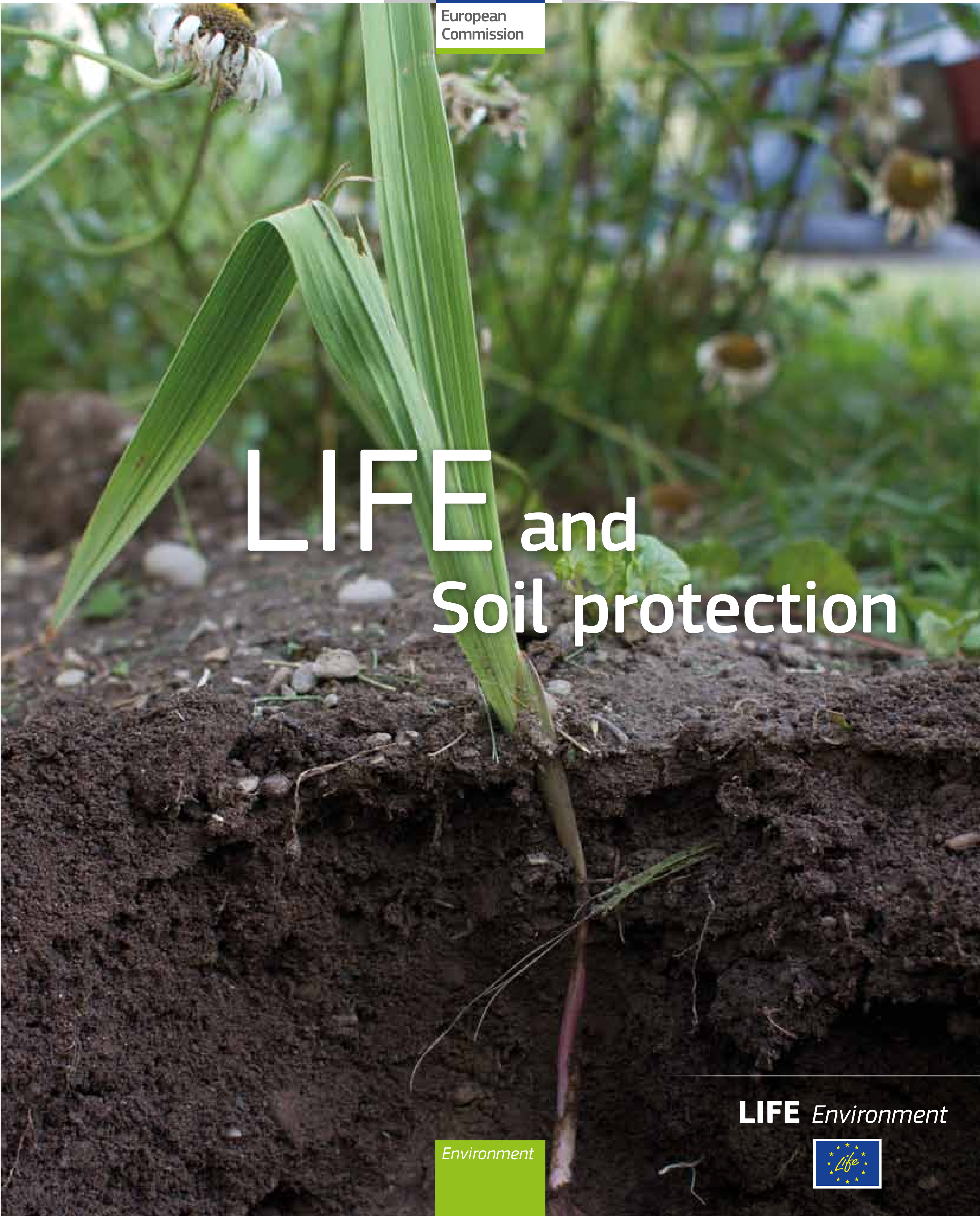
European Commission

LIFE and Soil protection



LIFE *Environment*

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EUROPEAN COMMISSION
ENVIRONMENT DIRECTORATE-GENERAL

LIFE ("*The Financial Instrument for the Environment*") is a programme launched by the European Commission and coordinated by the Environment Directorate-General (LIFE Units - E.3. and E.4.).

The contents of the publication "LIFE and Soil protection" do not necessarily reflect the opinions of the institutions of the European Union.

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Luxembourg: Publications Office of the European Union, 2014

ISBN 978-92-79-34664-4
ISSN 2314-9329
doi:10.2779/64447

Printed in Luxembourg
Printed on recycled paper that has been awarded the EU Ecolabel (http://ec.europa.eu/ecolabel/)

Foreword

Pia Bucella
Director of Natural Capital
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Soil is linked to everything around us. However, we still are not aware of its importance for life and the economy. Soils provide vital ecosystem functions, playing an important role in food production, the water cycle and the provision of renewable materials, such as timber. Their carbon storage capacity is essential to the fight against climate change and soil biodiversity is vital to soil fertility and wider biodiversity.

Soil is also a finite resource, meaning that once it is degraded, it is lost for future generations. The unsustainable use of soil threatens both the quality and quantity of Europe's soil stocks with major ramifications for important concerns such as food security (up to 80% of land lost to urban sprawl in recent years has been agricultural land).

The importance of soil sustainability is highlighted in the European Commission's Thematic Strategy for Soil Protection, suggesting a common and coherent European approach and the Roadmap to a Resource Efficient Europe. In response to the many challenges threatening soil sustainability, the Commission has supported the international soil conservation commitments of the Global Soil Partnership of the Food and Agriculture Organization of the United Nations and the European Landscape Convention of the Council of Europe.

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.

This LIFE Focus publication thus provides an opportunity to highlight and assess LIFE's important contribution to date, including proposals for ways in which LIFE's outputs may be better channeled and have an even greater impact in future.

The publication 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.

It also addresses in more detail LIFE actions relating to key issues around soil sustainability, such as land take and soil sealing, soil biodiversity, carbon capture, diffuse pollution, remediation of contaminated land, the link between soil and water protection, as well as soil monitoring. In each instance, LIFE can be seen to have field-tested new tools and best practices and helped further links between soil science, policy and the delivery of replicable solutions on the ground.

The new LIFE Programme (2014-2020) will increase the focus on soil, targeting land consumption, soil protection and cost efficiency as priorities for projects. This publication thus comes at an opportune moment. I hope it will raise awareness about soil and make an important contribution to debates about how to ensure the sustainability of this vital European resource.

TABLE OF CONTENTS

INTRODUCTION

Policy tools promoting **soil protection**

Soil is an essential ingredient for life, but often goes unseen. Its unsustainable use threatens the quantity and quality of Europe's soil stocks. Environmental policies can help to foster sustainable use of this limited resource and may act as useful benchmarks for targeting of LIFE co-finance.

Photo courtesy of USDA-NRCS

Soil is a vital natural resource that is at the heart of a healthy environment

A well-known environmental adage observes that practical actions at local level often lead to positive impacts on a global scale. High-level policies are therefore in place that can help to facilitate localised environmental actions and soil issues feature prominently in these policy initiatives.

Some of the most recent developments in global soil policies stem from the 2012 Rio+20 United Nations Conference on Sustainable Development. Outcomes from the conference[1] confirm an urgency for international soil conservation commitments, and reaffirm the long-term socio-economic relevance of such actions.

European Commission representatives at the Rio+20 summit endorsed the role of the 'Global Soil Partnership (GSP) for Food Security and Climate Change Mitigation and Adaptation'[2] as a useful policy mechanism for tackling soil degradation and maintaining healthy soil stocks.

Developed by the United Nations Food and Agriculture Organisation (FAO) in collaboration with the European Commission, this GSP initiative advocates improvements and harmonisation of soil monitoring systems, promotes sustainable soil management practice, reinforces the benefits from conserving soils' biodiversity functions, prioritises desertification problems, and encourages knowledge transfer in related fields.

The United Nations Framework Convention on Climate Change (UNFCCC) acknowledges the vital roles played by soils as carbon sinks and for controlling greenhouse gas emissions. The European Landscape Convention (ELC)[3] recognises the importance of holistic, territorial approaches to protecting landscapes

1 http://sustainabledevelopment.un.org/futurewewant.html
2 http://www.fao.org/globalsoilpartnership/en/
3 http://www.coe.int/t/dg4/cultureheritage/heritage/Landscape/default_en.asp

through joined-up working of regional and local authorities to prevent landscape degradation.

European Union policy

The 'Roadmap to a Resource Efficient Europe'[4], proposes that, "by 2020 EU policies take into account their direct and indirect impact on land use in the EU and globally, and the rate of land take is on track with an aim to achieve no net land take by 2050; soil erosion is reduced and the soil organic matter increased, with remedial work on contaminated sites well underway."

A wider review of European Union policies supporting soil management agendas reveals numerous interrelated strategic initiatives, directives and regulations. These cover topics as diverse as water, air, waste, pollution, industrial production, agriculture, pesticide use, urban planning, forestry, and rural development, amongst others. However, no overarching EU soil policy is currently operational.

Within the Thematic Strategy for Soil Protection (COM (2006) 231)[5] proposals have been prepared for a dedicated 'Soil Framework Directive'[6], but this directive has not been endorsed yet by the European Council. There remains opposition to the proposals in several Member States who say that soil protection solely should be up to Member States, with emphasis on sharing best practice examples and further development of (voluntary) guidelines.

Proponents of the draft directive believe that soils are so vital to the long-term sustainable growth of the EU that a specialised regulatory framework is essential, and that evidence regarding prevailing soil degradation pressures underscores weaknesses in the EU's current un-integrated approach to soil protection. It is feared that the continuation of the patchy and incoherent EU approach, combined with national legislations mostly limited to contaminated sites, will not prevent further soil degradation across the EU.

Environmental Action Programmes

Many LIFE projects working with soils have pointed to the Sixth Environment Action Programme (6th EAP)[7] as a key reference for their interventions up until 2012. Within the EAP, the Thematic Strategy for Soil Protection set out two main guiding principles for Member States to follow related to soil sustainability, namely:

- Preventing further soil degradation and preserving its functions; and
- Restoring degraded soils to a level of functionality consistent at least with current and intended use, thus also considering the cost implications of the restoration of soil.

Whilst LIFE can be seen to have assisted Member States in testing and demonstrating effective methods for preventing or restoring degraded soil, the scale of the problems involved still remain significant, as highlighted by the EU's new Environmental Action Programme to 2020 (titled: '*Living well, within the limits of our planet*' [8]).

This policy thus reinforces the need for Member States to introduce appropriate measures to protect EU soil stocks. In particular it notes the need for actions that: increase efforts to reduce soil erosion and increase soil organic matter; remediate contaminated sites and enhance the integration of land use aspects into coordinated decision-making involving all relevant levels of government; and support the adoption of targets on soil and on land as a resource. The new EAP proposals pay special attention to the need for future works on supporting soil sustainability, including high-level agreements on soil erosion, the rate of land take and soil organic matter. It is proposed that EU soil policy properly values natural capital and ecosystem services and takes into account its direct and indirect impact on land use. More sustainable agriculture and forestry methods are further components of the new EAP plans.

Policy context

This is the policy context within which future LIFE projects are expected to operate as they continue to explore cost-effective and innovative solutions for soil-related challenges. LIFE's own policy priorities for channelling more funds towards 'Integrated Projects'[9] are also anticipated to play a useful role in ensuring that localised soil protection activities generate more globalised positive policy impacts.

4 http://ec.europa.eu/environment/resource_efficiency/about/roadmap/index_en.htm
5 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2006:0231:FIN:EN:PDF
6 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52006PC0232:EN:NOT
7 http://ec.europa.eu/environment/newprg/archives/index.htm
8 http://ec.europa.eu/environment/newprg/pdf/7EAP_Proposal/en.pdf
9 http://ec.europa.eu/environment/life/about/documents/memorandum_faq.pdf

ANALYSIS

Integrated approach to soil - a strength of LIFE

The LIFE programme has funded many projects dealing with soil issues - from limiting and mitigating land take to remediating contaminated soil, pioneering innovative monitoring methodologies and providing stakeholders with vital decision-support tools.

Photo: LIFE07 ENV/GR/000278

Soil erosion on a mountainside in Greece - just one of the many soil-related issues that LIFE projects have helped tackle

Though soil has not been a core theme of the LIFE programme, many soil-related projects have been funded over the last 21 years, and in line with the policy context highlighted in the previous chapter, there has been an increasing focus on this topic since 2006.

LIFE and soil sealing

One of the most significant soil-related environmental challenges is land take or soil sealing (see pp. 13-19). To date, this phenomenon has been only partially addressed by LIFE. A number of projects have demonstrated ways of limiting or mitigating land take through partnership approaches that also provide best practice examples and lessons for decision-makers. However, in real terms there has been a relative lack of funding dedicated to sustainable urban drainage systems, green roofs and other green and blue infrastructure, and where such projects have taken place, mitigating soil sealing has tended to be a secondary consideration behind mitigating climate change. More projects have started addressing issues around land take since 2006 in parallel with the Thematic Strategy on Soil and its proposal of a directive. Further policy developments should inspire more soil sealing-related projects, including projects that attempt to compensate for the effects of land take by 'de-sealing' land or trialling 'eco-accounts' for enterprises.

Soil biodiversity and carbon capture

Soil biodiversity is another topic of growing interest because of its importance for the environment and ecosystem services. However, until now few LIFE Environment projects have addressed the

topic. There is a need to develop and apply more large-scale and low-cost biological activity assessment and monitoring methods for soils.

The LIFE programme as a whole has had a positive impact on this issue however, as numerous LIFE Nature projects have improved soil biodiversity by: reducing land degradation through the development of species-rich grassland and wetland communities; reducing soil erosion by re-establishing permanent native vegetation on arable land; or restoring forests to mitigate soil acidification.

The LIFE Nature strand has also indirectly made an immense contribution to carbon storage in soil through projects that, for nature conservation purposes, have converted intensively-farmed arable land to extensively-farmed grasslands and wet meadows, restored forests and conserved peatlands, helping to increase carbon stocks across Europe.

LIFE Environment projects by contrast have focused on encouraging better farming practices that have the potential to increase carbon storage and levels of soil organic matter. These have offered examples of applied methods such as organic farming and conservation agriculture practices (such as reduced or no tillage, crop rotation and cover crops) that ensure minimum standards of good agricultural and environmental conditions to achieve soil protection.

Some monitoring gaps apply: The effects of project measures for soil biodiversity and carbon storage should be better addressed in the project applications and more attention should be paid to the associated monitoring.

Soil sampling carried out by the SOILPRO project

Photo: LIFE08 ENV/IT/000428

Since LIFE Environment has mainly tackled carbon sequestration and soil biodiversity from an agricultural perspective, future projects could address these issues through other land-use practices and new monitoring tools.

Monitoring

To date there has been a notable lack of LIFE projects concerning general strategies for soil conservation and monitoring. This is not the fault of the programme *per se* as it is linked to the lack of specific EU legislation on soil, which has meant that it has not been a LIFE programme priority. However, those projects there have been have produced monitoring tools that can be readily used by non-soil experts (e.g. the DEMETER and MEDAPHON projects).

Point and diffuse sources of contamination

LIFE has been particularly supportive of projects addressing soil contamination issues. Point source contamination from industry, mining and landfills has been tackled through a range of innovative remediation techniques targeting various different chemical compounds (see pp. 52-57). LIFE co-funding has helped develop environmentally-friendly technologies such as In-Situ Chemical Oxidation and to remediate PCBs, lignite, asbestos, heavy metals and hydrocarbons, amongst other contaminants.

Despite these achievements, there is room for improvement: uptake of these remediation solutions has been lower than expected, partly because few projects have provided a blueprint for upscaling from a test site to a full contaminated area. There is also scope in future for LIFE projects to address the prevention of point source pollution (as foreseen by the "Environmental liability/damage Directive" - 2004/35/EC - and by the precautionary principle), for instance by developing tools for public authorities to promote policies that prevent contamination[10].

LIFE projects have also targeted contamination of soil from diffuse sources, namely agriculture, demonstrating cost-effective in-situ remediation techniques that farmers can manage themselves (such

10 *http://life.lifevideos.eu/environment/life/publications/lifepublications/generalpublications/documents/soil_study.pdf*

as phytoremediation or managing artificial wetlands). Many of the soil-related projects that have targeted the agricultural sector have aimed to prevent contamination in the first place, for instance by demonstrating and disseminating agri-techniques to reduce pollution from nitrates, pesticides and other compounds without affecting farmers' income. A strength of such LIFE projects, some of which (e.g. EcoPest – see pp. 50-51) have fed into legislation, has been the partnership they foster between farmers, agronomists, research institutes, universities and local and regional authorities.

Another diffuse source of soil pollution is via airborne pollutants, however this is not a topic that has been addressed by LIFE to date, perhaps linked to the wider lack of soil-related policy.

Integrated approaches

One of the great strengths of the LIFE programme is that, even if soil management and conservation has not been exclusively, primarily or explicitly targeted by many LIFE projects, numerous projects have had a positive impact on soil through pursuing an integrated approach that tackles multiple environmental issues at once[11].

Many water-related projects have had a positive impact on soil quality, for instance by restoring riparian vegetation, even if few of those projects explicitly mention or measure that impact. Indeed, the water-soil relationship is an element of many projects, not only from the LIFE Nature strand; many LIFE Environment projects have identified soil degradation (pollution, erosion, sealing, decline in organic matter) as a pressure on the water bodies and as an obstacle to good water quality. The soil and groundwater nexus is also evident in all of the contamination projects (point source or diffuse), which by necessity must address soil and groundwater decontamination simultaneously.

Since few LIFE Environment projects explicitly mentioned impacts on soil prior to the 2006 Soil Thematic Strategy (STS), it is hard to quantify how many projects have helped to reverse soil degradation and improve its functions as a secondary benefit of their main environmental goals: a rough estimate indicates at least three times as many as those that have directly targeted soil.

Photo: LIFE09 ENV/ES/000431

Sample taking for water and soil quality monitoring

Numerous LIFE Nature projects have also had positive effects on soil that were not taken into consideration during the lifetime of the project. Examples include projects implementing actions regarding the restoration of natural ecosystems that also produce positive effects on the chemical (i.e. organic matter content), carbon capture and physical characteristics of soil (structure).

Collecting data about soil quality is important for assessing the health of habitats and species. Thus, one of the conclusions of this publication is that the LIFE programme should encourage more projects focusing on the mapping and monitoring of soil quality. In addition, where a project has an impact on soil, that impact should be measured, even if the project is targeting other objectives.

Raising awareness

Awareness-raising has been carried out for environmental issues around water and air, but less so for soil. LIFE projects such as SOILCONS-WEB are

11 *http://life.lifevideos.eu/environment/life/publications/lifepublications/generalpublications/documents/soil_study.pdf*

beginning to make a start on this, but much more needs to be done.

More effort to date has gone into awareness raising amongst key stakeholder groups, such as farmers, where a variety of projects have encouraged the adoption of agricultural techniques to reduce soil degradation, with potential long-term economic and food security benefits. Such LIFE projects have gone beyond simple dissemination as they have focused on active involvement of farmers and agronomists in project actions and aim to achieve wider uptake of the techniques demonstrated through word-of-mouth networking by the farmers and agronomists they have trained.

Fewer projects have targeted awareness-raising activities at public authorities, which is a significant gap with regards to soil conservation. More information campaigns and decision-support tools for urban planners and staff within local and regional authorities (LRAs) should help bridge the knowledge gap between soil scientists and those implementing land use policy. LIFE Information & Communication projects could be a means to this end, as well as a tool for raising awareness amongst the wider public of soil-related environmental and health issues.

Soil and policy

Although many of the projects featured in this publication have produced positive results that could feed into soil policy, in practice this has rarely happened. The Athens Soil Platform Meeting – a thematic seminar for LIFE projects from across the EU - identified the need for projects to develop strategies for building contacts and fruitful working relationships with legislators at regional, national or EU level. Another proposal suggested establishing a Common European Platform to transfer knowledge from the scientific community to, for instance, public authorities and policy-makers, by making a range of decision-support tools widely available to members of such a pan-European network.

The Platform Meeting also highlighted the importance of verifying the results of pilot projects on a larger scale or in other locations, something that is not always possible during the course of a single project or its follow-up.

LIFE projects enabled farmers and agronomists to learn techniques that help protect soil

Photo: LIFE11 ENV/GR/000951

Conclusions

Given that soil is a complex system that interacts with other systems, especially water and air, soil policy should be integrated and LIFE projects should continue to show how it is possible to take an integrated approach to tackling a range of environmental issues. An instrument that encourages local policy-makers to take a more holistic approach to environmental, agricultural and trade issues would aid this process.

Knowledge transfer is essential and projects should focus more on developing ways of up-scaling techniques, transferring knowledge and involving stakeholders right from the project planning stage, throughout its duration and after LIFE. The bottom-up approach of LIFE projects is one of the programme's strengths and it pays to build on this.

As part of this knowledge transfer, it is important for projects to consider from the outset the potential impact in terms of soil policy, to monitor and measure soil quality and to foresee ways of transferring results to policy-makers at local, national or EU level.

Lastly, projects can and should do more to effectively communicate and raise public and stakeholder awareness on soil issues. Soil has a number of vital ecological functions that should be widely known and taken into consideration in decision-making and daily life. The LIFE programme has had a positive impact on Europe's soils, but with greater forethought, projects can make an even bigger difference in future.

EXPERT INTERVIEW

LIFE can help **translate science and policy into practice**

Dr Luca Montanarella is head of the SOIL Action, Joint Research Centre (JRC), European Commission. He was responsible for establishing the JRC's network of national soil services in 1992, known as the European Soil Bureau Network. This activity has grown and now the JRC soil team has some 25 people.

Dr Montanarella says there is "definitely" a need for a Soil Framework Directive (SFD), "but, as we said in the Soil Thematic Strategy, it's also about integrating with other legislation. Existing legislation is fine, but at certain moments when you need to address areas affected by soil degradation and properly implement measures to reverse degradation processes, you require a framework for legislation decisions," he believes.

Such a framework should also integrate other legislation and soil protection aspects, as well as research. In addition, says Dr Montanarella, awareness-raising is a "top priority. If we don't raise awareness in citizens I doubt we can go very far." Hence, one of the JRC's latest publications aims to explain to the public the importance of soil protection. "Legislation is nice, but at certain moments you need to do things to change the situation, to address areas affected by soil degradation and properly implement measures to reverse degradation processes," he points out.

Dr Montanarella says he was "surprised" that some Member States have been so resistant to the proposed SFD - citing the administrative burden and cost - because "The Commission proposed something that is extremely light and flexible for Member States to adopt. The text says that Member States have the flexibility to address soil problems as they wish. The only thing we ask is that they identify the problem and delineate the areas affected by the problem."

