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"Framework of the target degradation/desertification processes and the most feasible and reliable Nature Based Solutions"

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Author(s)	Costanza Calzolari (CNR-IBE), Edoardo Costantini (CNR-IBE), Francesca Ugolini (CNR-IBE), Fabrizio Ungaro (CNR-IBE)
Editor	

NewLife4Drylands LIFE20 PRE/IT/000007

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Executive summary

The present document reports about the “Framework of the target degradation/desertification processes and the most feasible and reliable Nature Based Solutions”. The document describes the state of the art of land degradation assessment at global and EU scale, mentioning the contributions of EU projects funded under different programs. The document presents a conceptual framework for achieving land degradation neutrality and the preliminary steps for its implementation in the six case NewLife4Dryland study areas. The document reviews the current indicators adopted to assess land degradation and desertification risk and reports examples of implementation of Nature Based Solutions (NBSs).

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1. Introduction

NewLife4Drylands deals with land degradation processes, of which desertification is one aspect, and considers restoration as a process. Both processes must be monitored resorting to status and trend indicators and time thresholds.

The United Nations Convention to Combat Desertification (UNCCD) in 1994 provided in Article 1 of the Convention text (UNCCD,1994), a binding definition of land degradation, whereby land degradation was defined as "reduction or loss, in arid, semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns including soil erosion, deterioration in physical, chemical, biological or economic properties of soil and long term loss of vegetation." In the definition "land" is intended as a "terrestrial bio-productive system that comprises soil, vegetation, other biota, and the ecological and hydrological processes that operate within the system".

The Millennium Ecosystem Assessments (MAE, 2005) has defined desertification as the reduction or loss of the biological and/or economic productivity of drylands resulting from various factors, including climatic variations and human activities, occurring in arid, semiarid and dry sub-humid areas. Land degradation results in a long-term loss of functionality and productivity of land or land-based ecosystems. Degradation processes affect all land system components: soil, vegetation, animals, air and water (WOCAT 2017). Examples of land degradation are soil erosion by water and wind, soil pollution and fertility decline, soil salinization, soil compaction, soil sealing due to urbanization and construction, the decline of water quality loss of vegetation and habitats (FAO 2017).

Land degradation assessments differ with regard to the forms of land degradation, but the most frequently addressed issues are soil sealing, soil and water contamination, soil salinization, soil compaction, loss of organic matter in soils, loss of biodiversity, nutrient imbalances, habitat fragmentation, loss of land productivity and alien species invasion. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) has recently provided a critical analysis of the state of knowledge regarding the importance, drivers, status, and trends of land degradation impacts on terrestrial ecosystems (Montanarella et al., 2018). According to IPBES, desertification is defined as land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities. Land is defined as degraded when it is in a state that results from persistent decline or loss of biodiversity and ecosystem functions and services that cannot fully recover unaided. In the IPBES definition, land degradation refers to the many processes that drive the decline or loss in biodiversity, ecosystem functions or services, and includes the degradation of all terrestrial ecosystems including associated aquatic ecosystems that are impacted by land degradation. This is then a broader definition than the one adopted by the UNCCD in 1994, and introduces the concepts of ecosystem services and functions.

2. Global assessment of land degradation

For conceptual and methodological reasons, i.e. what and when and how to measure land degradation, reliable maps of land degradation at the global level are not available (Gibbs and Salmon 2015; Prince et al. 2018; van der Esch et al. 2017). Land degradation occurs at different spatial and temporal scales (Warren 2002), and its quantification and mapping are not straightforward.

In their review Gibbs and Salmon (2015) illustrated the benefits and limitations of four major approaches used to map and quantify degraded lands: i) expert opinion; ii) Satellite-derived net primary productivity; iii) Biophysical models; and iv) Abandoned cropland. The Authors pointed out that benefits and limitations are mainly due to existing databases, not necessarily to the approaches, which could be improved to overcome limitations.

Kind of degradation	World	Asia	West Asia	Africa	Latin America and the Caribbean	North America	Australia and Pacific	Europe
Water erosion	1094	440	84	227	169	60	83	115
Wind erosion	548	222	145	187	47	35	16	42
Nutrient depletion	135	15	6	45	72	–	+	3
Salinity	76	53	47	15	4	–	1	4
Contamination	22	2	+	+	+	–	–	19
Physical	79	12	4	18	13	1	2	36
Other	10	3	1	2	1	–	1	2
Sum	1964	747	287	494	306	96	103	218

Table 1. GLASOD estimates of human-induced soil degradation (million ha) (Source: Bai et al., 2008)

An example of expert opinion based assessment of global land degradation is the Global Assessment Of land Degradation, GLASOD. It was commissioned by the United Nations Environment Program (UNEP) in the late 1980s and was the first attempt to map human-induced degradation worldwide (Oldeman, 1994; Oldeman et al., 1990). Oldeman et al. (1990) established a set of relatively uniform mapping units and then local experts assessed the status of land degradation in terms of the type, extent, degree, rate and causes of degradation within each mapping unit. The resulting data were then assembled and the estimates are "uniform" as they are based upon defined mapping units and carefully structured definitions (Table 1, Fig.1). As these estimates rely on local knowledge rather than measurements, GLASOD is considered subjective and rather qualitative. Furthermore, GLASOD was clearly intended for continental scale assessment and not to draw conclusions at national or sub-national scale.

GLASOD indicated that globally about 15% of land is degraded. The highest proportions were reported for Europe (25%), Asia (18%) and Africa (16%); the least for North America (5%). In terms of kind of degradation, as a proportion of the global degraded area, soil erosion affects 83% of the affected area (ranging from 99% in North America to 61% in Europe); nutrient depletion affects 4% globally but 28% in South America; salinity less than 4% worldwide but 16% in West Asia; chemical contamination about 1% globally but 8% in Europe; soil physical problems 4% globally but 16% in Europe.

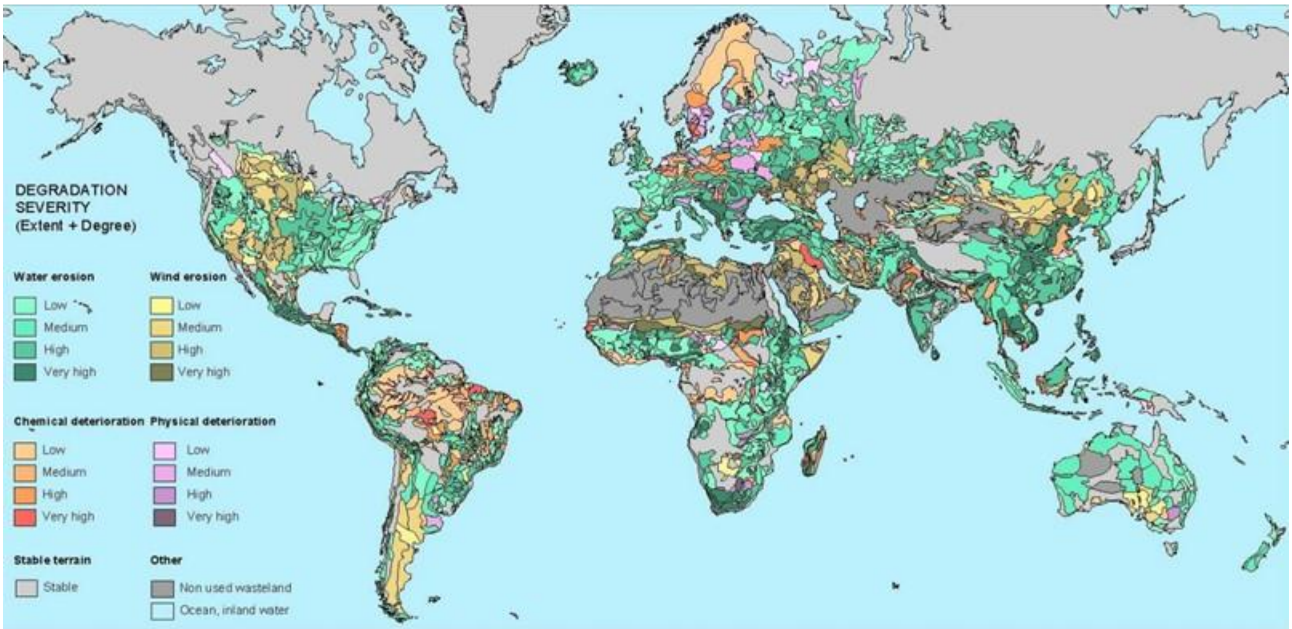

Fig. 1. GLASOD human-induced soil degradation map (https://isric.org/projects/global-assessment-human-induced-soil-degradation-glasod)

Notwithstanding these limitations, GLASOD is still the only complete and globally coherent source of information on land degradation, and is has been widely used. For example, the national level assessment led by FAO to create the TerraSTAT database used severity classes for degree and extent of soil degradation based on GLASOD estimates (Bot et al., 2000). A major difference between the two assessments is that FAO assumed that considering only the areas affected by actual degradation would have led to an underestimation of the problem ignoring its impacts on surrounding-lands, and off-site effects including their overall impacts on the economy. Therefore, while GLASOD assessment resulted in an estimated total area of 1964 million ha of degraded lands (15.5% of the world's lands), according to FAO TerraSTAT the global figure summed up to 6140 million ha (66% of the world's land).

More recently, the Land Degradation Assessment in Drylands project (LADA) was launched by the Global Environment Facility (GEF), implemented by UNEP and executed by FAO between 2006 and 2011 in support of the UNCCD. LADA developed an approach based on remotelysensed NDVI data (the Global Land Degradation Assessment – GLADA). The project also used an ecosystems approach that brought together and interpreted information from pre-existing and newly developed global databases to inform decision makers on all aspects of land degradation at a global scale (GLADIS: the Global LAnd Degradation Information System).

GLADA is an attempt to quantify the degradation processes occurred between 1981 and 2003 (later extended to 2006) using the normalized difference vegetation index (NDVI) with 5 arc-minute (9 km at the equator) spatial resolution. The index is commonly used as a proxy to assess vegetation condition and net primary productivity (Bai et al., 2008a, 2010). Other factors that can affect NDVI, such as climate, rainfall, and land use change are taken into account. For example, rain-use-efficiency (RUE) is used to adjust NDVI trends and exclude biomass variations related to rainfall. The RUE-adjusted NDVI trends form the basis to identify the areas that are degrading and those that are improving. Furthermore, to ensure changes in degradation status are not due to land use changes, a comparison is made between land use at the beginning of the time series and at the end using land use maps. GLADA is an attempt to follow up on the GLASOD study through a quantified and possibly objective global assessment of the status and trends of land degradation. The GLADA methodology has been applied globally and has been tested in six pilot countries (Argentina, China, Cuba, Senegal, South Africa, and Tunisia). Results from the analysis of the 23-year NDVI data indicate declining rain-use efficiency-adjusted NDVI on ca. 24% of the global land area with degrading areas mainly in Africa south of the equator (13% of the global degrading area and 18% of lost global NPP), South-East Asia (6% of the degrading area and 14% of lost NPP) and south China (5% of the degrading area and 5% of lost NPP), north-central Australia (5% of the degrading area and 4% of lost NPP), the Pampas (3.5% of the degrading area and 3% of lost NPP) and large areas in the Siberian and North American taiga. According to the assessment, the total land area affected worldwide by degradation processes amounts to 35058104 Km2, i.e. 23.54% of lands, with an average yearly loss in NPP of 41.5 M t C. It is interesting to highlight that globally, there is little correlation between land degradation and Turc's aridity index (r = -0.12); 78 % of degradation by area is in humid regions, 8 % in the dry sub -humid, 9 % in the semi-arid, and 5 % in arid and hyper-arid regions (Bai et al., 2008b). Actually, land degradation can lead to desertification in arid and semiarid climatic conditions, where land recovery is more difficult, but it is not limited to these climatic zones.

The LADA programme was not limited to the assessment of the land degradation but it also addressed the possibility to combat degradation with sustainable land management (SLM) practices. These are intended as "the use of land resources, including soils, water, animals and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions". To this aim, it used the World Overview of Conservation Approaches and Technologies (WOCAT) tools. WOCAT is a global Network established in 1992 with the aim of collecting, documenting, evaluating and sharing the existing knowledge on SLM (https://www.wocat.net/en/). At present WOCAT is recognised by the UNCCD as the primary recommended Global SLM Database for best practices.

WOCAT maintains a global field-tested SLM database (at present over 2000 SLM practices are stored) from all over the world. The database is freely accessible and new practices can be added following the WOCAT procedure (https://www.wocat.net/library/media/168/)

EU level assessment of land degradation

In Europe the GLADA methodology estimated that degrading lands sum up to 667809 km2, i.e. 11,3% of the land area. The resulting estimated loss in NPP over 23 years of monitoring is equal to 16136096 M t of C, i.e. 0.70 M t per year (Bai et al., 2008a). The following figures summarize the extent of land degradation and the consequent NPP loss for the different European countries. The major land degradation processes in Europe are soil degradation processes, i.e. erosion, organic matter decline, compaction, salinization, landslides, contamination, sealing and biodiversity decline, with an estimated cost of €38 billion annually for EU25 (Montanarella, 2007). In absolute terms of area under degradation, the top five ranking European countries are Sweden (78964 km^2), Spain (63266 km^2), Norway (57109 km^2), Ukraine (47414 km^2) and France (46691 km^2), while in relative terms of % of territory under degradation the top five ranking European countries are Andorra (60%), Hungary (33.8%), Austria (33.7%), Iceland (33.5%) and Belgium (17.7%). In terms of average yearly loss of net primary production (NPP tC/y), the top five ranking European countries are Iceland (117093 t C/y), Spain (74467 t C/y), Sweden (69318 t C/y), Ireland (59278 t C/y) and Norway (52738 t C/y), while in terms of NPP loss per unit area we find again Iceland and Ireland (26.1 and 19.4 t C/km^2), followed by Hungary (8.2 t C/km^2), Andorra (5.6 t C/km^2) and the Czech Republic (3.9 t C/km^2).

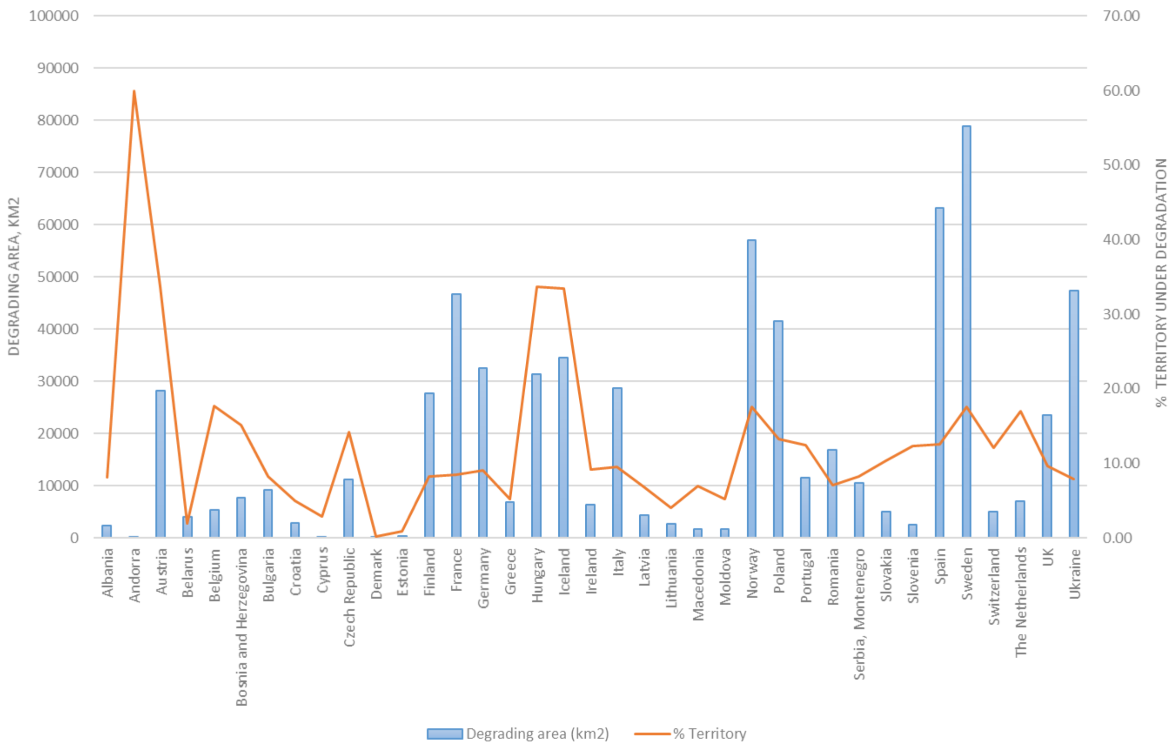

Fig.2. The extent of land degradation in the different European countries. Source: Bai et al, 2008a.

