity and existing bio-engineering tools used for soil restoration purposes. The questionnaire was sent to all TUdi partners providing indexes for each question to select from (Table 1). Additional space was also provided for notes or to further describe individual situations.

The farm survey (WP2 questionnaire) highlighted six main soil degradation threats farmers are commonly experiencing in all the surveyed countries (soil structure, organic carbon content, soil profile depth, soil compaction, drought and land soil water logging). At the monitored farm/experimental sites (WP1 questionnaire) the eight most common soil degradation threats observed were soil organic matter decline, nitrate leaching, drought water holding capacity, soil compaction, erosion, unbalanced nutrient availability, weak soil structure, leaching/runoff of pesticide. Considering both the WP1 and WP2 results we selected eight common **degradation threats** to focus on in our survey:

- **Soil organic matter decline** is the most common degradation problem in most farming practices.
- **Soil compaction**, **erosion** and weak **soil structure** are the most common soil physical degradation threats.
- **Nitrate leaching** and **leaching/runoff of pesticides** are often responsible for pollution of surface and ground water bodies.
- **Drought** and **soil water logging** are the threats that farmers are facing more often as a result of climate change.

Additionally, it was important to distinguish between **water** and **wind erosion** and specify the **depth of compaction** affecting the soil profile. **Soil biodiversity** acted as an indicator of soil resilience to environmental changes.

The level of degradation is an important indicator of the state of the agricultural landscape and its soil. It determines the type of restoration process required to successfully alleviate and reverse degradation. Data collected from the long-term experimental sites on degradation gradients would allow us to develop sustainable restoration techniques for various site conditions for future implementation.

The level of degradation has a major impact on land productivity, therefore data on the **stability of yield** was an important component of the questionnaire.

2.1 Structure of the questionnaire

2.1.1 Soil degradation threats and gradients

Each partner was asked to identify key soil degradation threats and gauge their intensity. For each threat, different levels of severity were identified (Table 1). Scoring values were set to quantify the qualitative predictions which would allow us to display (e.g., on a radar chart) the multivariate data from different countries and sites. This allows comparison and analysis of different degradation threats.

Table 1: Soil degradation threats and classification of degradation status, and how this relates to scoring values.

Threat	Degradation status	Additional description	Scoring values
1. Soil Organic Matter decline	- *None* - *25% reduction* - *50% reduction* - *75% reduction*		0 1 2 3
2. Nitrate leaching	- *Under regulatory limit in drinking water* - *Above the regulatory limit in drinking water*		0 4

3. Leaching of pesticides	- *No pesticide found in groundwater* - *Pesticide found in groundwater*		0 4
4. Weak soil structure	- *Stable aggregates* - *Moderately durable aggregates* - *Poorly formed from indistinct aggregates*		0 1 2
5. Water erosion	- *None* - *Splash* - *Sheet* - *Rill* - *Gully*		0 1 2 3 4
6. Wind erosion	- *None* - *Surface* - *Creep* - *Saltation* - *Suspension*		0 1 2 3 4
7. Surface compaction (top <40 cm)	- *None* - *Low* - *Moderate* - *Heavily compacted*	- *None* - *Rooting restricted for some plants, some reduction in the rate of infiltration and drainage, possible to alleviate by agricultural activity* - *Rooting restricted, reduced rate of infiltration and drainage, difficult to alleviate by agricultural activity* - *Rooting inhibited, infiltration and drainage are inhibited, alleviation by agriculture is not possible*	0 1 2 3
8. Sub-surface compaction (>40 cm deep)	- *None* - *Low* - *Moderate* - *Heavily compacted*	- *None* - *Rooting restricted for some plants, some reduction in the rate of infiltration and drainage, possible to alleviate by agricultural activity* - *Moderate: rooting restricted, reduced rate of infiltration and drainage, difficult to alleviate by agricultural activity* - *Heavily compacted: rooting inhibited, infiltration and drainage are inhibited, alleviation by agriculture is not possible*	0 1 2 3

9. Drought, soil water holding capacity	- *None* - *25% reduction of a pristine soil* - *50% reduction of a pristine soil* - *75% reduction of a pristine soil*	0 1 2 3
10. Flooding, ponding, saturation for long time	- *None* - *Soil saturated for <1 month* - *Soil saturated for 1<4 months* - *Soil saturated for >4 months*	0 1 2 3
11. Low soil biodiversity	- *No* - *Yes* - *Unknown*	0 1 -
12. Yield stability	- *Stable yield* - *< 10% reduction* - *10% < 30% reduction* - *>30% reduction*	0 1 2 3

2.1.2 Structure of crop cover

To develop comprehensive set of soil restoration strategies across diverse environments using vegetation traits as the main tool, the second part of the WP3 questionnaire (Table 2) aimed to collect available data on the use of vegetation cover for soil restoration purposes across long-term experimental sites. The questionnaire asked 17 questions (polar and open) offering specifications to choose from as well as space to list the partners' specifications when they differed from the list provided.

Table 2: Crop cover used as a tool for additional vegetation cover and its specifications.

Crop cover	Specifications
1. Vegetation Cover (VC) maintained through the year	- *Yes* - *No*
2. Reason for not using VC	- *Cost of seed/plant material* - *Competition for water* - *Competition for nutrients* - *Competition for light/space* - *Potential problem in future pest control* - *Potential to become a weed* - *Site conditions (too wet/dry etc)* - *Other*
3. Type of VC	- *Cover crop* - *Sward* - *Vegetation strip* - *Mulch* - *Other (Please specify)*
4. Surface Cover %	- *25%<* - *25-50%*

	- *50-75%* - *>75%*
5. Which type of plant material is used for VC?	- *Seed* - *Rhizome* - *Other*
6. Species used (please list)	
7. Composition of VC	- *Single species* - *Multispecies mixture*
8. Source of plant material	- *Local seed/plant* - *Commercially available* - *Farmer's selection*
9. Time of sowing Cover crop/putting on place	- *Before cash crop* - *Together with cash crop* - *After harvesting cash crop* - *Other*
10. What is the main crop/cash crop?	
11. Purpose of using VC	- *Improve soil physical properties* - *Improve soil chemical properties* - *Improve soil biological properties* - *Pest control* - *Weed control* - *Feed for animals*
12. Available plant trait data	- *Root* - *Leaf/stem* - *Biomass* - *Cover%* - *Other*
13. Length of being on the ground the VC	- *Temporary <1 year* - *Permanent >1 year*
14. Maintenance of permanent VC	- *None* - *Mowed* - *Grazed*
15. Termination of VC	- *Naturally killed (e.g., frost)* - *Mowed* - *Grazed* - *Chemically killed* - *Ploughed*
16. Subsidised for using VC	- *Yes* - *No*
17. Financial support from other bodies (water company etc.)	- *Yes* - *No*

3 Results of the questionnaire

Eight countries provided details on 32 long-term monitored farms and experimental sites (Figure 1). The information provided is based on collected data, model simulations and local experts` based judgment.