Policy integration

Since soil erosion is closely linked to watershed management, "soil policy is obviously linked to the Water Framework Directive – you cannot address soils alone," notes Dr Montanarella. He believes it is possible to integrate the SFD with other policies without increasing the administrative burden. He cites the example of the Common Agricultural Policy, "where we request farmers to limit soil erosion. This is not in contradiction to the proposed Directive, which says essentially the same thing but asks for the delineation of areas where erosion is happening."

The main issue to address with the SFD is the fact that two different sectors are involved: "the agricultural world, with threats to soils and loss of organic carbon, and the contamination part that is linked to industry and chemicals management. Bringing the two together is difficult because different scientific institutes and administrative entities deal with these two worlds," explains Dr Montanarella. "However, soil contamination is a big problem in Europe, with an estimated three million contaminated sites, and sooner or later something must be done," he adds.

LIFE's role

Dr Montanarella says he would like to see "a LIFE project that demonstrates how the Soil Framework Directive is applicable at a local level for huge problems. So, delineating local areas at risk from threats and demonstrating good practices to remedy these degradation processes."

He points out that priorities have been evolving since the Soil Thematic Strategy was first presented and identifies land take as the "main priority" in Europe today, "especially the sealing of soils by infrastructure and urbanisation."

Dr Luca Montanarella

World Reference Base for Soil Resources classification

Source: European Commission

Improving the transfer of results from LIFE projects "and scientific research in general" is something Dr Montanarella is passionate about: "Nice results are produced but they often end up in a cupboard and nothing happens. I have always advocated for the European Soil Data Centre – data from projects should be transferred to data centres, where it can be maintained and made available to other people," he believes.

Dr Montanarella says there are a couple of barriers to this data transfer, firstly the fact that "usually in the contractual arrangement we have no provision to oblige project beneficiaries to make this final step"; and secondly, "issues relating to ownership of products by LIFE projects", which is "something that needs to be clarified."

Working in the interface between science and policy has made Dr Montanarella acutely aware of the difficulty in translating scientific results into policy-relevant information: "Scientists want to publish papers and are not interested in policy development; the policy-maker needs information which, for a scientist, is often considered trivial. So you end up with a situation where the scientist continues to do research and the policy-maker waits for something useful to come out – and it never comes."

Bridging gaps

For Dr Montanarella, bridging the science-policy gap requires "a science-policy interface – something like the JRC." It needs scientists who are not academics needing to publish papers. He believes the JRC's soil services are well-positioned to translate scientific results "into something useful for policy. For example, at the end of the five-year Pan-European Soil Erosion Risk Assessment project there was a very nice model and case studies that tested the model in different parts of Europe, but there was no common European product. So the JRC decided to take this model and do the final step to produce a European soil erosion map for use by DG Environment for pan-European applications," he explains.

The frontiers of soil science are those areas of soils that are little known, in particular soil biodiversity: "The large amount of biodiversity in soil is not even classified. We should put the same effort into classifying and analysing biodiversity below-ground as we do above-ground," believes Dr Montanarella. "The problem is that biodiversity below-ground may not appear very exciting and it is not visible."

A second area where more work is needed is in linking the processes that affect soils to socio-economic developments: "If we don't make this link we may end up with good information systems about soil degradation but miss the link to why degradation is happening," he says.

There is a lack of research combining soil science, social science and economics, even though most of Europe's soils are not natural, but rather "the result of long historical developments... Even psychology links to the social dimension of soils in a fascinating way, with people having a bad image of soil through negative subconscious linkages; Heaven is usually in the clouds not in the soil. We talk a lot about threats to soils, but people in the street have a different perspective; they need houses and jobs that may depend on land uptake. There's a need for projects that change perceptions and raise awareness about the importance of soils," concludes Dr Montanarella.

POLICY INTERVIEW

Targeting LIFE to deliver **soil policy priorities**

Thomas Strassburger, Policy Officer of the Agriculture, Forest and Soil Unit of the European Commission's Directorate-General for the Environment, emphasises LIFE's contribution to soil conservation and the need to ensure better land management.

Through projects that directly and indirectly target an improvement of the condition of soil across Europe, the LIFE programme has played a significant role in furthering our knowledge of the threats to its conservation and how these can be overcome.

"The main impact of LIFE projects, besides the scientific value of a project, is awareness raising," says Mr Strassburger. Sometimes valuable results, however, are not adequately communicated. He believes that using plain language when it comes to 'selling' the work done would already improve understanding.

In September 2013, Mr Strassburger spoke at a platform meeting at the Benaki Phytopathological Institute in Athens, Greece, at which EU soil experts and LIFE+ project beneficiaries addressed environmental problems associated with soil. At this meeting, he underlined the "role of the project head to communicate what they have achieved, be it at community or regional level."

For example, he invited LIFE projects to provide the necessary information to the competent thematic units of the Commission services directly by sending them short summaries of the project's achievements and conclusions. As well as highlighting the value of projects in a clear and concise way, better distribution of results will mean they are more likely to feed into policy-making or serve as good practice examples. Whilst Mr Strassburger expresses disappointment that the results of some successful projects have not yet been taken up at a regional and national level, the potential for such an outcome is evident. "Even though not all the results of LIFE projects are immediately turned into practical policies, they certainly have a 'footprint'. We have to accept that sometimes it may take a while before they are appreciated more broadly," he argues.

"Clearly there is a range of projects which have really proved to be worth all the efforts, all the funding, and this is what I would really like to see LIFE continuing," he stresses.

Future priorities

The next LIFE programme, which covers the period 2014 to 2020, focuses on three priority areas for soil: land consumption, soil protection and cost efficiency. Land consumption is particularly important. According to Mr Strassburger, every year at least 1 000 km^2 of land is lost because of land consumption (an area more or less the size of Berlin) and with it all the vital ecological services we gain from soil – food production, water retention, habitat functions and so on.

Thomas Strassburger, Policy Officer of the Agriculture, Forest and Soil Unit

In 2012, the Commission published guidelines on how to limit, mitigate and compensate for soil sealing, trying to foster a more efficient use of our finite soil and land resources (see pp. 13-21).

Other soil protection issues to be targeted by LIFE include: improving land maintenance, management and efficiency; reducing land degradation and loss of fertility; and addressing the ongoing depletion of soil organic matter. Soil degradation problems such as erosion, compaction, acidification, desertification, landslides etc. must be tackled. Mr Strassburger also highlights the problem of the increasing release into the atmosphere of soil-based carbon and its impact on climate: "Land use plays a significant role for soils to be either a sink or a source of greenhouse gases."

Cost-efficiency in terms of soil refers to those LIFE projects that seek to develop and implement cost-effective means of identifying and remediating contaminated sites that present a risk to health or the environment. "This has been a strength of LIFE in the past and should continue to be a pillar of soil-related LIFE projects," says Mr Strassburger.

Towards a soil directive

Despite the achievements so far, Mr Strassburger emphasises that a binding scheme to ensure more sustainable use of soil and land resources is required, "Continuing with the patchy and incoherent approach, combined with poor national legislation in most countries, will not prevent further soil degradation across the EU, neither will it help in improving the bad status of some soils." He argues that "also because of the lack of legislation, soil is considered second ranking at the Member State level," hence a stronger focus is given to water and air protection, which are covered by overarching legislation. Consequently, "people perceive soil as not under as much threat when compared to other natural resources," he adds.

Furthermore, the lack of a common approach for all EU Member States has resulted in poor harmonisation of already sparse national datasets on soil. Without standardised data across Europe, it is difficult to make meaningful comparisons. "In the ongoing discussion on soil legislation, this lack of data is sometimes perceived as a lack of 'final proof' on our side to justify the need for action," he explains.

To tackle the main problems efficiently "we need to ensure a certain level of commitment; nobody can solve the challenges single-handedly," argues Mr Strassburger. "Despite claims about bureaucracy and additional burdens, looking at the ongoing loss of soil resources that we and future generations rely upon so heavily, we think it's essential to have a piece of central legislation, as suggested through the Soil Framework Directive." he concludes. "It would be good to raise the overall level of ambition of all Member States - most of which do not currently have specific legislation on soil - so that we at least have a minimum of protection ensured."

In the light of objections to new legislation from some Member States, the Commission is currently revisiting its soil policy: "We need to find out whether the objective of the proposal, to which we remain committed, is best served by maintaining the proposal or by putting something else on the table."

Alongside these developments at EU level, Mr Strassburger also points to the increasing awareness of soil policy globally, as illustrated in 2012 by the Rio+20 declaration on the goal of achieving a land-degradation neutral world. "It's a very ambitious objective and we need to see some serious commitment beyond words in the coming years in order to agree upon some effective measures at the international level," he says. "We have to go for progress in terms of sustainability and be more aware of consequences, otherwise – case lost."

Legislation is necessary to tackle soil degradation problems such as erosion

Photo courtesy of Tim Hudson

SOIL SEALING

LIFE, land take and **soil sealing**

Increasing land take and soil sealing is depriving us of the many vital services of our soil resources for future generations. Soil losses are one of the major environmental challenges facing Europe. LIFE projects have addressed some of the issues but more needs to be done.

Soils provide vital ecosystem functions, playing an important role in food production, the water cycle and the provision of renewable materials, such as timber. The European Commission's Soil Thematic Strategy (STS) identifies land take and soil sealing as amongst the main soil degradation processes, affecting ecosystem services and biodiversity.

Already one of the world's most urbanised continents, Europe faces growing urban sprawl and a spread of low-density settlements. This both threatens sustainable territorial development and exacerbates soil sealing.

Soil is sealed when agricultural or other rural land is taken into the built environment (land consumption), or when green zones in existing urban areas are reduced. Soil sealing and land consumption are closely interrelated and usually occur in parallel. In both cases, the conversion to artificial land covers (e.g. tarmac) causes adverse effects on, or loss of, soil functions. Soil loss from land consumption and sealing puts additional pressure on soil ecosystems as well as having other environmental impacts (see box).

Soil and landscape currently have weaker regulatory protection than air and water, for instance, and soil

Photo: LIFE11 ENV/FR/000746/EPAMSA

Urban green infrastructure and ecological corridors are being used for the sustainable development of the Chanteloup area in France

The impact of soil sealing

The European Commission's "Guidelines on best practice to limit, mitigate or compensate soil sealing"[12] identify eight major impacts of the practice:

- Major pressures on water resources – if soil is sealed the natural filtration processes and functions that moderate the flow to aquifers, removing contaminants and reducing the risk of flooding are altered;
- Impact on biodiversity;
- Impact on food security (because of the sealing of the most fertile soils);
- Impact on the global carbon cycle;
- Reduction in evapo-transpiration, contributing to the 'heat island effect' in urban areas;
- Impact on air quality from removal of vegetation growing in soil;
- Breaks link between the chemical and biological cycles of organisms, preventing the recycling of dead organic material; and
- Potential reduction in the quality of living.

is often not considered a finite resource. Factors contributing to land take and soil sealing vary between EU Member States, but common themes include the need for new housing, transport infrastructure and business and industrial development.

Given the environmental impacts of soil sealing, it is necessary to reverse a trend that has seen on average an area of land the size of the German capital taken every year in the EU between 1990 and 2006[13]. The use of natural assets such as soil and landscape must be carried out sustainably. To this end, the Roadmap to a Resource Efficient Europe foresees that by 2020 all EU policies must take into account their "direct and indirect impact on land use in the EU and globally and that the rate of land take is on track with the aim to achieve no net land take by 2050."

Limit, mitigate or compensate?

Best practices for dealing with soil sealing can be divided into three main categories:

1. Those that seek to **limit** soil sealing, by restricting land take and the conversion of green areas in cities. Re-using already built-up areas, e.g. brownfield sites, is also considered a way of limiting soil sealing.
2. Those that seek to **mitigate** the effects of soil sealing through such technological advances as permeable road surfaces, natural water harvesting systems and the addition of green infrastructure (e.g. green roofs) to urban and peri-urban areas. Where soil sealing does occur to enable economic growth, it should be mitigated through measures that maintain some soil functions whilst reducing such negative effects on the environment and human health as excess run-off water, the heat-island effect and soil degradation caused by the general uptake of land.
3. Those that seek to **compensate** for the effects of soil sealing through such measures as the re-use of topsoil elsewhere, 'de-sealing' previously taken land, establishing eco-accounts and land development trading schemes, or charging fees for soil sealing, to be used specifically for soil protection or other environmental purposes. The application of compensation measures is designed to sustain the overall soil function performance in a certain area.

LIFE projects to date have focused almost exclusively on limiting and mitigating soil sealing.

Limiting land take through spatial planning

Land take is usually a trade off between contrasting economic, social and environmental needs, such as housing, transport, infrastructure, energy production, agriculture and nature protection. Spatial planning aims to create a more rational territorial organisa-

SUDS reduce soil sealing and increase the water drainage capacity of surfaces

Photo: LIFE08 ENV/E/000099

12 *See Guidelines on best practice to limit, mitigate or compensate soil sealing SWD(2012) 101 final/2*

13 *According to the Soil Sealing Guidelines, estimated land take in the EU was some 1 000 km² per year between 1990 and 2000 and settlement areas increased by nearly 6%. From 2000 to 2006, although land take was reduced to 920 km² per year, there was a further 3% increase in settlement areas. As a consequence, the total soil-sealed surface in the EU in 2006 was an estimated 100 000 km².*

tion of land uses and the linkages between them, to balance demands for development with the need to protect the environment and to achieve social and economic objectives. Spatial planning is therefore an important lever for promoting sustainable land use by taking into account the importance of different land areas and soil functions in comparison with competing interests.

As the EU soil sealing Guidelines point out, "It is through regional and local spatial planning in the Member States that the principles of sustainable land use can be implemented on the ground." However, sustainable landscape management requires effective tools for assessing the multiple functions that soils and landscapes have for different users and stakeholders. As well as navigating a web of complex and sometimes conflicting interests, spatial planners also need to be aware of the many EU environmental directives and regulations pertaining to soil conservation and landscape management, a consequence of the multiple functions of soils and landscapes.

The LIFE SOILCONS-WEB project (**LIFE08 ENV/IT/000408**) has demonstrated a potential answer to this problem, developing a Web-based-Spatial Decision Supporting System (WS-DSS) aimed at urban planners and land-users (see pp. 20-21).

Sustainable industrial sites

Urban planners have to take into account several drivers of land conversion, including new housing, transport infrastructure and the development of business parks and industrial zones. The STS highlights the importance of limiting the conversion of green areas for such developments, instead encouraging the use of derelict land.

An ongoing LIFE Environment project in Spain is providing a practical example of the application of sustainable development principles when planning an industrial area. The PLATAFORMA CENTRAL IBERUM project (**LIFE11 ENV/ES/000538**) will control the whole water cycle through rainwater harvesting and re-use, creation of permeable structures to avoid sealing, constructing canals and reservoirs to allow for water to be collected for distribution, using Sustainable Urban Drainage Systems (SUDS) and the creation of storm ponds to maintain surface aquifers. Other project actions that will mitigate the impact of industrial development and, therefore soil sealing, include the creation of woodlands in the urban outskirts and the promotion of an agro-gardening system encouraging farming of autochthonous species and thus biodiversity.

Photo: LIFE05 ENV/UK/000128

The BioReGen project used energy crops to decontaminate 10 brownfield sites in the UK

Planning brownfield regeneration

An increasing number of EU countries have introduced planning recommendations that seek to limit the impact of land take, although these are often non-binding. Such recommendations include prohibiting or limiting building activities in rural areas or steering new developments towards less valuable soils in order to preserve soil functions. Soil formation is a slow process, being measured in centuries rather than decades, so the loss of fertile soils cannot be quickly remedied.

For a more rational use of soil, urban development should be steered towards low-quality soils and areas of degraded land that will need to be rehabilitated, such as brownfield sites. Their rehabilitation allows for urban regeneration and creates a sustainable urban environment.

There are many initiatives to re-use brownfield locations or regenerate them in a way that is better for the environment. Some cities offer incentives to builders and developers for using former brownfield sites rather than building new housing and commercial property on greenfields. Some brownfield sites are becoming conservation areas or parks to enrich communities. However, where brownfield sites contain hazardous materials or have contaminated watersheds it is important to establish the precise use of the land in order to avoid any health problems or other potential environmental liabilities later.


Photo: LIFE05 ENV/UK/000127

Green belts around metropolitan areas help mitigate urban sprawl

There is a need to find cost-effective and efficient solutions for brownfield regeneration to allow for greenfield sites for continuation of providing ecosystem services, such as food production. The LIFE projects TWIRLS (**LIFE04 ENV/GB/000820**) and BIOSOIL (**LIFE04 ENV/ES/000263**) have demonstrated ways to do this, based around the technique of 'compost remediation'. Aside from developing and demonstrating cost-efficient decontamination techniques (mainly bioremediation – see pp. 52-57) all these brownfield sites were rehabilitated for other uses, thus avoiding further greenfield uptake. In the case of BIOSOIL, a museum and housing have been built on the brownfields; the TWIRLS sites have been restored for a diversity of end uses, including grazing pasture, cereal production, beekeeping, conservation and recreation. A third project - BioReGen (**LIFE05 ENV/UK/000128** – see pp. 52-57) - used the decontaminated land to plant five different energy crops.

All three LIFE projects implementing compost remediation techniques also calculated the economic and social benefits of their actions. For TWIRLS and BIOSOIL, it appeared that compost remediation's low energy consumption and low application costs made the technique more cost-efficient than other polluted soil recovery methods. BioReGen's approach can have higher start-up costs than planting energy crops on farmland, but its operational costs are low and the crops have a market value.

Such projects show how requalification of brownfields could attract new businesses and jobs, thereby increasing prosperity, as well as improving environmental and living conditions. This is especially important where brownfield sites are located in disadvantaged areas, often characterised by high unemployment.

Green belts and eco-networks

Another means of limiting land take and soil sealing is through the designation of green belts around metropolitan areas to control sprawl. The Green Belt project (**LIFE00 ENV/E/000415**) was one of two to have used spatial planning to restore degraded peri-urban areas subjected to environmental stress on the outskirts of Barcelona. This project buffered urban development in the metropolitan region by converting high quality land into a greenbelt. The planting of endemic plant and tree species also helped safeguard local biodiversity.

The second project, Gallecs (**LIFE02 ENV/E/000200**), aimed at limiting the fragmentation of natural landscapes and protecting the rural town of the same name from urban and industrial expansion by creating a buffer zone between edge of the city and the outer countryside. Integrated measures adopted ranged from the restoration of degraded areas through the replanting of autochthonous species of plants, to the maintenance of hedgerows in agricultural fields so that they could function as natural corridors for species, to the creation of a wetland.

Lessons from the project are being integrated into urban-planning decisions affecting the region today, following the obvious environmental benefits provided by the green infrastructure aspects of the project.

Another example of such a project is Cheshire ECOnet (**LIFE99 ENV/UK/000177**), led by a local

authority in the north-west of England. The beneficiary used habitat conservation as a way of offsetting transport infrastructure as part of a project to create regional ecological networks through integrated land use planning and management. In light of conflicting views locally over land use, the project team's decision to initiate extensive stakeholder consultation was essential to the implementation of the networks. The project used GIS and digital aerial photography in order to identify concentrations of habitats of high value for wildlife as well as areas that have potential for the creation of new habitats and corridors for the movement of wildlife, including remediated former brownfield sites.

The model developed by Cheshire ECOnet can be easily applied in other, similar European contexts. Lessons from the project have been used by Chester and West Cheshire County Council to draft a functional ecological framework, which will feed into its Local Development Framework (LDF), a document that will guide urban planning decisions through to 2026. It is expected that the LDF will enable the needs for housing, economic development and ecological networks (including soil) to be balanced. The LDF will also emphasise the importance of linking Cheshire's network with those of neighbouring regions.

Mitigation measures: greening urban areas

A number of LIFE projects have incorporated principles of green infrastructure into urban design and spatial planning or designate and recover green urban areas.

Greening urban areas has been the focus of some 18 out of a total of 56 LIFE projects on urban planning and management since 1992. These include projects that have mainly helped local authorities to develop woodlands in cities, such as GAIA (**LIFE09 ENV/IT/000074**) which is developing a public-private partnership model for urban forestation through the adoption of the "green areas inner-city agreement" or the Life-QUF project in Spain (**LIFE12 ENV/ES/000092**), which will promote quick reforestation on different types of soil in urban areas, testing the effectiveness of water retainers and mycorrhiza for enabling quick tree growth without any additional water infrastructure.

LIFE projects have helped to integrate green infrastructure and biodiversity issues in urban planning as well as helping competent authorities throughout the EU to build capacity to protect nature and biodiversity. Examples include the Capital of Biodiversity project (**LIFE07 ENV/D/000224**) or the UK-led QUERCUS (**LIFE05 ENV/UK/000127**), which encouraged three local authorities (including one in the Netherlands) to reconnect urban areas to river corridors and create a network of green areas. More recently the SeineCityPark project (**LIFE11 ENV/FR/000746**) is demonstrating how the socio-economic development of an urbanised territory of 1 700 ha in the department of Yvelines, near Paris, can be combined with the improvement of local environmental conditions through the creation of green urban infrastructure. Through its urban management plan, the project will turn a neglected quarry into 113 ha of new green space – Bords de Seine Park. The project will also create an active 1.4 km

The SeineCityPark project is incorporating green infrastructure into a plan for socio-economic development of an area


Photo: LIFE11 ENV/FR/000746/Ports de Paris

strip to enable a good ecological transition between park and city.

Stakeholder involvement has been fundamental to the success of these and other LIFE projects carrying out soil sealing mitigation activities in urban and peri-urban areas. For instance, the QUERCUS project drew on the active partnership of local citizens to create ownership of the new green zones created (see *The Voices of LIFE* publication for further information). Another example is provided by the Sun project (**LIFE03 ENV/UK/000614**), which involved a range of new stakeholder groups in the process of managing urban green spaces, an innovative approach that raised awareness, created political and social support and improved and enhanced the environmental value of such spaces. This type of participatory approach also enables greater community awareness of the importance of soil protection and how to implement the kind of measures highlighted by the STS.

'Blue' and 'green' infrastructure

Sealed surfaces tend to generate surface run-off.. In urban environments this run-off water is usually collected, canalised and treated in wastewater treatment plants. There are different ways to mitigate this phenomenon, such as increasing the amount of open soil (de-sealing) or through the implementation of 'blue' and 'green' infrastructure such as SUDS and green roofs. Run-off can also affect the quality of surface waters as the cleaning function of soil is lost.

Green facades can help mitigate the 'heat island' effect

Photo: LIFE07 ENV/S/000908

Since 2008, three LIFE projects have focused on mitigating the effects of run-off water by adopting SUDS.

Aside from the previously-mentioned PLATAFORMA CENTRAL IBERUM, which intends to implement SUDS and other water management techniques in an industrial area, there are the AQUAVAL (**LIFE08 ENV/E/000099**) and LIFE Housing Landscapes (**LIFE12 ENV/UK/001133**) projects.