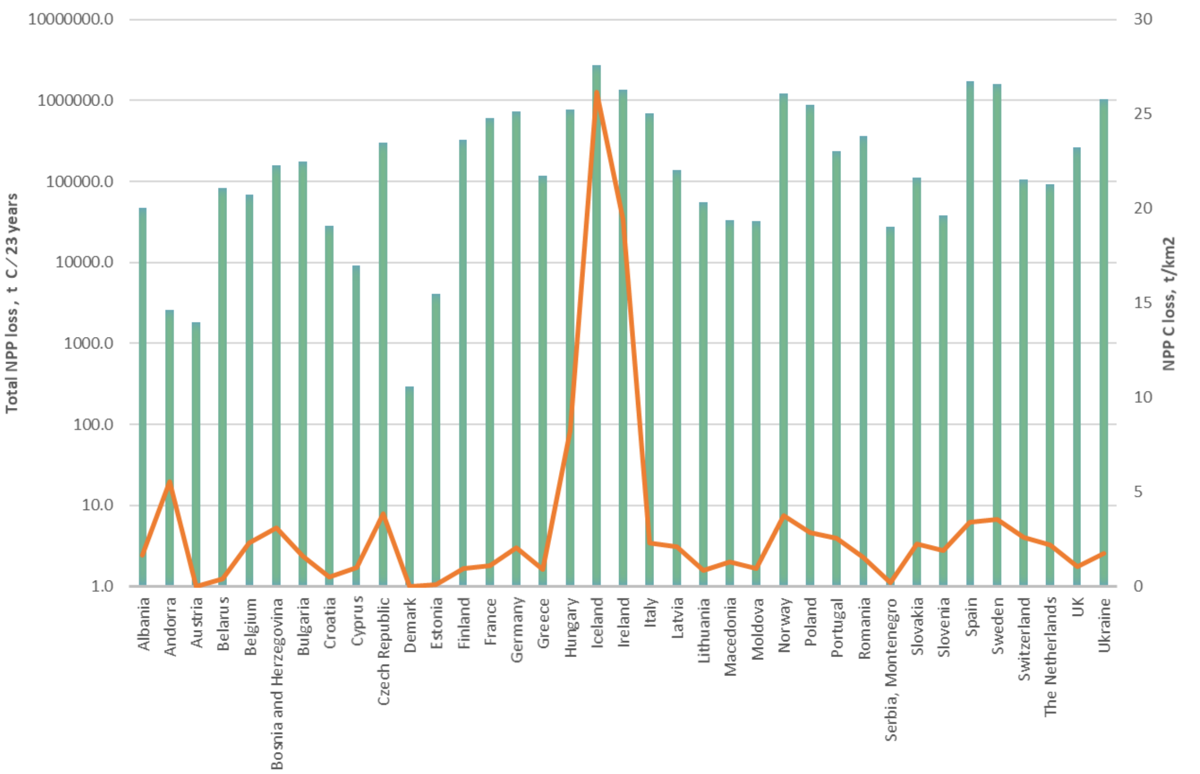

Fig. 3. Total NPP estimated losses in the different European countries and NPP losses per unit area. Source: Bai et al, 2008b.

More recently, within the frame of the Global Soil Partnership of FAO, an estimate has been produced of the soil degradation processes trends at global level (FAO and ITPS, 2015). The processes recognized by FAO (and European Union) are: soil sealing and land take; salinization and sodification; contamination; organic carbon loss; nutrient unbalance; soil erosion; loss in biodiversity; acidification; waterlogging; compaction. As for the European region, which encompasses Europe and Eurasia, the analysis showed a poor condition and a declining trend for soil sealing and salinization, and a fair condition and a declining trend for soil biodiversity. An improvement is assessment for soil erosion (Fig. 4).

Threat to soil function	Summary	Condition and Trend					Confidence	
		Very poor	Poor	Fair	Good	Very good	In condition	In trend
Soil sealing and land take	In densely populated Western Europe soil sealing is one of the most threatening phenomena.		↙				Adequate	Adequate
Salinization and sodification	Salinization is a widespread threat in Central Asia, and it is challenging in some areas in Spain, Hungary, Turkey, and Russia.		↙				Adequate	Adequate
Contamination	Soil contamination is a widespread problem in Europe. The most frequent contaminants are heavy metals and mineral oil. The situation is improving in most regions.		↗				Adequate	Limited
Organic carbon change	The loss of organic carbon is evident in most agricultural soils. Peatland drainage in northern countries also leads to rapid organic carbon loss. In Russia, extensive areas of agricultural lands were abandoned that resulted in quick organic mater accumulation; however, some of these areas are now again used for agriculture.		↗↙				Limited	Limited
Nutrient imbalance	In the western part of the region the loss of nutrients is compensated by application of high doses of fertilizers. In the eastern part the use of fertilizers is insufficient, and in most soils nutrient mining results in intensive mineral weathering.		↗↙				Limited	Limited
Soil erosion	Water erosion is active in all the cultivated mountainous and rolling areas; the worst situation is observed in Turkey, Tajikistan and Kyrgyzstan. Due to the attention paid to this threat it is controlled in most areas, especially in the EU.			↗			Adequate	Limited
Loss of soil biodiversity	Loss of biodiversity is expected in the most urbanized and contaminated areas of the region. However, there are almost no qualitative estimations of the biodiversity loss in soils.			↙			Low	Low
Soil acidification	Acidification due to acid rain was a challenge in Northern and Western Europe. The situation is now improving, though several decades will be needed for complete soil recovery.			↗			Limited	Limited
Waterlogging	Waterlogging is mostly associated with irrigation in Central Asian countries. Most cultivated irrigated soils there are waterlogged. This phenomena in Central Asia is commonly associated with salinization.			↗↙			Adequate	Limited
Compaction	The use of heavy machinery and overgrazing are threatening in almost all the agricultural areas.			↗↙			Limited	Limited

Fig. 4 Condition and trend of soil degradation processes in the European region (FAO and ITPS. 2015).

3. European research activities on desertification and land degradation

3.1 Research, Technology and Development (RTD) projects

Within Europe desertification has been a topic of active research since the 1980s and over the last four decades and eight research Framework Programmes (FP), the European Union has invested considerable amounts of funding into the causes and consequence of desertification. Moreover a long list of projects have been funded dealing with soil degradation (https://esdac.jrc.ec.europa.eu/projects/Eufunded/Eufunded.html)

The symposium Desertification in Europe, held in Mytilene in 1984, is cited as the birth place of European desertification research. Initially the focus of the programmes was on climate change as the main driver of desertification, but that quickly evolved to include the evaluation of human drivers too, with Mediterranean Desertification being recognised as an issue in its own right. The MEDALUS (I-II-III) project (1991-1999) paved the way for understanding and predicting the desertification processes in the Mediterranean countries of the European Union. The developed indexes used for defining the so-called environmentally sensitive areas (ESAs) are still widely used worldwide. The approach considers a multi-dimensional index (the ESA index) composed of partial indicators of climate, soil, vegetation, and management quality that are derived from the elaboration of 15 elementary variables (Ferrara et al., 2020).

With the start of FP5 (in 1998) and the newly ratified UNCCD, the EU funded Projects were expected to underpin EU policies relating to the UNCCD and the other environmental conventions. The attention then turned to scenarios and strategies for responding to land degradation and desertification (MEDACTION project, 2001-2004), and to tools to study and understand changes in the environment and underpin EU policies (DESERTLINKS project, 2001-2005).

By FP6 (2002), a significant body of research data and understanding of desertification processes (particularly bio-physical ones) had been accumulated and projects started to look at the exploitation and practical application of the research knowledge, with the development of detailed management options to combat desertification and their demonstration in affected areas (projects RECONDES, 2004-2007; DESURVEY, 2005-2010; LUCINDA, 2006-2008).

FP7 (2007) saw the focus shift slightly to the responses made to desertification and ecosystem services decline (projects SOILSERVICE, 2009-2012; UNDESERT, 2010-2015), with the links between bio-physical and socio-economic processes being emphasised plus support for decision-making and facilitating knowledge transfer to stakeholders, including those at the institutional level (projects RECARE, 2013-2018; LEDDRA, 2010-2014).

In Table 2 recent relevant projects details are reported.

Project ACRONYM	Type of project	TITLE	Start	End	Website
RECONDES	STREP FP6	Conditions for Restoration and Mitigation of Desertified Areas Using Vegetation	2004	2007	https://cordis.europa.eu/project/id/505361
INDEX	STREP FP6	Indicators and thresholds for desertification, soil quality, and remediation	2004	2006	https://cordis.europa.eu/project/id/505450
DESURVEY	IP FP6	A Surveillance System for Assessing and Monitoring of Desertification	2005	2010	https://cordis.europa.eu/project/id/3950
ENVASSO	STREP	Environmental Assessment of Soil for Monitoring	2006	2009	http://eusoils.jrc.ec.europa.eu/projects/envasso/
RAMSOIL	SSA FP6	Risk assessment methodologies for soil threats	2006	2009	https://cordis.europa.eu/project/id/44240
LUCINDA	SSA FP6	Land care in desertification affected areas: from science towards application	2006	2008	https://cordis.europa.eu/project/id/18347
DESIRE	IP FP6	Desertification mitigation and remediation of land - a global approach for local solutions	2007	2012	http://www.desire-his.eu/index.php/en/desire-project
PRACTICE	CSA-SA FP7	Prevention and Restoration Actions to Combat Desertification. An Integrated Assessment	2009	2012	https://cordis.europa.eu/project/id/226818
SOILSERVICE	CP-FP FP7	Conflicting demands of land use, soil biodiversity and the sustainable delivery of ecosystem goods and services in Europe	2009	2012	http://www.lu.se/soil-ecology-group/research/soilservice
LEDDRA	CP-FP-SICA FP7	Land and Ecosystem Degradation and Desertification: Assessing the Fit of Responses	2010	2014	http://leddra.aegean.gr/index.htm
UNDESERT	CP-FP-SICA FP7	Understanding and combating desertification to mitigate its impact on ecosystem services	2010	2015	http://www.undesert.neri.dk/
RECARE	CP FP7	Preventing and Remediating degradation of soils in Europe through Land Care	2013	2018	https://www.recare-hub.eu/recare-project
BIODESERT	ERC-COG H2020	Biological feedbacks and ecosystem resilience under global change: a new perspective on dryland desertification	2016	2022	http://biodesert.maestrelab.com/

Explanation of the "TYPE of PROJECT" Acronyms
IP: Integrated Project
STREP: Specific Targeted Research Projects
CSA: Coordination and Support Action
CP-FP: Small- or medium-scale focussed research project
SSA: Specific Support Action
SICA: Specific International Cooperation Actions
ERC: ERC Consolidator grants

Table 2. Relevant projects funded within the 6th and 7th Framework Programme for Research.

3.2 LIFE Projects

Although soil has not been a core theme of LIFE, the programme has funded many soil-related projects since its launch in 1992, and there has been an increasing focus on soil protection since the publication of the Thematic Strategy in 2006. LIFE has co-financed actions targeting erosion, landslides, contamination, loss of soil organic matter, sealing, compaction, and other soil management issues.

The following figures summarizes LIFE's important contribution between 2007 and 2013, including proposals for ways in which LIFE's outputs may be better channeled and have an even greater impact in future (LIFE Publication, 2014). This summary includes an overview of soil policy, analysis of LIFE's contribution to its implementation and interviews that link soil science to policy-making to practical action.

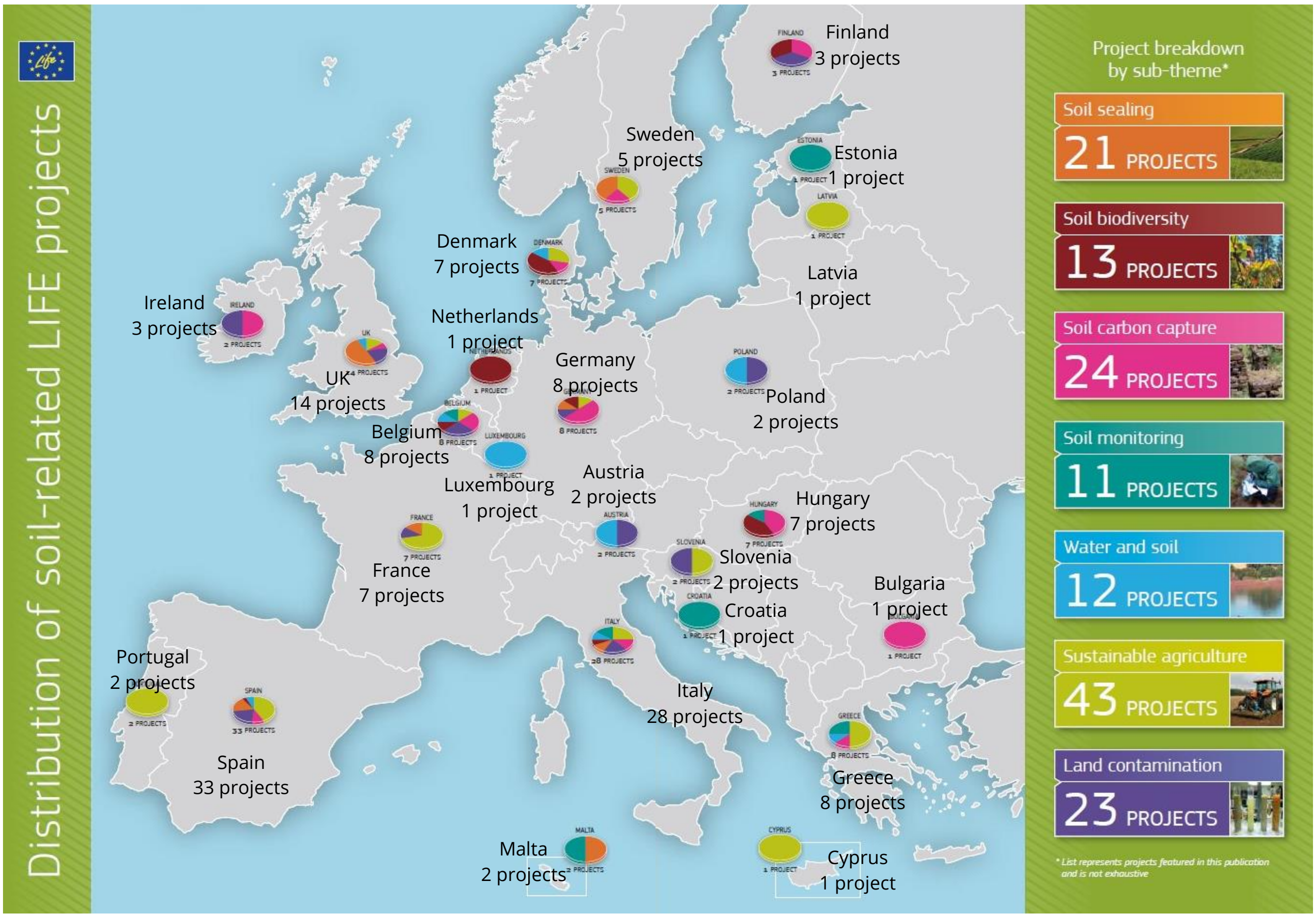

Figure 5. Soil-related projects by sub-theme funded under the LIFE programme 2007-2013 (Source; LIFE Publication 2014).

The following table reports a number of projects addressing soil quality funded under different schemes (2008-2013) addressing soil resources management and soil degradation.

Project ACRONYM	Type of project	TITLE - Brief Description	Start	End	Website
List of LIFE projects	LIFE+	LIFE projects lead the way in sustainable soil management.	2012	-	http://ec.europa.eu/environment/life/features/2012/soil_managmt.htm
SOILPRO	LIFE+	The SOILPRO project has the overall objective of halting soil degradation in EU Member States in line with the Thematic Strategy for Soil Protection. It will do this by encouraging co-operation between local authorities and research institutes within a transnational environment, as this can promote the development of spatial methodologies for monitoring and managing soil degradation.	2010	2013	http://www.soilpro.eu/en/home
CircUse	ERDF	CircUse contributed to the objective of integrated development strategies and investments by providing a viable framework, action plans and pilot projects on land use management as precondition for private investments (pilot projects). In order to support European soil awareness a number of illustrations have been produced in various language.	2010	2013	http://www.circuse.eu/
OSDDT	MED Programme (co-financed by the European Regional Development Fund)	Raise awareness among local agents of the adverse consequences for sustainable development of current land use and consumption models. Encourage local agents to adopt technical and operational tools that support economic development affected by land use.	2010	2013	http://www.osddt.eu
GS Soil	eContentplus	GS Soil aims at establishing a Best Practice Network dealing with a cluster of the data themes listed in the Annexes I to III of the INSPIRE Directive (2007/2/EC) and focused on soil related issues.	2009	2012	http://www.gssoil.eu/
URBAN-SMS	CENTRAL EUROPE Programme	URBAN SMS focuses on management of the resource soil in urban areas in order to steer the use of soils towards a sustainable way conserving the soil functions and eco-services as much as possible in order to support the regional development in the programme area.	2008	2012	http://www.urban-sms.eu/
CityChlor	INTERREG IVB North-West Europe (NWE)	CityChlor is a transnational cooperation project that aims to improve the quality and minimize the pollution of soil and groundwater. Our solution? An integrated approach to tackle the threats caused by contamination with chlorinated solvents in urban areas.	2010	2013	http://www.citychlor.eu/

Table 3. GLASOD estimates of human-induced soil degradation (million ha) (Source: Bai et al., 2008)

Between 2014 and 2020, the LIFE Programme funded 13 projects addressing soil degradation and 4 projects addressing land degradation (source: LIFE Programme 2014-2020 data hub, https://life.easme-web.eu/#). In the case of soil degradation projects, 73 partners were involved in 6 countries with an allocation of 13 M€. The main beneficiaries were Italy (4,302,304 €, 5 projects), Spain (4,041,226€, 5 projects), Belgium (2,330,961€, 1 project), Greece (1,572,678€, 1 project), Portugal (1,158,690€, 1 project) and France (84,124€, 1 project). In the case of land degradation projects, 41 partners were involved in 10 countries with an allocation of 9.3 M€. The main beneficiaries were Greece (3 216 944 €, 2 projects), Poland (1,004,034 €, 1 project), Italy (964,513 €, 1 project), Lithuania (701,395 €, 1 project), Estonia (690,670 €, 1 project), Portugal (622,136 €, 1 project), Germany (596,381 €, 1 project), Spain (591,122 €, 1 project), Latvia (557,000 €, 1 project), the Netherlands (356,187 €, 1 project). The following table lists the considered LIFE projects 2014-2020.

