European Commission

LIFE and Climate change adaptation

LIFE *Environment*

Environment & Climate Action

EUROPEAN COMMISSION
ENVIRONMENT DIRECTORATE-GENERAL

LIFE (*"The Financial Instrument for the Environment and Climate Action"*) is a programme launched by the European Commission and coordinated by the Environment and Climate Action Directorates-General. The Commission has delegated the implementation of many components of the LIFE programme to the Executive Agency for Small and Medium-sized Enterprises (EASME).

The contents of the publication "LIFE and Climate change adaptation" do not necessarily reflect the opinions of the institutions of the European Union.

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Luxembourg: Publications Office of the European Union, 2015

ISBN 978-92-79-52307-6
ISSN 2314-9329
doi:10.2779/429595

Foreword

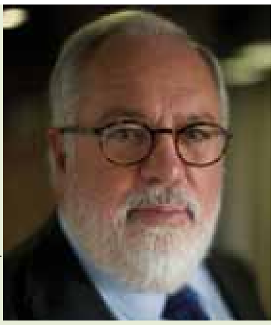

Photo: European Commission

Miguel Arias Cañete
EU Commissioner for Climate Action and Energy

The new global climate deal to be agreed in Paris is a unique opportunity to accelerate the transition to low-carbon, climate-resilient economies worldwide. This requires ambitious action to both reduce emissions and prepare for the impacts of climate change.

The EU has made a clear pledge to contribute to the global effort. We are committed to a binding, economy-wide greenhouse gas emissions reduction target of at least 40% by 2030, compared to 1990 levels.

We also want the Paris Agreement to provide a long-term vision to enhance climate-resilient sustainable development. The impacts of climate change are already widespread and are likely to increase. In Europe, key climate risks include increased economic losses and a growing number of people affected by flooding, heat waves, droughts or forest fires.

Adaptation action can address many of these risks. For instance, it has been estimated that each euro spent on flood protection could save six euros in damage costs.

Adaptation also means taking advantage of opportunities that may arise. As these pages show, this relatively new field offers room for creativity and for developing innovative approaches and technologies, which often bring co-benefits.

As President Juncker recently noted in his State of the Union 2015 speech, the battle against climate change will be won or lost on the ground and in the cities where most Europeans live and work. Adaptation measures will play an important role in this.

Action is needed at all levels – from local to international. The EU Adaptation Strategy, adopted in 2013, promotes adaptation action in all Member States to contribute to a more climate-resilient Europe. The strategy focuses on three key objectives: promoting action by Member States; 'climate-proofing' action at EU level; and better informed decision-making.

We are already making good progress. For instance, the number of Member States with a national adaptation strategy has risen from 13 in 2013 to 20 today. The Mayors Adapt initiative is helping cities and towns across the EU develop adaptation plans at the local level. The Climate-ADAPT platform is informing users about climate change adaptation, and work is progressing on knowledge gaps related to adaptation.

Adaptation to climate change, together with mitigation, has been included in all relevant EU funding programmes for 2014-2020, in line with our objective of spending at least 20% of the EU budget - as much as €180 billion - on climate-related action.

This funding includes €864 million available through the LIFE sub-programme for Climate Action for projects targeting both mitigation and adaptation efforts. The new round of funding builds on the €307 million that the LIFE programme has already mobilised to advance climate change adaptation. This has supported actions that range from strategic planning to specific measures in sectors such as agriculture, water management and forestry.

The European Commission will report to the European Parliament and Council in 2017 on the implementation of the EU adaptation strategy. The potential revision of the strategy offers the opportunity to reinforce certain aspects of key importance for the future. Lessons from LIFE projects included in this publication can contribute to that process.

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Adapting to climate change: **EU action for a global problem**

The success of EU climate policy requires an integrated approach to climate adaptation. Mainstreaming adaptation into all relevant sectors is vital to this.

Photo: LIFE04 NAT/DE/000028

LIFE has shown how nature-based approaches to adaptation strengthen the resilience of ecosystems whilst increasing biodiversity

In his first State of the Union address, President Juncker highlighted the need for the European Union to push for an "ambitious, robust and binding" climate deal at the global COP21 summit in Paris this December (see box - "The road to Paris"). "My Commission will work to ensure Europe keeps leading in the fight against climate change," he said.