AQUAVAL is being implemented by the municipalities of Xativa and Benaguasil in Valencia Region, Spain, which are using SUDS to solve the problem of sewer overflow discharges in the rivers Turia and Albaida. The project is a direct consequence of monitoring of the rivers, which has revealed a deterioration of vegetation, as well as deficiencies in the dissolved oxygen content and chemical concentrations, in excess of what is permitted by the Water Framework Directive (2000/60/EC).

The recently-started LIFE Housing Landscapes project has a more ambitious scope, based around demonstrating a holistic package of measures for adapting to climate change in a social housing context. Identified threats to such housing estates include a greater incidence of flooding, more pressure on sewer systems, diffuse water pollution and the alteration of the urban microclimate with heat stress.

The LIFE project will develop an integrated approach that increases local stakeholder engagement and includes measures for mitigating the impact of soil sealing through the retrofitting of blue and green infrastructure, including SUDS, rain gardens[14], drought resilient plants, micro green roofs and rainwater harvesting. Benefits will include a reduction in flooding risks, use of rainwater for garden irrigation, replenishment of aquifers and less wastewater treatment.

14 A rain garden is a planted depression or a hole that allows rainwater run-off from impervious urban areas, such as roofs, driveways, pavements, car parks, and compacted lawn areas, the opportunity to be absorbed. This reduces rain run-off by allowing stormwater to soak into the ground.

Green roofs

Several LIFE projects have demonstrated the benefits of green roofing, beginning with 1998's Roof Greening project (**LIFE98 ENV/S/000482**). This Swedish project had the ultimate goal of encouraging the wider application of green roofing techniques in the project area, at a time when green roofs were still in the experimental stages. Its demonstration of first impressive results in terms of reducing storm water run-off and flooding, water regulation, saving energy through better insulation and reducing noise led to a LIFE Environment Best Project Award for 2004-2005.

Later LIFE projects have extended their scope beyond simply demonstrating the benefits of green roofs in urban and industrial settings. For instance, the GreenClimeAdapt project (**LIFE07 ENV/S/000908**) is also implementing other appropriate technology for dealing with climate adaptation in urban areas, such as green facades and open storm water systems, whilst the UK's GRACC project (**LIFE07 ENV/UK/000936**) worked to develop national or pan-European green roof codes in collaboration with the European Federation of Green Buildings (EFB).

In other cases the focus has been on drafting local or national planning strategies for green roofs for local and national authorities. This is true of the LifeMedGreenRoof project (**LIFE12 ENV/MT/000732**), which will draft national guidelines for Italy and propose policies for the Maltese planning system. Another important aspect for the uptake of this type of infrastructure at a wider European scale is the existence of possible economic barriers. Thus the project will conduct a study to identify these barriers and suggest technically and economically viable solutions for the large-scale introduction of green roofs.

Compensation measures

As yet, no projects have explicitly dealt with compensating land take, e.g. through de-sealing (removing concrete and asphalt layers), or restoring the former soil profile by removing foreign materials and applying topsoil or other soil forming materials to improve the local conditions of a site. It should however be noted that some LIFE Nature projects (e.g. LIFE FRIULI FENS in Italy) have removed topsoil from agricultural land on Natura 2000 sites to, for instance, recreate traditional wet meadows. The topsoil has been used on brownfield sites. However, this kind of compensation has been an indirect consequence of the project, rather than an explicit goal.

Photo: ASTRALE EEIG/Donald Lunan

Green roofs minimise some of the negative effects of soil sealing by moderating the urban heat island effect

Conclusions

The examples we have highlighted illustrate the impact that individual LIFE projects can have in terms of helping to limit and mitigate soil sealing and land take, providing valuable lessons for decision-makers and examples of best practice. They also demonstrate the benefits of involving stakeholders as partners in the process. However, from a wider perspective, the limited number of projects dedicated to green and blue infrastructure, greening urban areas and spatial planning are indicative of the fact that the LIFE programme has not focused a lot of funding on these issues. It is however noticeable that more projects have started addressing the issues since 2006 in parallel with the Soil Thematic Strategy.

Further policy developments and clear political messages may inspire more projects. The lack of LIFE projects demonstrating compensatory tools such as 'de-sealing' and eco-accounts indicates a gap that could be filled in future funding rounds.

SOIL SEALING

SOILCONS-WEB helps address land consumption challenge

This Italian project is producing a user-friendly tool that helps land use decisions be taken on the basis of sound soil science.

Led by the University Federico II in Naples, the SOILCONS-WEB project (**LIFE08 ENV/IT/000408**) is developing a Web-based-Spatial Decision Supporting System (WS-DSS) to aid decision-making on landscape issues for a range of stakeholders, from urban planners to olive farmers, wine-makers and the forestry sector. This integrated platform combines information on soil quality with web GIS facilities and advanced modelling, including Digital Soil Mapping and soil-plant atmosphere data. "Today there are opportunities for better planning management and monitoring of our landscape. It is very important to us to have a multifunctional system... everything is strongly interconnected," explains project manager and soil scientist, Professor Fabio Terribile.

The WS-DSS includes tools on protection against groundwater pollution, soil erosion, soil sealing and other land management issues, linking them to relevant EU directives or communications. Each module is being targeted at specific end-users (in both Italian and English versions). The tool can also have a very specific geographic focus – from a municipality down to an individual farm or villa.

Professor Fabio Terribile, the project manager for the SOILCONS-WEB project

The user interface is being developed by project partner, ARIESPACE. "Our idea is to provide complex information in an easy way," says CEO Carlo De Michele, "providing just a subset of the system for different stakeholders." The aim is "not to simplify complexity, but to make complexity so efficient that it is not anymore an obstacle," says Prof. Terribile. "You don't need to be an expert on soil to use the system," he adds.

"We need these tools in urban planning in Italy – at the moment there are no such tools," says Amedeo D'Antonio from one of the project partners, SeSIRCA, the research, information, consultancy and experimentation office of Campania Region's Department of Agriculture. "Today it is too costly to invest in new soil analysis and soil systems, but if you have a system into which every external analysis can be incorporated, semi-automatically, to improve the performance and solve several issues at once, things change," explains Dr. Angelo Basile, a soil hydrology scientist with the National Research Council and co-leader of the project.

Soil sealing

The system includes modules that map urban fragmentation and urban development in the pilot area (20 000 ha of the Valle Telesina in the Region of Campania) from the 1950s to the present day. There is also a module on soil sealing that, over the same time frame, maps out the land area that has been ceded to urbanisation. "For soil sealing, the project area is interesting because it's not one where sprawl has already had an impact," says Prof. Terribile. Rather, much of this mixed-use landscape is given over to agriculture and viticulture and there are also conservation zones, as well as population centres.

The WS-DSS tool can calculate the extent of land take per inhabitant

The soil-sealing module gives urban planners and municipalities access to key aggregated data such as land use categories by area (number of hectares of cropland, woodland, urban areas); population; water resources; rainfall; geology and main soil types. Contemporary data can be compared with figures for 1954 (the year of a large aerial photographic survey of Italy) to generate reports showing things like the change in agricultural area or the extent of urban sprawl.

"For urban planners it's important to know if an olive grove was there in 1954 - if it is 'a structuring element of the environment' - or if it is more recent," explains Prof. Terribile.

The tool can also highlight the extent of soil take – land take per inhabitant for new inhabitants in m^2 – between 1954 and 2011, including showing the type of soil lost (from most to least fertile).

One interesting feature is the ability to simulate, for a predefined area, the impact of land take on key ecosystem services such as the production of food, water adsorption and carbon sink (related to CO_2 production). For instance, the system can be used to calculate the lost hydrological function from sealed soil, based on an analysis of the different soil types in the area. This would allow a local planner to know the loss of soil water absorption capacity caused by a new housing development on former greenfield land, for instance, and take an informed decision about whether it should go ahead.

Other aggregated figures showing the impact of soil sealing on food security should be very powerful in terms of increasing landscape awareness at city council level. "It's a democratic tool," believes Mr D'Antonio: "If a municipality decides on an urban expansion a farmers' organisation could use it to ask why one piece of land is used and not another."

"It's the first environmental reporting on what has been lost [when soil is sealed]," says Prof. Terribile. "That can be important in terms of understanding your environment." Specific tools for planners can also be used to assess rural fragmentation at 800 m (large areas) and 100 m (detailed planning) scale. "This is a very powerful tool because the terms fragmentation and biodiversity are strongly used by urban planners, but only in words, only in reports," suggests Prof. Terribile. "These are practical tools with a big potential for landscape awareness. Everybody from construction companies to environmental associations could use this system."

Going beyond the specific goals of the project, but thinking about EU policy needs, the SOILCONS-WEB team plans to expand the WS-DSS to national scale – by spring 2014 it aims to provide the ability to aggregate information by municipality and assess fragmentation for all Italy. The tool will be further honed in trials covering test areas in Lombardy, Austria and the UK (Scotland) before the end of 2014, hopefully demonstrating the flexibility, adaptability and replicability of the SOILCONS-WEB system.

Project number: LIFE08 ENV/IT/000408

Title: SOILCONS-WEB - Multifunctional Soil Conservation and Land Management through the Development of a Web Based Spatial Decision Supporting System

Beneficiary: Universita' di Napoli Federico II - Dipartamento di Scienza del Suolo, della Pianta, dell'Ambiente e delle Produzioni Animali (DISSPAPA).

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Period: 01-Jan-2010 to 31-Dec -2014

Total budget: €3 329 000

LIFE contribution: €1 592 000

SOIL BIODIVERSITY

LIFE helps to conserve and restore **soil biodiversity**

Often overlooked, soil biodiversity is essential to soil fertility. LIFE projects across the EU have given an important boost to this vital ecosystem service.

Soils are the habitat for a large variety of organisms, such as bacteria, fungi, protozoa, microarthopods, earthworms or millipedes. In a teaspoon of grassland soils you can find more than one billion organisms of up to 10 000 individual species. The primary role of soil organisms is to recycle organic material that is derived from the above-ground plant-based food web. Soil biodiversity is hugely important for the maintenance of fertile soils - "one of the most vital ecological services the living world performs" (Baskin, 1997) - since fertility and terrestrial nutrient cycles are controlled by the quantity and quality of living organisms in the soil.

2010 was a watershed year for awareness of soil biodiversity, thanks to the United Nations declaration of the International Year of Biodiversity and the first report on soil biodiversity[15] from the European Commission's DG Environment.

Despite these breakthroughs, there is a general lack of social awareness of the importance of soil biodiversity, which further enhances the problem of the loss of ecosystem services through loss of that biodiversity. So far, budgets spent on schemes for monitoring soil biodiversity remain insufficient.

Photo: schizoform

The identification of soil organisms is the first step to understanding the role of soil biodiversity

The Commission's 2010 report identifies a series of threats to soil biodiversity: soil degradation; changes in land use management; climate change; chemical pollution; and genetically-modified organisms (GMOs). Until now, few LIFE Nature projects have directly addressed soil biodiversity. However, numerous LIFE projects have contributed indirectly to the conservation, improvement or restoration of that biodiversity via a multitude of activities and measures.

15 Soil biodiversity: functions, threats and tools for policy makers - http://ec.europa.eu/environment/soil/biodiversity.htm

Increasing diversity by stopping soil degradation

Many human activities result in soil degradation, which affects the ecosystem services provided by soil biodiversity. Soil compaction, organic matter depletion, acidification, salinisation or soil erosion are influenced by inappropriate agricultural practices, over-grazing, vegetation clearance and forest fires.

Porosity, pore size distribution and pore continuity in soils govern the movement of water and oxygen in the soil and thus soil moisture and nutrient availability. Deep and frequent ploughing can destroy soil aggregates and lead to the filling of pore spaces, which has a negative impact on the water and gas household in the soil (i.e. their natural retention capacity). The soil structure decline consequently has a direct impact on soil and surface food chain and biodiversity. The dense root system of the re-established vegetation cover restores the physical soil structure and revitalises soil biodiversity.

A large number of LIFE Nature projects have aimed to develop species-rich grassland and wetland communities by the conversion of intensive arable land and intensive grasslands to species-rich meadows, pastures and wetlands. Although the main objective of these projects has been the restoration or improvement of the conservation status of the grasslands and wetland habitats listed in Annex I of the Habitats Directive, their restoration measures have also substantially contributed to the improvement or restoration of soil biodiversity (see box).

Erosion and acidification

Soil erosion is a major threat to soil biodiversity. It leads to a loss of topsoil, organic matter and nutrients; it breaks down soil structure and decreases water storage capacity, in turn reducing fertility and the availability of water to soil organisms and plant roots. Bare land will suffer much more from erosion than land covered by protective vegetation or mulch layers (up to more than 100 times faster). Thus, the many LIFE Nature projects that have aimed to re-establish permanent native vegetation on arable land can also be seen to have made a significant contribution to the reduction of soil erosion and the long-term enhancement of soil biodiversity.

Soil acidification also has a direct impact on soil biodiversity by reducing the numbers of most macrofauna, creatures that usually improve the physical structure of topsoil, a major characteristic of healthy soils. For example in soils of pH <4.5 there are just a few species of earthworms, which are of huge importance for the formation of organic-mineral complexes in the soil. Decomposition and nitrogen fixation may be also reduced because of acidification, which affects the survival of native vegetation; biodiversity may further decline as certain weeds and alien species proliferate under declining native vegetation.

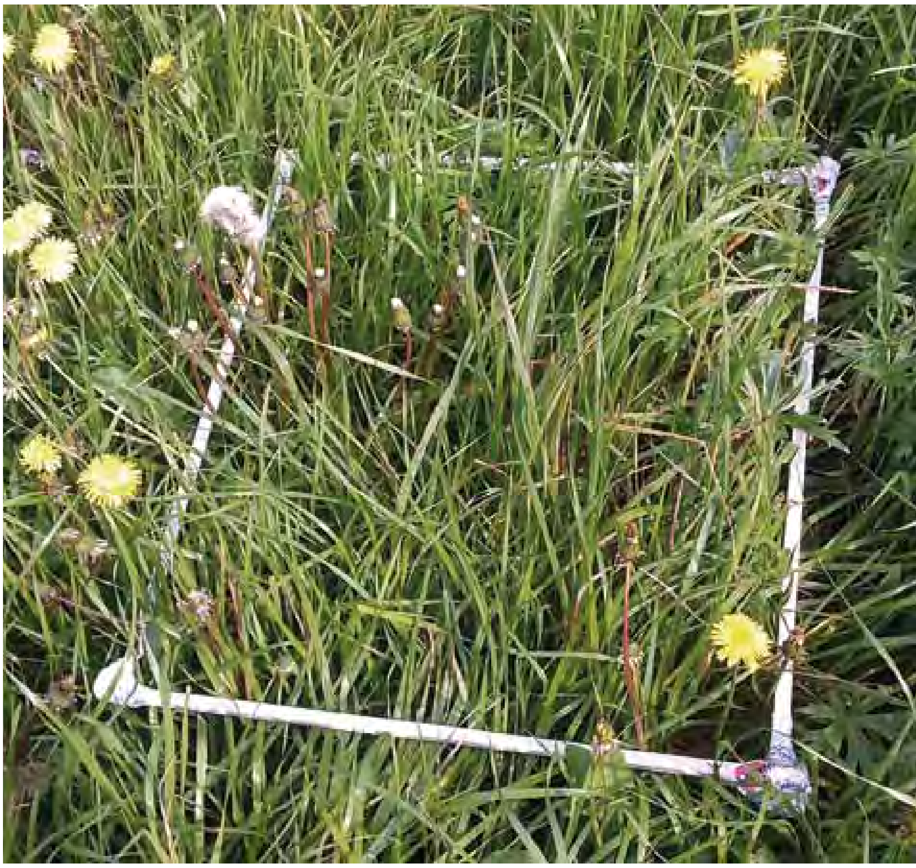


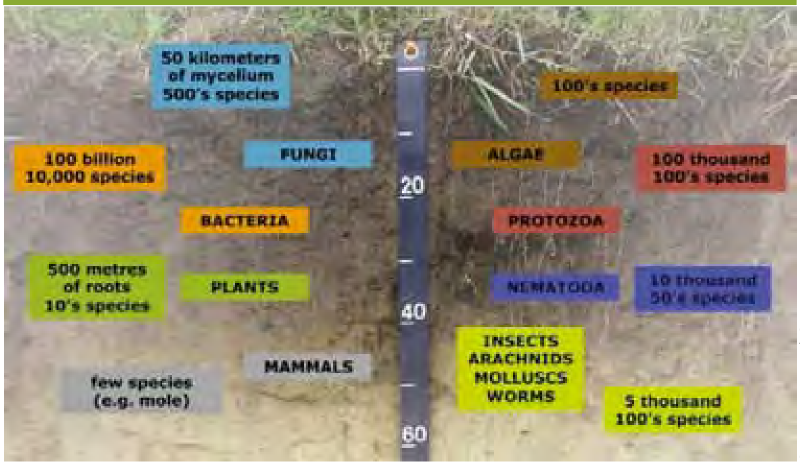
Photo: LIFE10 NAT/ES/000579

Soil organisms are extremely varied in terms of morphology, quantity and lifestyle. Therefore, surveys on soil biodiversity require specific tools depending on the specific group of organisms studied

Grasslands restoration helps soil biodiversity

There are numerous examples of LIFE Nature grassland restoration projects across the EU whose actions have helped restore soil biodiversity. For instance, the Hungarian project EPU(HNP) (**LIFE04 NAT/HU/000119**) used seed mixtures of native species to restore some 750 ha of steppe grasslands. In Italy, LAGO SALSO (**LIFE07 NAT/IT/000507**) recovered some 90 ha of Mediterranean salt meadows from agricultural lands, and the ongoing ECO-RICE (**LIFE09 NAT/IT/000093**). project is undertaking land purchase in order to restore a range of grassland habitats in former rice fields. Many Dutch projects have targeted the restoration of nutrient-poor Nardus grasslands, Molinia meadows and heathlands on former agricultural land, whilst a number of Danish projects, including Connect habitats (**LIFE09 NAT/DK/000371**), Dry Grasslands (**LIFE08 NAT/DK/000464**) and Total cover Helnaes (**LIFE08 NAT/DK/000465**) have contributed to the enhancement of soil biodiversity through the restoration of various grassland habitats.

Soil biodiversity in numbers



Source: Joint Research Centre

The approximate number and diversity of organisms typically found in a handful of grassland soil

Acid soils are increasingly found on sites where monocultural conifer forests have been planted outside of their natural occurrence. Numerous LIFE Nature projects have set out to convert such poor sites back to species-rich forests with more natural tree compositions.

Examples include the German project Eichenwälder bei Wesel (**LIFE10 NAT/DE/000009**), which is aiming to develop new habitats within 'Old acidophilous oak woods with Quercus robur on sandy plains' (919*), including the conversion of 25 ha of non-indigenous coniferous plantations to oak woods habitats. Elsewhere, the Belgian LIFE Nature project PLTTAILLES (**LIFE05 NAT/B/000089**) led to 335 ha of intensive coniferous forestry being extensified. Such restoration activities not only reduce soil acidification, in the long term it is expected that soil biodiversity will improve too.

Managing invasive plant species for soil biodiversity

Invasive plants can have major direct and indirect impacts on soil functions and native biodiversity. They may alter nutrient dynamics and thus the abundance of microbial species in soils, especially of those exhibiting specific dependencies (e.g. mycorrhiza). Natural biological regulator populations tend to be reduced by invasive species, especially when they have species-specific relationships with plants. What's more, plant invasions may be favoured by the release of their soil pathogens (allelopathy). The best known example, the North American alien tree species black locust (*Robinia pseudo-acacia*), is able to alter not only the herb layer but also the soil properties by its own mycorrhiza and allelopathic activity within a few years.

One LIFE project that has addressed this issue has been the Hungarian project HUNSTEPPICOAKS (**LIFE06 NAT/H/000098**), which focused on the total removal of black locust and black cherry (*Prunus serotina*) from a 420 ha target area. This would enable the restoration of the original forest composition and the creation of conditions for the natural regeneration of soil biodiversity.

"Lack of soil biodiversity projects"

As we have seen, a large number of LIFE projects have indirectly benefitted soil biodiversity. However, just two projects to date have directly targeted actions towards this aim. The Spanish project SOIL-Montana (**LIFE10 NAT/ES/000579**) demonstrates the viability of an innovative methodology for the conservation of soil and vegetation biodiversity in mountain and bottom valley grazing areas, based on the application of an Agro-ecosystem Health Card. In additional to the traditional physical and chemical indicators of soil quality, the health card will include (micro-) biological indicators. This should provide for the first time reference values in terms of soil diversity to be used in diagnosing the health of the grazing agro-ecosystems.

In the Netherlands, the project Blues in the Marshes (**LIFE11 NAT/NL/000770**) is preparing to transplant soil from one site in order to enhance biodiversity at other locations. This scientifically-monitored measure should facilitate not only the germination of plants, but also the diversity of soil fauna - ants and springtails.

Conclusions

Some LIFE Nature projects have made an immense contribution to the enhancement and conservation of soil biodiversity, often as a side effect. For the future, the respective impact of project measures should be better addressed in the project applications and more attention should be paid to the associated monitoring of the effects. In this respect the LIFE programme could provide a substantial contribution to the development of standardised and cost effective methods for measuring and monitoring soil biodiversity and the long-term success of nature conservation measures, especially restoration of habitats, should be evaluated also in terms of restoring soil biodiversity.

SOIL BIODIVERSITY

Monitoring soil biodiversity **in Hungary**

The MEDAPHON project developed a new tool - the EDAPHALOG System - for monitoring below-ground soil biodiversity in real-time.

The Soil Thematic Strategy (STS) designated the loss of biodiversity as one of the main threats to soils in Europe. However, there are currently no standard methodologies for monitoring techniques used at national or European level for soil biodiversity, with a particular lack of a methodology for measuring below-ground biodiversity.

Those LIFE projects aimed at developing innovative soil biodiversity monitoring systems have adopted three main approaches: (1) the direct counting of organisms, (2) the analysis of biochemical activity, or (3) the analysis of DNA in soil samples. Of these, direct counting is closest to being implemented on a large scale.

The LIFE Environment project MEDAPHON (**LIFE08 ENV/H/000292**) developed a new soil monitoring tool called the EDAPHOLOG System, which counts the below-ground microfauna, in-situ and in real-time, in a rapid and cost-efficient manner. The system comprises probes buried in the soil in which insects are trapped, data-logging boxes, and a central database with custom-made software. The beneficiary, the Institute for Soil Sciences and Agricultural Chemistry of the Hungarian Academy of Sciences, collaborated with the technology company Deák Delta Ltd., Kistelek, Hungary, which manufactured sophisticated probes and data logging boxes.