Theme	Name	Project	Title
Soil degradation	LIFE AGROWETLANDS II	LIFE15 ENV/IT/000423	SMART WATER AND SOIL SALINITY MANAGEMENT IN AGRO-WETLANDS
Soil degradation	LIFE GAIA Sense	LIFE17 ENV/GR/000220	Innovative Smart Farming services supporting Circular Economy in Agriculture
Soil degradation	LIFE NARMENA	LIFE18 ENV/BE/000286	Nature-based Remediation of Metal pollutants in Nature Areas to increase water storage capacity
Soil degradation	LIFE No_Waste	LIFE14 ENV/PT/000369	MANAGEMENT OF BIOMASS ASH AND ORGANIC WASTE IN THE RECOVERY OF DEGRADED SOILS: A PILOT PROJECT SET IN PORTUGAL
Soil degradation	LIFE REFOREST	LIFE17 ENV/ES/000248	Erosion prevention and flora REstauration of burnt FOREST areas through innovative fungal-technosol solution
Soil degradation	LIFE Regenerate	LIFE16 ENV/ES/000276	Revitalizing multifunctional Mediterranean agrosilvopastoral systems using dynamic and profitable operational practices
Soil degradation	LIFE SARMIENTO	LIFE15 CCM/ES/000032	Demonstration of an innovative solution to reduce GHG emissions in vineyards while improves the soil in arid areas
Soil degradation	LIFE agriCOlture	LIFE18 CCM/IT/001093	Livestock farming against climate change problems posed by soil degradation in the Emilian Apennines
Soil degradation	LIFE+ POLYFARMING	LIFE15 ENV/ES/000506	Demonstration of a new agro-silvo-pastoral land use to improve farm profitability in mountain areas
Soil degradation	LIFE-BIOREST	LIFE15 ENV/IT/000396	Bioremediation and revegetation to restore the public use of contaminated land
Soil degradation	SOS4LIFE	LIFE15 ENV/IT/000225	S.O.S. 4 LIFE - Save Our Soil for LIFE
Soil degradation	SUBproducts4LIFE	LIFE16 ENV/ES/000481	Innovative circular economy concepts by reusing industrial subproducts and waste
Land degradation	LIFE Andros Park	LIFE16 NAT/GR/000606	Conservation of priority species and habitats of Andros Island protected area integrating socioeconomic considerations
Land degradation	LIFE DESERT-ADAPT	LIFE16 CCA/IT/000011	Preparing desertification areas for increased climate change
Land degradation	LIFE Peat Restore	LIFE15 CCM/DE/000138	Reduction of CO2 emissions by restoring degraded peatlands in Northern European Lowland
Land degradation	LIFE TERRACESCAPE	LIFE16 CCA/GR/000050	EMPLOYING LAND STEWARDSHIP TO TRANSFORM TERRACED LANDSCAPES INTO GREEN INFRASTRUCTURES TO BETTER ADAPT TO CLIMATE CHANGE

Table 4. List of projects funded under the LIFE Programme 2014-2020 addressing soil and land degradation.

In addition, within the same time span (2014-2020) the LIFE program allocated 13 M€ funding 7 projects addressing desertification and aridification, involving 6 countries and 66 partners. In this case, the main beneficiaries were Spain (7,028,100€, 4 projects), Italy (2,092,623 €, 2 projects), Portugal (2,030,740€, 1 project), the Netherlands (1,071,949€, 1 project), France

(236,820€, 1 project), and Greece (201,241€, 1 project). Data about these projects are summarised in the following table (Table 5).

Theme	Name	Project	Title
Desertification/ Aridification	LIFE ZEOWINE	LIFE17 ENV/IT/000427	ZEOlite and WINEry waste as innovative product for wine production
Desertification/ Aridification	LIFE ADAPTAMED	LIFE14 CCA/ES/000612	Protection of key ecosystem services by adaptive management of Climate Change endangered Mediterranean socioecosystems
Desertification/ Aridification	LIFE AMDRYC4	LIFE16 CCA/ES/000123	Climate Change adaptation of dryland agricultural systems in the Mediterranean area
Desertification/ Aridification	LIFE DESERT-ADAPT	LIFE16 CCA/IT/000011	Preparing desertification areas for increased climate change
Desertification/ Aridification	LIFE LiveAdapt	LIFE17 CCA/ES/000035	Adaptation to Climate Change of Extensive Livestock Production Models in Europe
Desertification/ Aridification	LIFE The Green Link	LIFE15 CCA/ES/000125	Restore desertified areas with an innovative tree growing method across the Mediterranean border to increase resilience
Desertification/ Aridification	LIFE-Montado-adapt	LIFE15 CCA/PT/000043	MONTADO & CLIMATE; A NEED TO ADAPT

Table 5. List of projects funded under the LIFE Programme 2014-2020 addressing desertification/aridification.

Some COST actions were also addressing desertification. In particular the COST action ES1104 (2012-2016) Arid Lands Restoration and Combat of Desertification: Setting Up a Drylands and Desert Restoration Hub https://www.cost.eu/actions/ES1104/#tabs|Name:overview.

4. The conceptual framework for achieving land degradation neutrality

The concept of land degradation neutrality (LDN) was introduced into the global dialogue to stimulate a more effective policy response to land degradation. LDN was adopted as target for Sustainable Development Goal 15, and building capacity to achieve LDN is a primary goal of the UNCCD (UNCCD, 2016). LDN is defined as "a state whereby the amount and quality of land resources necessary to support ecosystem functions and services and enhance food security remain stable or increase within specified temporal and spatial scales and ecosystems" (UNCCD-GM, 2016). The three elements at the basis of LDN are then healthy ecosystems, food security and human wellbeing.

The 12th session of the Conference of the Parties of the UNCCD (COP 12) agreed to integrate the sustainable development goals (SDGs) and target 15.3 on Land Degradation Neutrality (LDN) in particular, into the implementation of the Convention, stating that "striving to achieve SDG target 15.3 is a strong vehicle for driving implementation of the UNCCD" (decision 3/COP 12). Therefore the UNCCD Science-Policy Interface (SPI) was requested by the UNCCD's Conference of the Parties (COP) to develop a scientific "Conceptual Framework for Land Degradation Neutrality" to provide a scientifically sound basis for understanding and implementing LDN. Such a framework would then allow informing the development of practical guidance for reaching LDN and monitoring signs of progress towards the LDN target. While the scope of the UNCCD is restricted to drylands, the LDN conceptual framework is valid for all land types, land uses, and ecosystem services. LDN will support the realization of multiple SDGs related to food security, environmental protection and the sustainable use of natural resources.

The need for a scientific-based framework stems from the need for a common understanding of concepts, processes and references, in order to assist countries to implement strategies to tackle land degradation and reach LDN. At the core of the LDN framework is the counterbalancing mechanism between the losses due to new degradations and the gains resulting from reverting past degradation. A no net loss balance would then ensure neutrality and the three key actions towards it would be avoid, reduce and reverse. Avoidance and reduction of new degradations are reached with sustainable land management (SLM), while reversal of past degradation is achieved via restoration and rehabilitation.

At the base of LDN implementation are the interactions between natural and social capital based on relationships and processes that sustain and enhance the resilience of land-based resources and deliver human well-being (e.g. food security, social stability). Figure 5 illustrates the casual relationships among drivers (D), pressures (P), state of natural capital (S), impact (I) and responses (R). The framework is an adaptation of the DPSIR framework by Smeets and

Weterings (1999) and the Driving force-Pressure-State-human/environment Impact-Response framework (DPSheIR) by UNCCD-AGTE (2013).

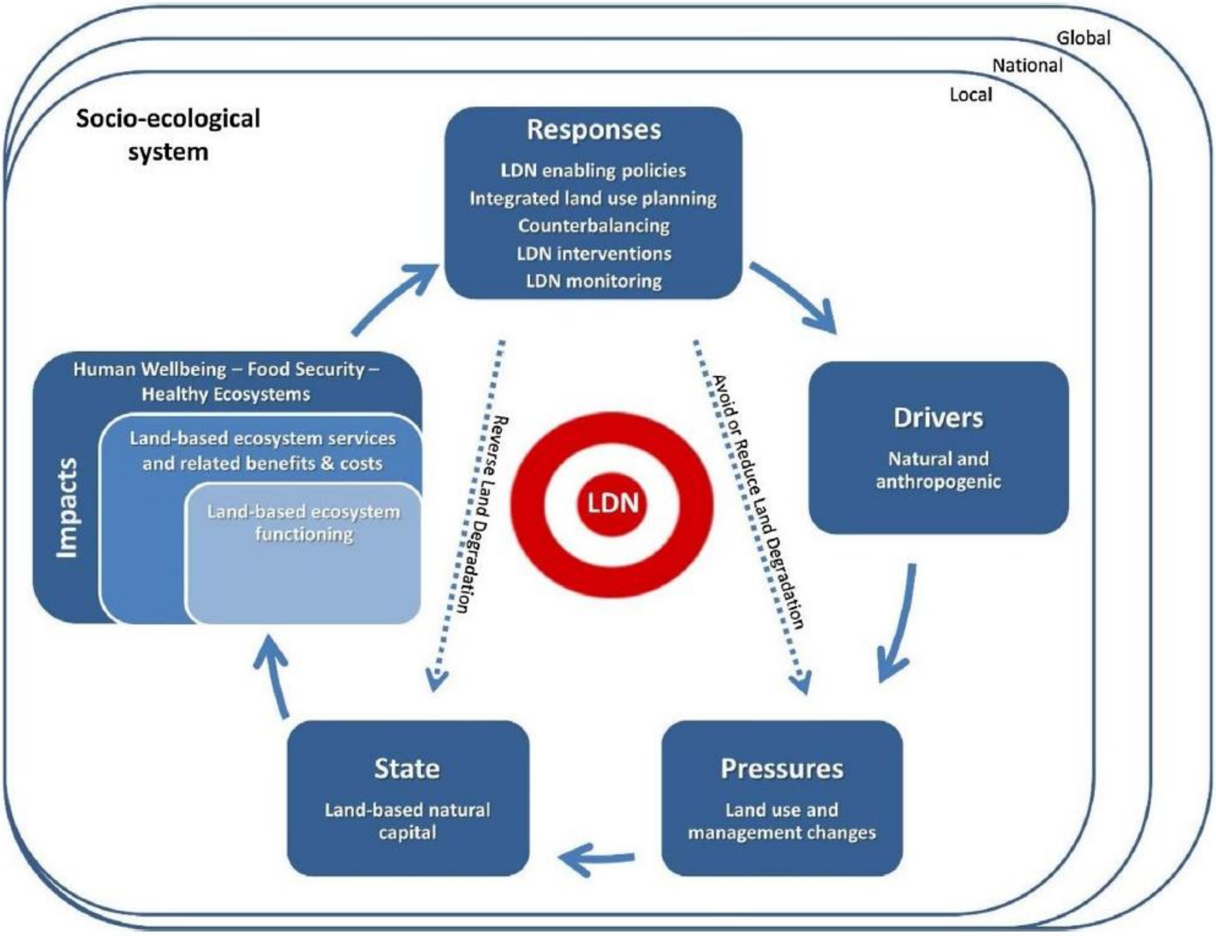

Figure 6. Land Degradation Neutrality conceptual framework: cause and effect relationships within the socio-ecological system (source: Cowie at al., 2018)

According to the framework, within a given socio-ecological system, considered at a scale ranging from global to local, natural and anthropogenic drivers exert pressures on the state of land based natural capital via land use and/or management changes. These in turn have impacts on the functioning of ecosystems, affecting the flow of ecosystem services with negative effects on human well-being. Responses based on targeting LDN aim to avoid or limit land degradation reducing pressures and reverse land degradation improving the state of land-based natural capital. These targets can be reached by enabling policies towards LDN, adopting integrated land use planning, counterbalancing degradation via direct interventions and monitoring.

The principles underpinning the implementation of the LDN framework, enabling context specific adjustments, are the following (Cowie et al., 2018):

1. Maintain or enhance land-based natural capital
2. Protect the right of vulnerable and marginalized land users
3. Set national LDN targets based on national circumstances
4. For neutrality, the LDN target equals (is the same as) the baseline
5. Neutrality is the minimum objective: countries may elect to set a more ambitious target
6. Integrate planning and implementation of LDN into existing land use planning processes
7. Counterbalance anticipated losses in land-based natural capital with interventions to reverse degradation, to achieve neutrality
8. Manage to counterbalance at the same scale as land use planning
9. Counterbalance “like for like” (within the same land type)
10. Seek solutions that provide multiple environmental, economic and social benefits, and minimize trade-offs
11. Base land use decisions on multi-variable assessments, considering land potential, land condition, resilience, social, cultural and economic factors
12. Apply the response hierarchy in devising interventions for LDN: Avoid > Reduce > Reverse land degradation
13. Apply a participatory process: include stakeholders, especially land users, in designing, implementing and monitoring interventions to achieve LDN
14. Reinforce responsible governance: protect human rights, including tenure rights; develop a review mechanism; and ensure accountability and transparency
15. Monitor using the three UNCCD land-based global indicators: land cover, land productivity (net primary productivity, NPP) and carbon stocks (soil organic carbon, SOC)
16. Use the “one-out, all-out” approach to interpret the result of these three global indicators
17. Use additional national and sub-national indicators to aid interpretation and to fill gaps for ecosystem services not covered by the three global indicators
18. Apply local knowledge and data to validate and interpret monitoring data
19. Apply a continuous learning approach: anticipate, plan, track, interpret, review, adjust, and create the next plan.

Following the above principles, the implementation of the LDN framework can be monitored resorting to indicators. Indicators are variables that can be used as proxies of a process of interest. Metrics are measures that are used to quantify or assess the state or level of the indicators and their changes over time once a reference baseline is established.

The monitoring of LDN is based on evaluating the significant changes (positive and negative) in three global indicators (via associated metrics) which serve as proxies of most ecosystem services flowing from land-based natural capital: land cover/land cover change, land productivity/NPP, carbon stock/SOC stock. At scales different from the global one, for other relevant processes and ecosystem services not covered by these, other SDG indicators, and/or national/local indicators should be identified and adopted.

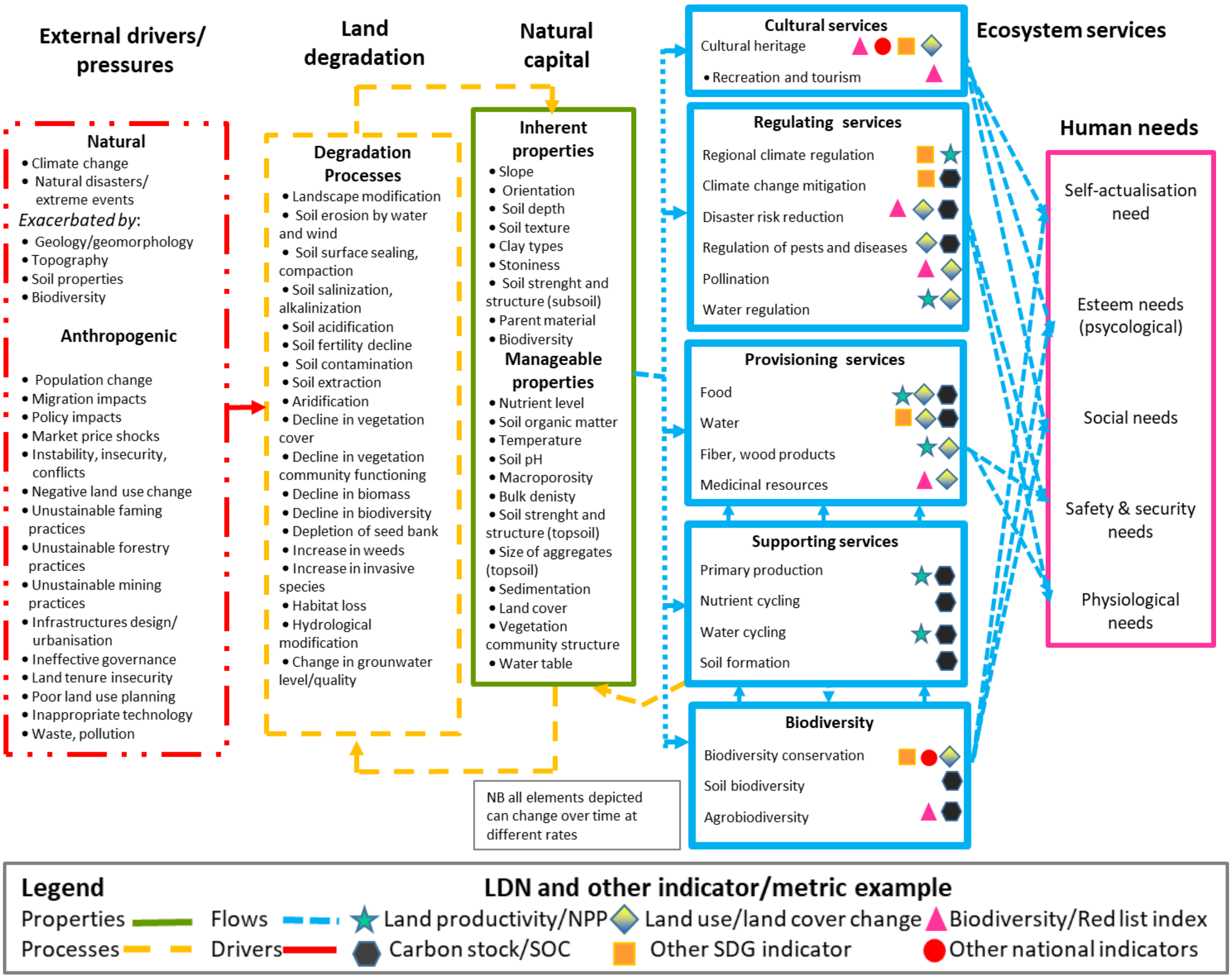

Figure 7. Relationships among land degradation and its drivers, ecosystem services provision and natural capital (modified from Dominati et al., 2010).

In order to tailor the LDN framework to the different conditions observed in the New Life 4 Drylands case study areas and to identify the indicators to monitor LDN, a more detailed framework is needed, coherent with the adopted study scale. To be of operational relevance, this must then describe in details the elements of the general LDN framework, with explicit reference to the different components of soil as natural capital, and to different land degradation processes and their impacts on the supply of ecosystem services, as depicted in Figure 7.