The European Union is devoting at least 20% of its budget from 2014-2020 to climate change mitigation and adaptation measures. We have already covered EU policy on climate change mitigation and the work of the LIFE programme in its implementation in a LIFE Focus brochure published at the beginning of 2015. In this latest brochure, we focus on LIFE and climate change adaptation.

The EU climate change Adaptation Strategy

The delayed impacts of past and current greenhouse gas emissions mean that even if global warming targets are achieved, adaptation

A global agreement to tackle climate change

The EU stresses that an increase in the global average temperature needs to be kept below 2°C above the pre-industrial level in order to prevent the worst impacts of climate change. Therefore, the EU supports a global, fair, ambitious and legally-binding international treaty that will prevent global warming from reaching dangerous levels. Ambitious action to cut greenhouse gas emissions and a clear pathway to achieving the below 2° objective will have to play a key role in the new agreement.

The EU further stresses that adaptation needs to be addressed with the same priority and urgency as mitigation in a balanced agreement. This agreement offers a unique opportunity to provide for renewed visibility on the importance of adaptation and gives all parties a long-term vision on adaptation.

The Environment Council conclusions adopted in September 2015 support a balanced Paris Agreement including strong action to cut greenhouse gas emissions and adapt to the impacts of climate change as well as adequate support for financing climate action.

measures will be necessary. The central plank of EU policy in this area is the *EU strategy on adaptation to climate change*, which was adopted by the European Commission in April 2013.

The Strategy aims to make Europe more climate-resilient and takes a coherent approach by complementing the activities of Member States.

It promotes adaptation action across the EU, ensuring that adaptation considerations are addressed in all relevant EU policies (mainstreaming), promoting greater coordination, coherence and information-sharing.

The EU is promoting action by encouraging all Member States to adopt a comprehensive national adaptation strategy. Through Mayors Adapt, now incorporated into the New Covenant of Mayors for integrated climate and energy action, the EU is encouraging a voluntary commitment for cities (see pp. 30-39). The Strategy also outlines the EU's commitment to provide financial support for adaptation through LIFE.

Member States are increasingly recognising that adaptation is an iterative process and that learning from existing practices and new information from research helps to improve adaptation interventions. Challenges in this regard include addressing knowledge gaps, such as on costs and benefits of adaptation, local-level analyses and risk assessments. The Strategy addresses key knowledge gaps and also aims to refine and identify ways to address them. LIFE is recognised as one of the relevant tools in this regard as well. In addition, the European Commission and the European Environment Agency (EEA) are improving access to information through Climate-ADAPT, the European Climate Adaptation Platform that serves as a 'one-stop shop' for adaptation information in Europe[1].

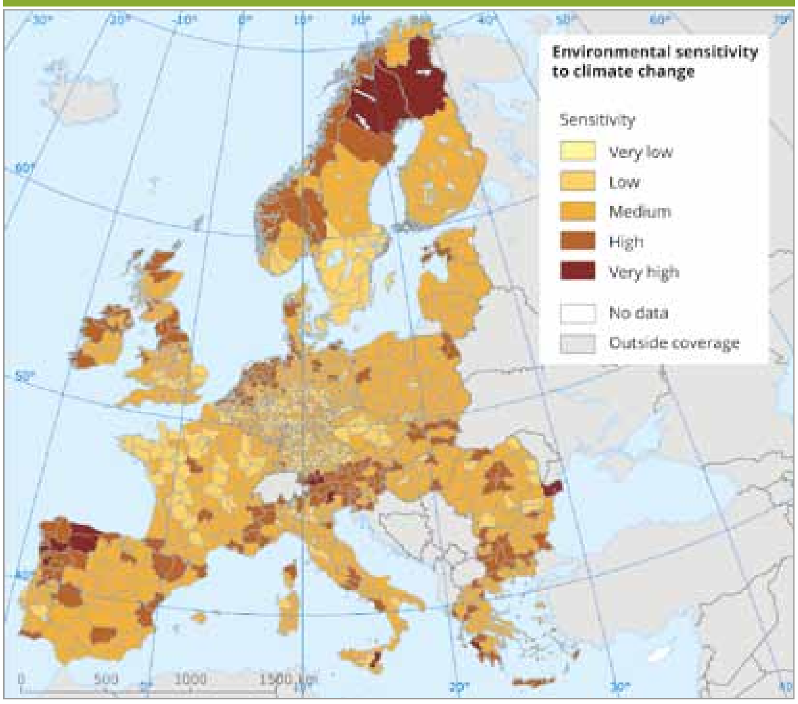
Promoting adaptation in key vulnerable areas will be achieved through mainstreaming adaptation measures into EU policies and programmes, as a way of 'climate-proofing' EU action. This includes integrating adaptation under the Common Agricultural Policy (CAP) and the Cohesion Policy and ensuring more resilient infrastructure.