Innovative technology

"The innovation is the automatic counting of trapped insects," says Miklós Dombos, the Senior Researcher at the Institute. "We constructed an optical sensor, which automatically counts the insects as they fall down the trap and also estimates their body size. The optical part comprises two lenses and an infrared diode, and we measured the light behind the lenses. Until now, for ground-dwelling insects, there was no such automatic counting trap."

Three different ecotypes of springtails (Collembola), identifiable through different body sizes, and other invertebrates (e.g. mites) active in the upper 15 cm of the soil are monitored using the probes. A comparison was made between the automated data and the trapped insects, preserved in alcohol in the base of the probes, and good correlations were found for number and body size.

Once in the ground, the probes can work for up to three months before the batteries need recharging. They also record soil temperature and humidity. The data from each probe are sent from radio antennae to a nearby data logger, up to 50 m away, and then to a central database using GPRS and Internet technology. Software remotely controls data logging, including the frequency of recording. "The data can help us understand the ecological state of soils, with biodiversity and ecological indices which can be automatically generated to answer particular questions posed by decision-makers," says Dr Dombos.

In general, soil biodiversity indices are indicators of organic matter content. "The ecological function of soil biota is organic decomposition, so if the microfauna is abundant the organic matter is higher," explains Dr Dombos. Several soil biodiversity indices can be derived from the data. "For instance, taxonomic biodiversity is the number of species, while indices such as Shannon Weiner use abundance of each species." Other useful indices for assessing soil conditions include the QBS (below-ground to above-ground species abundance ratio) and a functional index (ratio of fungal-feeding to bacterial-feeding organisms).

If commercialised, the EDAPHOLOG System could contribute to national soil monitoring systems and the harmonised soil monitoring system across Europe proposed in the STS. "It could be used in any

Probes buried in the soil capture and count the microfauna

Photo: Miklós Dombos

Photo: Miklós Dombos

The system allows the monitoring of the dynamics of soil biodiversity over time

European country", says Dr Dombos, "with the batteries moved to the above-ground section to shorten the probe for stony ground." Monitoring design and number of habitat types to be sampled would determine the number of probes needed. He estimates that for Hungary, with around 15 to 20 soil types, a national monitoring scheme would require around 800 probes and 200 data loggers.

"The challenge with soil biodiversity, in general, is that sampling is labour-intensive and species identification needs expert knowledge," notes Dr Dombos. "The soil's biological community is also patchily distributed and changes in time, so you need sufficient replication and frequent recording." In Hungary, as in other European countries, extensive soil monitoring has been done for agricultural land, but as an inventory done one time only. He adds: "The probes are very good for looking at the dynamics of biodiversity over time, because they record exactly when each organism was caught."

Real-time monitoring for farmers and ecosystem services

The system can be used generally, for instance to help farmers make decisions about best land use. However, the greatest benefits of the system derive from its automatic real-time recording capability. For instance, plant protection actions that affect soil biodiversity, such as insecticide spraying, can be followed in real time. It can be used to quickly identify risk areas of very low biodiversity for soil recovery programmes, as required under the STS, or 'biodiversity hotspots'. Soil contamination and bioremediation actions, in particular, can be assessed quickly for impacts on biodiversity. "For soil contamination situations, the probes can be used directly. With soil that has been bioremediated and with a biodiversity of zero, you can measure in real-time how the soil microfauna develops," explains Dr Dombos.

The EDAPHOLOG System could also be used to evaluate ecosystem services and monitor protected species. Soil ecosystem services rely on healthy soils with high biological activity. A climate change experiment using 50 probes is being conducted to look at below-ground soil biodiversity for known microclimatic conditions.

Other experimental studies with the system, initiated since the conclusion of the MEDAPHON project, include a collaboration with the Research Institute for Viticulture and Oenology in Tokaj to measure biodiversity between vine rows with and without protective soil covering.

As the first automated real-time counting device for soil microfauna, the EDAPHOLOG System has great potential as a tool for supporting local authority decision-making and helping EU Member States implement the recommendations of the STS.

Project number: LIFE08 ENV/H/000292

Title: MEDAPHON – Monitoring Soil Biological Activity by using a novel tool: EDAPHOLOG-system – system building and field testing

Beneficiary: Institute for Soil Sciences and Agricultural Chemistry, Centre for Agricultural Research, Hungarian Academy of Sciences

Contact: Miklós Dombos

Email: dombos.miklos@agrar.mta.hu

Website: www.medaphon.hu

Period: 01-Jan-2010 to 31-Dec-2012

Total budget: €2 063 000

LIFE contribution: €1 021 000

SOIL
CARBON CAPTURE

LIFE, **climate change** and soil

LIFE projects have successfully applied a range of soil management techniques for increasing carbon storage, including forest and peatland restoration and a range of extensive agriculture techniques and practical tools and procedures for farmers.

Carbon is taken out of the atmosphere by plant photosynthesis; globally, about 60 Gt/yr are incorporated into various types of soil organic matter, including surface litter, with at the same time some 60 Gt/yr respired or oxidised from the soil. Some organic carbon compounds are easily digested and respired by the microbes resulting in a relatively short mean residence time. Others, such as lignin, humic acids or substrate encapsulated in soil aggregates are much more persistent in soil.

The issue of quickly mounting CO_2 concentrations in the atmosphere brought soils into the climate change discussion because as the largest terrestrial pool of carbon and they can act as sources or sinks for greenhouse gases.

Soils store more carbon than the atmosphere or the total above ground biomass of the earth. An estimated 2 500 Gt of (organic and inorganic) carbon is stored in soils worldwide, with estimates for organic carbon – humus - stored in soils ranging from 1 115 to 2 200 Gt. The largest depository of organic soil carbon is in peatlands: recent estimates put the figure at 2.8 million km^2 of peatlands worldwide, storing some 445 Gt of organic carbon. Although EU peatlands are concentrated in a few, mostly northern European countries (primarily Finland, Sweden and the UK), they have great importance, storing over 17 Gt of carbon.

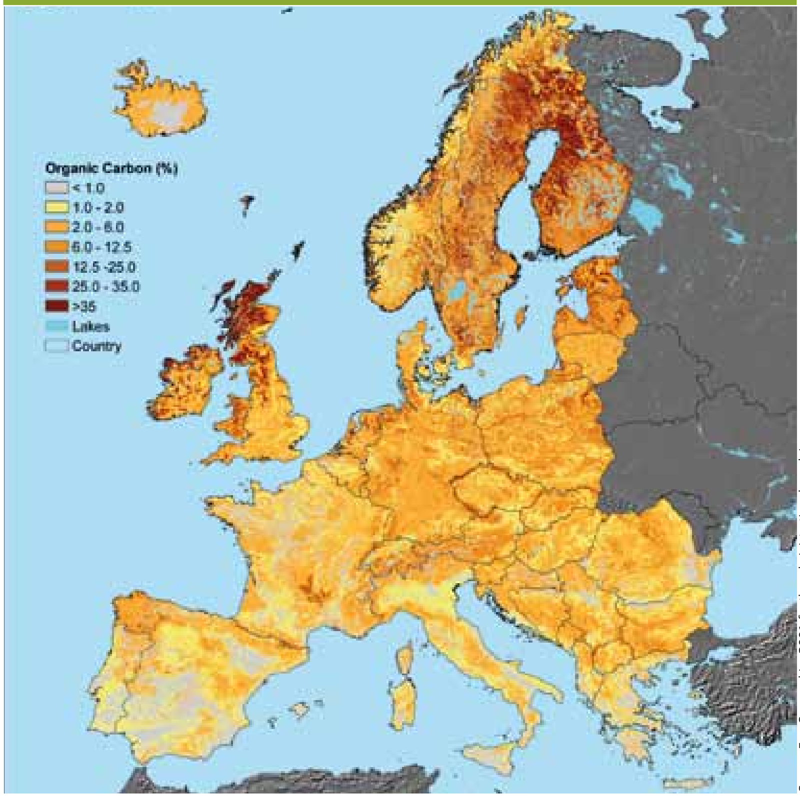
The Soil Thematic Strategy (STS) identifies climate change as a common element in many soil threats. It is important to gain a more robust understanding of interactions between soil under different land uses and climate change than is available now. The European Commission therefore intends to assess the contribution of soil protection to climate change mitigation as well as the effects of climate change on soil productivity and on the possible depletion of soil organic matter.

Land use significantly affects soil carbon stocks. Carbon losses occur when grasslands, near-natural forest or native ecosystems are converted to croplands or plantation forests, turning soils into net emitters. The sink effect occurs when CO_2 captured by plants from the atmosphere during photosynthesis

LIFE Nature projects targeting the restoration of traditional farming of grasslands have also indirectly helped boost carbon sequestration

Photo: LIFE11 NAT/DE/000344/H. Wilke

Topsoil organic carbon content



Source: EuroGeographics 2001 for the administratives boundaires

is released back into the soil as carbon (C) through biological processes, building up humus through decomposition of organic materials.

Soil management, soil carbon and LIFE

Soil management practices can have an important impact on soil carbon stocks. The ClimSoil Final Report identifies a range of currently available soil management strategies that it would be feasible to implement within all land use categories – cropland, grassland, forest lands and cultivated peat soils and lightly-managed or unmanaged heathlands and peatlands (see box).

Although few LIFE Environment and LIFE Nature projects specifically cite soil management as an aim, many projects have implemented the type of land use and site conservation strategies identified in the ClimSoil report, potentially contributing to increased carbon sequestration, although this has not been measured.

Extensive agriculture and carbon storage

In general, any LIFE projects that contain measures to farm habitats extensively rather than intensively will contribute to some extent to the increase of the carbon stock in soils within the project sites. Many LIFE Nature projects targeting the restoration of traditional grasslands, wet meadow and woodlands have thus indirectly helped boost carbon sequestration. These include projects that create grassland habitats on arable land using seeding or hay transfer, with subsequent mowing or extensive grazing to maintain the habitat; those that develop woodland habitats through land use abandonment, which allows spontaneous succession; and those that extensify croplands and grasslands.

Examples include the Hungary Egyek-Pusztákocs project (**LIFE04 NAT/HU/000119**), which restored some 750 ha of steppic grasslands. In Italy, the ongoing project LIFE MAGREDI GRASSLANDS (**LIFE10 NAT/IT/000243**) is producing seeds and plants of typical native species in a nursery to help speed up the restoration of Eastern sub-mediterranean dry grasslands in the Friuli lowlands of north-east Italy and to connect isolated patches of the target habitat into a network of grasslands. Other results are expected to include soil preservation, carbon storage, an enhanced landscape for tourists and improved awareness. An earlier Belgian-led project (**LIFE99 NAT/B/006296**) recovered wet ecosystems in Belgium and the Netherlands and encouraged farmers to use grasslands in a more

Currently available soil management strategies for increasing carbon storage

- On cropland, soil carbon stocks can be increased by (i) agronomic measures that increase the return of biomass carbon to the soil, (ii) tillage and residue management, (iii) water management, and (iv) agro-forestry;
- On grassland, soil carbon stocks are affected by (i) grazing intensity, (ii) grassland productivity, (iii) fire management and (iv) species management;
- On forest lands, soil carbon stocks can be increased by (i) species selection, (ii) stand management, (iii) minimal site preparation, (iv) tending and weed control, (v) increased productivity, (vi) protection against disturbances and (vii) prevention of harvest residue removal;
- On cultivated peat soils the loss of soil carbon can be reduced by (i) higher ground water tables and (ii) conversion of arable land to grassland; and
- On less intensively managed or unmanaged heathlands and peatlands, soil carbon stocks are affected by (i) water table (drainage), (ii) pH (liming), fertilisation, (iii) burning and (iv) grazing.

sustainable way. Although carbon sequestration is one outcome, this was not a direct aim of the project or a follow-on LIFE project in 2003.

It is also important to note the positive - and again indirect - impact on carbon storage in soils from projects focusing mainly on the improvement of bird populations listed in the EU Birds Directive. In order to provide better conditions for nesting or feeding, LIFE Nature projects have converted large areas of intensive agricultural land to low production sites with higher biodiversity and little or no use of fertilisers and pesticides, as well as transforming arable land to fallow land or grassland. For instance, the OTISHU project (**LIFE04 NAT/HU/000109**) converted more than 840 ha of intensively-used arable land in Hungary to low-production sites in order to improve the conservation status of the great bustard (*Otis tarda*). An ongoing project in Germany, Wachtelkönig & Uferschnepfe ("Corncrake & Black-tailed godwit") – **LIFE10 NAT/DE/000011**, is currently working to extensify more than 620 ha of intensively-farmed land to improve the nesting habitats of a number of meadow bird species with expected positive effects on soil carbon contents.

Conversion and restoration of forests

Even though the extent of the effect of tree species across various forest site types has not yet been fully clarified, there is evidence that forest stand management may influence the carbon sequestration of forest floors. Scientists believe that selective harvesting linked with reduced removal of harvest residue biomass and dead wood may decrease soil carbon losses compared with clear-cut harvesting. Studies comparing site preparation methods have found that the loss of soil carbon increased with the intensity of the soil disturbance.

A number of LIFE Nature projects have taken steps to convert intensive forest monocultures into close-nature forests stands with low disturbance and high species diversity, such as LIFE to Koli (**LIFE03 NAT/FIN/000035**). In Austria, the recently-commenced project LIFE-Ausseerland (**LIFE12 NAT/AT/000321**) is transforming some 2 600 ha of spruce-dominated montane forests to improve their ecological diversity. The Kinnekulle project (**LIFE02 NAT/S/008484**) designated forest habitats on a plateau mountain in Sweden as nature reserves or biotope reserves and introduced long-term management measures in co-operation with landowners, the local community and other interested parties. As a result, some 400 ha of forest were purchased or brought into conservation agreements with their owners, whilst a further 600 ha of grasslands and wooded pastures will be restored to native forest habitats.

Photo: ASTRALE EEIG/Jon Eldridge

One of Salzburg's few remaining manual peat digs can be found in Weidmoos. Today, peat is mainly dug from the site for personal use

These and other LIFE forest restoration projects have not only enlarged areas of target forest habitats, they have also changed management methods, reducing interference with soil and thus aiding carbon sequestration. Carbon storage generally increases on sites where forests have been re-established by LIFE projects on bare mineral soils after intensive agricultural use.[16] Examples include the 3 Bossen Vlaamse Ardennen project (**LIFE00 NAT/B/007156**), which implemented an action plan for the conservation and restoration of three woods in the Flemish Ardennes in Belgium.

Wise use, restoration and conservation of peatlands

Whilst many LIFE Nature projects are unable to quantify their (potentially substantial) contribution to soil carbon sequestration, an exception are those projects that focus on the restoration of mire and peatland habitats, as a result of the specific character of their organic carbon-rich soils.

In their natural state organic soils in mires and other wetlands represent a carbon sink. Dead plant material from mosses, sedges or reeds are not fully biologically decomposed and accumulate in peatland resulting in soil with a high carbon content.

16 Soil carbon sequestration can be achieved by increasing the net flux of carbon from the atmosphere to the terrestrial biosphere For soil carbon sinks, the best options are to increase carbon stocks in soils that have been depleted in C, i.e. agricultural soils and degraded soils, or to halt the loss of C from cultivated peatlands (Smith et al., 2007)

These carbon deposits (peat) are primarily in danger of being released by changes in the water balance. When drained, often accompanied by the use of fertilisers, the microbial degradation of the organic material and the release of greenhouse gases such as CO_2 and nitrous oxide (N_2O)[17] go unhalted. The carbon release rate depends strongly on the kind and intensity of land use. For example, the release of CO_2 from tillage on fens is 41 tonnes/ha, more than twice the rate of fens used as meadows (15-17 tonnes/ha)[18].

Although there are still gaps in information on land use in peatlands, an estimated 15-20% of the total peatland area within Europe has been drained for agriculture, with as much as 75-80% of peatlands in the Netherlands, Germany and Poland drained for this purpose. A further 28% of the total area has been drained for forestry. This is important because the largest emissions of CO_2 from soils result from land use change and related drainage of organic soils (see Table 1).

17 The impact of 1 pound of N_2O on warming the atmosphere is over 300 times that of 1 pound of carbon dioxide. Nitrous oxide molecules stay in the atmosphere for an average of 120 years before being removed by a sink or destroyed through chemical reactions. Globally, about 40% of total N_2O emissions come from human activities. Nitrous oxide is emitted from agriculture, transportation, and industry activities.

18 (Oleszczuk et al., 2008).

Total CO_2 emissions from degraded peat in Europe are an estimated 383 million tonnes/yr, of which 240 million tonnes/yr comes from peatlands drained for agriculture. Recent assessments show that it is possible to reduce these emissions by 35% through implementation of already-technically-possible land-use changes (see box).

It is important to distinguish between two types of peatland - fen habitats, which have been drained for crop production or intensively-farmed livestock; and nutrient-poor raised bogs and blanket bogs, which are drained for peat-cutting and forestry.

LIFE projects have targeted both fen and bog (including bog woodland) habitats. Common features of LIFE Nature projects targeting these disparate mire habitats focus on satisfactory re-wetting of the drained sites to stop peat oxidation and to support the re-establishment of peat-producing vegetation; and the introduction of suitable land use practices that reduce peat decomposition and carbon loss.

The importance of re-wetting needs to be emphasised: satisfactory water saturation of the drained organic soils is not only an indispensable pre-requisite for the restoration of the plant communities or the long-term conservation and development of peatland

Table 1 – Qualitative characterisation of the influence of different management practices on the principal compounds of peatland functioning

	Water level	Plan composition on the surface	Nutrients	Peat deposit C-store
Preparation for Forest introduction and peat-cutting	Moderate to severe drainage	Normally still untouched but changing due to changed water level	Mineralisation - but no input of fertilisers	Moderate loss
Forest	Moderate to severe drainage	Introduction of free species, partial removal of original vegetation	Mineralisation - only limited input of fertiliser (Limiting?)	Moderate to severe change – C store shifts from Peat (loss) to Biomass (gain)
Grassland	Severe drainage	Original vegetation removed, introduction of productive grass-species	Nutrient input as fertilizer at high levels	Fast loss
Arable	Severe drainage	Original vegetation removed, introduction of productive field species	Nutrient input as fertiliser at high levels	Very fast loss, because of enhanced aeration of the peat via ploughing. Fertilisation may also accelerate decomposition
Peat cut	Severe drainage	Original vegetation totally removed	Mineralisation but no input of fertiliser	Peat removed - immediate loss
Abandonment after peat cut	Drainage remains active over long periods	Succession of mostly woody species that are tolerant to water stress	Mineralisation but no input of fertiliser	Constant loss at moderate to fast rates
Restoration	Rewetting or even flooding	Succession or introduction of matrix species, establishment of original vegetation needs time	Aerobic mineralization limited or stopped depending on water level	Loss reduced or stopped – new build-up depends on species, water level and nutrients – and on time

species, it is also essential to be able to turn - in the long term, since these processes are measured in decades and centuries - the degraded organic soils from a carbon source back to a carbon sink.

Different techniques are needed to ensure the adequate and stable re-wetting of bog and fen habitats. Re-wetting of rain-fed raised bogs and blanket bogs involves the closure of drainage ditches and/or construction of retention dams combined with the removal of encroaching shrubs and trees on originally-treeless habitats. The re-wetting of groundwater-fed fens is more complicated. Numerous fen habitats have been progressively degraded because of successive drop off of the groundwater in the catchment area. Hence, in addition to closing drainage structures it is necessary to remove tree plantations in catchment areas, actively lead in surface waters or remove topsoil to reduce the distance to the groundwater. The latter measure, implemented on sites after intensive agricultural use, also efficiently reduces nutrient loads, which is often crucial for the re-establishment of the target vegetation.

From 2000 to 2013, 49 LIFE Nature projects focused on the restoration of degraded raised bogs, primarily in northern Europe (including 11 projects in Germany, nine in Latvia and seven in Belgium). Examples include LIFE Best Award-winners RERABOG-DK from Denmark (**LIFE05 NAT/DK/000150**) and Restoring raised bogs in Ireland (**LIFE04 NAT/IE/000121**). The ongoing German project Hannoversche Moorgeest (**LIFE11 NAT/DE/000344**) is aiming to optimise the hydrological balance in four large raised bogs north of Hannover to guarantee the ecological status (and carbon sink capacity) of 500 ha of active raised bogs and transition mires naturally free of forests and some 1 000 ha of typical bog woodlands, some of which are rich in peat moss.

A total of 16 LIFE Nature projects have carried out actions to restore blanket bogs, mainly in the UK and Ireland. For instance, a project in Scotland (**LIFE00 NAT/UK/007075**) removed commercial forestry from 1 556 ha of land that had previously been blanket bog and through hydrological works benefited the condition of more than 16 600 ha of peatland.

There have been 365 LIFE Nature projects that have directly or indirectly targeted fen restoration. Notable examples include LIFE FRIULI FENS (**LIFE06 NAT/IT/000060**), a LIFE Best Nature project 2012. In Germany, two projects (**LIFE98 NAT/D/005085** and **LIFE02 NAT/D/008456**) restored 2 200 ha of the Western Dümmer, a stopover area for migratory birds, by re-wetting drained degraded fen peatlands. The Hungarian project Grass-Tapolca (**LIFE06 NAT/H/000102**) led in surface water in two re-wetting channels to improve the hydrology of more than 100 ha of Molinia fen meadows.

Photo: LIFE05 NAT/DK/000150

Re-wetting a bog enables degraded organic soil to be converted from a carbon source to a carbon sink

Monitoring gap

We have already highlighted the fact that LIFE Nature projects have rarely measured the impact on soils of their actions. This also applies with regard to carbon storage[19]. Direct monitoring of the effects of re-wetting and mire restoration on carbon sequestration requires the use of specific techniques (e.g. close-chamber techniques and Eddy-covariance methods) and a series of long-term measurements. This is beyond the scope and time-scale of individual LIFE projects. However, in the meantime scientists have developed calculation models that would enable assessments of the contribution of LIFE Nature projects implemented on peatland sites to the reduction of carbon loss from Member States' organic soils. This could be a valuable exercise. It is clear that monitoring actions would be valuable if carried out more extensively in future LIFE projects.

Implementing new farming techniques

Soil management is one of the best tools for carbon storage. For example, no-tillage accompanied by crop residue management in the form of crop resi-

19 One exception is the Active Blanket Bogs in Wales project (LIFE06 NAT/UK/000134). Indeed, monitoring has also continued after LIFE: http://www.blanketbogswales.org/science/ukpopnet_212.html

dues left on the soil surface have the effect of reducing and slowing the decomposition of plant matter, which promotes the storage of CO_2 fixed in the plant as carbon and returned to the soil as plant debris.

The LIFE Environment strand of the programme has funded many projects that have encouraged better farming practices and which also have the potential to increase carbon storage and soil organic matter levels. Methods used have included organic farming and conservation agriculture practices (e.g. reduced or no tillage, crop rotation and cover crops).