The framework allows for the identification of the external drivers acting locally, either natural and anthropogenic, which trigger degradation processes affecting the state of the natural capital which is at the base of the provision of relevant ecosystem services for a given area. Among natural external drivers and pressures, the framework considers climate change, extreme events and natural disasters, exacerbated by geology, geomorphology, topography, soil properties and (lack of) biodiversity. As for anthropogenic drivers and pressures the framework includes the following: population change, migration impacts, policy impacts, market price shocks, instability insecurity and conflicts, negative land use change, unsustainable farming practices, infrastructure design and urbanization, ineffective governance, land tenure insecurity, poor land use planning, inappropriate technology, waste and pollution.

The following table summarizes the external pressures at the base of land and soil degradation in the six case study areas identified by the NewLife4Drylands project partners.

External pressure		El Bruc	Tifaracás	Palo Laziale	Alta Murgia	Nestos	Asterousia
	Summer rain shortage	x		x	x	x	x
	Heat waves	x	x	x	x	x	x
Climate change	Temperature rising	x	x	x	x		
	Episodes of drought	x	x		x	x	x
	Sea-level and wave exposure changes due to climate change						x
Natural disasters/extreme events	Fires	x	x	x	x	x	x
	Extreme rainfalls	x		x		x	x
	Windstorms	x					
	Habitat conversion and degradation (land conversion)	x	x	x	x	x	x
	Sports, tourism and leisure activities						x
Negative land use change	Roads, paths railroads and infrastructure (bridges, viaducts, tunnels)						x
	Wind, wave and tidal power, including infrastructure				x		x
	Extraction of minerals (e.g. rock, metal ores, gravel, sand, shell)				x		x
	Feral goats traditional breeding		x				x
	Intensive grazing or overgrazing by livestock				x		x
	Tillage practices (e.g. ploughing) in agriculture				x		x
Unsustainable farming practices	Application of synthetic (mineral) fertilisers on agricultural land						x
	Removal of small landscape features for agricultural land parcel consolidation				x		x
	Stone (rock) grinding				x		
	Increase of irrigated areas					x	x
Unsustainable forestry practices	Over-composition of the forest stands for resources			x			
	Lack of forest management	x					x
	Agricultural land abandonment	x					x
Poor land use planning	Lack of spatial plan of the primary sector					x	x
	Transformation of grassland pastures into agricultural (cereal crops)				x		
Pollution	Air pollution and nutrient enrichment			x			
Fauna	Feral goats herbivorism		x				x
Waste	Uncontrolled waste disposal				x	x	x
	Population change (decline due to internal migration)						x
Other anthropogenic pressures	Increase in tourist flows					x	x
	Policy impacts-conflicts						x
	Inadequate management and protection of protected areas						x

Table 6. Drivers of land degradation processes in the NewLife4Drylands study areas.

Following the cause-effect flow in the framework, the relevant degradation processes in the case study area were identified; these are summarized in Table 7.

Degradation processes	El Bruc	Tifaracás	Palo Laziale	Nestos	Alta Murgia	Asterousia	Num.
Aridification	x	x	x		x	x	5
Decline in vegetation community functioning	x	x	x	x	x	x	6
Decline in vegetation cover/biomass	x	x	x		x	x	5
Forest fires	x						1
Habitat loss	x	x	x	x	x	x	6
Hydrological modification	x	x		x		x	4
Landscape modification	x			x	x	x	4
Overgrazing		x					1
Soil salinization				x		x	2
Soil organic matter decline	x	x				x	3
Soil erosion by water and wind	x	x			x	x	4

Table 7. Main land degradation processes in the NewLife4Drylands study areas.

In table 7, the decline in vegetation community functioning encompasses decline in biodiversity, increase in weeds, trees encroachment and increase of invasive species, while hydrological modification includes also change in groundwater level and quality.

As for the ecosystem services, table 8 lists the main services highlighted by project partners in the six case study areas. Of these, 47% are regulatin and maintainance services, 27% are cutural services and 26% provisioning services.

ECOSYSTEM SERVICES	El Bruc	Tifaracás	Palo Laziale	Alta Murgia	Nestos	Asterousia
PROVISION						
Forest Water Use Effieciency	x	x	x		x	x
Water for domestic use and irrigation					x	x
Primary production(s) (e.g. food)	x		x		x	x
Wood /Raw materials					x	
Production of pharmaceuticals, Cultivation of edible, medicinal and ornamental plants					x	x
Energy production						x
Building materials (e.g. limestone)						x
REGULATING and MAINTENANCE						
Air quality regulation			x			
Biodiversity	x	x	x	x	x	x
Carbon sequestration - soil	x	x	x	x	x	x
Carbon sequestration - vegetation	x	x	x	x	x	x
Habitat	x	x	x	x	x	x
Moderation of extreme events	x	x	x		x	x
Nutrient cycling	x	x	x		x	x
Photosynthesis	x	x	x		x	x
Pollination	x				x	x
Soil erosion control	x	x				x
Soil formation	x	x			x	x
Water regulation (e.g. runoff decrease, flood control, water storage increase)	x	x				x
Protecting genetic diversity						x
CULTURAL						
Aesthetic value	x	x	x		x	x
Education	x	x	x		x	x
Place attachment, Wellbeing						x
Recreation (e.g. recreational opportunities, tourism)	x	x	x		x	x
Artistic inspiration					x	x
Wildlife observation					x	x
Ecotourism and outdoor activities					x	x
Spiritual-religious value of the mountains						x
Cultural and ethnic-linguistic diversity					x	x

Table 8. Major ecosystem services in the NewLife4Drylands study areas.

5. Indicators of soils and land degradation

In order to capture the complexity and the specificity of the land degradation phenomena identified in the in the New Life 4 Drylands case study areas (Table 7), specific indicators may be necessary. The selection of reliable indicators should consider the following characteristics: (a) objectively and scientifically measurable, (b) preferentially quantitative, (c) easy and cost-effective to be measured, (d) sensitive to environmental changes, (e) simple in concepts, and (f) able to support policy decisions (DESIRE, 2008)

Many studies have dealt with the assessment of potential and actual desertification risk using composite indices. The Environmentally Sensitive Areas (ESA) approach, developed within the framework of MEDALUS (I-II-II) projects and financed by the European Commission from 1991 to1999, has been one of the first methodology based on indicators to monitor land sensitivity to degradation and desertification. The output index of this procedure (the ESA index) is based on 15 key indicators, referring to the soil, climate, vegetation and land management (Kosmas et al. 1999, Fig. 6).

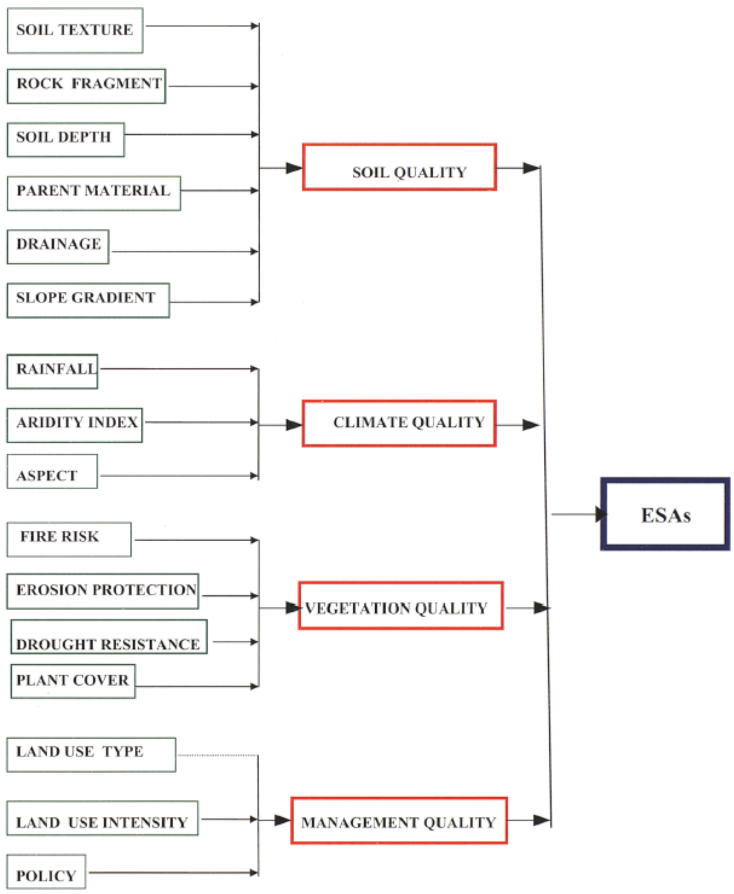

Figure 8. The MEDALUS indicators structure (source Kosmas et al., 1999).

All the variables are firstly scored in order to have an overall score for soil, climate, vegetation and management quality, and then combined in the general ESA index. The MEDALUS approach is still used in many assessments (Ferrara et al., 2020) even if it lacks of specifically addressing the socio-economic variables (Salvati and Bajocco, 2011; Kirkby et al., 2015).

Stemming from the MEDALUS experience, several projects developed indicators, integrating also the socio-economic aspect. Within the EU funded DESERTLINK project, individuated a list of about 150 indicators that were collected and described in the DIS4ME system, which also provides an online assessment tool. The system is still maintained within the JRC ESDAC facilities (https://esdac.jrc.ec.europa.eu/projects/dis4me). DIS4ME includes different kinds of indicators: i) Physical and ecological indicators: ii) Economic indicators; ii) social indicators; iv) Institutional indicators; v) Composite indicators.

A series of indicators from the above mentioned and other initiatives, have been revised in the EU DESIRE project (037046 GOCE, http://www.desire-his.eu/) which released a list of 70 candidate indicators subdivided in Physical and Socio-economic and Institutional, and related to the processes of land degradation and desertification (Kosmas et al, 2014). The classed values of indicators are then combined for defining the desertification risk class, namely very high, high, moderate, low, and none (table 9).

DRI	Desertification risk class	Description
5	Very high risk	Critical areas to desertification highly degraded and subjected to very high erosion rates due to intensive cultivation, overgrazing, frequent fires; or to very high salinization rates due to the presence of shallow groundwater table or irrigation with poor quality of water
4	High risk	Critical areas to desertification highly degraded subjected to moderate or slight erosion rates or fragile areas to desertification moderately degraded subjected to very high erosion rates due to intensive cultivation, overgrazing, frequent fires; or to high salinization rates due to the presence of moderately shallow groundwater table or irrigation with poor quality of water
3	Moderate risk	Fragile areas to desertification moderately degraded subjected to high or moderate erosion rates or potential areas to desertification subjected to very high or high erosion rates due to intensive cultivation, overgrazing, frequent fires; or to moderate salinization rates due to the presence of moderately deep groundwater table or irrigation with moderate quality of water
2	Low risk	Fragile areas to desertification moderately degraded subjected to low erosion rates or potential areas to desertification slightly degraded subjected to moderate erosion rates due to intensive cultivation, overgrazing, frequent fires; or to low salinization rates due to the presence of relatively deep groundwater table or irrigation with moderately good quality of water
1	No risk	Potential or non-threatened areas to desertification slightly or no degraded subjected to very low or no erosion; or fragile, potential, non-threatened areas to desertification subjected to no salinization risk due to the presence of very deep ground water table or irrigation with good quality of water

Table 9. Desertification risk index (DRI) and classes with the corresponding description (source: Kosmas et al., 2014)

Considering the land degradation processes identified in the NewLife4Drylands study areas, the relevant indicators according to the DESIRE approach are reported in Tables 10 and 11, for physical and socio-economic aspects respectively.

Physical and ecological indicators	Aridification	Forest fires	Overgrazing	Soil erosion by water and wind	Soil organic matter decline	Soil salinization
CLIMATE						
Air temperature	x	x	x	x	x	x
Rainfall	x	x	x		x	x
Aridity Index	x	x	x		x	x
Potential evapotranspiration	x	x	x	x	x	x
Rainfall seasonality	x	x	x	x	x	x
Rainfall erosivity	x	x	x	x	x	
WATER						
Water quality	x					x
Water quantity	x					x
Groundwater exploitation	x					x
Water consumption/demand	x					x
SOILS						
Drainage					x	x
Parent material			x	x	x	x
Rock fragments	x		x	x		
Slope aspect	x	x	x	x		
Slope gradient	x		x	x		
Soil depth	x	x	x	x		x
Soil texture	x		x	x	x	x
Soil water storage capacity	x		x	x		x
Exposure of rock outcrops			x	x		
Organic matter surface horizon	x		x	x	x	
Electrical conductivity	x		x	x		x
VEGETATION						
Major Land use	x	x	x	x	x	
Vegetation cover type	x	x	x	x	x	
Plant cover	x	x	x	x	x	
Deforested areas	x	x	x		x	
WATER RUNOFF						
Drainage density				x		
Flooding frequency						x
Impervious surface area				x		
FIRES						
Fire frequency	x	x	x		x	
Fire risk	x	x	x			
Burned area		x	x	x		

Table 10. Physical and ecological indicators

Using a minimum of 30 sampling points at field scale to characterize degradation processes in 17 DESIRE case study areas, desertification risk was estimated resorting to multiple linear regressions (MLR). In calibrating MLR, only the most appropriate and effective indicators retaining only those who entered the regression equations and that did not have very high covariance with other indicators. Results from Kosmas et al. (2014) showed that a single indicator could not effectively assess the risk of land degradation and desertification, but that a combination of indicators is required to assess such a risk as related to physical environment, socio-economic conditions and land management practices. For example, for soil salinization in agricultural soils and under natural vegetation 9 indicators out of 29 proved to be effective.

In the case of water stress, they were 12 out of 50, and for overgrazing and forest fires, 16 out of 44 and 8 out of 30 respectively.

Socio-economic indicators	Aridification	Forest fires	Overgrazing	Soil erosion by water and wind	Soil organic matter decline	Soil salinization
AGRICULTURE						
Farm ownership		X	X	X		X
Farm size	X		X	X	X	
Land fragmentation			X	X		
Net farm income		X	X	X		
Parallel employment			X	X		
CULTIVATION						
Tillage operations				X	X	
Tillage depth				X	X	
Tillage direction				X		
Mechanization index						
HUSBANDRY						
Grazing control	X	X	X	X		
Grazing intensity	X	X	X	X	X	
LAND MANAGEMENT						
Fire protection			X	X	X	
Sustainable farming	X			X	X	
Reclamation of affected areas						X
Reclamation of mining areas		X		X		
Soil erosion control measures	X	X	X	X	X	
Soil water conservation measures	X		X	X	X	
Terracing (presence of)	X		X	X	X	
LAND USE						
Land abandonment		X		X	X	
Land use intensity	X	X		X	X	
Land use type	X	X		X	X	X
Period of current land use				X		X
Distance from seashore						X
Landscape change (area)						
WATER USE						
Aquifer over exploitation	X					X
Irrigation percentage of arable land	X			X		X
Runoff water storage	X		X	X		
Water consumption by sector	X					
Water scarcity	X	X				X
TOURISM						
Tourism intensity		X		X		X
Tourism change		X				
SOCIAL						
Human poverty index		X				
Old age index			X	X		
Population density		X	X	X		X
Population growth rate			X	X		
Population distribution						
INSTITUTIONAL						
Farm subsidies			X	X	X	
Protected areas		X	X			
Policy implementation			X	X	X	X

Table 11. Socio-economic indicators

According to results, the most important indicators affecting land desertification risk under different land uses and for different dominant degradation processes are the following:

- Agricultural lands – water erosion: annual rainfall, rainfall seasonality, slope gradient, rate of land abandonment, land use intensity, policy implementation of existing regulation on environmental protection.
- Pastures – water erosion: rainfall seasonality, percentage of plant cover, tillage depth, farm subsidies, policy implementation.
- Forests – water erosion: rainfall seasonality, aridity index, soil depth, vegetation cover type, fire risk, rate of burned area, fire protection, population density.
- Agricultural lands – soil salinization: annual potential evapotranspiration, water quality, rate of ground water exploitation, soil drainage, flooding frequency, distance from seashore, irrigation percentage of arable land, population density.
- Agricultural lands and natural areas – water stress: rainfall seasonality, rate of land abandonment, tourism change, policy implementation.
- Pastures – overgrazing: rainfall seasonality, rainfall erosivity, aridity index, soil drainage, percentage of plant cover, fire frequency, rate of burned area, parallel employment, grazing intensity, fire protection, soil erosion control, rate of land abandonment, period of existing land use.
- Natural areas -. Forest fires: rainfall seasonality, major land use, grazing control.

According to these results, rainfall seasonality is the most important indicator of desertification risk in areas where the drivers of land degradation are water erosion, water stress, overgrazing, and forest fires.

The following are example of algorithms derived for assessing land degradation and desertification risks (DRI) under different land uses for different main degradation processes (all predictors are classed values after Kosmas et al. 2014):

- Overgrazing (R^2 = 0.85)
  DRI = 0.427 RS -0.306 RE +0.541 AI -0.308 SD +0.189 RO +0.413 PC +0.401 FF -0.496 BA+ 0.587 FaS +1.581 LFr +0.179 GC + 0.256 GI + 0.941 FP +0.435 SEC -0.971 LA – 0221 PELU

where RS is the rainfall seasonality, RE is the rainfall erosivity (mm $^{h-1}$), AI is the aridity index, SD is the soil drainage, RO is the exposure of rock outcrops (%), PC is the plant cover (%), FF is the fire frequency (years), BA is the burned area (ha burned 10 years^{-1} 10 km^{-2} of territory), FaS is the farm size (ha), LFr is the farm fragmentation (no. of parcels), GC is the grazing control, GI is the grazing intensity, FP is the fire protection (protected area/total area, %), SEC is the soil erosion control (area protected per total area, %), LA is the land abandonment (ha abandoned 10 years^{-1} 10 km^{-2} of territory), and PELU is the period of existing land use (years).