Implementation of the EU Adaptation Strategy is based on eight actions (see box).

How implementation is proceeding

Work is ongoing on all eight actions of the Strategy, and results are beginning to show. To give a couple of examples, as part of the Adaptation Strategy package the Commission provided guidelines to help Member States formulate adaptation strategies.

Environmental sensitivity to climate change



Copyright: European Environment Agency (EEA). Source: ESPON Climate, 2011

1 http://climate-adapt.eea.europa.eu/

Eight actions to implement the EU Adaptation Strategy

1. Encourage all Member States to adopt comprehensive adaptation strategies
2. Provide LIFE funding to support capacity building and step up adaptation action in Europe (2014-2020)
3. Introduce adaptation in the Covenant of Mayors framework (2013/2014) (Mayors Adapt and the New Covenant of Mayors))
4. Bridge the knowledge gap
5. Further develop Climate-ADAPT as the 'one-stop shop' for adaptation information in Europe
6. Facilitate the climate-proofing of the Common Agricultural Policy (CAP), the Cohesion Policy and the Common Fisheries Policy (CFP)
7. Ensure more resilient infrastructure
8. Promote insurance and other financial products for resilient investment and business decisions

To date, 20 Member States have developed a national adaptation strategy (compared with 13 NAS in 2013), and several more are under preparation. Mayors Adapt – the Covenant of Mayors Initiative on Adaptation to Climate Change was launched in March 2014. Cities signing up to the initiative commit to contribute to a more climate-resilient Europe (i.e. the overall aim of the EU Adaptation Strategy), to develop local adaptation strategies or to mainstream adaptation into relevant existing plans within the first two years of signing and review the outcomes on a biannual basis.

The EU Adaptation Strategy also proposes monitoring and evaluating the status and progress of climate change adaptation in the EU. In 2017, the European Commission will report to the European Parliament and the Council on the state of implementation of the EU Adaptation Strategy, and propose its review, if needed.

In April 2014, the EEA published a report on *National adaptation policy processes in European Countries*[2]. This report found that adaptation has most often been implemented by applying 'soft measures' (e.g. mainstreaming); that project-based support has been the most important financing mechanism for implementing adaptation; and funds from government budgets for adaptation have been allocated mainly to the water and agriculture sectors.