Later projects that have focused on soil directly have not only demonstrated improvements in agricultural practices but have also taken steps to measure the amount of carbon that is sequestered in the soil along with the organic matter increase. These projects either have demonstrated ways of improving farming techniques (e.g. pruning, crop cover, returning organic matter to the parcel soil) as in the oLIVE-CLIMA project (**LIFE11 ENV/GR/000942**), or they have demonstrated on-farm composting facilities that promote the valorisation of residual biomass from local agricultural activities (CarbOnFarm - **LIFE12 ENV/IT/000719**).

These projects have also developed methods to determine and calculate the carbon that is fixed in the soil. In one case, a soil carbon dynamics model that is adapted and calibrated to local conditions was created. This will demonstrate that farming practices can be linked to increases or decreases in the carbon content of soil. This could, potentially, be used as a basis for the expansion of the EU's emissions trading scheme (ETS) to agriculture. In the other instance, monitoring will be carried out to determine the soil organic carbon sequestration potential of agro-ecosystems. It is expected that results will support the technical and political commitments required for mainstreaming sustainable soil use methods for the improvement of soil organic matter in farm soils.

Conservation agriculture helps to minimise the carbon losses from farming techniques

Photo: LIFE08 ENV/E/000129

A number of projects used conservation agriculture methods to minimise carbon losses from farming practices. Tillage practices that involve periodic and extensive soil disturbances accelerate both carbon and nutrient cycling, resulting in a decrease in soil organic matter, reduced micro-organism biomass and loss of carbon. The LIFE projects demonstrating conservation agriculture have all experimented with low-tillage techniques and in one case, the SOWAP project (**LIFE03 ENV/UK/000617**), swapped ploughs for zero-till or non-inversion tillage. The project did not measure carbon sequestration, although it did highlight the additional business opportunities available to farmers embracing conservation tillage techniques, such as through carbon trading schemes.

More recent projects are trialling other good practices aside from zero or minimum tillage techniques and are measuring the carbon being sequestered under different climatic and agricultural conditions. In one project (REGEN FARMING - **LIFE12 ENV/ES/000232**) regenerative practices for soil conservation in pasture management will be used with the aim of increasing carbon fixation in grasslands by 10%. It will also develop cheap diagnostic and monitoring tools to evaluate soils, such as Agroecosystems' Health Cards (TSAs) and chromatograms.

Comparisons and measurements in terms of carbon fixation of a variety of different conservation agriculture techniques have been made in 20 different areas in Spain to determine best practices with regards to carbon capture in soil (AGRICARBON - **LIFE08 ENV/E/000129**). This project has also assessed how much carbon these practices fix over time according to soil type, type of agriculture and climatic conditions, with results indicating that carbon fixation is highest in the first 10 years and decreases thereafter.

The work of AGRICARBON and another Spanish project, AgriClimateChange (ACCÍON AGRICLIMATICA – see pp. 35-36) has led to their inclusion in the Spanish Survey of Surfaces and Crop Yields (ESYRCE) and is feeding into new legislation for measures supporting the implementation of conservation agriculture.

SOIL CARBON CAPTURE

Helping agriculture improve **carbon storage**

Outcomes from a LIFE project promoting climate action on farms demonstrate how LIFE can be used as an effective mechanism for orchestrating positive changes in policies affecting soil quality covering the entire EU.

Many LIFE projects are credited with making a difference to soil quality at local levels. The programme also offers Member States and environmental organisations useful opportunities for highlighting techniques, methodologies and tools that can be replicated around the EU, producing soil management results with a far wider reach.

Partners from the AgriClimateChange project (**LIFE09 ENV/ES/000441**) have used their LIFE co-finance to set in motion such achievements. Findings from the project's work (developing realistic systems for improving the carbon storage capacity of agricultural soils and reducing greenhouse gas emissions from farms) have attractive interest and support from highly influential bodies such as the European Commission's DG Agriculture and Rural Development (DG AGRI).

María Fuentes, DG AGRI's climate change project officer has followed the AgriClimateChange project closely and is particularly pleased with the practicality of its results. These include a specialised AgriClimateChange tool (ACCT) that assesses the carbon footprint of individual farms in order to provide a dedicated plan of action for each farm to improve its climate impact.


Photo: Jordi Domingo

A rice farm in Albufera (Valencia, Spain) has adopted best practices to reduce GHG emissions and improve soil carbon storage

These action plans are designed to formulate an agreed set of measures that can be applied on the farm. All the measures are site-specific and cover different activities, such as modernising crop production processes to boost soil's natural carbon storage functions and/or mitigating causes of climate change via, for example, low tillage techniques to reduce fossil fuel consumption by agricultural machinery.

An important aspect of the action planning process involves clarifying and quantifying the economic benefits to individual farms from adopting environmental improvements. A multi-lingual manual has also been prepared by the project team to facilitate knowledge transfer about how ACCT can be used by those with an interest in farm soils and agricultural carbon footprints.

Referring to LIFE's work in validating the relevance of ACCT for the EU28, Ms Fuentes says, "Projects like AgriClimateChange contribute in an effective way to a greater awareness of the issues and possible solutions, as well as sharing experiences in different contexts and farming systems. This manual proves that

Photo: ASTRALE EEIG/Tim Hudson

Knowledge transfer about soil conservation techniques was an important part of the LIFE project's activities

actions are possible and viable, showing some levers to mobilise and put forward successful initiatives. It contributes to the dissemination of information and climate-friendly farming practices in order to support sustainable growth."

Soil levers

A number of other RDP levers also exist as incentives to encourage Member States to make greater use of the LIFE project's toolkit. ACCT measures such as agro-forestry, cover crops, and extended rotations to increase carbon storage and reduce emissions from erosion are all eligible for RDP support. The reach and range of these actions can also be expanded by an increased emphasis within Pillar II on collective and territorial approaches to agri-environment action.

This could enable ACCT to be applied on a territorial scale by groups of farmers who can access RDP aid to set up and operate as 'producer groups' of 'environmental services'. ACCT's ability to improve the competitiveness of farms in these 'producer groups' further substantiates its usefulness as a rural development tool.

RDP managing authorities are also being asked to design support in ways that create synergies from packaging RDP measures, and there will be a greater emphasis on focusing RDP funds on projects that provide measurable results. ACCT complements these strategic policy goals well since packages of RDP support can be designed whereby funds for training and advisory services (in how to use ACCT) can accompany funding for the environmental and modernisation investments identified in ACCT's farm action plans.

ACCT's ability to quantify improvements in an individual farm's carbon footprint will also be seen as advantageous by RDP authorities tasked with improving the results-oriented characteristics of CAP support.

Growing uptake and support

Considering the clear benefits from this LIFE project it is not surprising that farmers themselves are also very interested in ACCT. Positive feedback was widespread amongst the 120 farms (from France, Germany, Italy and Spain) participating in trials of the tool. What's more the EU's leading agricultural lobby group, Copa-Cogeca, also appreciates the possibilities of the ACCT.

Speaking to delegates at this LIFE Environment project's closing conference, Antonia Andugar from Copa-Cogeca welcomed the progress made by ACCT. She also confirmed that her organisation is keen to see how this tool can be used to help better balance commercial and environmental drivers that influence the land/soil use practices of the 30 million European farmers that Copa-Cogeca represents.

Such support from high-level agricultural bodies can be considered a worthy accolade for AgriClimateChange's achievements. It reflects well on the efforts, innovation and commitment of the project team. In addition it highlights the LIFE programme's potential for making a real contribution to Europe's strategic goals concerning soils and climate action.

Project number: LIFE09 ENV/ES/000441

Title: ACCIÓN AGROCLIMÁTICA (AgriClimateChange) – 'Combating climate change through farming: application of a common evaluation system in the 4 largest agricultural economies of the EU'

Beneficiary: Fundacion Global Nature

Contact: Jordi Domingo
Email: jdomingo@fundacionglobalnature.org

Website: http://www.agriclimatechange.eu
Period: 01-Sept-2010 to 31-Dec-2013
Total budget: €1 589 000
LIFE contribution: €794 000

SOIL MONITORING

Supporting **soil monitoring** techniques

LIFE projects have helped address soil monitoring challenges identified in the Soil Thematic Strategy, funding new decision-support tools and innovative monitoring methods and providing information concerning soil conditions within regional or national programmes

One of the central pleas of the EU Soil Thematic Strategy (STS) is to harmonise soil monitoring methodology across Europe. The STS calls for the adoption of standardised methods and procedures, for example, to create comparability amongst Member States and Accession Countries for the three main types of soil information: mapping, inventories and monitoring systems. Soil surveys and soil mapping are well-established methods of classifying soil types, mainly for agricultural purposes; soil inventories organise soil information in databases using GIS technology; whilst soil monitoring looks at changes in soil parameters over time. However, a recent European Commission report[20] stated that, "some seven years after the adoption of the STS, there is still no systematic monitoring and protection of soil quality across Europe."

EU Member States' soil monitoring programmes vary because they were designed for different objectives and are often not integrated with other information sources. A more harmonised approach would increase the value of national programmes to European-wide soil information systems, such as the European Soil Information System (EUSIS) and the Land Use/Cover Area frame Statistical Survey (LUCAS), and vice versa.

20 'The Implementation of the Soil Thematic Strategy and on-going activities,' European Commission, COM(2012) 46 final.

LIFE and soil monitoring

Relatively few (16) LIFE projects have addressed soil monitoring, with the greatest frequency in 2006-2007, around the time of the adoption of the STS. Half of the projects have taken place in Mediterranean countries and soil contamination has been the main threat monitored.

Soilpro monitors the effectiveness of the measures applied in the Sicilian region

Photo: LIFE08 ENV/IT/000428

Photo: LIFE10 NAT/ES/000579

LIFE has developed monitoring tools for farmers to assess their impact on soil biodiversity and on agro-ecosystems

LIFE Third Country funding helped Malta and Croatia establish national soil monitoring programmes prior to EU accession. The Maltese project, MALSIS (**LIFE00 TCY/M/036**) increased the nation's technical competence in soil monitoring techniques and led to the development of a computer-based soil information system that was later harmonised with EUSIS. This system also helped the team draw up a code of good agricultural practice to reduce nitrates in groundwater

The Croatian project, Soil Monitoring (**LIFE05 TCY/CRO/000105**) established the first systematic measurement of soil parameters on a national scale. Information on land use (e.g., agriculture, forestry) was harmonised with EU standards and stored on a GIS database system. In a pilot study, the system was used to monitor soils contaminated by oil wells and leaky oil pipelines.

Support for decision-makers

So far, the LIFE programme has funded three projects that have adopted general strategies on soil conservation and monitoring, all in Italy or Greece and all since 2007 - Soil Sustainability (So.S) (**LIFE07 ENV/GR/000278**), SOILCONS-WEB (**LIFE08 ENV/IT/000408** - see pp. pp. 20-21) and SOILPRO (**LIFE08 ENV/IT/000428**).

Notwithstanding different methods, all three projects aim to help transfer knowledge from the scientific community to the local and regional authorities (LRAs) who are responsible for land and soil management but often lack the tools and know-how to take informed decisions concerning landscape planning, spatial planning and soil.

By identifying areas of risk within their respective pilot territories and creating tools or Soil Action Plans to implement appropriate measures the projects aid LRAs and other stakeholders in their decision-making.

The Greek So.S project sought to adopt and apply the provisions of the STS at river basin scale (the Anthemountas river basin near Thessaloniki), enhancing sustainable soil management through the development of a soil protection action plan and decision-support tools for farmers and local authorities. The project team monitored soils to prevent the risks of erosion, organic matter reduction, salinisation, contamination and sealing. Simple methodologies were applied to identify soil status in relation to the risks. These were then used to develop user-friendly decision-support tools for soil erosion and soil contamination from point sources. Ad hoc surveys were carried out to address a lack of baseline data (a common problem for soil-related projects). The So.S team implemented a programme of field sampling and laboratory analysis, and created a soil map and other thematic maps about soil-specific characteristics.

The two Italian projects focused on the development of web-based decision-support systems. The WS-DSS tool being developed by SOILCONS-WEB will target different stakeholder groups (urban planners, olive and wine producers) with relevant web-GIS-based information that will improve decision-making on soil and landscape conservation issues.

SOILPRO developed a tool called Soil Monitoring Software - SMS - to help LRAs effectively monitor, identify and assess areas at risk of soil degradation. Behind a web-based interface, there is a database that enables the user to determine soil conditions and threats to soil quality. The project brought together a public authority and a scientific institution to ensure that the database behind the tool was robust and would continue to be updated after LIFE.

Monitoring diffuse soil pollution

Other LIFE projects have focused on the management and monitoring of a single soil threat such as

loss of soil biodiversity or organic matter content, or soil degradation linked to nutrient, pesticide and herbicide applications from agriculture. Monitoring of such diffuse inputs is expected to help farmers to adopt Good Agricultural Practices (GAP).

LIFE projects have produced tools for farmers for monitoring. Some of those monitoring systems serve farmers to detect nutrient accumulations in their soils caused by nitrate and phosphate leaching (DEMETER - **LIFE10 ENV/BE/000699**), other systems monitor several basic chemical parameters to assess the quality of soils and waters affected by contamination from phenolic compounds and organic acids in olive waste, which are spread on soil as a means of disposal (PROSODOL - **LIFE07 ENV/GR/000280**).

All the projects developing monitoring systems in this area have also translated them into tools that can be used easily by different stakeholders. The DEMETER team created a decision-support tool for nutrient and soil organic matter management that will guide farmers towards good soil management practices. In PROSODOL, the monitoring system identifies likely results of olive waste disposal activity in the target area; information that can help public and private sector users to evaluate the degree of risk.

In one other case (the OptiMaN project - **LIFE04 ENV/IT/000454**), a monitoring network was developed to track nitrogen availability in the soils of farmlands and send farmers real-time information on soil nitrogen levels. One of the advantages of this approach is that it not only gives an idea of soil contamination, it also highlights groundwater quality, thus tackling a wider range of environmental issues linked to diffuse pollution from farming practices.

Monitoring for biodiversity

Current methods for the assessment of soil conditions can only provide "static" physical/chemical/biological reports about the status of soil at a given moment, upon which only short-term interventions can be based.

Biodiversity is an important indicator of a soil's ability to provide ecosystem goods and services. Abundant microfaunal and microbial communities with high biodiversity are association with healthy soils, often fertile soils of high organic matter content.

Three LIFE projects - MEDAPHON (see pp.27-28), BIOTAGENE (**LIFE08 ENV/EE/000258**) and BIOREM (**LIFE11 ENV/IT/000113**) - have developed or are developing novel methodologies to monitor soil biodiversity, through counting of organisms and molecular profiling.

The BIOTAGENE team developed an innovative monitoring method to characterise the genetic information contained in the DNA and RNA of microbes or other soil organisms. Soil microbiota are analysed at the metagenome level to determine soil status and biodiversity. The ongoing BIOREM project is developing an innovative system for dynamic monitoring of soil, which could prove extremely useful for the development of precisely targeted, far-sighted restoration and development strategies and policies. Operating at the molecular level, the project aims to characterise the biochemical profile of the soil and, by detecting and evaluating the presence and status of enzymatic processes, achieve advanced soil assessment.

Monitoring in the future

As we have seen, only a few LIFE projects to date have focused on general strategies for soil conservation and monitoring in order to map a whole area and provide a baseline inventory. The other soil monitoring projects have produced single tools for monitoring soil from agricultural contaminants in order to improve soil quality and organic matter.

Although the general strategy was lacking, the tools these projects have created are of use to planners and policy-makers. Indeed, it would be beneficial if there were more LIFE projects that focused on knowledge transfer and that led to better cooperation between the soil science community, local authorities and other stakeholders, such as farmers. There is an unmet need for means of converting soil data and maps (at national as well as regional/local level) into user-friendly tools that enable effective monitoring and allow key stakeholders to base decisions on the ground on scientific knowledge.

The fact that very few LIFE soil quality monitoring projects have considered soil biodiversity is consistent with wider trends. The current situation in Europe is that despite there being a number of soil monitoring networks, the vast majority of these are not measuring soil biodiversity. This could be another area for future project proposals aimed at making these tools readily available to LRAs and other users.

Photo: LIFE08 ENV/H/000292/Miklós Dombos

Using probes to measure the soil biodiversity of arable land

WATER AND SOIL

Addressing **soil and water challenges** simultaneously

LIFE projects have demonstrated the importance of connecting the practical application of soil and water policy.

The water household of soils (i.e. an account of all quantities of water added, removed or stored in a given volume of soil) plays a crucial role for ecosystem services such as water retention for agriculture, flood control in flood prone areas or the provision of drinking water. The degradation of soils as a consequence of human activities has negative implications for the quality and quantity of the water stored in soils, with potentially significant ecological and economic consequences.

An understanding of the hydrological cycle is essential for the effective management of rainwater and soil water - the water that infiltrates in soil through rainfall or other sources.

Establishment of riparian vegetation on the banks of the Fontana Mora (Italy)

Photo: LIFE09 NAT/IT/000093

Environmental balance

LIFE Environment projects can be grouped in different categories with regard to their impact on the water cycle.

The soil sealing chapter (pp. 13-21) provides an in-depth look at some of the blue and green infrastructure innovations trialled by LIFE in urban areas across Europe to mitigate the effects of surface run-off and low infiltration capacity. Techniques demonstrated include rainwater harvesting and re-use, creation of permeable structures to avoid sealing, construction of canals and reservoirs for water collection, Sustainable Urban Drainage Systems (SUDS), green roofs and rain gardens. Some projects utilised a single technique, whilst others incorporated a range of solutions. Results from projects indicate methods used have helped reduce flooding risks, surface run-off and pollution (less wastewater treatment), as well as saving water by replenishing aquifers and using rainwater for garden irrigation.

Water and soil contamination

As the sustainable agriculture and land contamination chapters (pp. 42-57) illustrate, whether from point source or diffuse pollution, it is impossible to address contaminated soil without also addressing water contamination. Numerous LIFE projects have recognised the inter-relationship between soil

functions and the water quality and targeted improvements in both through the application of novel bioremediation techniques.

All such techniques co-financed by LIFE, especially those that had a pre-emptive nature, also had the aim of restoring soil properties (such as pH, organic carbon content, microbial biomass and enzymatic activities) that have a beneficial effect on soil's water retention capacity and the infiltration rate of water, with benefits to the whole water cycle.

One of the achievements of LIFE has been to tackle water and soil pollution from diffuse agricultural activities at river catchment level through the introduction of buffer zones, riparian vegetation, grasslands or bio-geochemical barrier. However, with the exception of projects such as M^3 (**LIFE07 ENV/L/000540**), which analysed soil water as part of an innovative system for assessing the strength of pollution and eutrophication in waters, there has been little measurement of projects' impact on soil quality.

River restoration and wetlands

Land-use practices, combined with heavy rain and poor soil conditions can lead to soil erosion and contribute to the sedimentation of eroded soils in rivers and wetlands. Soils washed from exposed sites during heavy rains increase turbidity, transport pollutants, and generally degrade water quality.

A number of LIFE projects that implemented River Basin Management Plans (a requirement of the Water Framework Directive (2000/60/EC) designed to achieve the good ecological status of Europe's waters) have introduced good practices to help counter soil erosion, such as restoring buffer zones of native riparian vegetation next to water bodies. These pollutant traps help reduce run-off, snagging sediments and protecting surface waters from contamination. The roots of the plants also bind soil together and stop it being washed away. Projects of this kind have included Ythan Project (**LIFE00 ENV/UK/000894**), Odense PRB (**LIFE05 ENV/DK/000145**) and EH-REK (**LIFE08 ENV/PL/000517**). Other LIFE projects have targeted changes in farming techniques as a means of reducing erosion, run-off and water pollution, whilst maintaining yields.

Wetlands have an important role to play in providing natural water retention measures that regulate the water cycle, in contributing to Europe's "green infrastructure" and in delivering such ecosystem services as water purification and provision. They also maintain soil functions. Soil processes are particularly important as soil organic matter, texture, and other properties are directly linked to critical wetland functions such as water quality improvement.

Socio-economic pressures (drainage for agriculture or housing, industrialisation) have led to a deterioration of many of Europe's wetlands. A host of LIFE Environment and LIFE Nature projects have taken steps to restore wetlands, whether to improve water quality and water retention capacity or for the purposes of conserving protected species or habitats. The range of cost-efficient methods used has been of great benefit to the soil-water household.

In addition to bogs and fens, LIFE projects have restored other types of wetlands, such as floodplains and riparian areas. They have also helped re-establish the natural erosion of river beds and the natural hydromorphology of rivers, through measures such as re-meandering, river widening and the connection of side channels, oxbows and standing waters. This is has not only contributed significantly to the development of an EU framework for green infrastructure at the same time as improving the ecosystem services provided by the rivers and floodplains targeted, it has also restored the hydrological processes of the floodplains and rivers – which entails restoring the functions of soils.

River restoration projects such as Walphy help to reduce flooding and erosion and improve water and soil quality

Photo: LIFE07 ENV/B/000038/A. Peeters

Outcomes of measures introduced by projects such as LiRiLi (**LIFE02 ENV/A/000282**), Ythan Project, Walphy (**LIFE07 ENV/B/000038**), Inhabit (**LIFE08 ENV/IT/000413**) and a series of restoration projects along the Danube and its tributaries in Austria, have helped reduce the threat of flooding, limit siltation and erosion and improve water and soil quality.