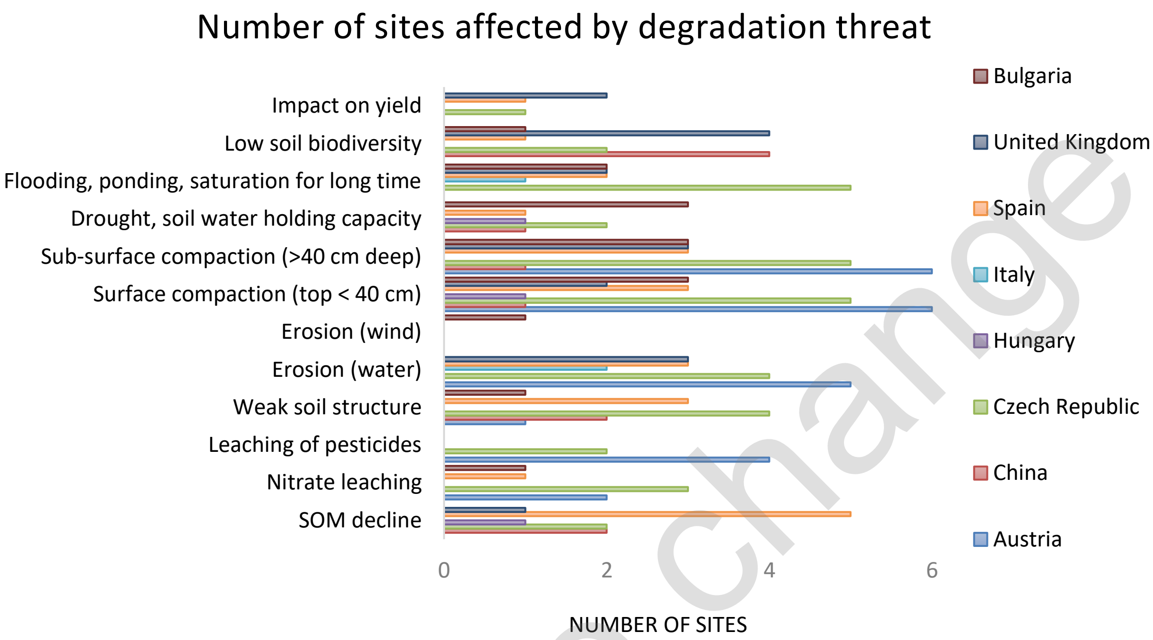
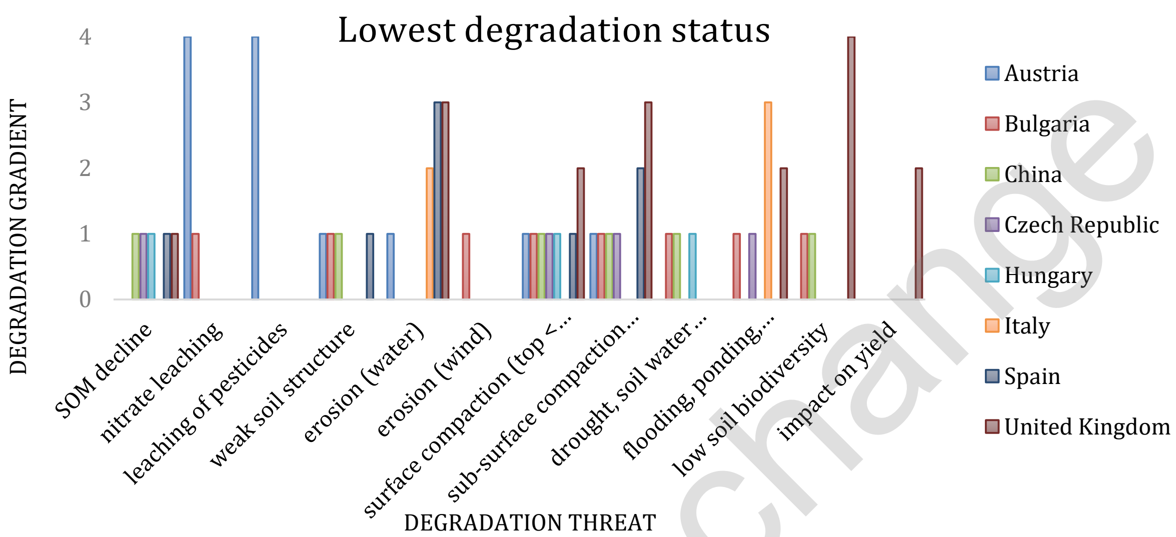


Figure 1: Number of experimental sites affected by degradation threats in the different TUdi partner countries.

Results on degradation gradients (see section 2.1.1.) were site specific across the monitored farms. Figure 2A shows the lowest values found whilst 2B the highest degradation status determined across the sites in EU and China.

2A



2B

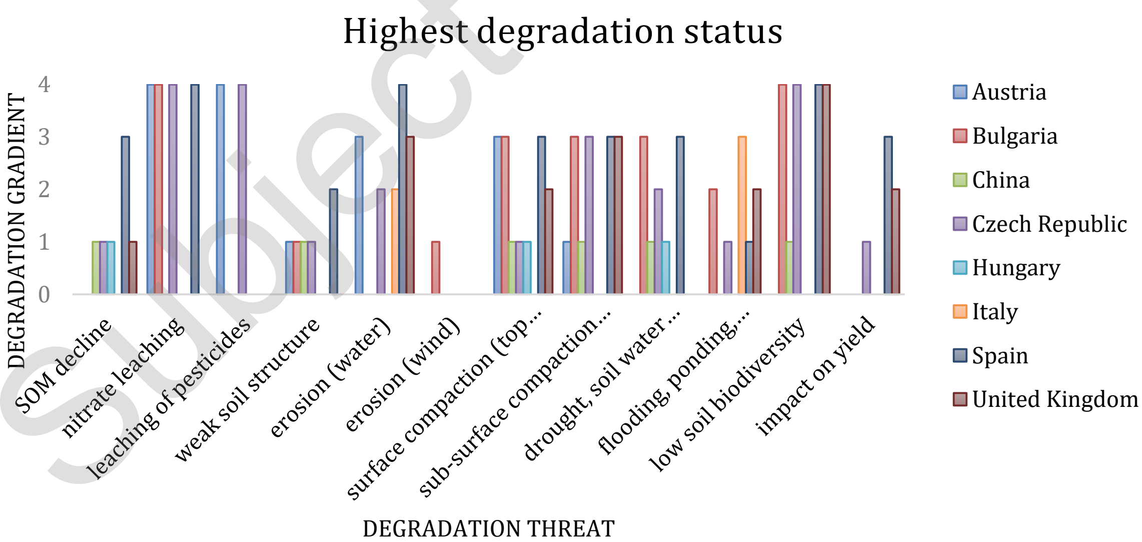


Figure 2: 2A The lowest, 2B the highest soil degradation status measured across the sites in EU and China.

3.1 Soil degradation gradients and their effects on yield

3.1.1 Austria

Six, long-term study sites were listed by the Austrian partners indicating the type and level of degradation present. The sites were chosen to represent various degradation threats in Austrian agricultural production areas. Six degradation threats were observed at least once (Figure 3) (nitrate leaching, leaching of pesticides, weak soil structure, water erosion and surface and sub-surface compaction) with different levels of degradation (Figure 4) resulting from the tillage systems (no-till, reduced till and conventional till) used on site. All sites were affected by at least two degradation threats; mostly surface and sub-surface compaction and water erosion. Three sites were subject to particular focus on observing runoff so long-term data on the level of erosion is accessible. None of the sites had issues with drought or over saturation. One site had moderately weak soil structure. Four sites were affected by leaching of pesticides regularly or irregularly. Data on soil biodiversity, wind erosion and SOM were only available for several sites, those were free from degradation threats. Information on the impact of degradation threat(s) on yield was not provided.

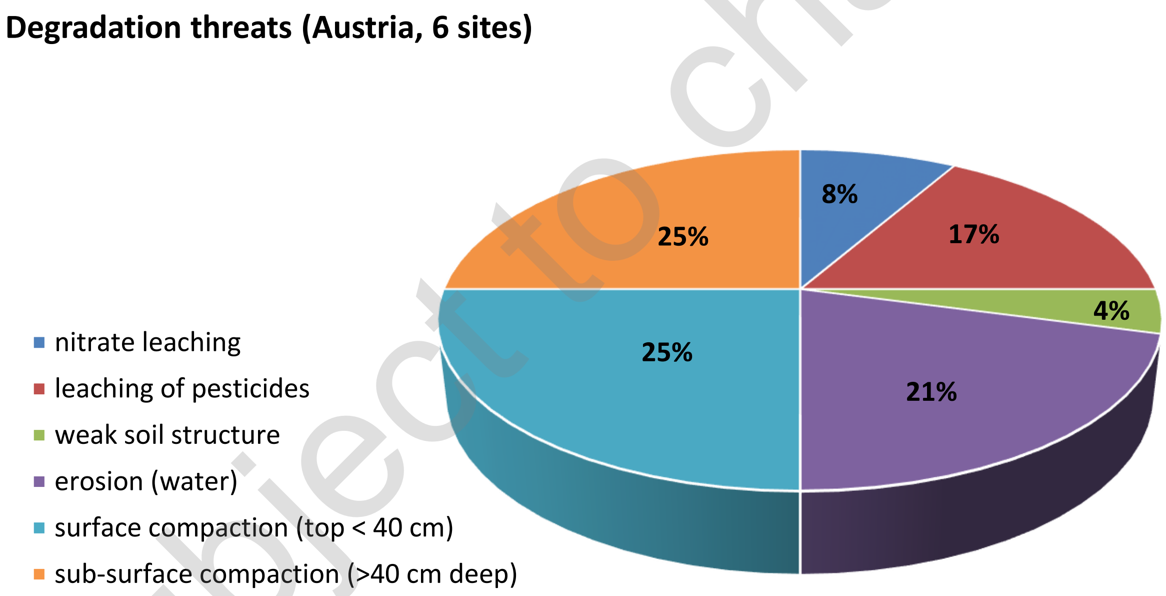


Figure 3: Distribution of degradation threats at the 6 Austrian experimental sites.