- Forest fires ($R^2 = 0.42$)
  DRI = 0.361 RS – 0.284 LU + 0.106 LFr +0.616 GC + 0.167 FP + 0.120 LUI + 0.117 OAI -0.111 PGR

where RS is the rainfall seasonality, LU is the major land use (classed values), LFr is the farm fragmentation (no. of parcels), GC is the grazing control, FP is the fire protection (protected area/total area, %), LUI is the land use intensity (classed values), OAI is the old age index (% population >65), and PGR is the population growth rate (% $year^{-1}$).

- Soil salinitization ($R^2 = 0.65$)
  DRI = 0.225 PET_0 + 0.346 WQ + 1.467 GE +0.413 SDr -0.295 FQ+ 0.152 FO + 0.297 DfS + 0.836 Irr - 0.573 PD

where PET_0 is the annual potential evapotranspiration (mm), WQ is the water quality (µS, classed values), GE is the groundwater exploitation, SDr is the soil drainage class (4 classes), FQ is the flooding frequency (protected area/total area, %), FO is the farm ownership, DfS is the distance from seashore, Irr is the irrigation % of arable land and PD is the population density.

6. Nature Based Solutions (NBS)

Nature Based Solutions (NBSs) are defined as “Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions” (https://ec.europa.eu/info/research-and-innovation/research-area/environment/nature-based-solutions_en).

NBSs provide a solution to environmental and societal challenges that are exacerbated by climate change and other pressure factors. The term “nature-based solutions” was first used in the late 2000s (MacKinnon et al. 2008, Mittermeier et al. 2008) in the context of finding new solutions to mitigate and to adapt to climate change effects whilst simultaneously protecting biodiversity and improving sustainable livelihoods. The IUCN referred to NBS in a position paper for the United Nations Framework Convention on Climate Change (IUCN, Dudley et al., 2009), after which the term has been quickly taken up by policy, viewing NBS as an innovative mean to create jobs and growth part of a green economy. Currently, the European Commission is developing an EU research and innovation policy on NBS in the context of its Horizon 2020 Framework Programme (EC 2015), aiming at positioning Europe as a world leader in this field.

Indeed, most publications about NBS date back to recent times, as can be seen in Fig. 8.

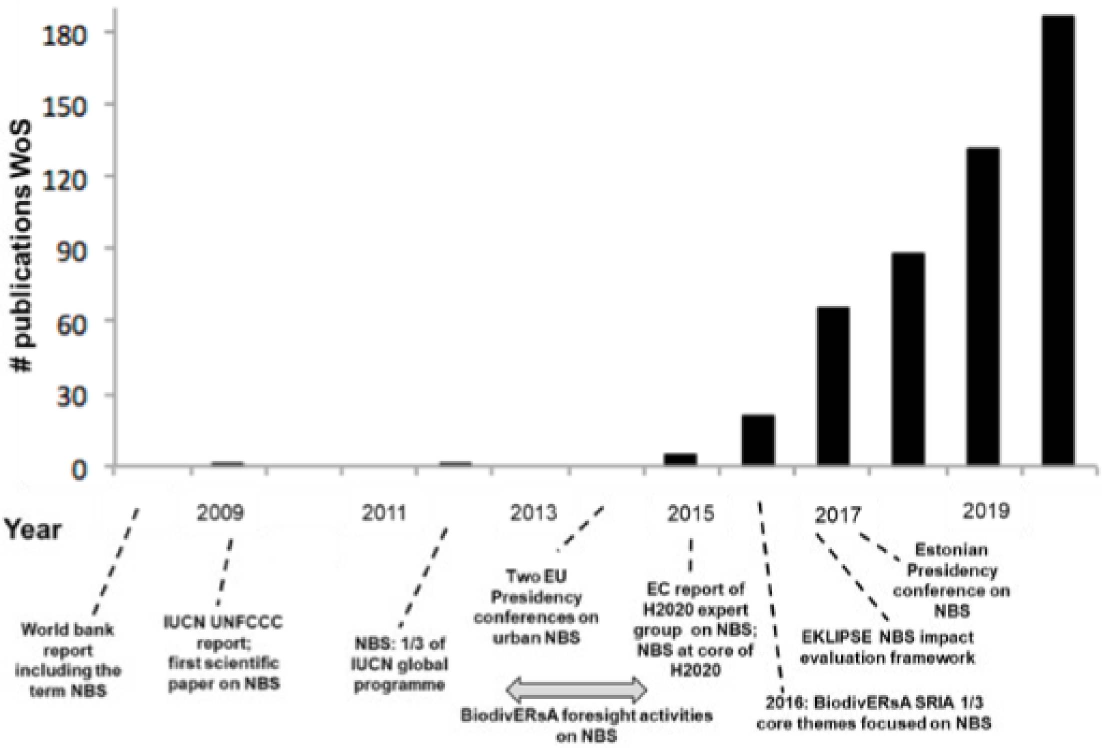

Figure 8. NBS publications and policy development timeline (source: Nature-Based Solutions - State of the Art in EU-funded Project, 2020).

Until 2020, EU funded tens of projects dealing with NBS (28 until April 2020), for about €243 million (about 1% of the total requests for funding).

According to the bibliography, there are many types of NBS and during the years, a few tentative classifications have been published. The former experiences and published works referred to NBSs as ideas connected to natural systems agriculture (Jackson 2002), natural solutions (Dudley et al. 2010), ecosystem-based approaches (Cowan et al. 2010), green infrastructures (Benedict and McMahon 2006), and ecological engineering (Borsje et al. 2011). Eggermont (2015) distinguishes three typologies based on two gradients: 1. "How much engineering of biodiversity and ecosystems is involved in NBS?", and 2. "How many ecosystem services and stakeholder groups are targeted by a given NBS?" (Figure 9, Table 12).

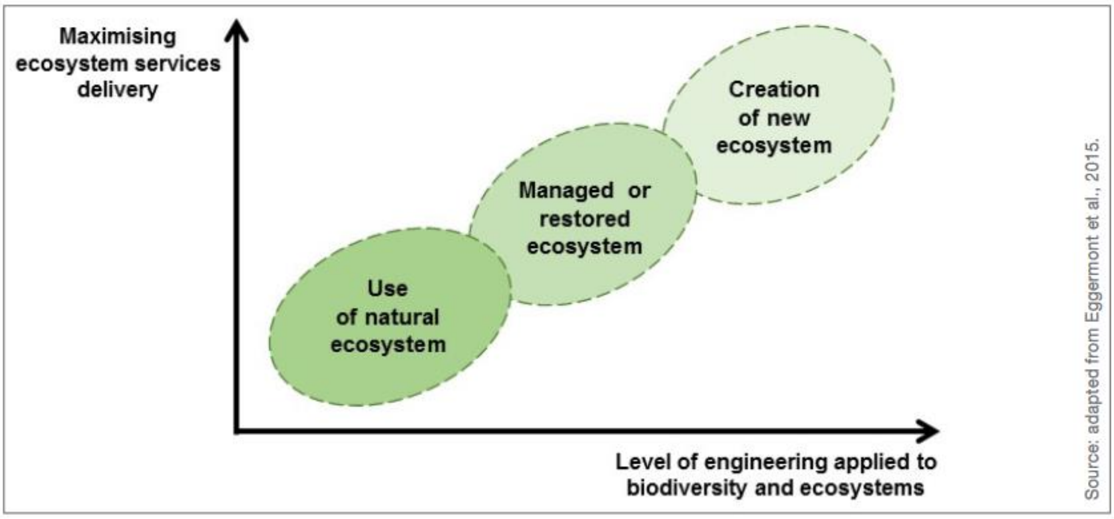

Figure 9. Nature based solution main categories, based on natural, restored and new ecosystems as classified by Eggermont (2015). From: Cohen-Shacham et al., 2016

	Type 1	Type 2	Type 3
Level of intervention (engineering)	None or minimal intervention in ecosystems	Management aimed at creating sustainable and multi - functional ecosystems and landscapes	Management aimed at improving ecosystems in very intrusive ways or even creating new ecosystems
Objectives in ES	Maintaining or improving the delivery of a range of ES	Improving the delivery of selected ES with respect to conventional practices	Improving/Generating the delivery of ES
Examples	Protection of ecosystems to limit risks associated with extreme weather conditions and to provide benefits and opportunities to local populations; biodiversity conservation.	Innovative planning of agricultural landscapes to increase their multifunctionality; approaches for enhancing tree species and genetic diversity.	Green and blue infrastructures; restoration of heavily degraded or polluted areas.

Table 12. Classification of Nature Based Solutions (source: Eggermont, 2015).

A different approach to classify the different types of NBSs is given by Keestraa et al. (2018) who classify them into Soil-Vegetation and Landscape solutions. Soil-Vegetation solutions are based on the concept of soil health (Abbott and Manning, 2015) and enhance soil functions and soil resilience. The implementation of NBSs can influence, with impacts at different scales, geomorphological processes, surface process, soil and chemical processes as summarized in table 13.

Scale	Parameter
Soil processes	Porosity
	Soil structure
	Aggregate stability
	Soil organic matter
	Water repellency
	Walter holding capacity
Surface processes	Vegetation cover
	Mulch cover
	Surface roughness
	Shear strength
	Surface crusts
	Combustible fuel load
Geomorphological processes	Hillslope geomorphology
	Runoff pathways
	Topographic wetness
	Water and sediment sinks
	Connectivity
Chemical processes	CEC
	Nutrient content
	Carbon content
	Solute transport and precipitation

Table 13. Scale dependent parameters that can be affected by Soil-Vegetation NBSs.

The second group of NBSs can be defined as Landscape Solutions as they modify the connectivity of the landscape as resulting from the interaction of soil and geomorphological processes. The concept of connectivity (Bracken et al., 2015; Parsons et al., 2015; Masselink et al., 2017) provides a useful conceptual tool to model water and sediment dynamics and to assess system responses following changes in drivers. The implementation of NBSs can reduce the connectivity of a system at different spatial levels in the system, from the plot to the catchment. For example, mulching reduces flow connectivity at the plot scale, increasing infiltration and reducing surface runoff, with positive effects on water availability for plants and crops. This in turn results in mitigation of agricultural drought and extreme soil erosion events, with a positive effect on the provision of ecosystem services.

The main ecosystem services that can be relevant for NBSs are soil protection, flood regulation, water quality regulation, carbon sequestration, fire prevention, biomass growth, biodiversity, ecosystem resilience and nutrients regulation. Table 14 summarizes the scale, the physical processes and the impacted ecosystem services that are relevant for NBSs based on the evidences from a number of case studies from literature (Keesstra et al., 2018).

Case	Process scale (soil/hillslope/landscape)	Physical processes	Ecosystem services
Organic farming (Cerdà et al., 2016; Novara et al., 2016)	Soil/Hillslope	Infiltration Interception Ponding Soil surface protection Ecosystem resilience	Soil protection Biodiversity Carbon sequestration Water quality regulation Biomass growth Nutrient regulation Flood regulation
Managed rewilding (Keesstra et al., 2009)	Soil/Hillslope	Infiltration Interception Soil surface protection Ecosystem resilience Dis-connectivity	Soil protection Biodiversity Carbon sequestration Water quality regulation Flood regulation
Agro-forestry (Pinto-Correia, 1993)	Soil and landscape	Infiltration Soil water retention Soil surface protection Tree resilience	Soil protection Drought regulation Water quality regulation Carbon sequestration Biodiversity
Land restoration (Finger et al., 2016)	Soil/Hillslope	Infiltration Interception Ecosystem resilience Dis-connectivity Water and sediment retention	Soil protection Biodiversity Carbon sequestration Water quality regulation Biomass growth Nutrient regulation Flood regulation
Wetland restoration (Kalantari and Folkeson, 2013)	Landscape	Dis-connectivity Water and sediment retention	Biodiversity Water quality regulation Nutrient regulation Flood regulation
Trapping vegetation with vegetational measures (Mekonnen et al., 2015)	Landscape	Dis-connectivity Infiltration Ponding Interception Water and sediment retention	Soil protection Carbon sequestration Water quality regulation Biomass growth Nutrient regulation Flood regulation

Table 14. Scale, physical processes and impacted ecosystem services that are relevant for NBSs

The strength of the NBSs concept is to be found in its integrative, systemic approach, which prevents it from becoming just another “green communication tool” that provide justification for a classical model of natural resources exploitation and management measure (Nesshöver et al., 2017)

In the EU, EU-funded projects on NBS addressed many and very diverse environmental challenges, with consequential impacts at economic and social level. An interesting and useful product of EU-funded project is the web-platform Oppla (https://oppla.eu/), the EU Repository of Nature-Based Solutions. Over 60 universities, research institutes, agencies and enterprises (https://oppla.eu/contributors) are contributing to Oppla as part of a joint activity between the OPERAs (OPERATIONAL POTENTIAL OF ECOSYSTEMS RESEARCH APPLICATIONS; Grant agreement ID: 308393) and OpenNESS (OPERATIONALISATION OF NATURAL CAPITAL AND

ECOSYSTEM SERVICES; Grant agreement ID: 308428; http://www.openness-project.eu/) projects, funded by the European Commission FP7 Programme. Actively supported by the European Commission, the Oppla web-infrastructure has been used to develop the IPBES Catalogue of Policy Support Tools & Methodologies and has also links with more than 100 projects, platforms and networks, such as European Environment Agency, BES-NET, LIFE WATCH, IUCN, ThinkNature, EKLIPSE, IUCN, and numerous other) Horizon 2020 projects. Oppla features a case study finder at different scales, from global to local, for a total of 318 case studies. Of these 244 refer to European case study areas, 141 of which characterized by the implementation of NBS.

More recently, a project funded by the European Commission under the Horizon 2020 programme developed NetworkNature (grant agreement No. 887396) as a resource for the nature-based solutions community, creating opportunities for local, regional and international cooperation to maximize the impact and spread of nature-based solutions (https://networknature.eu/). The goals of NetworkNature are: i) synthesize and strengthen the NBS evidence base by gathering experiences, knowledge, tools and services from over 30 Horizon 2020 projects; ii) Engage existing stakeholders and expand the NBS community to new sectors and target audiences,; iii) Ensure NBS science informs the policy agenda and vice versa; iv) accelerate the uptake of NBS across science, business, policy and practice; v) coordination of the EU H2020 Nature-based Solutions Task Forces.

In the next section, we aim to provide some examples of application of Nature Based Solutions addressed to solve important environmental challenges linked to land degradation that have consequential impacts at environmental, economic and social level.

The bibliographical research of European funded projects covered EC's reports (EC, 2020a, 2020b), the European repository of Nature Based Solution projects (Oppla), and IUCN (Ventin and Marin, 2019) report "Towards Nature-based Solutions in the Mediterranean" and other publications. Being inspired by the European report "Nature-based Solutions - State of the Art in EU-funded Projects" (EC, 2020c) which identifies main thematic addressed by European projects on NBS, we have focused the attention on three main areas that are connected to a greater extent to land degradation to great extent: "climate change mitigation", "biodiversity protection and restoration" and "water quality and regulation".

For each theme, we give a brief overview on the environmental challenge, the pressure factors and the types of NBS that can limit the consequences and solve environmental issues. Each theme is followed by a selection of case studies / projects about NBS, that have been implemented in European countries or in the Mediterranean if non-EU projects. Such projects were selected for the relevance of their objective linked to nature protection and prevent land degradation, but also for their transferability potential in contexts that are different from the environmental and socio-economic point of view, from the one in which they have been developed.

6.1 Climate mitigation

Climate change is connected to the emission of greenhouse gases, exacerbated by the anthropogenic activities. The Paris Agreement set a limit to warming to less than 2 °C to 2030 and this can be reached only by taking actions for the reduction of emissions (decarbonization) but also increasing the capacity of the carbon sinks to sequester and store carbon.

Pressure factors:
Soil erosion and intensive use of agriculture.
In the natural and agricultural ecosystems, the most important challenges that reduce the potential capacity of a system to sequester and store carbon, are soil erosion and intensive use of soils in conventional agricultural systems.
Intensive use of soils and machinery can transform an agricultural soil into a carbon source rather than carbon sinks (Lugato et al., 2016) and soil erosion provokes a loss of carbon due to the removal of the fertile topsoil that has been estimated 86% in the European agricultural soils (Pérez-Soba et al., 2018). Therefore, land management is an important way to regulate such factors.

NBS functions:
C sequestration and climate mitigation
NBS can be used to reduce CO_2 emissions or remove CO_2 from the atmosphere through specific measures such as "reforestation, forest conservation and management, agroforestry, cropland nutrient management, conservation agriculture, coastal wetland restoration, and peatland conservation and restoration" (Belamy and Osaka, 2020). In addition, they can mitigate climate conditions by the shading and evapotranspiration effects.

Examples of NBS:
Agro-forestry systems: the tree component of the agricultural system can improve soil organic carbon (Hernández-Morcillo et al., 2018) but also the biodiversity; (Type 2-3)
Land management practices in agricultural areas that enhance carbon storage, water infiltration, biodiversity and reduce soil erosion (e.g. use of natural mulching, agro-ecology practices); (Type 2)
Forest preservation, restoration and management and afforestation plans are the main tools for climate mitigation (Type 1-2-3) as the trees have the greatest capacity to absorb and store CO2. Obviously, this capacity depends on factors such as the climate, the ecological composition, the age of the forest and the type of management which in some cases should also consider the trade-off between the environmental ecosystem services provided and the economic productivity.
Urban forests allow the mitigation of microclimate in the urban contexts as well as other services such as pollutant removal, reduction of the energy demand due to climate mitigation – reducing the effect of heat waves, and shading, besides social benefits.

Ecosystem services provided:
NBS applied with the purpose of climate change mitigation have effects on other ecosystem services, such as water regulation and climate mitigation, carbon sequestration, primary production (wood, cork and other products) and biodiversity, besides cultural services.