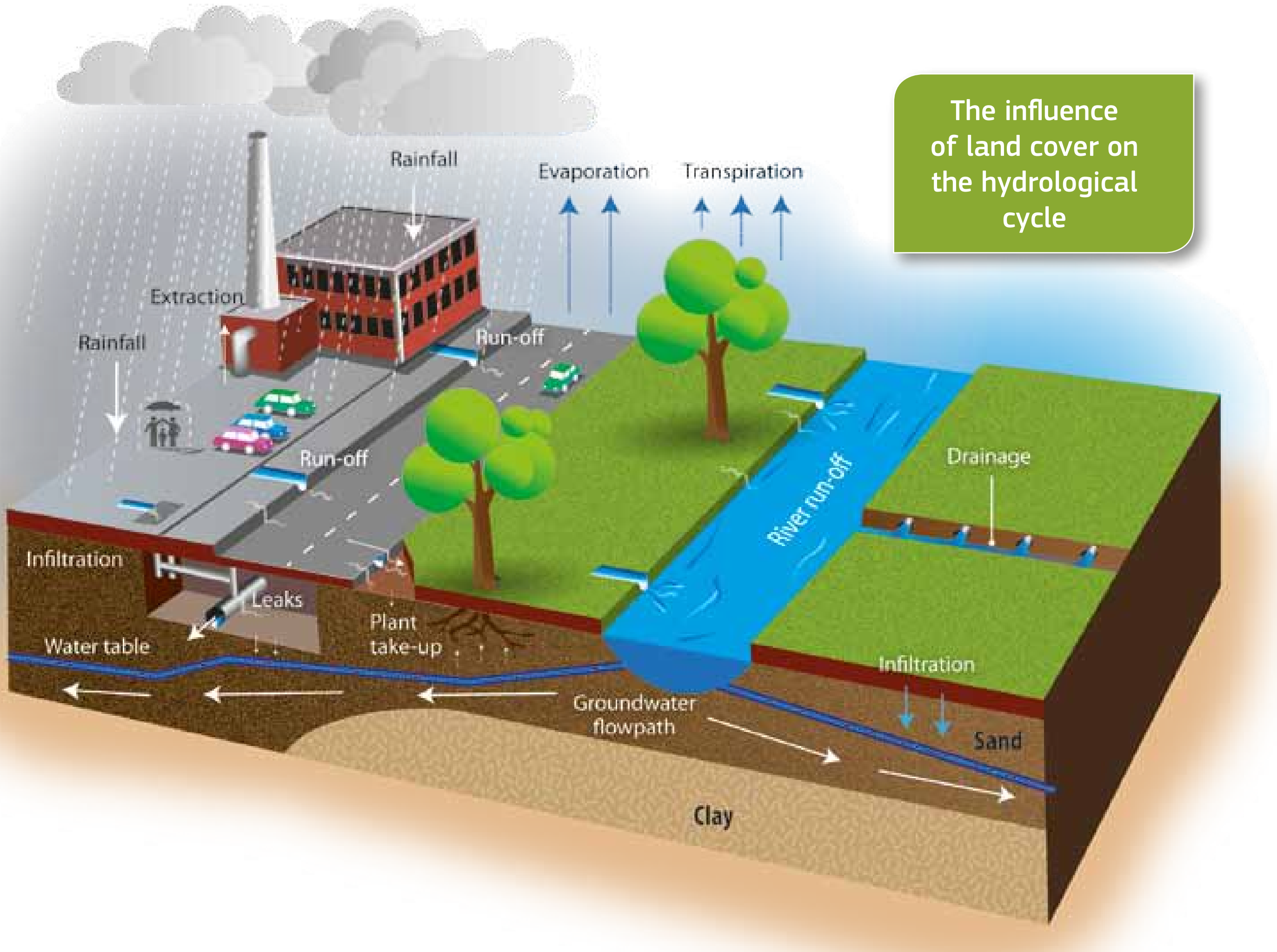
Numerous LIFE Nature projects have focused on the improvement or restoration of alluvial and riverine habitats that are affected by channelling water courses, deforestation of alluvial forests and intensification of agrarian use.

The essential prerequisite of the restoration of these habitats is the rehabilitation of the hydrological regime. This is achieved mainly by restoration of the natural water course, allowing periodic flooding, as well as by various rewetting measures, e.g. building dams and sluice gates. Only measures that allow the successful rehabilitation of the key physical and hydrological functions of the soils will guarantee the successful ecological restoration of the target vegetation and fauna. In other words: to provide satisfactory and sustainable results, restoration of biodiversity must imply also the rehabilitation of soils and water functions of the respective sites. By taking such a holistic approach, these LIFE Nature projects allow the improvement of a multitude of ecosystem services, such as the retention of water, ground water recharge and reduction of flood risk.

Peatland and grassland restoration

Improvement of soils and soil hydrology is the main focus also for LIFE Nature projects dealing with peatland restoration. There are numerous rare or endangered habitats listed in Annex I of the Habitats Directive that are linked to hydromorphic soils (peat and other organic soils), such as *Molinia* meadows, raised bogs, mires and fens and bog woodland.

The conversion of natural peatlands to land used for agriculture, forestry or peat cutting has led to a significant drop in the water table of many European organic soils. The lowering of the water table, combined with non-natural fluctuation, leads to secondary soil development (shrinkage, aggregation and earthification of the peat), which has serious negative implications for the ability of the soil to allow



The influence of land cover on the hydrological cycle

water infiltration and storage. Open oxidised organic soils are susceptible to water and wind erosion. Reduced infiltration and lowering of the surface by peat subsidence enhances the risk of flooding and longer-lasting accumulated water on the surface. Drained peatlands lose their ability to store and slowly release water, thus further increasing the occurrence and magnitude of droughts or flood events.

As with alluvial habitats, the re-establishment of the hydrological regime is an essential pre-condition for the successful and stable improvement of the conservation status of degraded peatland sites. Technical measures vary depending on the hydro-genetic mire types and the extent of degradation, but may include closing ditches, building retention dams, redirecting surface water or removal of topsoil. Conditional on the restorability, successfully rehabilitated peatlands again can provide their numerous ecological services, including water retention and storage, reduction of floods and droughts, improved ground and surface water quality in the catchments and carbon sequestration (see pages 27-34).

Restoration of species-rich natural grasslands on arable land also has substantial positive implications for soil health and hydrology. The main objective of the relevant LIFE Nature projects has been to improve the conservation status of the targeted grassland habitats by reestablishing this habitat on arable land and connecting fragments of grasslands into larger areas. The consequence has been higher water infiltration rates in the reestablished grassland in comparison to the arable land, positively influencing ground water recharge, reducing the extent of flood events and diminishing water erosion of the soil. Another positive impact of the restoration of grassland habitats on formerly intensively-used farmland is the ending of fertiliser and pesticide use, which can pollute surface and/or groundwater.

Hydraulic balancing

Aquifers in many parts of Europe are under pressure from anthropogenic activities such as intensive agriculture, industry, energy production and urbanisation. LIFE co-finance has helped develop techniques for studying soil characteristics from a geophysical perspective in order to establish the infiltration rate of water in soil. These enable scientists to calculate rates of seepage and groundwater recharge of aquifers and subsequently to determine water storage dynamics and how much water is available in a certain area for competing uses, especially in light of climate change.

Photo: LIFE07 ENV/B/000038/VERNIERS G.

Monitoring the ecological status of the Meuse basin

The CAMI project studied topsoil using electric tomography, with a 3D reconstruction that allows for continuous monitoring. This technique provides a means of defining aquifers in terms of dimensions and exploitability.

The TRUST project set out to establish the water balance of north-east Italy's Veneto and Friuli plain. To do this, it modelled in detail the soil's water retention capacity. Data on land coverage and soil exposure, evapo-transpiration rates and soil characteristics were used to calculate the hydraulic balance of the area, water content and run-off coefficients.

Conclusions

Although few LIFE Environment and LIFE Nature projects have directly addressed soils, a substantial number have carried out actions that have had an impact on the improvement or restoration of the water-soil cycle in the landscape. Actions to enhance or recover soil's water retention functions, aid habitat and species conservation, river and wetland restoration and so on have also indirectly improved soil quality. However, the vast majority of these projects have not measured that improvement.

SUSTAINABLE AGRICULTURE

Reducing degradation of **agricultural soils**

Soil acts as a sink for almost all substances released into the environment by human activities. Numerous LIFE projects have demonstrated useful solutions to the problem of contamination on agricultural land and from farming practices.

One of the more common and most serious threats to soil identified by the Soil Thematic Strategy (STS) comes from contamination. Contamination is a problem in all parts of Europe and can also be a trans-boundary issue. It may be diffuse or localised and caused by a wide range of anthropogenic activities, including industrial production, traffic, waste disposal and farming practices.

A Spanish project used leguminous plants to fix atmospheric nitrogen into the soil and improve soil quality

Photo: ASTRALE EEIG/Gabriella Camarsa

Soil pollution above a defined background value causes a risk to human health, plants, animals, ecosystems or other media (e.g. water). When soils' buffering, filtering and transforming capacities are exceeded there is a release of contaminants into the environment, impairing groundwater and/or surface water and causing a potential health hazard. It also creates a problem for food safety given the uptake through the food chain.

In order to avoid clean-up costs being borne by Member States other than those from where the contamination originated, it is of utmost importance to act at source to prevent damage and subsequent remedial actions. The major diffuse sources of contamination are acidification, heavy metals and the effects of surplus nutrients.

The STS identifies a series of measures needed to prevent soil degradation processes that can lead to contamination. Prevention of soil contamination is closely linked to policies on chemical substances, to environmental protection policies for water, air and waste and to policies concerning certain land uses - such as agriculture - that have to function in an integrated way, for instance the Industrial Emissions Directive (2010/75/EU).

Agri-environment measures under the Common Agricultural Policy (CAP) and certain legislation

(such as the Sustainable Use of Pesticides Directive (2009/128/EC)[21] have helped spread good farming practices and led to a general reduction in agricultural inputs. Nevertheless, overuse and mismanagement of fertilisers and pesticides has impacts on soil and water quality and on food safety.

The use of fertilisers with a high phosphorus (P) and nitrogen (N) content, or of slurry (livestock manure) and sewage sludge beyond the need of crops, can have a significant impact on the environment in general and on soil in particular, where it affects the buffering and filtering capacity and the ability to provide nutrients for plant growth. Excess nutrients and heavy metals and other persistent pollutants may be leached from the soil, eroded or simply washed off into the groundwater, waterways and coastal systems, causing drinking water pollution and eutrophication.

The role of LIFE

With regards to agricultural contamination, LIFE has co-funded two types of projects: those that focus on prevention and those that attempt to mitigate contamination. Preventative projects have developed and implemented best practices to avoid or reduce soil contamination. This is in line with the long-term goal of sustainable land-use and protection of natural resources.

LIFE has helped in the mainstreaming of many GAP solutions, such as organic agriculture, conservation agriculture, nutrient and crop protection management practices, manure management and reduction and correct management of farm waste. Together these have helped to reduce nutrient leaching, established better or more informed ways of applying nutrients or pesticides, and encouraged farmers to use tools that eliminate sources of soil contamination.

One of the main strengths of the programme is that almost all the projects highlighted in this article have applied an integrated approach, addressing the demands of legislation such as the Water Framework Directive (WFD), Groundwater Directive, Nitrates Directive, Sustainable Use of Pesticides Directive and climate change policy, as well as soil policy.

21 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32009L0128:EN:NOT


Photo: LIFE09 ENV/ES/000459

One of the strengths of LIFE projects is that they involve farmers and encourage them to try out new techniques and tools

Techniques for sustainable agriculture

Several projects have focused on promoting organic farming techniques – one means of preventing soil and water pollution whilst also ensuring carbon storage in soils (e.g. Sinergia (**LIFE03 ENV/E/000085**), CropsforBetterSoil (**LIFE10 ENV/ES/000471**), SOLMACC Life (**LIFE12 ENV/SE/000800**) or AgriClimateChange – see pp. 50-51). Such techniques have been applied across a range of crops, from viticulture, to citrus plants, leguminous plants and wheat. A common feature of all these projects have been techniques that seek to deliver optimal combinations of methodologies targeted to the specific soils and climatic conditions. The techniques include: land preparation, crop rotation, optimisation of nutrient application, tilling, fertilisation, crop protection, irrigation and reintroduction of traditional crops such as leguminous plants (whose roots fix nitrogen, thus requiring less fertiliser).

Promotion of the techniques was, for most of these projects, a more important consideration than organic certification. This meant teaching the methods to the farmers to reduce their impact on soil, air and water. Economic considerations are of course a vital part of persuading farmers to adopt the new methods: for instance farmers involved in the CropsforBetterSoil project have started applying the same methods on other parts of their land, as well as passing on the know-how to neighbouring farmers who are doing likewise. Many wineries participating in the Sinergia project are now producing organic wine, whilst others (without certification), are following similar soil-friendly rules.

EMAS[22] certification of farms has been part and parcel of a wave of LIFE projects. This involved the evaluation of many different farming systems (dairy, cattle, poultry, viticulture, olive and agriculture) to determine their environmental impact and establish procedures to reduce it at the same time as lowering costs. Projects such as ExtEnSity (**LIFE03 ENV/P/000505**), Humedales Sostenibles (**LIFE04 ENV/ES/000269**) and EMAS-Farming (**LIFE00 ENV/E/000387**) translated EMAS procedures into a set of measures or codes of best practices for farmers that highlight ways to improve crop protection, fertiliser use and waste management.

Other holistic approaches to farming are the methods of conservation[23], regenerative and precision agriculture in projects such as SOWAP (**LIFE03 ENV/UK/000617**), REGEN FARMING (**LIFE12 ENV/ES/000232**) and HelpSoil (**LIFE12 ENV/IT/000578**). For instance, the SOWAP project reduced leaching and run-off by 90% by applying techniques such as minimum tillage, direct sowing, spontaneous or sown cover crops and nutrient management.

22 The EU Eco-Management and Audit Scheme (EMAS) is a management instrument developed by the European Commission for companies and other organisations to evaluate, report, and improve their environmental performance: http://ec.europa.eu/environment/emas/

23 Conservation agriculture consists of several farming practices adapted to cultivation demands and local conditions that involve ways of managing the soil that protect it from erosion and contamination, improve fertility and organic matter biodiversity and contribute to the preservation of natural resources such as water and air, without detriment to production levels.

Precision agriculture is a farming management concept based on observing and responding to intra-field variations. It has been demonstrated by projects such as AGRICARBON. Precision agriculture makes use of satellite imagery and geo-positioning systems, enabling farmers to vary fertiliser rates when spraying, thus optimising its use. Applying the right amount of inputs in the right place and at the right time benefits crops, soils and groundwater, and thus the entire crop cycle.

Another, recently started project, HelpSoil, is combining conservation agriculture with soil management techniques to reduce the use of manure and pesticides and improve the ecological functions of soil, e.g. to act as a fix for greenhouse gases, sequestering organic carbon.

One of the strengths of LIFE's efforts to prevent soil contamination from agriculture has been the development of many easy-to-use tools for farmers that support decision-making out in the field or that have helped in monitoring (see pp. 35-37). These range from a real-time system that calculates nitrogen manuring requirements for individual balances, reducing them by 30% (the OptiMa-N project – **LIFE04 ENV/IT/000454**) to decision-support tools to optimise fertilisation and soil organic matter management (the DEMETER project – **LIFE10 ENV/BE/000699**) and systems for real-time monitoring of pesticide use, which will allow potential reductions to be determined (the aWARE project – **LIFE11 ENV/ES/000606**).

Regenerative farming techniques are being tested to promote real improvements in soil quality and biodiversity conservation

Photo: LIFE12 ENV/ES/000232

Manure management and crop control

The application of manure and slurry in intensive livestock farming regions can cause excessive nutrient loads and contamination, with subsequent leaching and run-off in water bodies. LIFE project experiences extend across a variety of practical techniques for reducing soil contamination risks caused by inappropriate disposal of manure or ammonia-containing slurry. The most common focus of such projects has been on demonstrating biogas production treatments that make the manure a more efficient fertiliser, whilst also making it safer to handle and easier to store. Examples include the LIVE-WASTE (**LIFE12 ENV/CY/000544**) and MIX_FERTILiSER (**LIFE12 ENV/ES/000689**) projects. Other projects - e.g. PIGS (**LIFE00 ENV/P/000829**) or Zero Nuisance Piggeries (**LIFE04 ENV/FR/000337**) - validated applied composting techniques that increase the amount of stable organic matter in pig manure or other liquid slurries and mix them with other forms of organic waste to produce a high quality fertiliser.

A standalone project worth mentioning is ES-WAMAR (**LIFE06 ENV/E/000044)**, which reduced ammonia release and nitrogen overload pressures on the soil surrounding pig farms. Other LIFE examples have addressed specific issues around nutrient management or crop protection (pesticides) – see for instance the EcoPest project, which focused on the impact on soil and water of implementing the Sustainable Use of Pesticides Directive (pp. 50-51)

LIFE has trialled a range of bottom-up approaches to nutrient and crop protection management. For instance, the AGRI-PERON project (**LIFE04 ENV/FR/000319**) disseminated GAPs amongst farmers and persuaded them to use diagnosis tools to calculate the impact of their farming practices. The participants then set up soil-and-water protection measures such as changing crop rotation and pesticide use practices, installing 'nitrate traps' and planting hedgerows and grass strips in sensitive areas. The individualised approach to farm analysis was a novel element of the project and led to the proposal of site-specific measures that were more likely to achieve farmer buy-in to the environmental goals.

Similar efforts have been made elsewhere: WAgriCo (**LIFE05 ENV/D/000182**) worked with farmers on a one-to-one basis to determine farm-specific measures for applying nutrients without causing contamination, whilst the AGWAPLAN project (**LIFE05 ENV/DK/000155**) produced individual plans for farms to reduce the amounts of N and P being applied to land and subsequently leaching into ground and surface waters. The project's integrated participatory advisory approach helped in the implementation of GAPs in the target area in Denmark.

Photo: LIFE06 ENV/E/000044

The ES-WAMAR project developed a system for applying correct doses of pig slurry as fertiliser to agricultural fields

Composting and waste management

In line with the recommendations for composting[24], the LIFE programme has shown ways to reduce the amount of organic municipal waste going to landfill, instead composting it for agriculture and other uses. The numerous projects of this type[25] can be grouped in two categories: those that involved working with citizens to collect household organic waste and convert this into a commercially-useful material. The COMPOSTDISSEMINATION project (**LIFE00 ENV/E/000543**) produced three types of compost for silviculture, nurseries and landscaping. Other projects in this category emphasised the importance of developing the best techniques for the cost-effective production of high-quality composts with good nutrient loads.

The second category is a batch of projects that have taught farmers how to properly manage their farm waste in order to produce good quality compost. For instance in the BIOCOMPOST project (**LIFE00 ENV/E/000555**) rice farmers were taught to collect - rather than burn - straw and combine it with sludge from wastewater treatment to make compost.

24 REPORTS OF THE TECHNICAL WORKING GROUPS VOLUME – IV CONTAMINATION AND LAND MANAGEMENT http://ec.europa.eu/environment/soil/pdf/vol4.pdf
25 Others include Miniwaste, Urswastech and Fertilife

Photo: LIFE04 ENV/ES/000269

Humedales Sostenibles used conservation agriculture to reduce soil run-off and siltation on nearby wetlands

Waste from olive cultivation is high in polyphenols and its direct application to land may lead to soil contamination. LIFE projects such as Envi-Friendly (**LIFE05 ENV/GR/000245**) and PROSODOL (**LIFE07 ENV/GR/000280**) showed methods of treating these effluents at individual or cooperatively-run wastewater treatment plants, as well as decantation methods to reduce nutrient levels and the amount spread on land (sometimes combined with *phyto-decontamination*).

An ongoing project, AgroStrat (**LIFE11 ENV/GR/000951**) is targeting similar actions at pistachio farmers in Greece. The project team will analyse the properties of pistachio waste and its potential impact on soil, as well as testing the effectiveness of adding a natural zeolite to the compostable mixtures to improve nutrient retention, slow its release, immobilise heavy metals and toxic organic compounds and reduce running costs (water, fertilisers) when used in crop cultivation.

Mitigation efforts

The second category of agricultural contamination-related projects includes those where LIFE's support has contributed to ex-post interventions to mitigate contamination via the implementation of remediation techniques.

The remediation techniques with the highest contaminant-removal efficiencies are those where soil is excavated and transported for treatment offsite (ex-situ). These include thermal remediation, soil scrubbing, biopiling and use of bioreactors. Despite their efficacy, the cost of such techniques is often prohibitive. Onsite (in-situ) remediation is cheaper, but frequently less effective.

To address this issue, the bulk of LIFE co-funding for remediation has focused on increasing the effectiveness of in-situ techniques whilst maintaining low costs (this also applies to industrial sites, as shown in the following chapter – see pp. 52-57). Such projects have targeted a wide range of contaminants, as well as pursuing an integrated approach to implementing policy that, in addition to soil, covers directives on water, nitrates and pesticides[26].

The range of techniques that LIFE has backed includes bioremediation, phytoremediation, use of zeolites, in-situ alkaline hydrolysis and revegetation strategies. The importance of the soil-water nexus is highlighted by remediation projects using artificial wetlands or permeable reactive barrier technology.

Bioremediation techniques have been those most-commonly explored by LIFE. Projects dating back to 1997 have developed different methods addressing a variety of contaminants, including organic chlorinated compounds, pesticides, polychlorinated biphenyls (PCBs), Polycyclic aromatic hydrocarbons (PAHs), nitrates and phosphates. Solutions have focused on in-situ application with cost-effectiveness and ease of application by farmers high priorities.

PCB removal was targeted by two projects, both of which mixed micro-organisms and soil in a bioreactor to produce an inoculant that can be applied to soil. The first (**LIFE97 ENV/IT/000024**) took a technology-led approach, producing a superactive inoculant that can be applied to soil on or offsite; by contrast, FREEPCB (**LIFE03 ENV/IT/000321**) worked with farmers to help them integrate this bioremediation technique in their normal agricultural practices. An important part of this latter project was matching micro-organisms to contaminants to find the most efficient, knowledge that is still not mainstream. The micro-organisms identified as most effective were cultivated and innoculated into agricultural soil, degrading 40% of PCBs and preventing them entering the food chain.

Phytoremediation is a technique still under development and there is little regulatory experience with phytoremediation. The technique's use is limited to lightly-contaminated soils, sludges and waters where the material to be treated is at a shallow or medium depth and the area to be treated is large enough to make planting and harvesting of suitable crops both technically and economically viable. In

26 The Water Framework Directive (2000/60/EC), the Drinking Water Directive (98/83/EC), the Nitrates Directive (91/676/EEC) and Sustainable Use of Pesticides Directive (2009/128/EC).

other instances, such as when additional organic and inorganic compounds are present, further phytoremediation techniques may need to be applied.

No LIFE projects in the agricultural sector have focused exclusively on the use of phytoremediation. However, a number of projects have used it as one of a suite of remediation measures. Of particular note in this regard are two Greek projects working to decontaminate soils polluted by wastewater from olive oil production – EnviFriendly and PROSODOL. Phytoremediation using poplar trees was one of 10 techniques trialled by EnviFriendly as a means of remediating oil and groundwater contamination from phenolic compounds present in the olive oil effluent. PROSODOL additionally reduced nitrogen, iron and boron contamination in soils in the project area in Greece.

Other techniques

The PROSODOL project also made use of zeolites, a group of minerals that can be applied in-situ on polluted soils where they draw up nitrogen and release it at a rate slow enough for it to be taken up by plants. Reducing the N content thus helps to reduce contamination of soil and water. PROSODOL and another project, ZeoLIFE (**LIFE10 ENV/IT/000321**), are helping farmers introduce zeolites in order to stabilise and reduce the amount of nitrogen in soils from fertilisers or organic waste being applied to land. This will also improve the general characteristics of soils, such as increased ventilation, water retention capacity and so on, ensuring the healthy functioning of the water cycle.