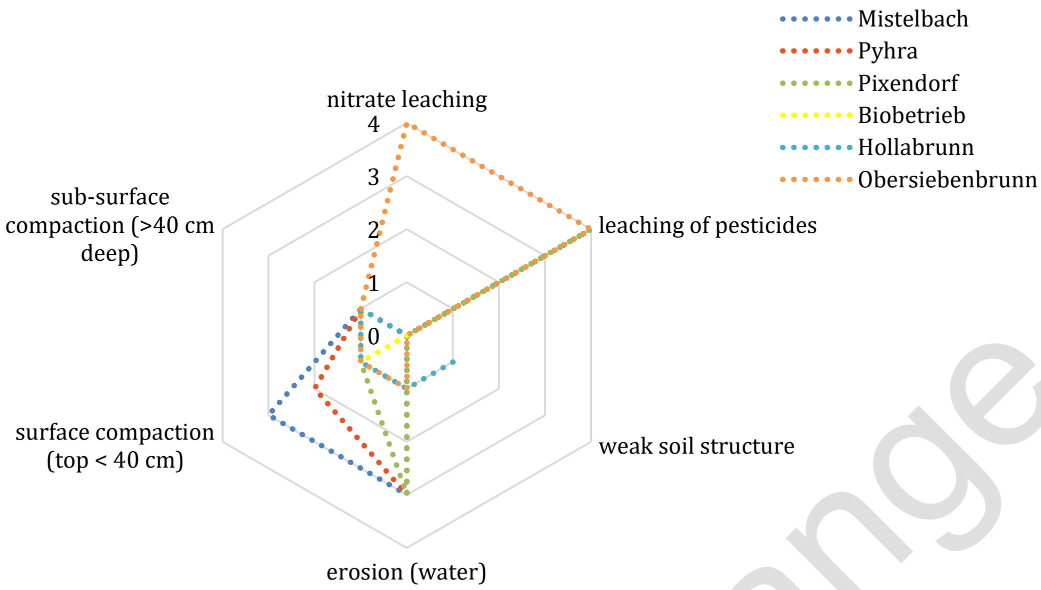


Figure 4: Soil degradation threats and their gradients at the 6 Austrian experimental sites. Scoring values (0 no threat - 4 high threat) are listed in Table 1.

3.1.2 Bulgaria

Three long-term study sites were listed by the Bulgarian partners indicating the type and the level of degradation present. Eight degradation threats were observed (Figure 5) (nitrate leaching, weak soil structure, wind erosion, surface and sub-surface compaction, drought, over saturation and low soil biodiversity) with different levels of degradation (Figure 6). Low to moderate surface and sub-surface compaction were present on all three sites with a 25-50% reduction in the water holding capacity of the soil. Two sites were affected with over saturation for a duration of 1 to 4 months. Low soil biodiversity and wind erosion was detected on one site and moderately week soil structure and nitrate leaching on another.

Information on the impact of degradation threat(s) on yield was provided for all three sites. All sites have stable yield despite the listed threats.

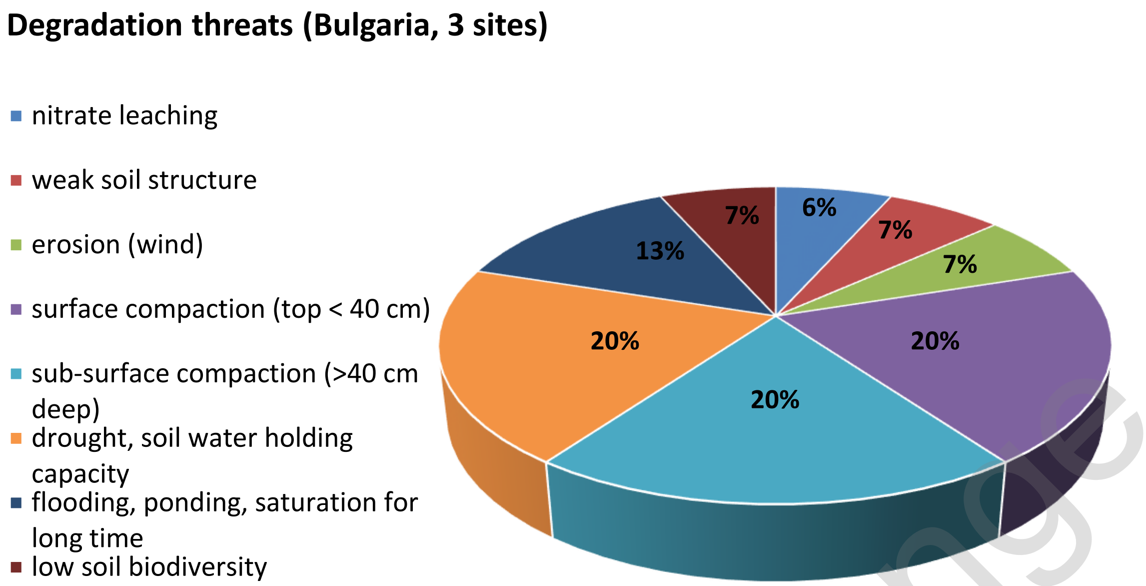


Figure 5: Distribution of degradation threats at the 3 Bulgarian experimental sites.

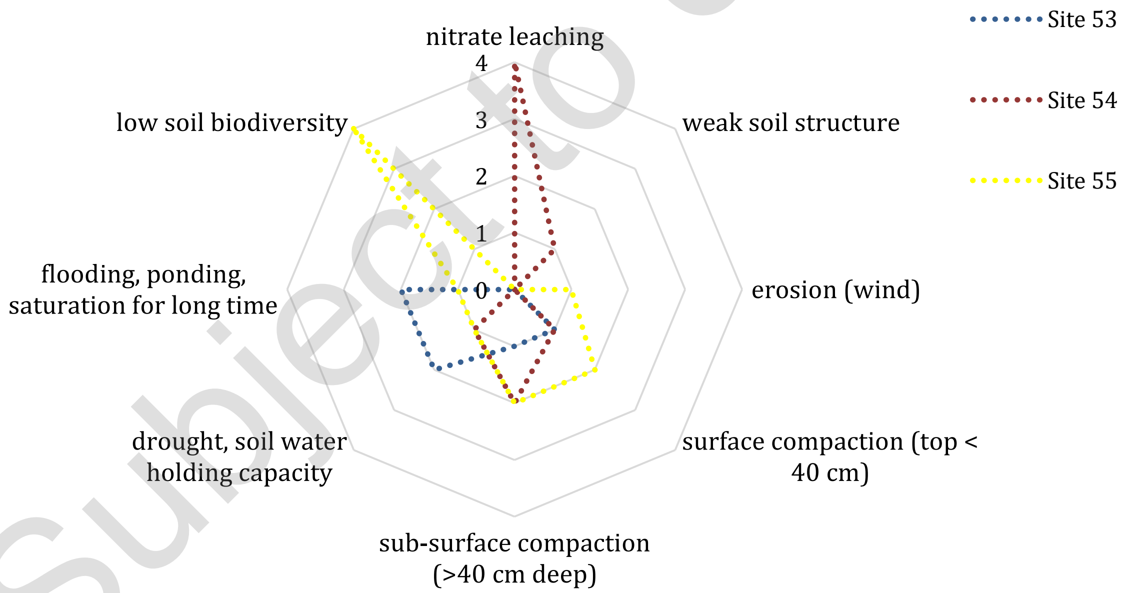


Figure 6: Soil degradation threats and their gradients at the 3 Bulgarian experimental sites. Scoring values (0 no threat - 4 high threat) are listed in Table 1.

3.1.3 China

During the time of data collection and report compilation the Chinese partners official participation in the project has not been confirmed. Therefore, we would like to acknowledge their effort to voluntarily contribute to the task with their answers. One experimental station was listed by the Chinese partner, indicating the type and level of degradation. The data was obtained from simulations. Six threats (SOM decline, soil structure, surface and sub-soil compaction, drought and soil biodiversity) were listed (Figure 7) and their levels of degradation indicated (Figure 8). Soil Organic Matter (SOM) decline was simulated to reach 50% with poorly formed soil structures and low sub- and surface compaction. The water holding capacity of the soil was reduced by 25% and with low soil biodiversity issues.