Selection of projects and other good practices on NBS for carbon sequestration and climate change mitigation

Project title:
Forest management promotion for climate change mitigation through the design of a local market of climatic credits (Spain, Italy)
(2017-2021, LIFE16 CCM/ES/000065, Acronym: Life Climark)

Objectives: The project aimed at maintain and improve the mitigation capacity of European Mediterranean forests and design a local market of climate credits in order to promote a multifunctional and mitigatory forest management.

Applied Nature Based Solutions:
- Management of forests in the post-fire regeneration phase by decreasing the density to favor the species with greater growth capacity (selection of trees of different species with greater potential growth capacity), decreasing the competition towards natural resources such as water, light and nutrients. This implies also a greater carbon absorption, biodiversity but also improves the wood structure that will reduce the risk of fire.
- Forest cuttings (vertically or horizontally) to create fire breaks and break the continuity of forest cover that might provoke fire spreading.
- Management of forests in relation to the tree height in order to more significantly reduce water consumption while promoting the potential growth of remaining trees, which will not have to compete for water resources and will present a consequent greater carbon fixation.
- Conservation of elements important to maintain and stimulate biodiversity (e.g. large diameter trees or trees with dendro-microhabitats, as well as the creation of dead wood. These elements have a high capacity to accommodate biodiversity.
- Agroforestry actions and plantations that increase the environmental sustainability of productive systems.

Results: The project is still ongoing, however, it planned to create 85 ha of demonstration parcels with forest sustainable management in four landscape units in Catalunya for improving different ecosystem services: climate and water regulation (more efficient use of water), carbon sequestration, production (wood, cork and other products) and biodiversity. In addition, the project foresees the creation of a market of climatic credit that will be piloted in Catalunya and France and extended to other countries to assess its reliability and replicability.

Link:
https://lifeclimark.eu

Project title:
Innovative approach to soil management in viticultural landscapes (Italy)
(2017-2021, Life Programme, Acronym: SOIL4WINE)

Objectives: this project aimed at improving soil management in the agriculture sector and at defining tools and methodologies aimed to support soil's functions and ecosystem services.

Applied Nature Based Solutions:
- Cover crops with Leguminosae and Brassica cover crops mixture to limit tillage and reduce compaction and hard pan, with the aim also to reduce water logging at vineyard bottom and erosion on the top and increase soil organic carbon.
- Permanent mulching under-the-vine organic,
- Re-vegetation of remnants and buffer zones: permanent artificial grassing with a mixture of Festuca, Lolium and Poa or Fabaceae and Poaceae to reduce erosion, soil compaction in the inter-row and to increase soil organic matter content
- Preliminary superficial water control followed by underground drainage
- Mowing of herbaceous green manure and incorporation into the soil

Results:
The project applied new soil management practices as NBS in nine farms in the western part of Emilia Romagna region (Italy) and developed a Decision Support System for viticulture, with the aim at optimizing costs and economic benefits connected with production (both in terms of quantity and quality) in viticulture. The system identifies the main characteristics of the farm, including the environmental features and threats and suggests farmers the appropriate soil management practice to apply in the vineyards, in order to improve the quality and quantity of the product. In the long run, this is expected to increase the willingness of young farmers to continue and implement farming.

Strengths and weaknesses:
The strengths of the project are represented by a DSS tool that help farmers in improving soil management and reducing the application of agro-chemicals. This reduction will benefit not only direct users but also the local community, to a different extent. Soil erosion, landslides, hydrogeological instability in hilly and mountainous areas are important environmental issues that are exacerbated by extreme meteorological events. The practices adopted in the demonstration farms have positive effects not only at farm level but also at the hydrological basin level as soil erosion is contrasted.
Among the project's objectives, there was the development of a decision support systems for farmers to help them in increasing their income as the areas of the project suffer the low income from wine production. However, another problem connected to the economic aspect is the lack of young farmers involved in this sector – that are not attracted due to the low income.

Some of the agricultural operations (soil tillage and germination and plant growth) need proper environmental conditions that weather events such as prolonged rains or low temperature might hinder. However, some strategies to overcome such issues were: anticipation of the autumn sowing to obtain early growing in more favorable conditions, and choosing winter cereals and Brassicas to protect soil against rain erosion; while permanent grasses can be integrated y to sowing in bare soil areas.

Link:
http://www.soil4wine.eu/

Project title:
Montpellier, France: Agroforestry: Agriculture of the future? The case of Montpellier (France)

Objectives: This project was carried out in France, in the region of Montpellier, in Southern France. Climate predictions state that the climate in this area will change in the future with higher temperature and more frequent droughts conditions and such conditions will pose serious threats to the agricultural sector. Therefore, it is important to prevent associated risks y making food production more sustainable, efficient and adapted to the future climate conditions. The aim of this project was to make agriculture more resilient to climate change.

Applied Nature Based Solutions:
- Agroforestry practice (association between tree and crops in production systems)

Results:
Agroforestry represents a solution to face climate change impacts (e.g. raising temperature, prolonged draughts and rainfall) that have direct and indirect effects on primary production systems, but also for the increase of biodiversity. The presence of trees protects crops from strong winds and heat waves as they act as barriers, while the whole system generates a better use of resources. The association between trees and crops is also a way for the farm diversification, allowing a differentiation of farm incomes, especially in the long term. In Montpellier, a combination of walnut trees and wheat was tested and it was shown that 1 ha of such mix produces as much as 1.4 ha with trees and crops separated. This represents a 40% increase in productivity.

Strengths and weaknesses:
Agroforestry can be a solution for a more sustainable agriculture, especially in marginal rural areas. This project showed how the productivity in mixed systems (trees and crops) can increase, making agriculture potentially more attractive. Agroforestry provides several benefits: it is less vulnerable to climate change as trees provide shelter to crops; regulate water retention and water regulation thanks to rain interception by canopies, increases biodiversity as different habitats are generated and carbon sequestration. In addition, it acts in controlling pests and enhancing pollination. At farm level, it allows diversification, income increase and reduces soil

erosion and improves water use. A weakness of agroforestry is the selection of the most effective combination between the tree and crop species, overcoming the limitation of mechanization. It has been found that over time, agroforestry farms can become less dependent on crop subsidies, and less susceptible to crop price variations, as timber generates a significant part of their income.

Link:
https://oppla.eu/casestudy/18469

Project title:
The Adaptation of Forest Ecosystems and Forestry to Climate Change in the Seyhan Basin (Turkey)
(2009-2010, funding: UN Joint Programme, supported by the Millennium Development Goals Achievement Fund MDG-F)

Objectives: Climate change is threatening the habitat suitability for some species and the project focused on vulnerable sites of the project area (Seyhan Basin) considered as hotspots to implement actions in forestry based on general silvicultural measures, species specific measures, location-vulnerability based measures, complete adaptation measures, including socio- economic and resource use for the most highly vulnerable areas. The aim of the project was to implement sustainable use of forest resources to face long-term impacts of climate change, towards biodiversity and other ecosystem services conservation.

Applied Nature Based Solutions:
- Ecosystem-based adaptation, by considering the tree species migration (North-south), identifying stand islands for the future and building up monitoring systems.
- Forest landscape restoration, with recommendations for the management of the tree species.

Results:
The project developed some forestry management recommendations for the study area (the Seyhan Basin) aimed to support and maintain ecosystem services and biodiversity under climate change scenarios. Those adaptation recommendations included:
- Considering the migration speed of trees,
- Supporting expected change in tree species selection,
- Assisted migration,
- Supporting the migration of understory,
- Transforming disturbances to opportunity,
- Building stand islands for the future,
- Building monitoring system,
- Building stand hubs for protection,
- Using participatory approaches to support the adaptation management,
- Building decision support systems,

- Carrying out the timber production in small scales,
- Supporting diversity to increase the resistance of ecosystem.

Strengths and weaknesses:
The project was the first study carried out in Turkey and aimed to have important economical, ecological and socio-cultural impacts. The project had the potential to be adopted and carried out by the General Directorate of Forestry in other forest units in the Mediterranean Region and others in Turkey but there is not information about its replicability.
The project involved groups of volunteers and students through academia and non-governmental organizations while the forestry sector was directly involved in the project as project partners.

Some direct effects of integrating silvicultural measures into the forestry management plans are:

- Increase in the climate change adaptation capacity of forestry sector in the region,
- Increase in the resilience of the region’s forests to climate change,
- Integration of climate change, biodiversity and ecosystem services into the forest management,
- Sustainability of life quality of the population in the basin,
- Prevention of changes causing natural disasters like flood, erosion etc.,
- Prevention of threats by dense forest fires near settlements,
- Sustainability of the economy of forest villagers based on wood production.

6.2 Biodiversity

Most of the services provided by ecosystems rely on biodiversity. Monocultures and low spatial diversity represent potential ecological and economic risks when are subjected to a pressure factor. Biodiverse systems enable to provide various ecosystem services to the greatest extent: soil carbon storage, carbon sequestration, water infiltration, pollutant removal, health and wellbeing, besides – obviously – creating an ecologically rich environment. The European Green Deal and the EU Biodiversity Strategy to 2030 have recognized the alarming status of conservation of species and habitats in the EU, therefore the new policies should take biodiversity more into consideration in the sectoral policies.

Pressure factors:
Land use and land use change
Abandonment as well as intensive use of ecosystems are the main threats to the loss of biodiversity as they alter habitats and species composition. There is a need to protect the natural ecosystems and provide species healthy habitats, enlarging the networks and creating connectivity between ecosystems.

NBS functions:
Provision of ecosystems/habitats.

NBS represent a worthy tool for the enhancement of biodiversity in systems that are traditionally characterized by low biodiversity such as the agricultural ecosystems, and in those where land degradation has altered the potential biodiversity of the ecosystem. EU policies protect the biodiversity in specific networks such as Natura 2000 sites, but there is a need to maintain or increase the species abundance, diversity and community habitat structure and species richness. This can be done even extending the connectivity of ecosystems at the landscape level, finding also a linkage between rural and urban areas.

Examples of NBS:

i) Creation of new ecosystems, restoration of degraded ecosystems likely in connection to other ecosystems at the landscape level and between rural and urban areas (e.g. forest landscape restoration, floodplain management, river restoration, constructed wetlands or (re)introducing green corridors. (Type 1-2-3)
ii) Nature-based farming practices such as agro-ecological agronomic practices - examples include cover crops, minimum or no-tillage, retaining crop residues on the field, use of perennial crops, crop rotations, permaculture, promotion of agroforestry, woody landscape features or food forests, enhancing agrobiodiversity for resilient farming systems, and ‘functional agrobiodiversity’. (Type 2)

Ecosystem services provided:

NBS aimed to biodiversity conservation and restoration, not only increase biodiversity, but they enhance also other services and benefits, among which: water regulation, climate regulation, provision services (e.g. production) and cultural services.

In the following section, some European-funded projects and other project funded at local level are reported as examples of Nature Based Solutions applied in a variety of ecosystems aiming to restore the biodiversity. The projects have been taken from the official reports of the European Commission and other publications.

Selection of projects and other good practices on NBS for biodiversity

Project title:

Transboundary habitat restoration in the valley of the Dommel (Netherlands and Belgium) (2005-2011, funding: Life Programme, LIFE05 NAT/B/000091, Acronym: Dommeldal)

Objectives: This project aimed at restoring a variety of habitats between Peer in Flanders up to Valkenswaard in the Netherlands, that were threatened by modern agricultural practices developed during the 20th century. Indeed, agriculture contributed to intensify land use, drain ponds and fens, destroy heathlands and transform the landscape by planting pines and poplars. The project aimed to restore nature by establishing an ecological corridor between the heath habitats from Peer in Flanders up to Valkenswaard in the Netherlands, and expand and improve the quality of riparian forest habitats "Calcareous fens with great fen-sedge (Cladium mariscus)" and "Alluvial forests with black alder (*Alnus glutinosa*) and ash (*Fraxinus excelsior*)" and enhance breeding habitats of the great bittern (*Botaurus stellaris*) and other reed-inhabiting birds and to carry out large-scale restoration of a complex of fens, heaths and inland dunes with transition mires and quaking bogs besides other specific habitats.

Applied Nature Based Solutions:
- creation of ponds along with transitions towards drier sandy land,
- creation of small patched of heath
- restoration of Molinia meadows.
- restoration of wet forests

Results: restoration of valuable habitats, such as land dunes, heathlands, ponds, irrigated grasslands, orchid-rich hayfields and alluvial forests, and new opportunities were created for threatened species.

- creation of ponds along with transitions towards drier sandy land, which consisted in the removal of 130000 m^3 of soil.
- creation of small patched of heath (15 ha) by the removal of man-created softwood stands and removing the topsoil. This was expected to regenerate the heath cover in order to connect two main heathlands.
- restoration of 8 ha of Molinia meadows along the Dommel river, which were rewetted by creating small-scale depressions and impounding the ground water level.
- restoration of 20 ha of wet forests

Strengths and weaknesses: The restoration actions increased the quality of habitats (fens and alluvial forests) and expanded habitats of breeding for a large variety of birds and insects. The NBS allowed plants typical of hay meadows to return, such as Meadow Saffron, Meadow Saxifrage and Cowslip. Approximately 70ha of heathlands were restored and the area of wet heaths, dry heaths, land dunes and oligotrophic fens increased substantially. This favored the Grayling and Blue-winged Grasshopper.
It was observed an increased number of breeding pairs of European Nightjar, the spread of Common Lizard and Moor Frog throughout the whole area, re-colonization of Dommeldal by rare plants such as Lousewort and Round-leaved Sundew, increase of Marsh Gentian, favoring the butterfly Alcon Blue, but also the Queen of Spain Fritillary. In the Molinia meadow there was an increased number of orchids.

Links:
https://webgate.ec.europa.eu/life/publicWebsite/index.cfm?fuseaction=search.dspPage&n_proj_id=2921
https://www.natuurpunt.be/pagina/inleiding-life-dommeldal

Project title:
Conservation of Botaurus stellaris and Aythya nyroca in SPA Medzibodrozie (Slovakia)
(2011-2018, funding: Life Programme - LIFE09 NAT/SK/000395, Acronym: AYBOTCON).

Objectives: The project aimed to halt and reverse the unfavorable population trends for the two bird-species, the bittern and the ferruginous duck in East Slovakia, especially within the Medzibodrozie SPA, which remains an important migration route and breeding area for these and other wetland bird species.

Applied Nature Based Solutions:

- Green belts
- Water regime restoration and fish reintroduction to increase the food supply to birds
- Wetland restoration

Results: The project succeeded to restore and manage around 280 ha of water biotopes in the Medzibodrozie SPA Natura 2000 network site, within an intensively-used agricultural area. The work significantly improved habitats for bittern, ferruginous duck, and other waterfowl species and also it made the whole area more attractive to visitors. Specifically, 4 ha of buffer zones (green belts) were created; 141 ha of wetlands were restored and 1770 m of electricity power lines were modified to reduce bird collisions. In addition, it purchased 54 ha of land for nature conservation. Water regimes were restored on an area of 65-75 ha to improve the environmental quality of wetlands, especially to make them more suitable for bittern, ferruginous duck and other bird species.

Strengths and weaknesses: the project increased the number of localities where bittern and ferruginous duck occurred, compared to the previous years. The project demonstrated how low management input and cooperation between different stakeholders (e.g. fisherman, water management authority, nature conservation agency) can effectively contribute to save and enhance biodiversity. The weakness was identified in the gaps in agricultural policy, and the threat of climate change that should be considered in the future management.

Links:
https://webgate.ec.europa.eu/life/publicWebsite/index.cfm?fuseaction=search.dspPage&n_proj_id=3824
http://www.medzibodrozie.vtaky.sk/

Project title:
Demonstrating functional biodiversity in viticulture landscapes (Portugal, Spain and France) (2010-2014, funding: Life+ Programme LIFE09 NAT/FR/000584, Acronym: BioDiVine).

Objectives: to implement biodiversity conservation/restoration actions and demonstrate the benefits that come from integrating these actions in landscape structures as a means to restore and conserve biodiversity in cultivated vineyards in three European countries, Portugal, Spain and France.

Applied Nature Based Solutions:
The NBS applied in the project were biodiversity-friendly practices. They consisted in:
- Establishment of an herbaceous inter-row ground cover
- Plantation of diverse hedges;
- Building and restoration of traditional stone walls;
- Using pheromones to control pests, specifically the *Lobesia botrana*, the European grapevine moth;
- Managed headlands or fallows as non-productive areas.

Results: Results were useful to develop an ecological landscape action plan intended to effectively combine wine production with biodiversity conservation actions.
The Nature Based Solutions applied were monitored and evaluated and they resulted positive effects in terms of biodiversity, on several taxa: arthropods, soil micro-organisms, birds, mammals, and plants, with an increase of arthropod diversity and abundance as well as on biological soil activity in natural herbaceous ground cover, in areas with greater landscape complexity, semi-natural landscape and extensive headlands. Birds were more abundant where old buildings, trees and meadows were present and mammals especially in the interfaces between the vineyards and the surrounding. The following were created:
- 324 ha of sown and natural inter-row ground cover;
- 21 km of diverse hedges (2-10 km per site);
- Building or restoration of 1250 m of traditional low walls;
- Using 1,237.68 pheromone dispensers (a mating disruption technique, limiting the use of insecticides) in vineyards to disrupt the mating of *Lobesia botrana*, the European grapevine moth, over about 250 ha of vineyards;
- 77 ha of extensively managed headlands or fallows (non-productive areas).

Strengths and weaknesses: BioDiVine demonstrated the possibility to improve the biodiversity in agricultural areas, specifically in vineyards, in connection to the restoration of landscape elements typical of the project regions. However, among the weaknesses, it evidenced the difficulty to highlight all the environmental benefits of the biodiversity enhancement actions and how wine-growers are not yet familiar such practices and assessment techniques.