One ongoing LIFE project in Denmark (NorthPestClean – **LIFE09 ENV/DK/000368**) is conducting the first large-scale trial of a technology known as in-situ alkaline hydrolysis. This technique has been used to treat accidental spills but previously only small-scale field trials of its capacity to remediate soil and groundwater contaminated with organophosphorous insecticides had been carried out. Projections from the project beneficiary suggest that in-situ alkaline hydrolysis is capable of removing up to 90% of pesticides at a cost of €6-9 million (as opposed to €15-53 million using conventional treatment methods).

LIFE co-funding is also helping to test revegetation strategies on farmlands. The Italian project BIOREM (**LIFE11 ENV/IT/000113**) will use sewage sludge (turning a valueless waste into an input) as a fertiliser for plants conditioned for remediation and adapted to semi-arid conditions. The method used is expected to restore degraded soils on 30 sub-plots of land in Lombardy, enhancing physical-chemical properties and biochemical activity and increasing fertility up to 25%.

Remediating water and soil

As we have seen already, soil is also fundamental for the correct functioning of the whole water cycle. The most problematic environmental impacts are related to water pollution caused by run-off of contaminants from soil to water bodies, nutrient and pesticide leaching of substances in groundwater, soil erosion, and soil and water eutrophication.

NorthPestClean demonstrated the use of alkaline hydrolysis to clean soil and groundwater contaminated by pesticides

Photo: LIFE09 ENV/DK/000368


Photo: LIFE09 ENV/DK/000368

Alkaline hydrolysis is capable of removing up to 90% of pesticides at a lower cost

All LIFE projects on soil contamination from agricultural practices have addressed the inter-relationship between soil functions and the water cycle, even if at a regulatory level they are separated. All of these, all projects first sampled soil and groundwater quality to determine the best methods for remediating compounds in both mediums.

The bioremediation techniques where this intimate relationship between soil and water is most evident are those using artificial wetlands (e.g. ArtWet – **LIFE06 ENV/FR/000133**, SWAPP-CPP – **LIFE04 ENV/FR/000350**) and other natural ecosystem structures, such as riverbank forests (e.g. CREA-MAgua – **LIFE09 ENV/ES/000431**) to reduce the run-off of nitrates, phosphates and pesticides from agricultural land entering into surface and groundwater.

The integrated approach to soil and water is a benefit of the artificial wetlands technology demonstrated by LIFE projects. However, they are also a relatively costly bioremediation solution because of the need for land purchase, earthworks, maintenance of structures and so on, even if this is partially compensated for by the lower cost of treating drinking water.

LIFE has demonstrated further techniques for the combined remediation of soil and water, including permeable reactive barrier technology. The NITRIBAR project (**LIFE05 ENV/UK/000137**) tested this method, in which groundwater passes through a trench containing a mixture of natural materials such as gravel or sand and organic matter and is converted into harmless nitrogen gas in the process. Simpler LIFE-supported remediation techniques have included the creation of riparian buffer zones, catch crops and forest plantations to manage and reduce nutrient loads in agricultural soils. One project in particular (Farms for the Future – **LIFE12 ENV/ES/000647**) used willow trees as a bio-filter to treat nitrogen and phosphorous run-off from farms in adjacent water bodies.

An offsite first

We have already highlighted the fact that LIFE projects have focused on improving the efficacy of lower cost in-situ remediation methods, rather than further develop more expensive ex-situ treatment options. However, it is important to note that the first LIFE Environment project to explore ex-situ remediation started recently in Slovenia. LIFE ReSoil (**LIFE12 ENV/SI/000969**) will demonstrate an innovative technology for soil washing that removes toxic metals and organic pollutants using chelant ethylenediamine tetraacetate (EDTA). This method is soil friendly and enables re-use of remediated soil as a plant substrate (for agriculture). However, to date it has only been tested at laboratory or pilot scale. The project aims to scale-up the technology by building a remediation plant in an urban area. It is hoped to demonstrate that ex-situ treatment can also be cost-effective (the goal is a treatment cost of under €50 per tonne of heavily-polluted soil).

Conclusions: prevention projects

The LIFE programme has invested a lot in projects to prevent diffuse contamination from agriculture, passing on techniques that not only avoid soil contamination, but also increase such ecosystem functions as soil fertility, soil organic matter, carbon storage, and the correct function of the water cycle (through improved infiltration and buffering capacity).

One of the major strengths of LIFE has been in developing farmer involvement, encouraging farmers to actively engage with new techniques (often overcoming initial concern about the impact on yields and incomes). The fact that many farmers have adopted such soil-friendly techniques and continued to use them after the project end is a testimonial to the fact that such practices can be environmentally and economically viable.

A common feature of all the contamination prevention projects highlighted is the need for appropriate tools and training from agronomists or consultants to help farmers acquire the knowledge and put it

Photo: ASTRALE EEIG/Gabriella Camarsa

Photo: LIFE04 ENV/GR/000245

EnviFriendly made use of poplar trees for the remediation of soil and groundwater contaminated with phenolic compounds from olive oil effluent

into practice to support their livelihoods. Projects have indicated the need for such advisory services or bodies to be made permanent and to have a bottom up farmer led approach.

Going beyond mere communication, active stakeholder involvement and dialogue with the scientific community, agronomists and local planners has been central to the success of projects. However, more can be done at project design stage and at programme level to improve synergies with LRAs and encourage wider take up of ideas and practices trialled by LIFE, investment in permanent advisory bodies, or the roll out of effective tools for decision-making concerning agricultural land management.

It is when practices are picked up by the authorities that they continue to work in an integrated way with farmers and other stakeholders, whilst also providing an example to other local communities who may replicate similar solutions.

With notable exceptions (e.g. EcoPest, EnviFriendly, AgriClimateChange) LIFE projects have not been that effective in feeding their results into policy and legislation, even when those results have been exemplary and could help to develop or strengthen EU or national policy. It is necessary to put more thought at the planning stage into ways of involving or influencing policy-makers at a later stage of project implementation.

Conclusions: mitigation projects

LIFE has demonstrated the efficacy of a range of decontamination techniques that address the impact of agriculture, most frequently bioremediation techniques based on the use of micro-organisms, plants and wetlands. In-situ remediation methods have until very recently been the sole focus of LIFE funding in this field, with some projects successfully scaling up existing low-cost techniques and improving their effectiveness in terms of the amount and type of pollutants removed.

The cost-benefit analyses carried out by these projects is an important step towards wider uptake of such solutions, but this is an outcome that has rarely happened in practice. Thus strategies for scaling up techniques and applying them over larger areas should be considered by projects right from the planning phase.

This means projects developing studies for full-scale remediation. Such studies give decision-makers the knowledge and tools to identify the possibilities, costs and benefits of proposed remediation strategies.

There is also the related need for more LIFE finance to be targeted at bridging the gap between remediation science and those who make decisions about the decontamination of sites. An effective means of transferring results to responsible authorities is often missing in projects. ECOREMED (**LIFE11 ENV/IT/000275**) is one exception to this rule, a project that will produce a protocol for agricultural-based bioremediation of contaminated agricultural soils and create an operative link between the technical-scientific protocols and the local and regional administrations, whilst also supporting farmers with regulatory and financial tools. More LIFE funding should be targeted at following such a lead.

SUSTAINABLE AGRICULTURE

Success factors for territorial soil management strategies

The Greek EcoPest project has produced replicable results that demonstrate LIFE's ability to help Member States progress useful new tools for tackling soil contamination issues in agricultural areas.

The LIFE Environment EcoPest project (**LIFE07 ENV/GR/000266**) targeted its attention on 9 000 hectares of agricultural land in mainland Greece. The main aim of the project was to find ways to prevent contamination from diffuse sources, such as the application of pesticides, that have a negative impact on soil and water. In doing so, it applied for the first time in a single area all the requirements foreseen by the Sustainable Use of Pesticides Directive.

Outcomes from the project provide valuable insights for sustainable soil management initiatives throughout Europe, particularly those interested in identifying success factors associated with soil monitoring, contamination mitigation, and participation of farmers.

Understanding the relationships between soil and water quality remains vital to establishing more sustainable land use practices. Healthy soils provide a natural buffering medium that can filter and clean water, protecting it against pollution threats such as pesticide and fertiliser residues.

The project worked closely with farmers. Here, members of the team check nozzle flow on spraying equipment

Photo: BP/TSAKIRAKIS

Conversely, soils suffering from contamination of these residues commonly experience functionality problems and this often hinders their ability to conserve water quality. The effects on water organisms and other species that rely on water have far-reaching and long-term adverse impacts.

Within this context, EcoPest tested and demonstrated cost-effective methods for safeguarding the functionality of farm soils. The project followed a good practice approach that recognised the importance of basing soil management interventions on sound and robust know-how.

Accurate and consistent data collection systems therefore first needed to be established. Where feasible, phreatic groundwater monitoring wells were selected in a way that made it possible to correlate directly hydrochemical findings between leachates and phreatic groundwater. A number of monitoring sites were also selected at the deep karstic aquifer and along the river Viotikos Kifissos. Accredited laboratories determined selected soil and water parameters from the collected samples and data analysis was performed in accordance with a certified protocol for the assessment of environmental quality.

Monitoring systems

Soil quality is a dynamic phenomenon, which requires on-going monitoring to track, analyse, draw conclusions, and target associated management actions. LIFE funding allowed the EcoPest team to design and operate a rolling programme of soil sampling and monitoring. This good practice provided results that were fed into a digital model to provide a set of maps capable of measuring and illustrating soil and water changes. Building maps for water enabled the team

to assess how contamination from soil infiltrates into water bodies.

A standardised sampling method was agreed in order to produce data that could be easily compared to identify the effects of different soil quality influences in different areas. It is important to take a long-term perspective when agreeing such standards in order to establish soil monitoring systems that can be sustained (both technically and financially) over time.

At the same time as noting the importance of using non-variable soil monitoring techniques, the project also highlighted the need to design a common monitoring framework that was able to provide data from different sampling sources. For example, samples at different depths in soils exhibiting different properties (texture, slope, hydromorphy, drainage etc.) as well as surface water and groundwater sources. It confirmed that some indicators are relevant to most territories whereas others remain site-specific.

This focus on using a flexible yet consistent set of monitoring indicators complements the goals of the Sustainable Use Directive and was a success factor confirmed by EcoPest, which applied biological indicators including bacteria, earthworms, phyto- and zooplanktonic organisms. Other indicators used by the project related to agri-chemical inputs from farmers and land use patterns. The usefulness of this information was highly dependent on commitments to the monitoring process by farmers.

Stakeholder participation

The EcoPest project was particularly successful in harnessing the time and interests of farmers in its territorial approach to sustainable soil management. Respected public figures played a pivotal role in facilitating, convincing and motivating local farmers to get involved.

A step-by-step approach to participation proved effective. It helped the farmers to understand how their actions influence soils, water, and biodiversity (including ultimately human health). Farmers reported an increased willingness to participate following this awareness-raising phase, which also highlighted the economic benefits to their businesses from changing land use practices.

EcoPest took proactive measures to involve farm advisors throughout the project. These can act as useful 'multipliers' providing an outreach mechanism that could spread awareness further and longer than the project's immediate actions. Advisors joined the farmers during training in soil monitoring and soil improvement measures.

Farmers thus played a vital role in providing the territorial data that informed the development of the project's soil management interventions, which were coordinated and rolled out on farms via a series of site-specific 'Low Input Crop Management' systems. Participating farmers changed their land management practices and began using agri-chemicals in ways that are more soil-friendly and cost-efficient. They also implemented a protocol for proper soil management and fertilisation that was prepared for the region's three major crop types (corn, tomatoes and cotton). The project piloted 'substitution' principles for the first time in Greece, using LIFE support to rank plant protection products (PPPs) according to their risk and assess opportunities for either replacing high risk PPPs or minimising their application. In total, results significantly reduced threats to soil and water contamination by farmers.

Policy tools

The Greek authorities recognised the relevance of the lessons learned from the measures introduced by EcoPest, inviting the project's staff to help draft the content of policy tools within a National Action Plan targeting improvements in sustainable pesticide use.

LIFE in this project example can therefore be seen to have provided national and regional authorities with important new know-how about success factors for territorial soil management strategies. The project's legacy continues to be sustained through mainstreamed soil management measures.

Photo: LRI

EcoPest used a standard soil sampling method to produce easily comparable data

Project number: LIFE07 ENV/GR/000266

Title: EcoPest - 'Strategic plan for the adaptation and application of the principles for the sustainable use of pesticides in a vulnerable ecosystem'

Beneficiary: Benaki Phytopathological Institute

Contact: Kiki Machera

Email: K.Machera@bpi.gr

Website: http://www.ecopest.gr

Period: 01-Jan-2009 to 31-Mar 2012

Total budget: €1 645 000

LIFE contribution: €823 000

LAND CONTAMINATION

LIFE works to **remediate contaminated land**

Soil acts as a sink for almost all substances released into the environment by human activities. Many LIFE projects have demonstrated cost-effective techniques and tools for dealing with local soil contamination on industrial, landfill, mining and military sites.

Soil contamination can have lasting environmental and socio-economic consequences and be extremely difficult and costly to remediate. In addition to diffuse contamination from agriculture, the programme has also tackled contamination at source. Local soil contamination occurs where intensive industrial activities, inadequate waste disposal, mining, military activities or accidents introduce excessive amounts of contaminants.[27]

27 Management of contaminated sites is a tiered process, starting with a preliminary survey (searching for sites that are likely to be contaminated), followed by site investigations to define the extent of contamination and its environmental impacts and concluding with the implementation of remedial and after-care measures. One important step of action is for Member States to identify the relevant sites in their national territory and establish a national remediation strategy, including a mechanism to fund the remediation of orphan sites where the polluter pays principle can't be applied.

Soil samples from the New Life project

Photo: LIFE10 ENV/IT/000400

Nearly a quarter of a million sites around Europe are considered as potentially affected by soil contamination. The actual number could be much higher, since EEA estimates that potentially-polluting activities have occurred at nearly 3 million sites across the EU[28]. Further investigation is needed to establish the extent of the damage and whether clean up (soil remediation) is required.

Although considerable efforts have been made in some Member States - over the last 30 years approximately 80 000 sites have been cleaned up in the countries where data on remediation is available - the legacy of soil contamination is likely to be with us for decades. We pay today for errors committed in the past. This clearly shows that, though it does not come for free, soil protection pays.

The range of polluting activities varies considerably across the EU – as does their relative importance as localised sources of soil contamination. However, the most important sources have been identified as industrial and commercial activities and the treatment and disposal of waste. The most frequently-noted soil contaminants at investigated sites are heavy metals and mineral oil. In groundwater, mineral oil is again one of the most frequent contaminants, along with chlorinated hydrocarbons.

28 http://www.eea.europa.eu/themes/soil/soil-threats


Photo: LIFE09 ENV/ES/000472

LOS TOLLOS is recovering degraded soil through phytoremediation of a mining site.

LIFE and contamination

LIFE projects have addressed diverse polluting activities that are considered the sources of local contamination, including landfills and waste treatment plants, industrial production, mining and quarrying and military uses. Indeed, if diffuse (agricultural) and local sources are considered as one, contamination is the theme tackled by more soil projects than any other.

Projects dealing with local contamination have been oriented towards removing heterogenous types of contaminants from various sources, mainly heavy metals and hydrocarbons. However a couple of projects, such as EKOHEMPKON (**LIFE11 ENV/PL/000445**) in Poland, have targeted more specific and unusual contaminants such as lignite[29].

The remediation techniques

Projects addressing local contamination have largely focused on improving or demonstrating the suitability of various in-situ remediation techniques, most commonly forms of bioremediation. These techniques have been applied to the treatment of a wide range of contaminants.

Mineral oils and petroleum hydrocarbons have been the target in a couple of LIFE projects, both of which used bioremediation. In one instance (BIOSOIL - **LIFE04 ENV/ES/000263**), enriched compost bioremediation techniques were used to decrease mineral oil concentrations at a brownfield site in an urban area that posed threats to human health. Different types of indigenous micro-organisms were tested, with the advantage that they adapt more easily to the hostile conditions of polluted soils, thus improving remediation results. Compost remediation was also used in another project that went further than BIOSOIL by building a synergy between the need to find new markets for compost, the demand for energy crops and the importance of reclaiming contaminated land. BioReGen (**LIFE05 ENV/UK/000128**) demonstrated the possibility of growing high productivity plants that not only act as bio-accumulators of certain metals in soil, thus offering cost-effective options for the remediation of contaminated land, it also targeted plants that could be used to supply biofuels, presenting a possible alternative to the conversion of high-value agricultural land for energy crop production.

The DEMO-MNA project (**LIFE03 ENV/FIN/000250**) proved the validity of Monitored Natural Attenuation (MNA) as a tool for in-situ biodegradation of petroleum hydrocarbonates in oil contaminated sites. This technique requires a thorough site investigation involving soil and groundwater to assess risks from microbiological, chemical, hydro-geological and ecotoxicological perspectives. The project demonstrated the applicability of MNA at full-scale, highlighting its suitability in particular for areas that have no pressures for changing land use, or as a finishing option with other remediation processes.

Both techniques reduced contamination by 80-90%. Both methods are also potentially cheaper than current ex-situ decontamination practices, since there are no transport or excavation costs. The costs for

29 http://life.lifevideos.eu/environment/life/publications/lifepublications/generalpublications/documents/soil_study.pdf

compost bioremediation were around 90% lower than for incineration or landfilling, whilst also recovering a valuable resource, thus demonstrating a practical application of the goals of the Resource Efficiency Roadmap.

LIFE has also helped restore contaminated soils from organic pollutants (such as PAHs) and heavy metals through bioremediation. The TWIRLS project (**LIFE04 ENV/GB/000820**) found that compost from mixed waste streams produced more mineral-based soil materials, leading to the microbial removal of the contaminants and the conversion of heavy metals into stable non-toxic forms. A 20% increase in soil organic matter, half of it organic carbon, was measured during the short time span of the project.

One of the notable achievements of LIFE projects has been to address the need on former industrial sites to simultaneously remediate multiple organic contaminants through a single treatment process. Typically it is necessary to apply different techniques at the same time on such sites, with a subsequent increase in costs. Even after treatment, many contaminants remain, potentially spreading to soil and groundwater or migrating offsite.

Thus, two ongoing LIFE projects - BIOXiSOIL and VOPAK-EXPERO3 - are testing In-situ chemical oxidation[30] (ISCO) of industrial and military sites polluted by a cocktail of contaminants. Both projects aim to remediate groundwater and soil in one fell swoop, with monitoring of results in soil and water. BIOXiSOIL will combine ISCO with other soil remediation technologies, such as phytoremediation and biodegradation and will test a new automated injection method for sites close to designated nature conservation areas (Natura 2000 network sites). The goal of VOPAK-EXPERO3 is to test the use of perozone as an oxidant in the process. It will also carry out a full-scale remediation, with the aim of providing useful lessons for replicability elsewhere.

30 In situ chemical oxidation (ISCO), a form of advanced oxidation processes and advanced oxidation technology, is an environmental remediation technique used for soil and/or groundwater remediation to reduce the concentrations of targeted environmental contaminants to acceptable levels. ISCO is accomplished by injecting or otherwise introducing strong chemical oxidisers directly into the contaminated medium (soil or groundwater) to destroy chemical contaminants in place. It can be used to remediate a variety of organic compounds, including some that are resistant to natural degradation. In ISCO, oxidising compounds, compounds that give electrons away to other compounds in a reaction, are used to change the contaminants into harmless compounds.

The New Life project will use mechanical and chemical treatment processes to decontaminate soil, combining the mixing of exhausted soils with other solid matrices

Photo: LIFE10 ENV/IT/000400

The benefits of phytoremediation for cleaning up lead-contaminated soils and heavy metals have been demonstrated by a number of LIFE projects since 1999. Projects such as PHYLES (**LIFE99 ENV/IT/000078**) and RIVERPHY (**LIFE11 ENV/ES/000506**) used metal hyperaccumulators and agronomic plants to decontaminate soil from sites with medium-high lead levels (500-1 000 mg/kilo dry weight). In five years, PHYLES reduced concentrations of contaminants from 1 500 mg/kg to 100 mg/kg, giving urban planners and policy-makers a valuable indication of the time needed to decontaminate a whole site. The project also demonstrated three times lower costs than conventional remediation methods (although monitoring costs are higher). The RIVERPHY project is using similar methods to extract heavy metals along a riverbed in an industrialised valley. The project is reestablishing more than 75% of the riparian vegetation to help restore the physical, chemical and biological properties of the soil, with a rapid turnover of plants to ensure effective decontamination.

Mining and quarrying

LIFE projects have also applied forms of bioremediation to remove the high concentrations of chemicals such as arsenic, sulphuric acid and mercury in soil and water bodies as a results of mining activities.

Mining activities may have adverse effects on soil and surface and groundwater if protective measures are neglected, resulting in the contamination of soil and water bodies with chemicals such as arsenic, sulphuric acid and mercury. A handful of LIFE projects have focused on these activities and remediation techniques have varied. In two cases, phytostabilisation, a form of phytoremediation that focuses on the long-term stabilisation and containment of the pollutant using plants, was employed by both the DIPFOLMINE (**LIFE02 ENV/F/000291**) project

and the later MIPOLARE (**LIFE09 ENV/ES/000439**). The former project tested phytostabilisation at lab-scale to develop a pollution transport model simulating water and arsenic flows. MIPOLARE is providing a practical application of the method, combining phytostabilisation with in-situ soil amendments using waste from the pig and marble industries. This waste will be usefully recycled by being applied on soil to neutralise acidity, immobilise toxic elements and stop translocation from the polluted site.

Another bioremediation method successfully trialled by a LIFE project (BIOMAN – **LIFE03 ENV/UK/000605**) was the use of dealginated seaweed as a bioabsorber for the removal of hazardous/toxic metals, such as cadmium, nickel, zinc and lead, from waters draining from abandoned mines at sites in Wales and Italy.

Existing remediation methods for lignite mines had proven ineffective, so the EKOHEMPKON project team trialled a new bioremediation method based on the cultivation of industrial hemp and alfalfa. As well as biologically reactivating the soil in degraded areas of land, the hemp is being used as biomass for energy production, an added economic benefit, whilst the alfalfa's ability to fix nitrogen in soil will help restore the degraded land back to agricultural land.

Socio-economic benefits of LIFE remediation efforts are also evident from the EcoQuarry (**LIFE04 ENV/ES/000195**) and LOS TOLLOS (**LIFE09 ENV/ES/000472**) projects in Spain, both of which, in addition to recovering the functional ecosystems of soil and water through phytoremediation and mine filling and sealing, have focused on remodelling the topography of contaminated areas to integrate them back into the landscape.

Landfills and waste management

Leachates from landfills can contaminate soil as well as surface and groundwater as they may contain a wide array of pathogens and chemical pollutants. The extent of soil contamination arising from seepage of leachate from older landfill sites is unknown. In modern landfills, leachate is contained by impermeable membranes and may be treated on site, tankered to sewage treatment works, recirculated through the landfill or sprayed onto nearby land.