Information on the impact of degradation threat(s) on yield was not provided.

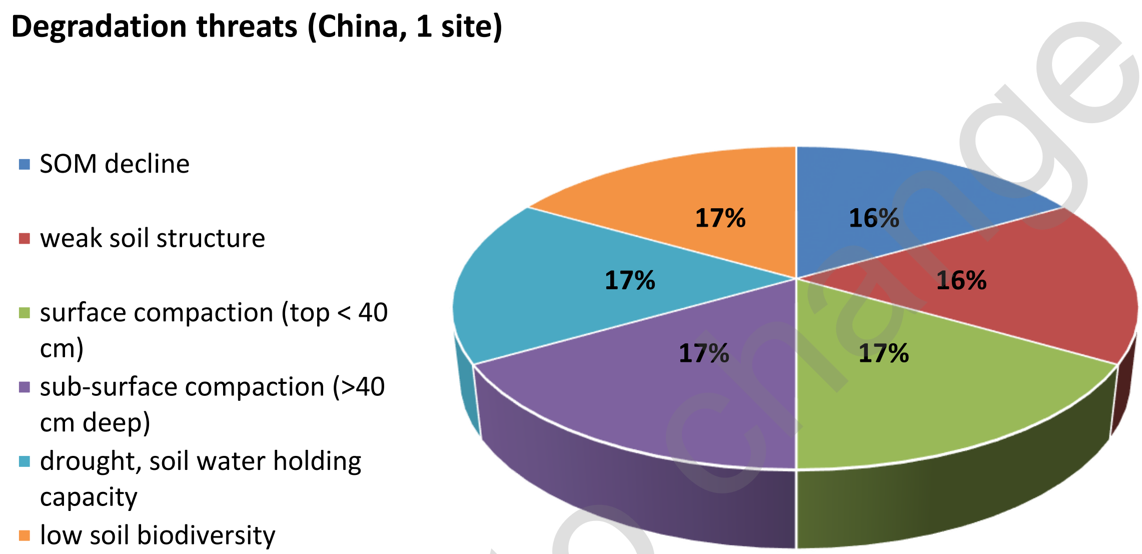


Figure 7: Distribution of degradation threats at the Chinese experimental station. The data was obtained from simulation.

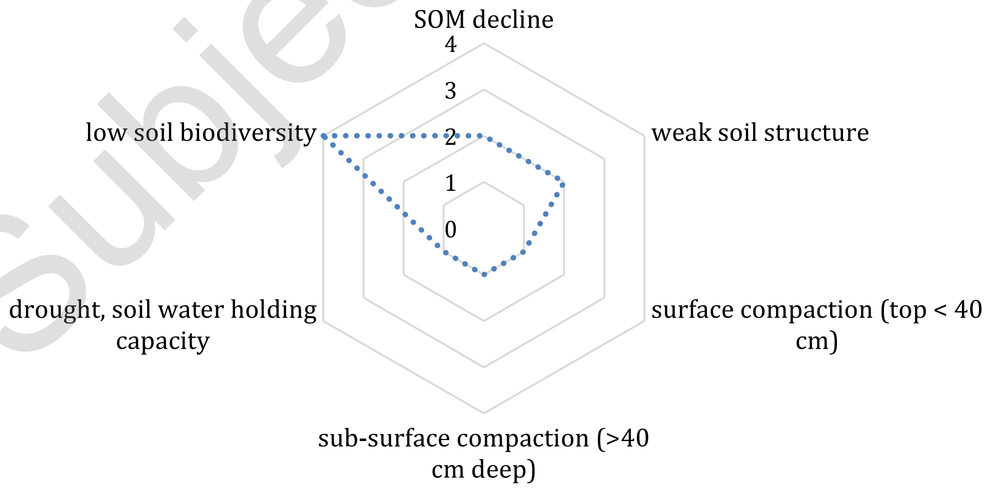


Figure 8: Soil degradation threats and their gradients at the Chinese experimental station. The data was obtained from simulation results. Scoring values (0 no threat - 4 high threat) are listed in Table 1.

3.1.4 Czech Republic

Five long-term study sites were listed by the Czech partners indicating the type and level of degradation present. Both surface and sub-surface compaction as well as ground with over saturated soil were common threats on all five sites (Figure 9). A low degree of surface and a low to high degree of sub-surface compaction was detected on all sites. Moderately weak soil structure and sheet erosion affected four sites. Nitrate and pesticide leaching, as well as low soil biodiversity were common threats on the same two sites. A 25% SOM decline and a 25 to 50% reduction in water holding capacity were challenging issues on two long-term study sites. None of the sites had issues with wind erosion (Figure 10).

Information on the impact of degradation threat(s) on yield was provided for all five sites. Four sites had stable yield, one site had a < 10% yield reduction.

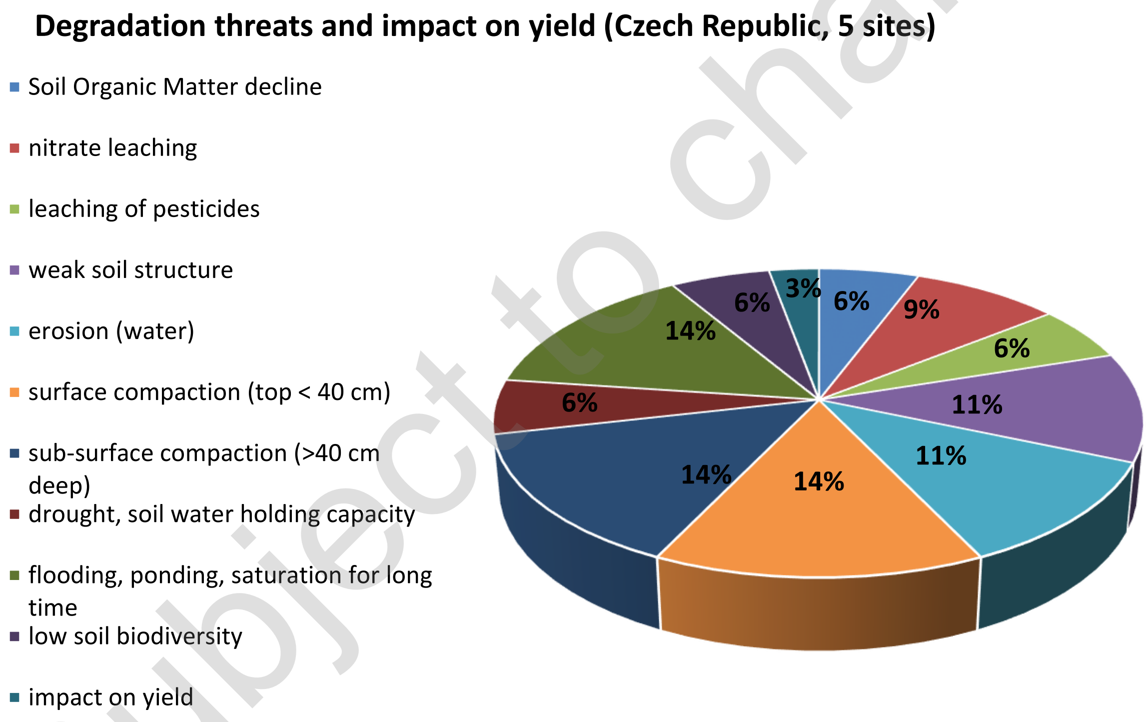


Figure 9: Distribution of degradation threats at the 5 Czech experimental sites.