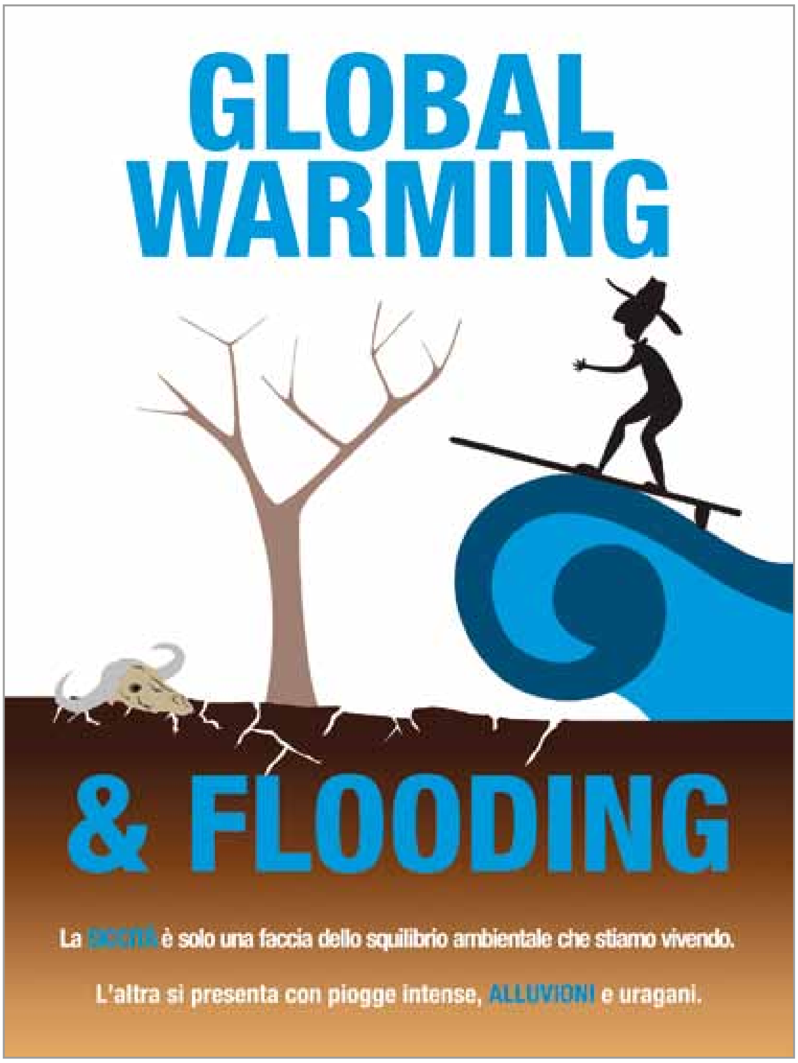
Water, agriculture and forestry are the sectors most advanced in terms of implementing portfolios of adaptation measures at all administrative levels, notes the EEA report, with biodiversity a sector where options were being identified at national level.

Mainstreaming adaptation

The scale of the challenge presented by climate change makes it imperative to mainstream climate adaptation across sectors and funding mechanisms.

The AQUOR project aims to develop an adaptive strategy to support the sustainable governance of upper Vicenza's groundwater

Photo: LIFE10 ENV/IT/000380



2 *http://www.eea.europa.eu/publications/national-adaptation-policy-processes*

Mainstreaming adaptation through ESIF

There are opportunities to mainstream climate adaptation into all five European Structural and Investment Funds (ESIF):

European Regional Development Funds (ERDF) - at least 5% of national ERDF resources should be allocated to integrated actions for sustainable urban development. This could help tackle climate challenges affecting urban areas. Manchester City Council's 'City Green Infrastructure Plan' is one mainstreaming example supported by ERDF under the 2007-2013 financial framework.

European Social Fund (ESF) - The ESF can support the labour force in shifting to a low-carbon economy through training for the workforce and the unemployed, creating networks of skilled advisers, supporting social enterprises and devising curricula for green skills in vocational training.

The Cohesion Fund (CF) - The CF could be used to support a number of climate adaptation measures, including 'blue infrastructure' to provide additional flood storage capacity and reduce overheating risks in urban areas.

European Agricultural Fund for Rural Development (EAFRD) - Climate adaptation can be mainstreamed into agriculture through Rural Development Programme (RDP) measures. In Austria, for instance, adaptation has been addressed through the protection of biodiversity by conserving hedgerows, environmentally sustainable farm operation through adapted plant selection, and reduced pesticide inputs; in Scotland, the RDP includes support for investments to improve the resilience of forest ecosystems.

European Maritime and Fisheries Fund (EMFF) - Support for planning initiatives such as Marine Spatial Planning, Integrated Coastal Zone Management and sea-basin strategies can help to improve the climate change resilience of fishing communities. EMFF can also support community-led local development that involves local approaches to adaptation. For instance, where climate change impacts will lead to changes in fish stocks, local development strategies could encourage diversification of fisheries and aquaculture and the diversification of the local economy into other sectors. Further examples of mainstreaming climate action into ESIF can be found in a series of fact sheets [1].

1 Mainstreaming of climate action in the European Structural and Investment Funds 2014-2020; available at: http://ec.europa.eu/clima/publications/index_en.htm

Many mainstreaming initiatives in national sector legislation are driven by EU legislation that recognises adaptation. For example the Water Framework Directive and Floods Directive have led to EU Member States making legislative changes that have taken into account the need to adapt to climate change.