Link:
https://webgate.ec.europa.eu/life/publicWebsite/index.cfm?fuseaction=search.dspPage&n_proj_id=3800

Project title:

Adapting Mediterranean Forests to Climate Change in the Konya Region (Turkey) (2013-2016)

Objectives: The main goal of the project was to contribute to the long-term preservation of Turkish Mediterranean forests against climate change and their capacity of delivering ecosystem services, through climate change adaptation measures integrated into the forest management plans. The capacity to withstand climate change increases with biodiversity as species have different adaptation and resistance to stress conditions. Having a variety of species at one site increases the likelihood that some of these species will be well adapted to the future climatic conditions. The measures to adapt to climate change, include soil and understory protection techniques, prioritization of adapted species and assisted migration of species to ensure the continuity of the forest cover.

Applied Nature Based Solutions:
- Ecosystem-based Adaptation solutions,
- Climate Adaptation Services,
- Solutions for Ecosystem-based Disaster Risk Reduction.

Results:
This project produced a set of recommendations for forest management to increase forest resilience to climate change. Such recommendations aim to:
- increase the species diversity of the managed forests. Higher variety of species was used in reforestation plans and more species were kept on site during cuttings. In addition, such management plan was implemented in the most vulnerable sites.
- support the genetic diversity for increasing resilience to climate change, by selecting and acquiring seeds and seedlings used for reforestation from a diverse set of "seed stands" in order to ensure a more genetically diverse and healthy forest.
- support and monitor species migration: a shift of genes northward and towards higher altitudes is observed. Average temperatures are expected to increase and climate will resemble that of the sites at lower altitudes and in more southern parts.

The project also provided recommendation and guidance on locations where the seeds ought to originate from more southern locations and from lower altitudes to be used in northern and higher altitude locations.
- Support native species with draught resistance that are more suitable to adapt drier climates (e.g. oaks, junipers) as compared to those usually used in reforestation plans. These species have been used in vulnerable areas with low forest biodiversity while stands have been recommended to be managed by thinning and to support the most resistant species and thinned.
- Soil protection to ensure moisture retained by vegetation and avoiding use of heavy machinery and avoiding all forestry activities at sites with already poor soil conditions.
- Promoting and ensuring the continuity of forest cover in the region will help reduce the impacts of catastrophes such as storms, floods and droughts expected to increase in intensity due to climate change.

Strengths and weaknesses:
The project was carried out in close cooperation with the forest sector entities and local stakeholders. WWF-Turkey worked with the Directorate of Forests and forest planners to integrate climate change adaptation considerations into these management plans for the most vulnerable forest subunits.
It also included an analysis of forest ecosystem services to improve the management of the forests to better cater to the economic and cultural needs of forest villagers.

Links:
https://www.iucn.org/sites/dev/files/content/documents/towards_nature-based_solutions_in_the_mediterranean.pdf
https://mava-foundation.org/grants/adapting-mediterranean-forests-to-climate-change/

Project title:
Securing rights and restoring lands for improved livelihoods (Jordan)
(2009-2010)

Objectives: The project aimed at strengthening local community capacities and customary laws, to protect and manage land resources for social economic growth and conservation of natural resources in the Zarqa River Basin. This area, in the north of Jordan, is where about half of the country's population live, and has seen severe land degradation, which has in turn resulted in high levels of poverty and unemployment. Land degradation in this area is characterized by biodiversity loss, land use changes and ground water extraction that drove to unsustainable development and mismanagement of natural resources. Livelihood strategies have shifted to high-intensity agriculture which uses most of the available water resources, while the region is subject to desertification and unpredictable precipitation, further increasing the pressures on the ecosystems and people of the river basin. Traditionally, the Bedouin tribes used to conduct a grazing system which seasonally sets aside heavily grazed rangeland for regeneration and recovery, pushing them to wander across political borders to allow this regeneration. However, most Bedouins now live permanently in Jordan and the communities.

Applied Nature Based Solutions:
- Traditional ecosystem management,
- Ecological restoration.

Results:
The project supported various government and community partnerships in support of sustainable rangeland management. A revolving fund was established to offer loans for income-generating projects to improve community livelihoods.
Employment opportunities were created for Hima participants, as technical veterinarians or assistants. In Bani-Hashem, a marketing study identified several microenterprise development

opportunities, such as in the spice market. Local women were hired to organize the collection, drying and packaging of indigenous medicinal herbs, providing additional income for their families.

Strengths and weaknesses:
The project allowed to recover the traditional Bedouin's rangeland management systems to avoid land degradation and biodiversity loss, with special attention and involvement of the community. Management rights were given to the communities of the local areas and land was allocated by the government to such communities.

Links:
https://portals.iucn.org/library/sites/library/files/documents/2016-036.pdf
https://www.iucn.org/sites/dev/files/content/documents/towards_nature-based_solutions_in_the_mediterranean.pdf

Project title:
Collecting and preserving scarce Natural Range seed plants and restoring natural pastures in large areas to improve Bedouin community livelihoods (Egypt)
(2012-2015)

Objectives:
This project was carried out in an arid Mediterranean zone of Egypt (Sidi Barani - Matrouh Governorate) that is facing a decrease in water resources due to climate change. The local Bedouin community had to face such challenge together with the decrease in livestock (sheep and goats) due to the degradation of the natural rangelands (intense grazing). Therefore, the project aimed at increasing and consolidating the Bedouin community participation in this area, not only to achieving sustainable environmental development, but also to preserving their natural range and plants.

Applied Nature Based Solutions:
- Area-based conservation solutions,
- Ecological restoration solutions

Results:
The partners of the project succeeded in the preservation of six endangered types of natural grassland seeds, through the involvement of the Bedouin community especially women, youth and children.
They collected indigenous and rare natural rangelands plant seeds from their original locations; initiated a breeding farm with such seeds and using irrigation with low quality water; they collected perennial fodder shrubs seeds and produced seedlings to be planted in contour lines; and they were trained on the sustainable use of rangelands and regulation of livestock grazing. The project contributed to the conservation of 6 significant kinds of extinct species (fodder for animals) and within it, nurseries were established.

Strengths and Weaknesses:
The initiative succeeded in establishing strong and effective collaboration between local authorities, NGOs, academia, and community members towards the sustainable use of rangelands, raising their awareness on the importance of such lands.
The project developed a natural pasture in a large area although its success very much depends on the amount of rains. However, it also contributed to change the traditional intense grazing into a light grazing aimed at establishing the pastures.
The positive impacts raised the awareness and attracted more participation in training and seminars and to put into practice the project activities also in other parts of Egypt.
The project was included among the projects implemented by Egypt in the updated Egyptian National Report to Combat Desertification (2014-2024) due to its importance.

Links:
https://www.iucn.org/sites/dev/files/content/documents/towards_nature-based_solutions_in_the_mediterranean.pdf

6.3 Water quality and regulation

In Europe, around 69% of surface water bodies are characterized by a non-sufficient quality and most of the water that is abstracted very often is returned polluted to the environment. Natural water bodies are in general in better conditions than those heavily modified and artificial water bodies, particularly rivers and transitional waters (EC, 2019).

Pressure factors:
water use/pollution and climate change
Nowadays, the main pressure factors of freshwaters are diffuse pollution, hydromorphological changes and water abstraction which are greatly connected to the anthropogenic pressure in response to intensive agricultural practices and energy production. In addition, climate change is threatening the amount of water storage and flow, increasing the need for either flood protection or drought management. Therefore, environmental and agriculture management are extremely important and the implementation of available solutions such as water retention measures, buffer strips, smart water pricing, more efficient irrigation techniques and precision agriculture will increasingly become of crucial importance.
https://www.eea.europa.eu/publications/soer-2020/chapter-04_soer2020-freshwater/at_download/file

NBS functions:
flood regulation, habitat restoration.

NBS can be used to prevent erosion of river banks and flooding with natural materials thanks to the role of roots in their mechanical function on sediments of river banks, and regulating the water flow along streams, as riparian vegetation can decrease the water speed and erosivity. In addition, plants absorb water and can regulate pollutants such as nitrates and phosphates from agricultural origin, but also heavy metals with effective species.

Examples of NBS:

- planting vegetation (riparian species such as willows and poplars) and reeds at different depths along the river banks
- installation of logs at the bottom of the river
- nature-based shoreline protection against floods and erosion
- Rainwater Harvesting
- Bioretention
- Infiltration trenches

Ecosystem services provided:
NBS aimed to improve water quality and water regulation provide a variety of ecosystem services other than water regulation. For instance, they can be useful to increase biodiversity, carbon sequestration and cultural services.

In the following section, some European-funded projects are reported as examples of Nature Based Solutions applied in a variety of ecosystems aiming to enhance water quality and regulation for the prevention of floods or increase water retention. The projects have been taken from the official reports of the European Commission and other publications. We also recommend to consult the European Commission website https://ec.europa.eu/environment/water/adaptation/ecosystemstorage.htm where a comprehensive literature is available on a large variety of measure for water regulations.

6.4 Selection of projects and other good practices on NBS for water regulation

Project title: ***Riparian Forest Restoration and River Bank Protection, Evrotas River, Greece***

(2006-2010, LIFE05ENV/Gr/000245 EE, Acronym: LIFE-EnviFriendly)

Objectives:
This project was carried out in the province of Laconia (Greece) in the Evrotas River Basin which is substantially used for agricultural productions and affected by pollution and water extraction. In addition, in the past, intensive meteorological events have caused significant erosion to the river banks and to the local forest. LIFE-EnviFriendly project aimed to demonstrate how low cost, nature based solutions applied by all farmers within a watershed can improve the water

quality of the basin. The NBS used in the project was a riparian forest restoration coupled with a river bank erosion protection.

Applied Nature Based Solutions:

- Forest restoration solutions
- River bank restoration with large stones

Results:
During the project, 120 m of river bank of an agricultural field was restored with large stone hedge combined with a riparian forest restoration. This allowed to stabilize the river bank and the riparian zone from future flood events. The large stones were chosen because they can alleviate the force of water flow during floods as well as allowing space for fish to spawn. In addition, a riparian forest of 200 poplar trees was planted to decrease nutrient loads due to uptake and enhanced denitrification. The trees were planted in two rows about 1.5 m apart and the spacing between them was also 1.5 m. In this way, phytoremediation together with river bank erosion control represent a combination of Nature Based Solution against nutrients pollution. The data on nitrates monitoring showed a reduction of such compounds into the river water.

Strengths and weaknesses:
On the average, the riparian forest provided a 70% reduction of nitrates in the groundwater, in addition, long term monitoring actions showed how the riparian forest restoration and the stabilization of the river banks increased:

- Biodiversity.
- Quality and quantity of green and blue infrastructures.
- Connectivity and functionality of green and blue infrastructures.
- Carbon sequestration and storage.
- Resilience to floods as extreme events
- Protection of agriculture

The project demonstrated the suitability of the applied solutions also to other river systems but among the weaknesses, it identified Policy/Legislation barriers:

- Farmer should obtain topographic, hydrologic, hydraulic studies – erosion control studies –forest restoration study – environmental impacts study in order to store important information with respect to hydrological events.
- The bureaucracy: studies must be approved and permits should be obtained from the Municipality, the Region (three Departments – water, environment and forestry), the Ministry of Environment

Link:
https://connectingnature.eu/oppla-case-study/18366

Project title: ***Constructed wetlands as a multipurpose green infrastructure in Gorla Maggiore*** (Italy)

Objectives: This project was carried out in Gorla Maggiore (Lombardy Region, northern Italy) where green infrastructure was established by a set of constructed wetlands, surrounded by a park on the shore of the Olona River. The objective of the project was to implement a blue-green infrastructure to treat sewage overflows, and investigating the multiple benefits that provides and its relevance for water management (e.g. reduction of pollution and buffering flood events, biodiversity and recreational opportunities for people).

Applied Nature Based Solutions:

- A grid and sedimentation tank and 4 vertical sub-surface flow constructed wetlands
- a surface flow constructed wetland
- restoration of riparian trees, green open space, information panels, walking and cycling paths and other services.

Results:

The project was carried out in an area of 6.5 ha and it offered a findings and practical tools to apply the concept of ecosystem services provision for the selection of the best option between a multi-purpose green infrastructure and a grey alternative with regard to solutions to the combined sewer overflow as required by the EU Water Framework Directive.

The project has demonstrated how green infrastructure (constructed wetlands and park) performs equal to or even better than the grey alternative for water purification and flood protection. It provides additional benefits (wildlife support and recreation) specially valued by the local residents and stakeholders, and it has similar costs.

Strengths and weaknesses:

The project provided a useful example based on Nature Based Solution that aim to improve a variety of ecosystem services and benefits to the community. For their maximization, it is also necessary to collaborate with local stakeholders and community, with the aim to increase the awareness about the wide range of benefits that are provided by new or restored ecosystems. The applied NBS improved management of water resources for the benefit of people and biodiversity and provided evidence that green infrastructures, besides complying with the existing water regulations, provide additional services. The regional government was provided with a cost-benefit analysis suitable to be replicated in other locations.

However, it seems that stakeholders (local residents, municipality, water & environmental managers, experts and NGOs) were not so much actively involved but at least informed about the initiatives and the results.

Link:

https://oppla.eu/casestudy/17252

Project title: ***NAIAD Case Studies: Brague Demonstration site (France)***

Objectives: The area of the project is located in the region between Nice and Cannes (French Riviera), and it is characterized by a hilly catchment area until the sea, where most population lives. Extreme meteorological events have caused dramatic flash floods events in the past, therefore it is important to study torrential flood hazards and risks and the effects on ecosystems and identify the most effective and suitable Nature Based Solutions to manage the territory and reduce flood risk.

Applied Nature Based Solutions:
The project identified a few Nature Based Solutions as recommendation for the water flow regulation to limit floods hazards:
- Large-wood trapping facilities upstream of bottleneck sections (bridges, dams)
- Sufficiently large river beds
- land-use, land cover control

Results:
The project partners have provided the local area with a biophysical hazards and risks analysis, regarding in the specific:
• The forest vulnerability to wildfire (as a consequence, the flood risk might be exacerbated by wildfire for run-off and erosion generation).
• Simple and advanced flood modelling to demonstrate that the traditional use of retention basins and channelization of water courses is not suitable at the time of extreme events. A new framework of cost-effectiveness analysis is developed to appraise different civil engineering, NBS and hybrid protection strategies http://eprints.whiterose.ac.uk/147624/1/mainrevRRA.pdf.
• A global framework for NBS effectiveness assessment based on a multicriteria decision-aiding and global integrated approaches.
• Runoff-damage model to compute the efficacy of small retention areas in protecting the assets located in the basin.
• Economic valuation of NBS efficiency and a survey on public perception of flood risks and NBS for flood mitigation.
These modelling actions and the selection of NBS with simulations on effects of river floods aim to promote the benefits of NBS, such as:
- Developing climate change adaptation; improving risk management and resilience
- Better protection and restoration of coastal ecosystems
- Flood peak reduction
- Reduce drought risk
- Reduce flood risk
- Increase awareness of NBS solution & their effectiveness and co benefits
- Increase population & infrastructures protected by NBS
- Increase stakeholder awareness & knowledge about NBS
- Increase willingness to invest in NBS

Strengths and weaknesses:
La Brague DEMO proposes some pathways to contribute to reduce the flood risk in Mediterranean basins. Building and choosing solutions on physical evidences must be then accepted and understood by traditional (technical) flood risk managers. The chosen approach is multisectoral, including social and economic evaluations to make it accepted and implemented by stakeholders.
The choice of Nature Based Solutions and effectiveness assessment require specific principles mixing multidisciplinary quantitative and qualitative criteria and indicators but the choice of indicators depend on many important factors, among which data availability, time, spatial scales and decision-making contexts.

Link:
https://oppla.eu/casestudy/19924

Project title: *North Somerset Levels and Moors Partnership Project*
(Wessex Water)

Objectives: This case study is located in the North Somerset Levels and Moors in England (7950 ha) and it is characterized by coastal and floodplain grazing marsh that are under the threats of future housing developments and changes in land use. The objective of the project was to involve and collaborate with landowners to promote soil management to help mitigate flooding, improve water quality and to improve habitat management for wildlife such as wetland birds.

Applied Nature Based Solutions:
- Multi-functional nature-based watershed management
- Ecosystem restoration

Results:
The collaborative partnership was established in a former phase when a survey was launched to assess the perception of the water regulation systems in farmland areas. The survey evidenced how ditches were neglected and needed a collaborative approach to be improved. Therefore, a local partnership with different stakeholders (e.g. Avon Wildlife Trust, Environment Agency, Natural England, Wessex Water, North Somerset Council, Farming and Wildlife Advisory Group and the International Drainage Board) was established to coordinate annual programs for habitat management, to prevent flooding, improve water quality, ditch management and restoration of Sites of Special Scientific Interest (SSSI). Among the works, the partnership created shallow pools to provide nesting sites for lapwings, and they worked with farmers to manage the land appropriately for lapwing breeding such as cutting the grass the right height and modifying cattle grazing.
Ditches were re-profiled allowing water to run off the fields into the ditches as well as into the shallow pools and grasslands were re-seeded.

Strengths and weaknesses:
Two were the main strengths of the project: the application of effective NBS in the restoration of specific habitats and the creation of a partnership aimed to an integrated large-scale ecosystem restoration project and funding which is necessary to build and sustain relationships and trust between organisations and landowners/farmers. Training and promotional events and initiatives are crucial to raise stakeholders' awareness and acquire their support in the management of ditches and ecosystems. However, the availability of small grants for the restoration of the ditches was an incentive to support the project.

Link:
https://oppla.eu/casestudy/19191

References

Abbott, L.K.,Manning, D.A., 2015. Soil health and related ecosystem services in organic agriculture.Sustainable Agriculture Research 4 (3), 116.

Bai, Z.G., Jong, R. de, van Lynden, G.W.J., 2010. An update of GLADA – Global assessment of land degradation and improvement. ISRIC report 2010/08, ISRIC – World Soil Information, Wageningen.