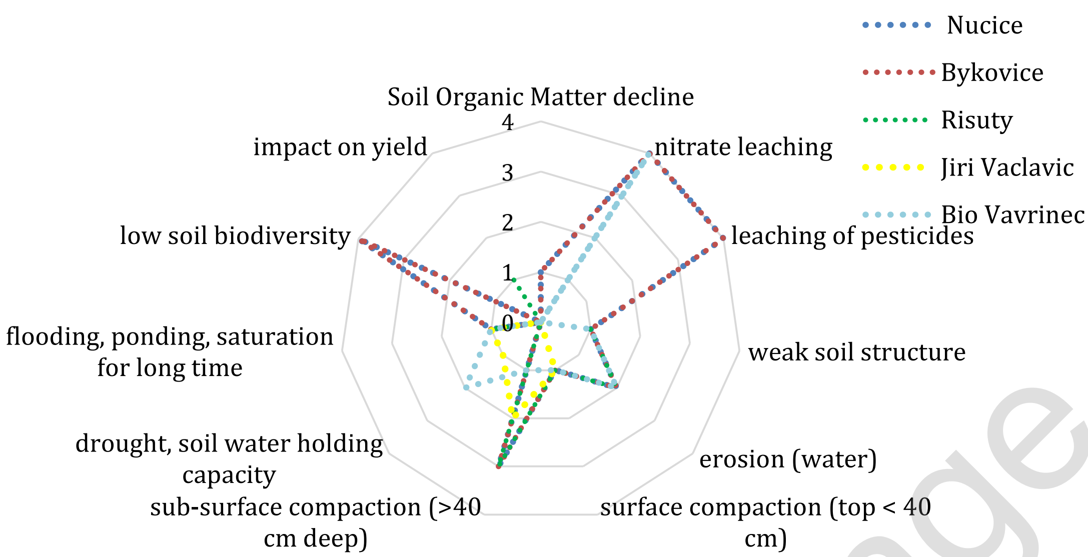


Figure 10: Soil degradation threats and their gradients at the 5 Czech experimental sites. Scoring values (0 no threat - 4 high threat) are listed in Table 1.

3.1.5 Hungary

Four long-term study sites were listed by the Hungarian partners indicating the type of degradation observed. One site has three different types of degradation (Figure 11); SOM decline, surface compaction, and drought. SOM decline and soil water holding capacity (indicated by drought) had a 25% reduction and a low level of surface compaction was also observed (Figure 12). The remaining three sites have one common threat; nitrate leaching where the level of degradation was not specified due to missing data on groundwater analysis or having a deep groundwater level.
Information on the impact of degradation threat(s) on yield was not specified.

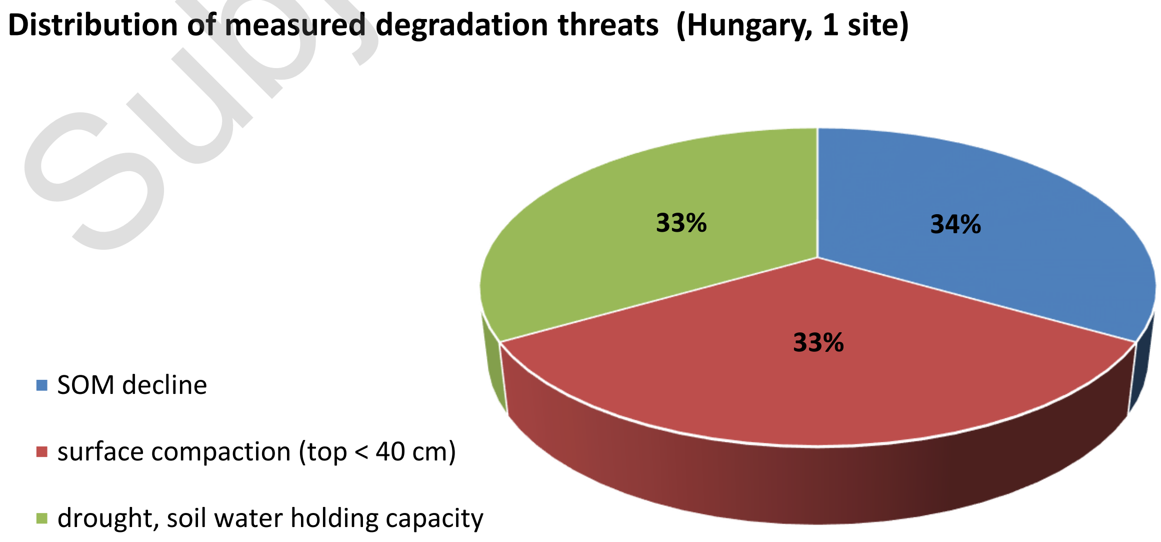


Figure 11: Distribution of degradation threats at the Hungarian experimental site.

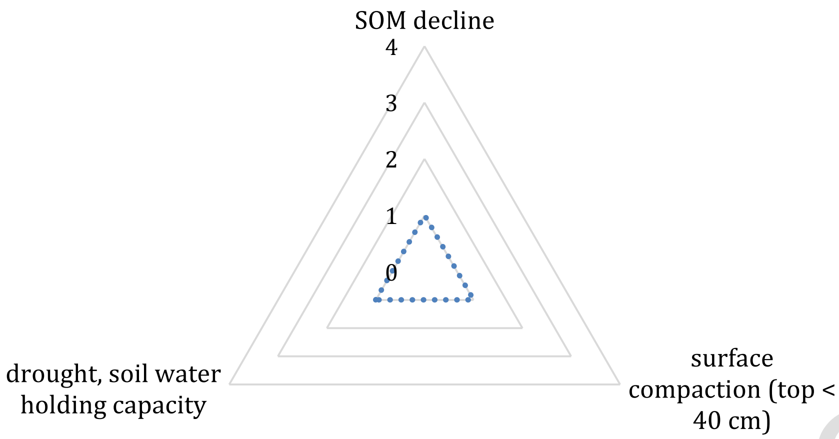


Figure 12: Soil degradation threats and their gradient at the Hungarian experimental site. Scoring values (0 no threat - 4 high threat) are listed in Table 1.

3.1.6 Italy

Seven long-term study sites were listed by the Italian partners, indicating the type and level of degradation. Five sites have nitrate leaching as a threat but in all cases with levels of under the regulatory limit for drinking water. Two sites have issues with sheet erosion by water and one site with degradation linked to flooding, ponding, and over saturation of soil (Figures 13, 14).

Information on the impact of degradation threat(s) on yield was provided for all seven sites. All sites have stable yield despite the listed threats.

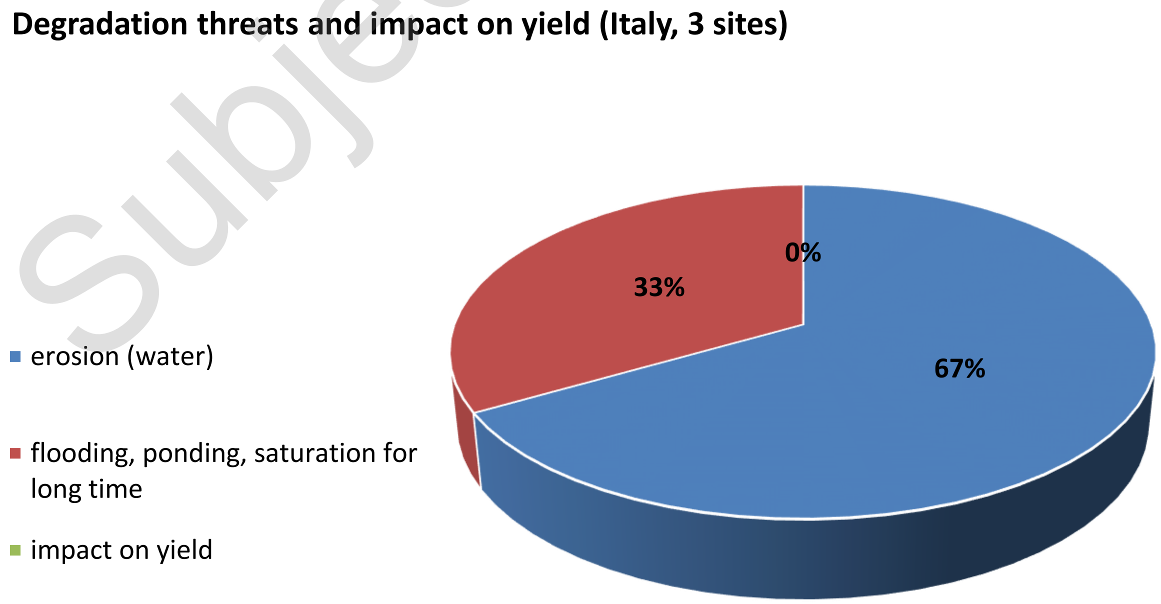


Figure 13: Distribution of degradation threats at the 3 Italian experimental sites.