As part of the Adaptation Strategy package the Commission has provided guidance on how to further integrate adaptation into the CAP, Cohesion Policy and the CFP. This guidance aims to help managing authorities and other stakeholders involved in programme design, development and implementation during the 2014-2020 budget period. Member States and regions can also use funding under the 2014-2020 Cohesion Policy and CAP to address knowledge gaps, to invest in the necessary analyses, risk assessments and tools, and to build up capacities for adaptation.

In February 2013, based on a Commission proposal, the European Council concluded that "climate action objectives will represent at least 20% of EU spending in the period 2014-2020 and therefore be reflected in the appropriate instruments to ensure that they contribute to strengthen energy security, building a low-carbon, resource-efficient and climate-resilient economy that will enhance Europe's competitiveness and create more and greener jobs."

The European Structural and Investment Funds (ESIF)[3] represent more than 43% of the EU budget in the period 2014-2020. ESIF thus have a significant role to play in reaching the "at least 20%" overall target for climate related expenditure and contributing to Europe's transition to a low-carbon and climate-resilient economy. To make this happen, climate action has been included in the relevant legal basis for ESIF, such as the Common Provisions Regulation[4] (CPR), a number of fund-specific regulations, implementing regulations and acts.

There is scope for a wide range of climate action, both mitigation and adaptation, across all the 11 thematic objectives and the corresponding investment and Union priorities. More importantly, there are two thematic objectives that are exclusively dedicated to contributing towards the achievement of climate change objectives i.e. thematic objective 4 supporting the shift towards a low-carbon economy in all sectors and thematic objective 5 promoting climate change adaptation, risk prevention and management.

Preliminary data indicates that the overall share of climate-related expenditure in the indicative ESIF budget for 2014-2020 will be about 25%. This money will support such climate change-related actions as development of renewable energy sources, energy efficiency, sustainable urban mobility, climate adaptation measures, green infrastructure, ecosystem services, sustainable agriculture and forestry, climate-related innovation, business development and green jobs.

3 include five funds: the European Regional Development Fund (ERDF), Cohesion Fund (CF), European Social Fund (ESF), European Agricultural Fund for Rural Development (EAFRD), and the European Maritime and Fisheries Fund (EMFF).
4 Regulation (EU) No 1303/2013 of the European Parliament and the Council of 17 December 2013.

INTRODUCTION

LIFE and **climate change adaptation**

LIFE has been one of the main funding sources for demonstration projects that have facilitated the implementation and enforcement of EU climate adaptation policy and mainstreamed adaptation in many other policy areas.

Since 2000, the LIFE programme has co-funded nearly 150 projects that focus – in whole or part - on climate change adaptation. These have mobilised some €307 million for climate change adaptation (with an EU contribution of €152 million), a figure that excludes the many millions spent, for instance, on agri-environmental measures relevant to adaptation but not branded as such, or on green infrastructure to increase ecosystem resilience.

LIFE has helped mainstream adaptation in many policy areas, bringing stakeholders together to work on common objectives and raising awareness on adaptation issues. The programme has been most active in mainstreaming climate adaptation in water policy (43 projects), including a strong focus on water scarcity and floods; in agriculture (25 projects); and in creating resilient urban and peri-urban areas (22 projects).

Adaptation projects have been led mainly by NGOs, universities and local and regional authorities, and they have involved as stakeholders farmers, agronomists, forest managers, citizens, businesses and public authorities.

There has been a significant increase in the number of LIFE climate change adaptation projects since climate change became a policy priority under the LIFE+ programme (2007-2013). The first LIFE+ projects mainly tested single solutions and defined best practice for adaptation. More recent projects have tended to adopt integrated or ecosystem-based approaches to flood

LIFE is adopting nature-based solutions to increase resilience

Photo: LIFE10 NAT/IT/000241

management, agriculture and urban resilience. There have been fewer LIFE Nature & Biodiversity projects than LIFE Environment projects that have directly targeted climate adaptation.