As yet, few LIFE projects have covered prevention of soil pollution from leachates or mitigation of the effects through decontamination. LIFE projects

Photo: LIFE09 ENV/ES/000439

The MIPOLARE project involved phytostabilisation, a technique in which vegetation is used to immobilise the metals in the soil of a former mining site

concerning leachates can be divided into three categories: those that attempted to apply systems for sealing in the leachate; those that focused on monitoring techniques for soils contaminated from landfill leachates; and those that developed innovative leachate treatment systems.

In the first category are earlier projects such as Capillary barrier for landfill (**LIFE96 ENV/D/000197**), which applied capillary barriers[31] to closed landfills in order to test the technical requirements and costs of full-scale application of such a landfill sealing system.

The second series of (monitoring) projects includes UK (Landfill Monitoring for LIFE – **LIFE94 ENV/UK/000650**) and Italian (**LIFE95 ENV/IT/000357**) examples, both of which used cross-borehole electrical resistivity soil physics, geochemistry and hydrogeology to establish the spatial distribution and infiltration rate of the pollutant in the subsoil of the landfill. Another project (**LIFE94 ENV/IT/000147**) used an integrated monitoring system for evaluating and managing the risks of a controlled landfill and adopted a permanent system to monitor soil, air and aquifers in the surrounding environment.

31 Capillary barriers consist of a finer grained soil layer overlying a coarser-grained soil layer (usually sand or gravel) . The difference in the saturated hydraulic properties between the two layers minimise percolation in the coarser grained layer.

The third set of projects has showcased a range of innovative means of treating landfill leachate. These treatment systems have varied from using microwave and ultrafiltration pre-treatment of asbestos fibres in leachates from hazardous waste landfills (FALL – **LIFE03 ENV/IT/000323**) to the testing of several new treatment methods (membrane bioreactor, 'epuvalisation'[32], biological treatment) for different types of pollutant on both active and closed landfills (**LIFE97 ENV/B/000403**).

Projects have used low cost natural treatment systems to avoid transportation costs of leachates, including a peatbed filtration system that reduces ammonia concentrations and biological oxygen demand (BOD) - the LAOIS project (**LIFE96 ENV/IRL/000098**) - and wetlands and woodlands, which successfully formed a water barrier to avoid contamination from nitrogen, phosphorous, ammonia, bacteria and heavy metals (LIMNOTOP – **LIFE03 ENV/SLO/000557**). This second method was found to be up to 51% cheaper than conventional treatment systems, with the added advantage of being able to use the woodlands as energy crops.

In addition, an ongoing LIFE Environment project in Italy, New Life (**LIFE10 ENV/IT/000400**), is testing an innovative method for the reclamation of soil around landfills, which, if successful, could be applied to any degraded soil. New Life will use both mechanical and chemical treatment processes, combining the mixing of exhausted soils with other solid matrices (mostly waste materials from quarries and paper mills), soil disintegration processes and a subsequent reconstruction phase, resulting in an aggregate that has economic value. The reconstituted soil should be more fertile, have improved water retention and heat capacity, as well as being more biodiverse (greater bacterial population).

Costs and social benefits

LIFE funding for local soil decontamination projects has strengthened the development of remediation technologies that, on average, have reduced contamination by some 70-90%. They have helped demonstrate the feasibility of innovative technologies and, in certain cases (e.g. ISCO), shown they can be successfully applied at full scale to deal with more than one contaminant at once. This makes replication and uptake easier and more likely.

Nearly all the techniques analysed are applied in-situ, which has cost benefits in comparison with ex-situ remediation. Indeed, projects dealing with remediation of industrial sites and mines, have been shown to reduce costs by 60-90% when compared with conventional treatment methods (soil extraction, soil scrubbing, bioreactors or pump and treat-

32 http://www.epuvaleau.eu/Docs/epuvalisation/EPUVALISATION-fiche-en.pdf

Preparatory groundworks at a disused mining site. The Polish project EKOHEMPKON cultivated crops such as hemp to remediate the contaminated soil.

Photo: LIFE11 ENV/PL/000445

ment of groundwater) an important result given the large number of contaminated sites in the EU. Compost remediation's low energy consumption and low application costs made the technique more cost-efficient than other polluted soil recovery methods. In the case of the BioReGen project it is also necessary to factor in the costs of preparing the sites for planting, however, the operational costs are low, since the crops do not need to be replanted annually and require little maintenance and few chemicals, as well as having a market value.

In addition, LIFE's actions in support of soil remediation have had knock-on benefits for society. Remediation enables the re-use of brownfield sites in cities for housing, enterprise or sport; in rural areas, it can lead to the requalification of natural areas, such as the wetlands of the LOS TOLLOS projects. This improves the quality of life of local communities as well as helping create economic opportunities and new jobs. New employment also extends to the experts (geologists, microbiologists. engineers) working to decontaminate the sites.

Integrating policies

In terms of the practical application of policy, one of the greatest strengths of many LIFE soil decontamination projects has been a tendency to tackle several environmental problems in one go. As highlighted in this publication's chapter on the soil-water nexus, pollution of soil, surface water and groundwater are closely linked and it is essential to address them simultaneously. Thus all the projects featured have set out to monitor pollution of aquifers and wetlands, whilst those using phytoremediation methods have successfully demonstrated cost effective decontamination of both soil and water. The restoration of soil functions relating to water retention capacity and infiltration rate is an important collective outcome of LIFE's remediation efforts, with benefits for the whole water cycle. Most of the projects recognise the importance and impossibility of evaluating and regulating soil and water separately given that they are interlinked.

LIFE has provided a practical demonstration of the value of a single regulatory regime for soil and water. Indeed some projects - such as MNA[33] - have also explicitly called on policy-makers to bring about such a unified regime.

33 http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=home.showFile&rep=file&fil=LIFE03_ENV_FIN_000250_LAYMAN.pdf

A weakness of the programme could be said to be the fact that no projects have focused on preventing the pollution that causes contamination, as foreseen by the Environmental Liability and Damage Directive (2004/35/EC)[34].

One way in which LIFE co-funding could be mobilised to this end would be for projects to develop methodologies for prevention of contamination and make them readily available to regional and local policy-makers, for instance through web-based tools. LIFE can also do more to raise awareness amongst landowners of best practices to avoid or reduce the emission of pollutants into soil, helping obviate the need for remedial procedures.

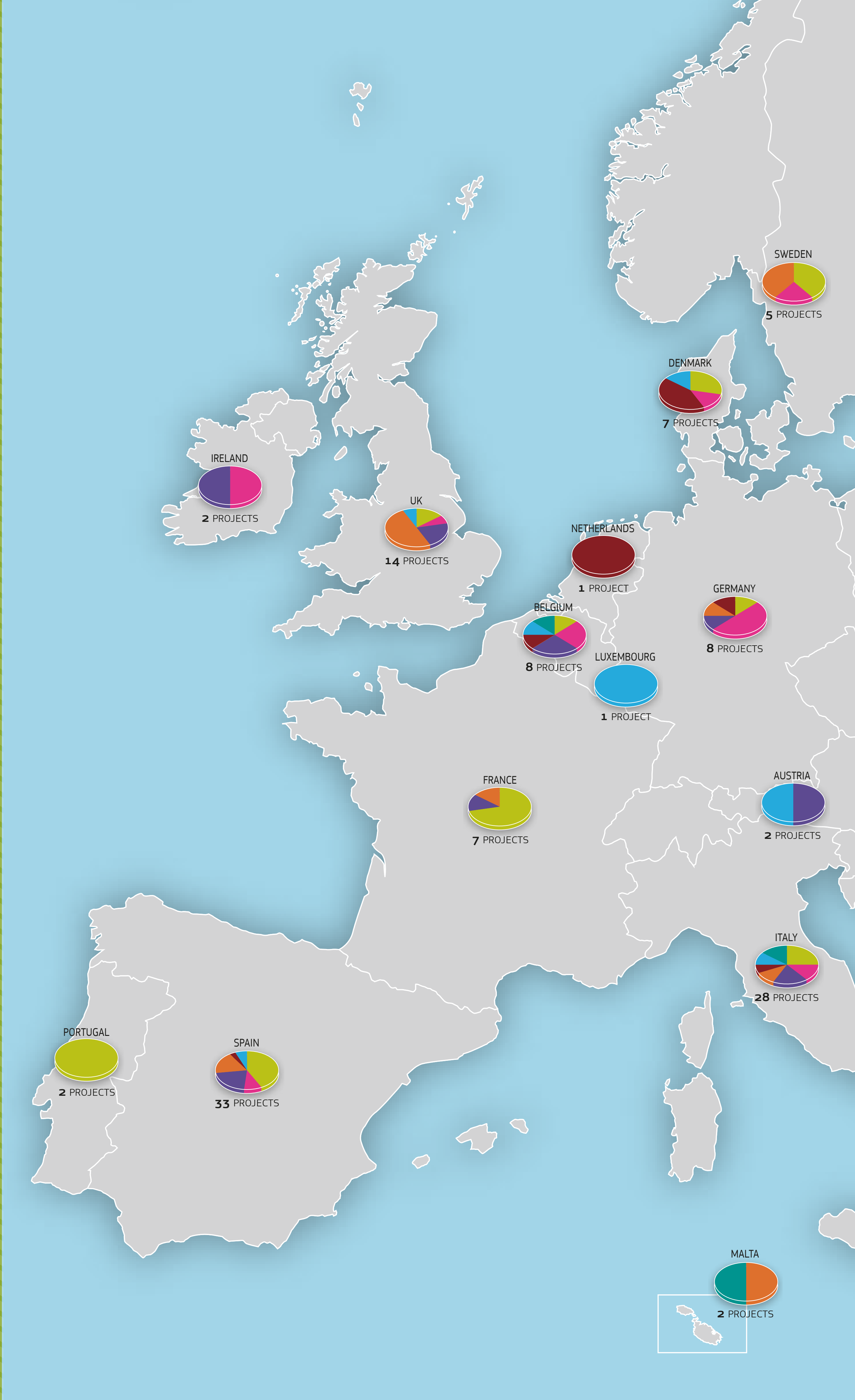
To date, only one project - BIOSOIL - has produced a proposal for the local authorities that includes objectives for prevention and methods and suggestions for integrated planning to achieve this goal. In general, project results do not feed into local, national or EU legislation. In LIFE's favour, it should be noted that a few projects (for instance, I+DARTS in Spain), whilst not proposing new legislation on soil, are providing some input at regional level in updating current environmental policy on soil contamination[35].

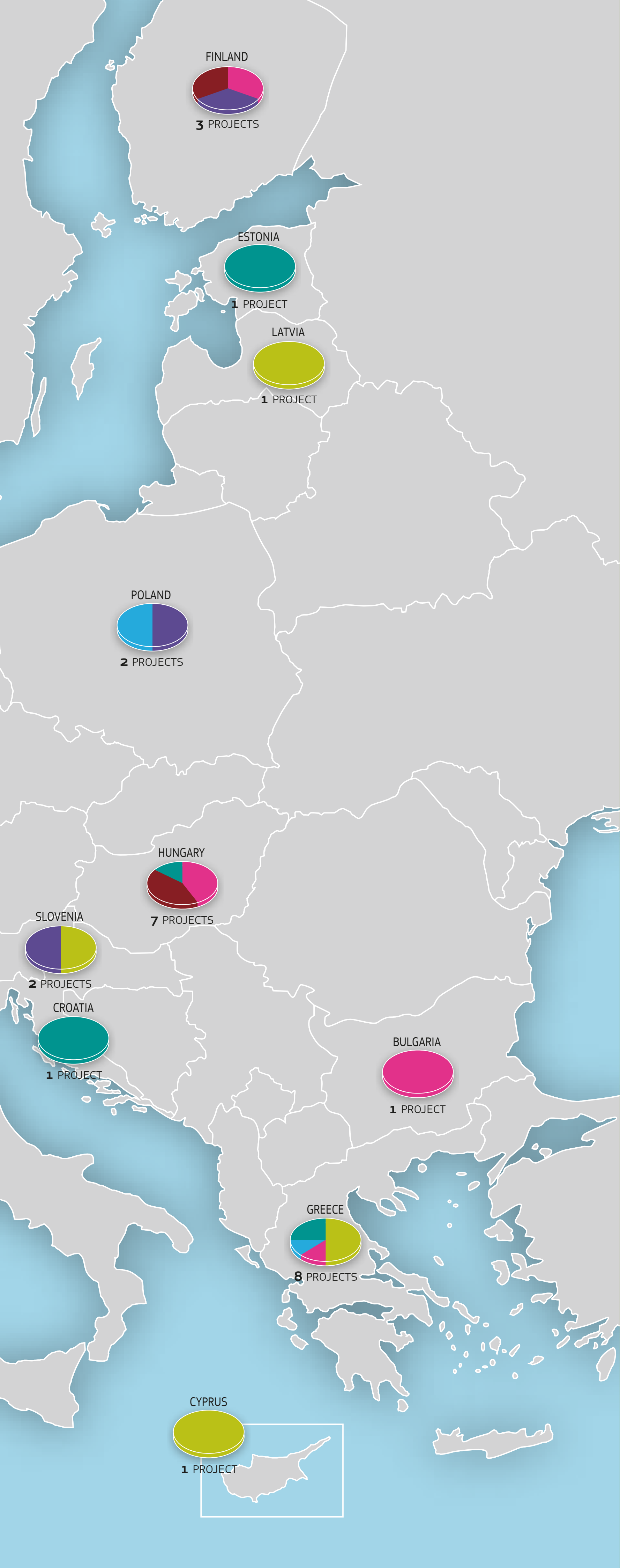
34 http://life.lifevideos.eu/environment/life/publications/lifepublications/generalpublications/documents/soil_study.pdf
35 http://life.lifevideos.eu/environment/life/publications/lifepublications/generalpublications/documents/soil_study.pd

Phytoremediation of a former industrial site using Ditricchia viscosa plants

Photo: LIFE11 ENV/ES/000547

Distribution of soil-related LIFE projects

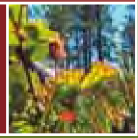




Project breakdown by sub-theme*

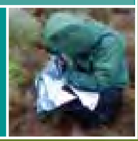
Soil sealing
21 PROJECTS

Soil biodiversity
13 PROJECTS

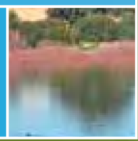


Soil carbon capture
24 PROJECTS

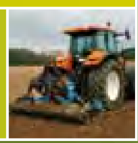
Soil monitoring
11 PROJECTS



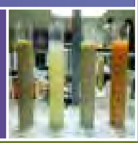
Water and soil
12 PROJECTS



Sustainable agriculture
43 PROJECTS



Land contamination
23 PROJECTS



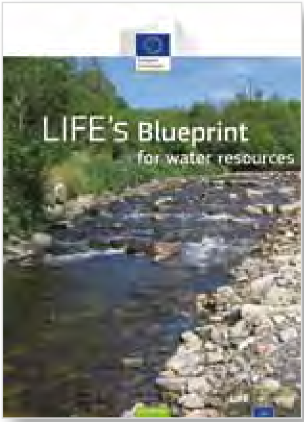
** List represents projects featured in this publication and is not exhaustive*

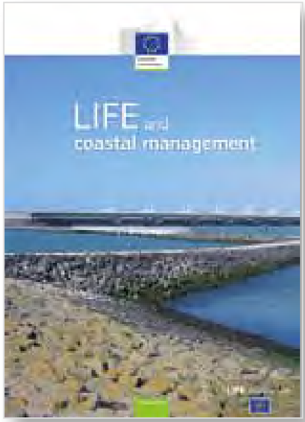
Project list

The table below provides the complete list of LIFE projects related to soil mentioned in this publication. For more information on individual projects, visit the online database at: http://ec.europa.eu/environment/life/project/projects/index.cfm

PROJECT REFERENCE	ACRONYM	TITLE	PAGE
1. LAND TAKE AND SOIL SEALING			
LIFE11 ENV/ES/000538	PLATAFORMA CENTRAL IBERUM	Sustainable urban development in "PLATAFORMA CENTRAL IBERUM"	15
LIFE99 ENV/UK/000177	Cheshire Econet	A demonstration model which integrates environmental considerations in sustainable land use planning and management through the use of ecological networks	16
LIFE00 ENV/E/000415	GREEN BELT	A proposal for sustainable territorial planning	16
LIFE02 ENV/E/000200	GALLECS	Demonstration project on land use and environmental management of the physical planning in Gallecs as a biological and stable connector in the fringe space of Barcelona metropolitan area	16
LIFE04 ENV/ES/000263	BIOSOIL	Project to demonstrate the feasability of compost bioremediation technology for the reclamation and sustainable urban management of brownfields	16
LIFE04 ENV/GB/000820	TWIRLS	Treating Waste for Restoring Land Sustainability	16
LIFE05 ENV/UK/000128	BioReGen	Biomass, remediation, re-generation: Re-using brownfields sites for renewable energy crops.	16
LIFE05 ENV/UK/000127	QUERCUS	Maintaining quality urban environments for river corridors users and stakeholders	17
LIFE07 ENV/D/000224	Capital of Biodiversity	Promoting the Protection of Natura and Biodiversity in Urban Areas: Award European Capital of Nature and Biodiversity	17
LIFE09 ENV/IT/000074	GAIA	Green Areas Inner-city Agreement "GAIA"	17
LIFE11 ENV/FR/000746	SeineCityPark	Development of an urban green infrastructure in the Chanteloup loop	17
LIFE12 ENV/ES/000092	Life-QUF	Quick urban forestation	17
LIFE03 ENV/UK/000614	SUN	Sustainable Urban Planning Networks for green spaces	18
LIFE08 ENV/E/000099	AQUAVAL	Sustainable Urban Water Management Plans, promoting SUDS and considering Climate Change, in the Province of Valencia	18
LIFE12 ENV/UK/001133	LIFE Housing Landscapes	Climate-proofing Social Housing Landscapes	18
LIFE98 ENV/S/000482	Roof greening	Extensive roof greening	19
LIFE06 NAT/IT/000060	LIFE FRIULI FENS	Conservation and restoration of calcareous fens in Friuli	19
LIFE07 ENV/S/000908	GreenClimeAdapt	Green tools for urban climate adaptation	19
LIFE07 ENV/UK/000936	GRACC	Green roofs against climate change. To establish a UK green roof code to support climate change mitigation and adaptation.	19
LIFE12 ENV/MT/000732	LifeMedGreenRoof	Constructing two demonstration green roofs to illustrate the potential of meeting environmental and energy targets	19
LIFE08 ENV/IT/000408	SOILCONS-WEB	Multifunctional Soil Conservation and Land Managment through the Development of a Web Based Spatial Decision Supporting System	20
2. SOIL BIODIVERSITY			
LIFE04 NAT/HU/000119	EPU (HNP)	Grassland restoration and marsh protectin in Egyek-Pusztakócs	23
LIFE07 NAT/IT/000507	LIFE+ AVIFAUNA DEL LAGO S	Conservation actions for priority bird life in Lake Salso Oasis	23
LIFE08 NAT/DK/000464	DRY GRASSLAND	Dry Grassland in Denmark - Restoration and Conservation	23

Available LIFE Environment publications





LIFE Environment brochures

LIFE creating green jobs and skills (2013, 76 pp. – ISBN 978-92-79-25091-0 – ISSN 1725-5619)

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LIFE among the olives: Good practice in improving environmental performance in the olive oil sector (2010, 56 pp. – ISBN 978-92-79-14154-6 – ISSN 1725-5619)

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Breathing LIFE into greener businesses: Demonstrating innovative approaches to improving the environmental performance of European businesses (2008, 60 pp. – ISBN 978-92-79-10656-9 – ISSN 1725-5619)

LIFE on the farm: Supporting environmentally sustainable agriculture in Europe (2008, 60 pp. – 978-92-79-08976-3 – ISSN 1725-5619)

LIFE and waste recycling: Innovative waste management options in Europe (2007, 60 pp. – ISBN 978-92-79-07397-7 – ISSN 1725-5619)

Other publications

Environment Policy & Governance Projects 2012 compilation (2013, 157 pp. – ISBN 978-92-79-29479-2)

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Information & Communication Projects 2011 compilation (2012, 17 pp. – ISBN 978-92-79-25248-8)

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Information & Communication Projects 2010 compilation (2011, 19 pp. – ISBN 978-92-79-20027-4)

Best LIFE Environment projects 2009 (2010, 32 pp. – ISBN 978-92-79-16432-3 ISSN 1725-5619)

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Information & Communication Projects 2009 compilation (2010, 14 pp. – ISBN 978-92-79-16138-4)

Environment Policy & Governance Projects 2008 compilation (2009, 107 pp. – ISBN 978-92-79-13424-1)

Information & Communication Projects 2008 compilation (2009, 21 pp. – ISBN 978-92-79-13425-8)

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http://ec.europa.eu/environment/life/publications/lifepublications/index.htm

A number of printed copies of certain LIFE publications are available and can be ordered free-of-charge at:
http://ec.europa.eu/environment/life/publications/order.htm

KH-AJ-13-004-EN-N

LIFE+ "L'Instrument Financier pour l'Environnement" / The financial instrument for the environment

Period covered (LIFE+) 2007-2013.

EU funding available approximately EUR 2 143 million

Type of intervention at least 78% of the budget is for co-financing actions in favour of the environment (LIFE+ projects) in the Member States of the European Union and in certain non-EU countries.

LIFE+ projects

> LIFE Nature projects improve the conservation status of endangered species and natural habitats. They support the implementation of the Birds and Habitats Directives and the Natura 2000 network.

> LIFE+ Biodiversity projects improve biodiversity in the EU. They contribute to the implementation of the objectives of the Commission Communication, "Halting the loss of Biodiversity by 2010 – and beyond" (COM (2006) 216 final).

> LIFE+ Environment Policy and Governance projects contribute to the development and demonstration of innovative policy approaches, technologies, methods and instruments in support of European environmental policy and legislation.

> LIFE+ Information and Communication projects are communication and awareness raising campaigns related to the implementation, updating and development of European environmental policy and legislation, including the prevention of forest fires and training for forest fire agents.

Further information further information on LIFE and LIFE+ is available at http://ec.europa.eu/life.

How to apply for LIFE+ funding The European Commission organises annual calls for proposals. Full details are available at http://ec.europa.eu/environment/life/funding/lifeplus.htm

Contact

European Commission – Directorate-General for the Environment LIFE Unit – BU-9 02/1 – B-1049 Brussels – Internet: http://ec.europa.eu/life

LIFE Publication / LIFE and Soil protection

Luxembourg: Office for Official Publications of the European Union

2014 - 68p - 21 x 29.7 cm
ISBN 978-92-79-34664-4
ISSN 2314-9329
doi:10.2779/64447

Publications Office

ISBN 978-92-79-34664-4
9 789279 346644
doi:10.2779/64447