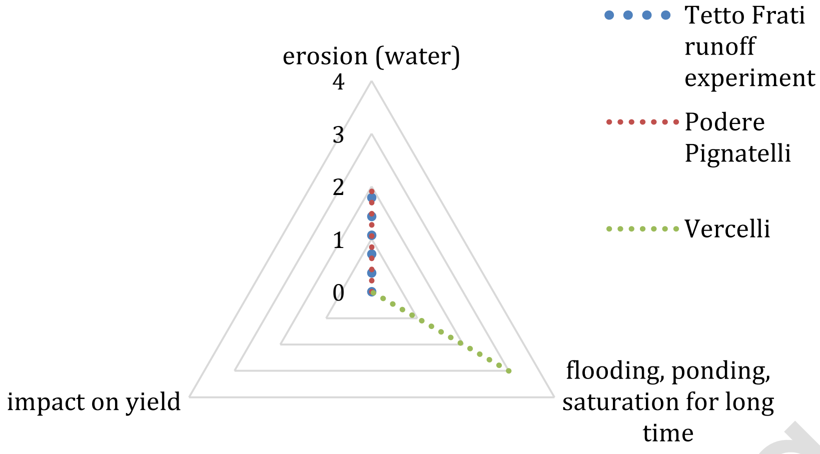


Figure 14: Soil degradation threats and their gradients at the 3 Italian experimental sites. Scoring values (0 no threat - 4 high threat) are listed in Table 1.

3.1.7 Spain

Five long-term study sites were listed by the Spanish partners, indicating the type and level of degradation present. Three sites have detailed descriptions on all eleven threats listed, one site provided data on the most challenging threat and one site showed no degradation. None of the sites had issues with leaching pesticides or wind erosion but SOM decline, water erosion, surface and sub-surface compaction, and weak structure were threats to the majority of sites (Figure 15). SOM decline varied between 25% and 75%, water erosion from sheet to gully, compaction from low to heavy, and soil structure from moderately durable to poorly formed indistinct aggregates. Two sites were listed as having issues with over saturation for less than a month and one site had a 50% reduction in water holding capacity (Figure 16).

Information on the impact of degradation threat(s) on yield was provided for all five sites. One site suffered from over 30% loss of yield; the other four sites had no loss of yield.

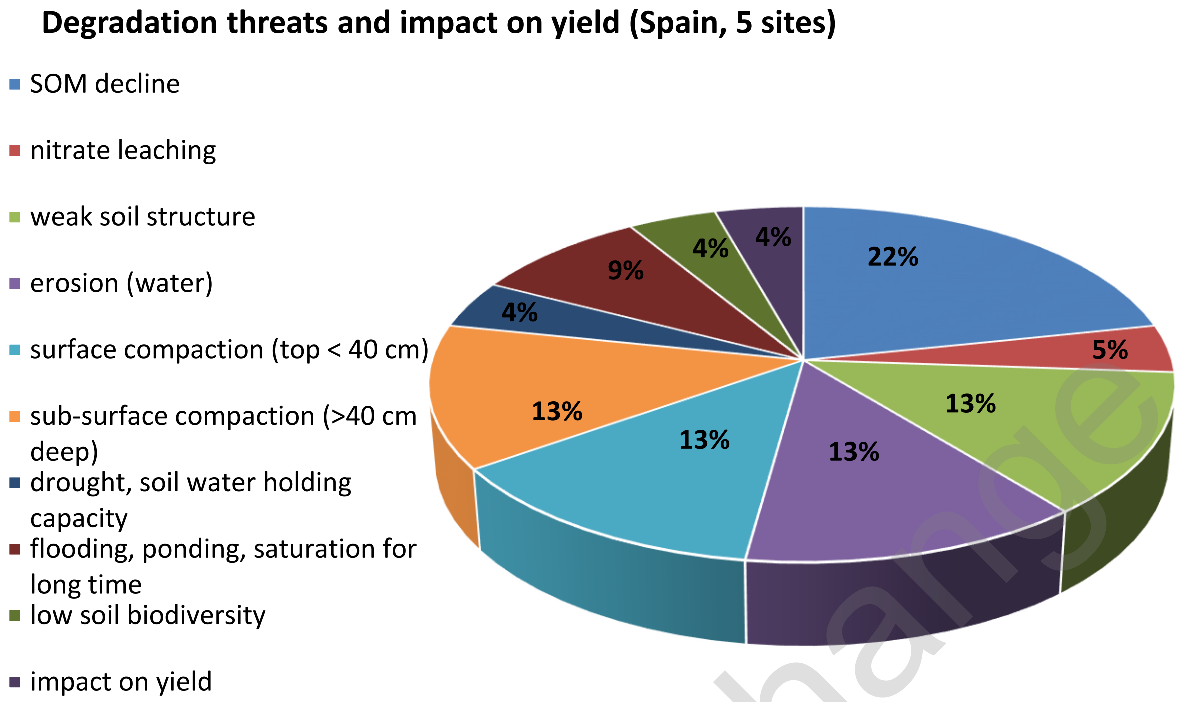


Figure 15: Distribution of degradation threats at the 5 Spanish experimental sites

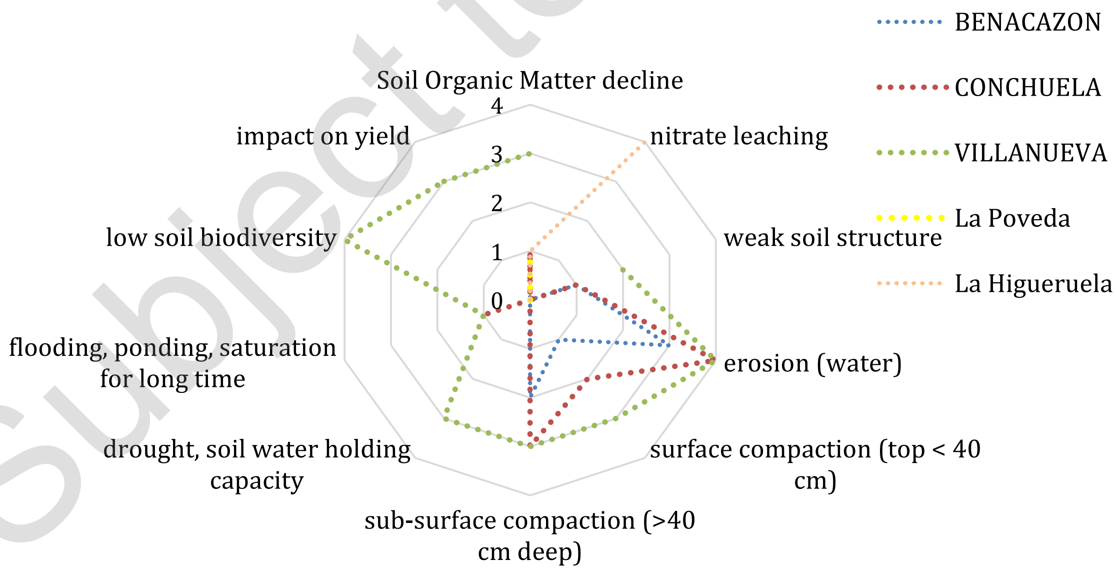


Figure 16: Soil degradation threats and their gradients at the 5 Spanish experimental sites. Scoring values (0 no threat – 4 high threat) are listed in Table 1.

3.1.8 United Kingdom

One long-term study site in the United Kingdom provided information on the type and level of degradation present. The site has detailed descriptions on nine listed threats (Figure 17) (SOM decline, water and wind erosion, soil compaction both in the top and sub-surface, drought was indicated by the soil water holding capacity, soil over saturation by flooding or ponding, and soil biodiversity). No data was given on nitrate leaching, leaching of pesticides or soil structure. The site had a 25% reduction in SOM, rill erosion and had a moderate surface and heavy sub-surface compaction. The ground is over saturated for 1 to 4 months a year and had a low soil biodiversity. (Figure 18).

Information on the impact of degradation threat(s) on yield was shown to reach between 10-30%.