The implementation of adaptation policies and measures is still at a relatively early stage. This, together with the need to maintain political commitment to adaptation and related expenditure, makes it imperative to understand which adaptation actions work in which contexts and to know the reasons why. LIFE 2014-2020 funding can support projects that help monitoring and assess the progress of adaptation measures. To do this, proxies for measuring 'reduced vulnerability' or 'increased resilience' will have to be developed. Projects can also help in developing indicators that provide evidence that a certain condition exists or certain results have or have not been achieved.

The current funding period offers significant scope to finance projects that improve or extend best practices developed by earlier LIFE projects in areas such as adaptation planning, forestry practices or green/blue infrastructure. It can also address the opportunities presented by newer developments such as nature-based approaches, ecosystem services, monitoring and measuring resilience. Importantly, action grants for 'traditional' projects are now supplemented by newer tools such as Integrated Projects (see box) and the Natural Capital Financing Facility (NCFF – see. pp. 13-14).

LIFE has trialled green roofs in Mediterranean and northern European countries

Photo: LIFE07 ENV/UK/000936/NEEMO EEIG/Donald Lunan

Strategies and planning

Since 2007, nine LIFE projects have supported the development of climate adaptation strategies or plans (total budget: €16 million), including one project to develop a national adaptation strategy (for Cyprus – see pp. 26-29). The majority of projects have worked at sub-national level, helping to turn strategies into action plans at regional or local level.

An important aspect of these LIFE projects has been the involvement of stakeholders, which should increase acceptance and implementation of proposed adaptation measures. Future projects could also involve stakeholders in monitoring and reviewing measures.

LIFE projects have also focused on capacity building and providing tools for risk and vulnerability assessments, modelling and monitoring. Adaptation planning should integrate mitigation and adaptation measures, rather than treating them as distinct issues.

In the current funding period, the LIFE sub-programme for Climate Action can continue to support adaptation planning at national, regional and local level.

Urban resilience

The LIFE programme has co-funded 22 urban resilience projects since 2000 to the tune of €44 million. Spain, Italy, and France have been the recipients of most of this support. Beneficiaries in Member States across the EU also could use LIFE co-funding to demonstrate best practices and solutions for urban areas.

Since 1998 a small cluster of projects have demonstrated the adaptive potential of 'green infrastructure', including the ability of green roofs to reduce storm water run-off and the positive effects of requalifying green areas and creating green belts and corridors in peri-urban areas. In recent years, there has been a noticeable evolution in the scope of LIFE projects funded, moving beyond single solutions (e.g. a green roof or a sustainable urban drainage system – SUDS) to integrated, ecosystem-based solutions for whole districts or even whole cities. This has been achieved by integrating green and blue infrastructure in local planning, by creating collective participation and a sense of responsibility, and by getting businesses on board.

With urban resilience as a funding priority for the current period, there is an opportunity for new projects to build on these achievements by developing and deploying innovative adaptation technologies within the water, energy and construction sectors, and increasing the focus on health-related issues. There is also scope for capacity-building and increased stakeholder collaboration.

Agriculture

LIFE has supported the development of best practices in agriculture that help to increase resilience. Since 2004, there have been nearly 30 adaptation projects in this sector, with a total budget of €54 million. Many of these projects, particularly those in Spain and Italy, have been closely linked to the implementation of EU water policy. In tackling water scarcity issues, they have implemented sustainable irrigation techniques that avoid over-abstraction of groundwater and increase water availability during the droughts and dry spells that will be more frequent because of climate change.

A sizable cluster of projects have focused on demonstrating and disseminating resilient agricultural practices such as no-tillage, crop rotation, use of cover crops, afforestation and reduced grazing. These methods increase soil fertility and reduce soil erosion, thus increasing resilience. Some projects have even helped influence policy and led to measures being included in Rural Development Programmes. A great strength of LIFE is that projects actively engage with farmers; those featured in this publication have provided training in climate resilient agricultural techniques and built support networks involving agronomists and farmers. The demonstration effect has been visible in the use of the same techniques elsewhere on participating farms or on neighbouring farms, even after the projects have ended.

Despite these successes, more can be done in other areas of agricultural practice. Few LIFE projects have explored pest control, intercropping or the use of adapted crops, for example. Moreover, LIFE projects have yet to focus on animal rearing conditions or livestock diversification in the context of climate change adaptation. LIFE could also apply research done by other programmes into the effects of climate change on certain crops.