Bai, Z. G., Dent, D. L., Olsson, L., Schaepman, M. E., 2008a. Proxy global assessment of land degradation. Soil Use and Management, 24(3), 223e234. http:// dx.doi.org/10.1111/j.1475-2743.2008.00169.x.

Bai Z.G., Dent D.L., Olsson L ., Schaepman M.E., 2008b. Global assessment of land degradation and improvement. 1. Identification by remote sensing. Report 2008/01, ISRIC – World Soil Information, Wageningen.

Bas W. Borsje, Bregje K. van Wesenbeeck, Frank Dekker, Peter Paalvast, Tjeerd J. Bouma, Marieke M. van Katwijk, Mindert B. de Vries, 2011. How ecological engineering can serve in coastal protection. Ecological Engineering, 37 (2), 113-122. https://doi.org/10.1016/j.ecoleng.2010.11.027

Bellamy, J., Osaka, S., 2020. Unnatural climate solutions? Nature Climate Change 10, 98-99.

Benedict, M.A., McMahon, E.T., 2006. Green Infrastructure: Smart Conservation for the 21st Century. Sprawl Watch Clearinghouse Monograph Series, 36 pp.

Borsje, B.W., van Wesenbeeck, B.K., Dekker, F., Paalvast, P., Bouma, T.J., Marieke, van Katwijk, M., de Vries M.B., 2011. How ecological engineering can serve in coastal protection. Ecological Engineering 37 (2), 113-122. https://doi.org/10.1016/j.ecoleng.2010.11.027

Bot, A. J., Nachtergaele, F. O., Young, A., 2000. Land resource potential and constraints at regional and country levels (L. a. W. D. Division, Trans.). Rome: Food and Agriculture Organization of the United Nations.

Cerdà, A., González-Pelayo, O., Giménez-Morera, A., Jordán, A., Pereira, P., Novara, A., Brevik, E.C., Prosdocimi, M., Mahmoodabadi, M., Keesstra, S., Orenes, F.G., Ritsema, C.J., 2016. Use of barley straw residues to avoid high erosion and runoff rates on persimmon plantations in Eastern Spain under lowfrequency-highmagnitude simulated rainfall events. Soil Res. 54 (2), 154–165.

Cohen-Shacham, E., Walters, G., Janzen, C., Maginnis, S. 2016. Nature-based Solutions to address global societal challenges. Gland, Switzerland: IUCN. xiii+97pp. ISBN: 978-2-8317-1812-5. http://dx.doi.org/10.2305/IUCN.CH.2016.13.en.

Cowan, C., Epple, C., Korn, H., Schliep, R., Stadler, J., 2010. Proceedings of the ENCA/BfN workshop on "Developing ecosystem-based approaches to climate change - why, what and how", International Academy for Nature Conservation, Isle of Vilm, Germany, 22-25 June 2009. BfN - Skripten (Bundesamt fur Naturschutz) 2010 No.264, pp. ii + 79 pp.

Cowie, A.l., Orr, B.J., Castillo Sanchez, V.M., Chasek, P., Crossman, N.D., Erlewein, A., Louwagie, G., Maron, M., Metternich, G.I., Minelli, S., Tengberg, A.E., Walter, S., Welton, S., 2018. Land in balance: The scientific conceptual framework for Land Degradation Neutrality. Environmental Science and Policy, 79, 25–35. dx.doi.org/10.1016/j.envsci.2017.10.011

van der Esch, S. et al. 2017. Exploring future changes in land use and land condition and the impacts on food, water, climate change and biodiversity: Scenarios for the Global Land Outlook. Netherlands Environmental Assessment Agency, The Hague, The Netherlands, 116 pp.

DESIRE, 2008. WB2 MANUAL for Describing Land Degradation Indicators. Compiled by Agricultural University of Athens.

Dominati, E., Patterson, M., Mackay, A., 2010. A framework for classifying and quantifying the natural capital and ecosystem services of soils. Ecol. Econ. 69, 1858–1868.

Dudley, N., S. Stolton, A. Belokurov, L. Krueger, N. Lopoukhine, K. MacKinnon, T. Sandwith and N. Sekhran [editors] (2010); Natural Solutions: Protected areas helping people cope with climate change, IUCNWCPA, TNC, UNDP, WCS, The World Bank and WWF, Gland, Switzerland, Washington DC and New York, USA

Eggermont, H., Balian, E., Azevedo, J.M.N., Beumer, V., Brodin, T., Claudet, J., Fady, B., Grube, M., Keune, H., Lamarque, P., Reuter, K., Smith, M., van Ham, C., Weisser, W.W., Le Roux, X., 2015. Nature-based Solutions: New Influence for Environmental Management and Research in Europe. GAIA - Ecological Perspectives for Science and Society, 24 (4), 243-248. https://doi.org/10.14512/gaia.24.4.9

EC (European Commission), 2015. Towards an EU Research and Innovation policy agenda for nature-based solutions & re-naturing cities. Final Report of the Horizon2020 Expert Group on Nature-Based Solutions and Re-Naturing Cities. Brussels: European Commission.FAO, 2017. FAO Soils Portal. Available at: http://www.fao.org/soils-portal/soil-degradation-restoration/en/.

EC (European Commission), 2020a. Nature-Based Solutions: State of the Art in EU-funded Projects. Luxembourg: Publications Office of the European Union, ©European Union. doi:10.2777/236007, ISBN 978-92-76-17334-2.

EC (European Commission), 2020b. Biodiversity and Nature-based Solutions. Analysis of EU-funded projects. Luxembourg: Publications Office of the European Union, ©European Union. doi:10.2777/183298, ISBN 978-92-76-18204-7

EC (European Commission), 2020c. Nature-based Solutions for Flood Mitigation and Coastal Resilience. Luxembourg: Publications Office of the European Union, ©European Union. doi:10.2777/374113, ISBN 978-92-76-18197-2

FAO, 2017. FAO Soils Portal. Available at: http://www.fao.org/soils-portal/soil-degradation-restoration/en/.

FAO and ITPS. 2015. Status of the World's Soil Resources (SWSR) – Main Report. Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy

Ferrara, A., Kosmas, C., Salvati, L., Padula, A., Mancino, L., Nolè, A., 2020. Updating the MEDALUS-ESA framework for worldwide land degradation and desertification assessment. Land Degrad. Dev., 31 (2020), pp. 1593-1608, 10.1002/ldr.3559

Finger, D., Þórsson, J., Pétursdóttir, Þ., Halldórsson, G., 2016. Enhancing the resilience of water resources through land restoration in Rangárvellir, Iceland - an overview of the HydroResilience project, Extended abstract 10th European Conference on Ecological Restoration, Freising, Germany. SER Europe Knowledge Base (www.ser.org/europe), 5pp. ISSN2295-5704.

Gibbs, H.K., and J.M. Salmon, 2015. Mapping the world's degraded lands. Appl. Geogr., 57, 12–21, doi:10.1016/J.APGEOG.2014.11.024.

Hernández-Morcilloa, M., Burgess, P., Mirck, J., Panterad, A., Plieninger, T., 2018. Scanning agroforestry-based solutions for climate change mitigation and adaptation in Europe, Environmental Science and Policy 80, 44 – 52.

Jackson, W., 2002. Natural Systems Agriculture: A radical alternative. Agriculture, Ecosystems and Environment, 88, pp. 111-117

Kalantari, Z., Folkeson, L., 2013. Road drainage in Sweden: current practice and suggestions for adaptation to climate change. Journal of Infrastructure Systems (ASCE) 19 (2), 147–156.

Keesstra, S.D., van Dam, O., Verstraeten, G., van Huissteden, J., 2009. Changing sediment generation due to natural reforestation in the Dragonja catchment, SW Slovenia. Catena, 78, 60–71.

Keesstra, S. , Nunes, J., Agata, M., Finger, D., Avelar, D., Kalantari, Z., Cerdà, A., 2018. The superior effect of nature based solutions in land management for enhancing ecosystem services. Science of the Total Environment, 610-611, 997-1009. http://dx.doi.org/10.1016/j.scitotenv.2017.08.077

Kirkby, M, Bracken, L.J, Brandt, J., 2015. John Thornes and desertification research in Europe. In: Alan P. Dykes, Mark Mulligan, John Wainwright (Eds), Monitoring and Modelling Dynamic Environments: (A Festschrift in Memory of Professor John B. Thornes). John Wiley & Sons, Ltd. 10.1002/9781118649596.ch16

Kosmas C, Kirkby M, Geeson N., 1999. Manual on: key indicators of desertification and mapping environmentally sensitive areas to desertification. European Commission, Energy, Environment and Sustainable Development, EUR 18882, p 87, https://op.europa.eu/it/publication-detail/-/publication/73f845d2-9043-48bb-837e-61df0f34a642

Kosmas, C., Kairis, O., Karavitis, C., Ritsema, C., Salvati, L., Acikalin, S., Alcala, M., Alfama, P., Atlhopheng, J., Barrera, J., Belgacem, A., Sole-Benet, A., Brito, J., Chaker, M., Chanda, R., Coelho, C., Darkoh, M., Diamantis, I., Ermolaeva, O., Fassouli, V., Fei, W., Feng, J., Fernandez, F., Ferreira, A., Gokceoglu, C., Gonzalez, D., Gungor, H., Hessel, R., Juying, J., Khatteli, H., Khitrov, N., Kounalaki, A., Laouina, A., Lollino, P., Lopes, M., Magole, L., Medina, L., Mendoza, M., Morais, P., Mulale, K., Ocakoglu, F., Ouessar, M., Ovalle, C., Perez, C., Perkins, J., Pliakas, F., Polemio, M., Pozo, A., Prat, C., Qinke, Y., Ramos, A., Ramos, J., Riquelme, J., Romanenkov, V., Rui, L., Santaloia, F., Sebego, R., Sghaier, M., Silva, N., Sizemskaya, M., Soares, J., Sonmez, H., Taamallah, H., Tezcan, L., Torri, D., Ungaro, F., Valente, S., de Vente, J., Zagal, E., Zeiliguer, A., Zhonging, W., Ziogas, A., 2014. Evaluation and selection of indicators for land degradation and desertification monitoring: methodological approach. Environmental Management 54, 951–970., https://doi.org/10.1007/s00267-013-0109-6

LIFE Publication 2014. LIFE and Soil protection. Luxembourg: Office for Official Publications of the European Union, 2014 - 68pp. ISBN 978-92-79-34664-4, ISSN 2314-9329. doi:10.2779/64447

Lugato, E., Paustian, K., Panagos, P., Jones, A., Borrelli, P., 2016. Quantifying the erosion effect on current carbon budget of European agricultural soils at high spatial resolution. Global change biology, 22(5), 1976-1984.

MacKinnon, K., van Ham, C., Reilly, K., Hopkins, J., 2008, Nature-Based Solutions and Protected Areas to Improve Urban Biodiversity and Health. In Marselle, M.R., Stadler, J., Korn, H., Irvine, K.N., and Bonn, A. (Eds.) Biodiversity and Health in the Face of Climate Change. ISBN 978-3-030-02317-1 ISBN 978-3-030-02318-8 (eBook), https://doi.org/10.1007/978-3-030-02318-8, pp. 363 – 381.

MAE (Millennium Ecosystem Assessment), 2005. Ecosystems and Human Well-Being: Synthesis. Island Press, Washington D.C.

Mekonnen,M., Keesstra, S.D., Stroosnijder, L., Baartman, J.E.M., Maroulis, J., 2015. Soil conservation through sediment trapping: a review. Land Degrad. Dev. 26 (6), 544–556.

Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-Being: Synthesis. Island Press, Washington D.C.

Mittermeier, R A., Totten, M., Pennypacker, L.L., Boltz, F., Mittermeier, C.G., Midgley, G., Rodriguez, C.M., Prickett, G., Gascon, C., Seligmann, P.A. and Langrand, O. (2008). Climate for Life, Washington DC: Conservation International.

Montanarella L. (2007) Trends in Land Degradation in Europe. In: Sivakumar M.V.K., Ndiang'ui N. (eds) Climate and Land Degradation. Environmental Science and Engineering (Environmental Science). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-72438-4_5

Montanarella, L., R. Scholes and A. Brainich, 2018. The IPBES Assessment Report on Land Degradation and Restoration. Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany. 744 pp. doi: 10.5281/zenodo.3237392.

Nesshöver, C., Assmuth, T., Irivne, K.I., Rusch, G.M., Waylen, K.A., Delbaere, B., Haase, D., Jobes-Walters, L., Keune, H., Kovacs, E., Krauzer, K., Külvik, M., Rey, F., van Dijk, J., Vistad, O.I., Wilkinson, M.E., Wittmer, H., 2017. The science, policy and practice of nature-based solutions: An interdisciplinary perspective. Science of the Total Environment, 579, 125-1227. https://doi.org/10.1016/j.scitotenv.2016.11.106

Novara, A., Keesstra, S., Cerdà, A., Pereira, P., Gristina, L., 2016. Understanding the role of soil erosion on co2-c loss using 13c isotopic signatures in abandoned Mediterranean agricultural land. Sci. Total Environ. 550, 330–336.

Oldeman, L. R. (1994). The global extent of soil degradation. Soil Resilience and Sustainable Land Use, 99e118.

Oldeman, L. R., Hakkeling, R. U., Sombroek,W. G., 1990.World map of the status of human-induced soil degradation: An explanatory note. Wageningen: International Soil Reference and Information Centre.

Pérez-Soba, M., Paracchini, M. Rega, C., Barredo, J., Caudullo, G., de Rigo, D., van Eupen, M., Verweij, P., Nabuurs, G-J., Hendriks, K., Nad Clement, J., 2018. D2.3: Report on patterns and trends of Public Goods/Ecosystem Services in relation to land management systems, PEGASUS: Public Ecosystem Goods and Services from land management - Unlocking the Synergies, European Commission

Pinto-Correia, T., 1993. Threatened landscape in Alentejo, Portugal: the "montado" and other "agro-silvo pastoral" systems. Landsc. Urban Plan. 24, 43–48.

Prince, S. Prince, S., Von Maltitz, G., Zhang, F., Byrne, K., Driscoll, C., Eshel, G., Kust, G., Martínez-Garza, C., Metzger, J. P., Midgley, G., Moreno-Mateos, D., Sghaier, M., Thwin, S., Bleeker, A., Brown, M. E., Cheng, L., Dales, K., Ellicot, E., Fernandes, G. W., Geissen, V., Halme, P., Harris, J., Izaurralde, C., Jandl, R., Jia, G., Li, G., Lindsay, R., Molinario, G., Neffati, M., Palmer, M., Parrotta, J., Pierzynski, G., Plieninger, T., Podwojewski, P., Ranieri, B. D., Sankaran, M., Scholes, R., Tully, K., Viglizzo, E., Wang, F., Ying, Q., Xiao, N. and Zhao, C. 2018. Status and Trends of Land Degradation and Restoration and Associated Changes in Biodiversity and Ecosystem Functions. In: Montanarella, L., Scholes, R. and Brainich, A. (ed.) The IPBES Assessment Report on Land Degradation and Restoration Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). Bonn, Germany, pp. 221-338.

Salvati, L. Bajocco, S., 2011. Land sensitivity to desertification across Italy: Past, present, and future, Applied Geography, 31, 1, https://doi.org/10.1016/j.apgeog.2010.04.006.

Smeets, E., Weterings, R., 1999. Environmental Indicators: Typology and Overview. European Environment Agency, Copenhagen.

UNCCD-AGTE, 2013. Refinement of the set of impact indicators on strategic objectives 1, 2 and 3. Recommendations of the ad hoc advisory group of technical experts ICCD/ COP(11)/CST/2 and Corr.1. 10 July 2013. United Nations Convention to Combat Desertification (UNCCD).

UNCCD-GM, 2016. Achieving Land Degradation Neutrality at the country level. Building blocks for LDN Target Setting. Global Mechanism (GM) of the United Nations Conventions to Combat Desertification (UNCCD), Bonn, Germany Available online: http://www2.unccd.int/sites/default/files/documents/160915_ldn_rgb_small%20%281%29.pdf.

UNCCD. (1994). United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa - Final Text.

van der Esch, S., ten Brink, B., Stehfest, E., Bakkenes, M., Sewell, A., Bouwman, A., Meijer, J., Westhoek, H., van den Berg, M., van den Born, G.J. and Doelman, J., 2017. Exploring future changes in land use and land condition and the impacts on food, water, climate change and biodiversity: Scenarios for the UNCCD Global Land Outlook. The Hague, PBL: Netherlands Environmental Assessment Agency. 116 pp.

Ventin, P., Marín, L. 2019. Towards Nature-based Solutions in the Mediterranean. IUCN Centre for Mediterranean Cooperation, Spain. https://www.iucn.org/sites/dev/files/content/documents/towards_nature-based_solutions_in_the_mediterranean.pdf

Warren, R., J. Price, J. VanDerWal, S. Cornelius, and H. Sohl, 2018: The implications of the United Nations Paris Agreement on climate change for globally significant biodiversity areas. Clim. Change, 147, 395–409, doi:10.1007/s10584-018-2158-6.

WOCAT, 2017. WOCAT Glossary. Available at: https://www.wocat.net/glossary#section-l [Accessed February 1, 2017].

Websites

GLASOD: https://www.isric.org/projects/global-assessment-human-induced-soil-degradation-glasod

TerraSTAT: http://www.fao.org/3/a0118e/a0118e08.htm

LADA: https://www.thegef.org/project/land-degradation-assessment-drylands-lada

GLADIS: http://www.fao.org/land-water/databases-and-software/gladis/es/

WOCAT: https://www.wocat.net/en/, https://www.wocat.net/library/media/168/

LIFE Programme 2014-2020 data hub: https://life.easme-web.eu/#

ESDAC facilities: https://esdac.jrc.ec.europa.eu/projects/dis4me

GOCE, http://www.desire-his.eu/

NBS: https://ec.europa.eu/info/research-and-innovation/research-area/environment/nature-based-solutions_en

Oppla: https://oppla.eu/