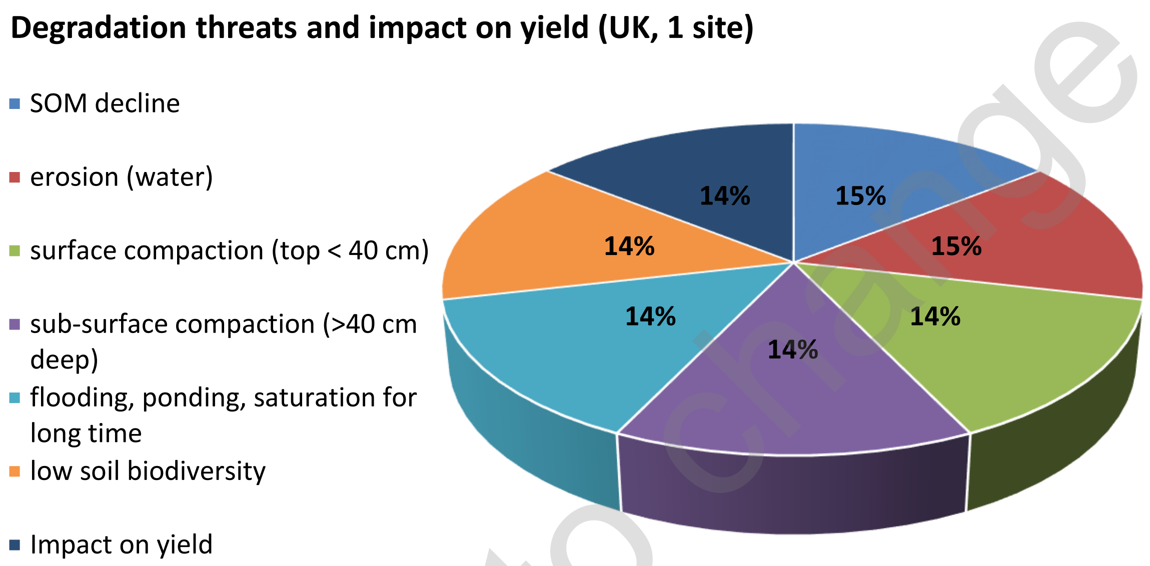


Figure 17: Distribution of degradation threats at the United Kingdom experimental site.

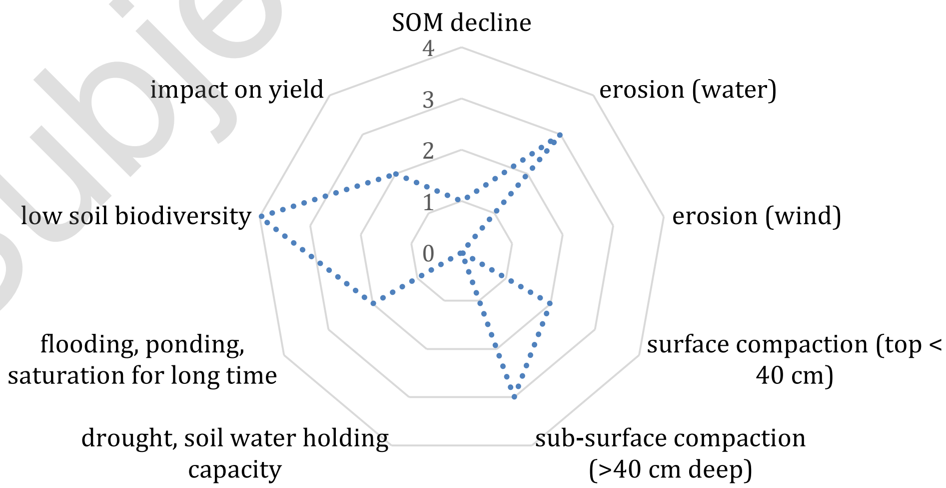


Figure 18: Soil degradation threats and their gradients at the United Kingdom experimental site. Scoring values (0 no threat – 4 high threat) are listed in Table 1.

3.2 Vegetation cover for soil restoration

3.2.1 Austria

Out of the six long-term study sites, four sites used additional vegetation cover with the aim to prevent or mitigate water erosion, improve the soil physical, chemical and biological properties, and to control weeds and pests (Table 3). Crop rotation was employed with a main cash crop of sunflower, maize or winter wheat. Commercially available seed and/or seed mixtures were used to establish the vegetation cover seeded before or after the cash crop. Cover crops and green manure were used to provide approximately 50 to over 75% cover. The vegetation cover left without maintenance. As in all cases, the vegetation cover provided temporary (1< year) cover and at the end of its vegetative season it was either died of naturally and was incorporated into the soil or on one site was terminated by a combination of physical and chemical means as part of the experimental treatment. Subsidies were received for using vegetation cover for soil conservation purposes.

Two sites did not use crop cover in their treatments as the primary focus of these experiments was only on the effects of the different tillage systems without using vegetation cover.

Table 3: Description of the experimental sites using vegetation as a restoration strategy in Austria.

Austria													
	Cash Crop	**Purpose of using Vegetation cover (VC)**	**Type of VC**	**Plant material used for establishing (VC)**	**Composition of VC**	**Source of plant material**	**Time of establishing VC**	**Surface Cover %**	**Length of being on the ground**	**Maintenance of VC**	**Termination of VC**	**Subsidy provided**	**Available plant trait data**
Mistelbach	Crop rotation (sunflower, maize, winter wheat)	Erosion control, Improve soil physical, chemical, biological properties, Pest and weed control	Cover Crop + Green manure	Seed	Multispecies mixture	Commercially available	Seeded before or after cash crop	>75%	Temporarily present <1 year	None	Naturally + Incorporation into soil	Subsidized	
Hollabrunn													
Biobetrieb													
Pyhra					Single species		Varied	50-75%			Varied		
Pixendorf	Various crops	Don't use Vegetation Cover the Focus is on the effect of different tillage systems											
Obersiebenbrunn													

3.2.2 Bulgaria

All three listed sites used some type of vegetation cover (Table 4). Two sites had permanent (>1 year) vegetation cover (sward and natural grass) with the aim to control weeds and provide feed for animals. The vegetation cover was established from local multispecies plant material (seeds, rhizomes) providing less than 75% ground cover. Both sites were regularly mowed during the vegetative season and data on biomass, leaf/stem traits and cover % was recorded. Subsidies were received to establish the sward but not natural grass.

Cover crops were established on one experimental site using commercially available single species seeds. Cover crops were sown in October and provided less than 75% ground cover for 10 months receiving no maintenance. Subsidies were received for the use of cover crops and data on root traits, biomass, cover %, and leaf/stem traits was recorded.

Table 4: Description of the experimental sites using vegetation as a restoration strategy in Bulgaria.

Bulgaria													
	Cash Crop	**Purpose of using Vegetation cover (VC)**	**Type of VC**	**Plant material used for establishing VC**	**Composition of VC**	**Source of plant material**	**Time of establishing VC**	**Surface Cover %**	**Length of being on the ground**	**Maintenance of VC**	**Termination of VC**	**Subsidy provided**	**Available plant trait data**
Site 53	Wheat		Cover Crop	Seed	Single species	Commercially available	October		10 month	None		Subsidized	Roots, Leaf/Stem, Biomass, Cover %
Site 54		Weed control	Other	Other	Natural grass	Local seeds/plant material		< 75%	Permanent >1 year	Mowed		Not Subsidized	Leaf/Stem
Site 55		Feed for farm animals	Sward	Rhizome	Multispecies mixture	Local seeds/plant material					Mowed	Subsidized	Biomass

3.2.3 Czech Republic

Mulch or cover crops were established in three experimental sites using commercially available single species seeds with the aim to improve the physical properties of the soil (Table 5). On two sites the seeding was carried out after harvesting the cash crop (wheat or rapeseed) and on the third site at various times. The temporary cover was able to provide 50-75% cover and died of naturally or when necessary, chemically. Data on cover % was recorded. Subsidies were received for using cover crops or mulching for soil conservation. One organic site employed cover crops in its crop rotation cycle using commercially available multispecies seed mixtures after harvesting the cash crop. Cover crops provided 50-75% cover and terminated naturally. Data on biomass was recorded.

One site was described as a permanent grassland/pasture.

Table 5: Description of the experimental sites using vegetation as a restoration strategy in Czechia.

Czech Republic													
	Cash Crop	**Purpose of using Vegetation cover (VC)**	**Type of VC**	**Plant material used for establishing VC**	**Composition of VC**	**Source of plant material**	**Time of establishing VC**	**Surface Cover %**	**Length of being on the ground**	**Maintenance of VC**	**Termination of VC**	**Subsidy provided**	**Available plant trait data**
Nucice	Wheat, Rapeseed	Improve soil physical properties	Mulch or Cover Crop	Seed	Single species	Commercially available	Seeded after harvesting cash crop	50-75%	Temporarily present <1 year	None	Naturally + Chemically	Subsidized	Cover %
Bykovice													
Risuty							Varied						
Bio Vavrinec	Crop rotation (wheat, oat, potatoes, maize, alfalfa)	Improve soil physical properties	Cover Crop (not always in use)	Seed	Multispecies mixture	Commercially available	Seeded after harvesting cash crop	50-75%	Temporarily present <1 year	Mowed	Naturally	Subsidized	Biomass
Jiri Vaclavic	Permanent grassland, Pasture												

3.2.4 Hungary

Annual crops were grown as cash crops in all four long-term experimental sites. Two sites included crop cover in their treatments for the purpose of improving the physical properties of the soil (Table 6). Mulching was used from local single species plant residues, providing 25-50% surface cover. Afterwards the mulch was ploughed into the soil. Data is available on leaf/stem traits. Subsidies were received for using vegetation cover for soil conservation purposes.