Photo: LIFE 08/ENV/GR/000554/EKBY Photo Archive/L. Logothetis

Climate change can increase the damage caused by domestic forest pathogens and pests

Forests

The LIFE programme has been an important source of support for implementing forest adaptation actions. It has been involved in co-financing some of the EU's earliest forest adaptation work (some 20 projects in all) with a combined budget of €38 million. Projects have tackled the impacts of warmer temperatures, especially forest fires in the Mediterranean region, changes in tree species composition, and biotic disturbance such as the spread of pests and pathogens. They have also built capacity to adapt to climate change and raised awareness of the issue amongst specialist audiences and the general public. Completed LIFE projects have helped Member States to adopt forest management techniques that enable climate change adaptation.

With its greater focus on climate action, the LIFE Programme for 2014-2020 provides additional opportunities for forest-related projects. The new generation of projects could focus on tackling the effects of atmospheric pollution, promoting adapted species compositions within forests and promoting advanced forest management to decrease threats and improve responses. In addition to climate action grants for adaptation actions, the programme now has the potential to increase its impact via the NCFF, which could be used to support projects that adopt ecosystem-based approaches that enable forest managers to address identified risks associated with current and projected impacts of climate change.

Water management and flooding

The impact of the Water Framework Directive, the Floods Directive and the Water Blueprint Initiative, policies that seek to mainstream climate adaptation, means that there have been more LIFE climate adaptation projects related to water than to any other sector: 43 projects with a total budget of €93 million. These projects are helping overcome barriers to the implementation of EU water policy where climate change adaptation has been mainstreamed.

Regarding water management, LIFE has been particularly good at funding projects that concern water scarcity issues, by developing modelling tools or exploring different managed aquifer recharge methods. It has also addressed water quality and eutrophication issues and has been at the forefront of promoting a water saving culture. More could be achieved on determining variations in river flows. Additional attention could be paid to identifying and finding solutions for the effects that poorer water quality exacerbated by climate change can have on species composition, organism abundance and productivity, and phenological shifts in some freshwater ecosystems.

More LIFE projects have targeted flooding than any other climate adaptation theme: 26 projects with a budget of €63 million. LIFE has helped map flood risks, provide early flood warnings and reduce the impact of inundations through river and wetland restoration. It has demonstrated the practical value and cost effectiveness of natural water retention measures. In so doing, projects have shown ways of cost effectively implementing the Water Framework and Floods Directives. In the future more emphasis should be given to projects that use ecosystem-based approaches and to increasing cross-border cooperation amongst Member States (again possibly through Integrated Projects and the NCFF).

Coastal areas

Europe's coasts are amongst the areas most vulnerable to climate change and thus mainstreaming adaptation measures is of particular importance, especially considering the ecosystem services that coastal areas provide. To date, 16 LIFE projects (budget: €35 million) have addressed climate adaptation issues, including higher sea temperatures, sea level rise, coastal erosion and loss of ecosystem services. Projects have demonstrated risk mapping and modelling tools for assessing the full extent of those impacts and ways of increasing

LIFE has helped restore wetlands thus helping to regulate floods and droughts

Photo: LIFE02 NAT/D/008456

the resilience of Europe's coastal ecosystems. The greatest strength of the programme has been to fund projects that have tackled coastal erosion and that have increased coastal resilience through the restoration of coastal lagoons and wetlands through the LIFE Nature strand.

Future LIFE projects should focus on addressing climate change needs through integrated coastal management, maritime spatial planning and ecosystem-based approaches. The latter is of particular importance to those responsible for establishing priorities for coastal management.

Biodiversity

A small percentage of LIFE Nature & Biodiversity funding has directly targeted climate change adaptation (15 projects with direct actions, with a total budget of €41 million). Many more projects have indirectly increased climate resilience by applying restoration measures, reducing fragmentation and increasing connectivity in ecological networks through the development of green infrastructure. Habitat restoration actions have also made landscapes more permeable for species dispersion and water flow, increased landscape diversity and restored the range of functions, services and goods provided by ecosystems. This makes them more resilient and more likely to withstand risks and vulnerabilities such as fires, droughts, floods and alien species invasions.