Crop cover was not use on two site treatments.

Table 6: Description of the experimental sites using vegetation as a restoration strategy in Hungary.

<table>
<tr><th colspan="14">Hungary</th></tr>
<tr><th></th><th>Cash Crop</th><th>Purpose of using Vegetation cover (VC)</th><th>Type of VC</th><th>Plant material used for establishing (VC)</th><th>Composition of VC</th><th>Source of plant material</th><th>Time of establishing VC</th><th>Surface Cover %</th><th>Length of being on the ground</th><th>Maintenance of VC</th><th>Termination of VC</th><th>Subsidy provided</th><th>Available plant trait data</th></tr>
<tr><td>Karcag</td><td rowspan="4">Annual crop</td><td rowspan="2">Improve soil physical properties</td><td rowspan="2">Mulch</td><td rowspan="2">Residues</td><td rowspan="2">Single species</td><td rowspan="2">Local plant material</td><td rowspan="2"></td><td rowspan="2">25-50%</td><td rowspan="2">Temporarily present <1 year</td><td rowspan="2">None</td><td rowspan="2">Tillage</td><td rowspan="2">Subsidized</td><td rowspan="2">Leaf, stem</td></tr>
<tr><td>Józsefmajor</td></tr>
<tr><td>Őrbottyán</td><td rowspan="2" colspan="12">Don't use Vegetation Cover</td></tr>
<tr><td>Nagyhörcsök</td></tr>
</table>

3.2.5 Italy

Vegetation strips were incorporated into two maize fields for runoff mitigation and filtration (Table 7). Cover crops and swards were incorporated into treatments on three sites growing maize, soyabeans and wheat to help reduce nitrate leaching, improve soil chemical properties, and to use as feed. The remaining two sites are rice paddy fields where added vegetation cover is not common practice due to the risk of toxic fermentation.

Commercially available multispecies seed mixtures were used to establish the permanent vegetation strips, providing more than 75% cover. The permanent cover was regularly maintained by mowing and data on biomass was recorded. Data availability on an additional maize field using vegetation strip was scarce.

The single or multispecies cover crops were sown after harvesting the cash crops using commercially available seeds. Cover crops provided 50 to over 75% cover, receiving no maintenance. To make space for the following cash crop, cover crops were ploughed into the soil. Data on biomass was recorded.

The sward was established after harvesting the main crop from single species commercially available seeds. When the sward acted as a permanent cover it was maintained by mowing. As temporary cover, by ploughing. Sward provided more than 75% cover and received no subsidies for establishment. Data on biomass was recorded.

Table 7: Description of the experimental sites using vegetation as a restoration strategy in Italy.

Italy													
	Cash Crop	**Purpose of using Vegetation cover (VC)**	**Type of VC**	**Plant material used for establishing (VC)**	**Composition of VC**	**Source of plant material**	**Time of establishing VC**	**Surface Cover %**	**Length of being on the ground**	**Maintenance of VC**	**Termination of VC**	**Subsidy provided**	**Available plant trait data**
Tetto Frati runoff experiment	Maize	Runoff reduction and filtering	Vegetation strip	Seed	Multispecies mixture	Commercially available		>75%	Permanent	Mowed			Biomass
Podere Pignatelli				Other						None			
Tetto Frati LTE	Maize, Soyabean, Wheat	Reduce N leaching, Improve soil chemical properties, Feed for animals	Sward	Seed	Single species	Commercially available	Seeded after harvesting cash crop	>75%	Temporarily present <1 year, Permanent depending on treatment	Mowed	Ploughing	Not Subsidized	Biomass
Lombriasco			Cover Crop		Multispecies mixture			50-75%	Temporarily present <1 year	None		Subsidized	
Cussanio					Single species			>75%				Not Subsidized	
Vercelli	Rice paddy	Do not use Vegetation Cover to avoid toxic fermentation											
Crescentino													

3.2.6 Spain

The main cash crop on all five sites was olive. Three olive plantations used additional vegetation cover to prevent or mitigate soil erosion or improve the physical properties of the soil (Table 8). Commercially available or local seed and seed mixtures were used to establish vegetation cover in late autumn, early winter and on one site by self-seeding. Cover crops and mulching were used along the laines or along the inter-tree rows providing 25% to 75% cover. The vegetation cover was either left without any maintenance or mowed regularly during the time of cover. In all cases vegetation cover was temporary (< 1 year), its termination carried out by a combination of mowing, chemical means under the tree laines, or dying naturally. Subsidies or any other financial compensation were not received for using vegetation cover for soil conservation purposes.

Individual site conditions prevented the use of additional vegetation cover for the two remaining sites.

Table 8: Description of the experimental sites using vegetation as a restoration strategy in Spain.

Spain													
	Cash Crop	**Purpose of using Vegetation cover (VC)**	**Type of VC**	**Plant material used for establishing (VC)**	**Composition of VC**	**Source of plant material**	**Time of establishing VC**	**Surface Cover %**	**Length of being on the ground**	**Maintenance of VC**	**Termination of VC**	**Subsidy provided**	**Available plant trait data**
Benacazon	Olive orchard	Erosion control, Improve soil physical properties	Cover Crop + Mulch	Seed	Single species	Commercially available	Seeding late Fall early Winter	50-75%	Temporarily present <1 year	Mowed	Mowed + Chemically	Not Subsidized	Cover %, Biomass
Villanueva					Multispecies mixture			<25%		None	Naturally		
Conchuela				Self-seeded	Single species	Local seeds	Self-seeds	25-50%		Mowed	Mowed + Chemically		Cover %
La Poveda		Site conditions prevent the use of Vegetation Cover											
La Higueruela													

3.2.7 United Kingdom

One experimental site with maize as the main crop had additional vegetation cover incorporated into its management system to mitigate soil erosion and to improve the physical properties of the soil (Table 9). Commercially available single and multispecies seed mixtures were used to establish cover crops to provide an additional 25 to 50% surface cover. The combination of different cover crops was seeded together with maize and ploughed into the soil. Data on cover % is available. Subsidies were received for using cover crops for soil conservation purposes.

Table 9: Description of the experimental sites using vegetation as a restoration strategy in the United Kingdom.

United Kingdom													
	Cash Crop	**Purpose of using Vegetation cover (VC)**	**Type of VC**	**Plant material used for establishing VC**	**Composition of VC**	**Source of plant material**	**Time of establishing VC**	**Surface Cover %**	**Length of being on the ground**	**Maintenance of VC**	**Termination of VC**	**Subsidy provided**	**Available plant trait data**
Thornbarrow	Maize	Erosion control, Improve soil physical properties	Cover Crop	Seed	Single species + Multispecies mixture	Commerciall y available	Seeding together with cash crop	25-50%	Temporarily present <1 year	None	Ploughing	Subsidized	Cover %

3 Conclusions

This deliverable aimed to provide a comprehensive set of data on existing soil degradation threats, their level, and their effect on yield. The data was collected from 32 long-term Tudi experimental sites in 7 EU countries as well as China. Surface and sub-surface compaction was the most commonly listed threat; present in nearly all TUdi countries (7). Low soil biodiversity, over saturation, drought, water erosion, SOM decline, and weak soil structure were detected in most countries (5). Leaching of nitrate (4) and pesticides (2) was recorded in several countries and only Bulgaria listed wind erosion as an existing soil degradation threat on their sites. Data on the level of degradation for all the listed threats were not always available. Degradation levels were site specific, varied from no degradation to highly degraded. Four countries (Bulgaria, Czech Republic, Spain and the UK) provided data on the effect of degradation on crop yield, the degree of which of varied among the different sites.

The directory also aimed to collect information on the use of vegetation cover for soil conservation purposes on the TUdi long-term experimental sites. All seven EU partners provided data on additional crop cover. The most commonly provided crop cover were cover crops, mulching and swards with the aim to mitigate erosion, or improve the physical, chemical and biological properties of the soil. The majority of cover was established from commercially available single or multispecies seeds and temporarily (< 1 year) covered 50 to75% of the ground. The termination method of crop cover varied from site to site but often used the combination of physical and chemical processes. Data on cover %, leaf/stem traits and biomass were the most commonly measured plant traits. Most sites received subsidies for the use of crop cover.

4 References

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