Projects have increased spatial connectivity by linking the habitats of threatened species (e.g. brown bears, European mink, migratory fish and amphibians) to strengthen populations through genetic exchange.

Other defragmentation actions have focused on habitat types listed in Annex I of the Habitats Directive. Projects have reconnected prime core habitats or linked core areas with newly restored sites through green corridors and ecological stepping stones. Examples include: reconnecting rivers with floodplains; continuous grasslands; coastal meadows; networks of bogs and mires; old growth and boreal forests.

To further help biodiversity adapt to climate change, LIFE could in future fund more projects that trial ecosystem-based approaches to adaptation and, in particular, projects that trial methods that experts can subsequently use to measure their impact on increasing resilience. Aside from traditional LIFE Nature and LIFE Climate Action projects, the NCFF could be used for this end. The new funding facility can finance projects that use new approaches to ecological restoration and/or conservation or innovative business models to protect biodiversity or increase the resilience of communities.

Photo: LIFE98 NAT/S/005371/Alf Kjellström

LIFE has aimed to halt the Arctic fox's decline and increase its breeding population

Integrated Projects (IPs)

LIFE Climate Action Integrated Projects are jointly funded projects operating on a large territorial scale that aim to implement climate policy into other policy areas. The first Climate Action Integrated Projects will be chosen from applications submitted in the 2015 LIFE call for proposals. There is scope for Integrated Projects to address climate adaptation challenges in all the thematic areas covered in this brochure. Some specific examples are presented below:

Strategies and planning: IPs could potentially address transboundary issues relating to adaptation (e.g. relating to shared water basins).

Urban resilience: IPs could contribute to the goals of building capacity and increasing stakeholder collaboration, as well as helping local and regional authorities to take an integrated approach to mitigation and adaptation action that starts at the planning phase.

Water management and flooding: Member States could propose Integrated Projects that address flood management in a cross-border river/coastal area, thus creating synergies with the water, coastal and urban policies.

Coastal areas: IPs could be a tool to enable Member States to address transboundary hazards (disaster risk reduction) and to ensure coastal management is able to adapt effectively to climate change impacts.

Biodiversity: IPs could be used to implement climate change adaptation strategies, plans or address specific climate change vulnerabilities and synergies with other environmental policies such as biodiversity.

INTRODUCTION

Meeting adaptation challenges: **DG CLIMA's perspective**

Humberto Delgado Rosa is Director responsible for Mainstreaming Adaptation & Low Carbon Technology, DG CLIMA. In this interview, he talks about adaptation at Member State and local level and his expectations of the United Nations Climate Change Conference in Paris in December 2015.

"National adaptation strategies are key to improving the coherence of Member States' adaptation planning activities, policies and measures. When the EU strategy on adaptation to climate change was adopted in 2013, 15 Member States had adopted national adaptation strategies. Now 20 have done so, and there are more strategies in the pipeline. Due to the relative novelty of the field, these strategies are quite heterogeneous and some are already in the process of being revised and improved.

These achievements demonstrate Member States' commitment to adaptation despite the challenges existing in this sector. We are making progress in the implementation of the EU Adaptation Strategy as a whole and getting closer to our goal of having national adaptation strategies in all EU Member States by 2017.

There are numerous tools that are used to achieve this goal. They include the upgraded European Climate Adaptation Platform (Climate-ADAPT), the highly successful urban initiative on adaptation Mayors Adapt, and the LIFE Programme, of course, for which two calls for proposals have already been published under the new Climate Action sub-programme. Work is also being done as part of the research framework programme Horizon 2020: climate-related expenditure should exceed 35% of the programme's total budget. In addition, a large share of the European Structural and Investment Funds (ESIF) are being invested in climate change mitigation and adaptation. At least 20% of the EU's Multi-annual Financial Framework 2014-2020 must be earmarked for climate action, opening up substantial sources of financing for climate adaptation.

Photo: European Commission

Humberto Delgado Rosa

A joint effort

The Commission is engaging with Member States to share knowledge and best practices. In collaboration with DG RTD, the Joint Research Centre, the European Environment Agency and the Member States, several knowledge gaps have been identified where more research and development are needed. These areas include information on damage costs and costs and benefits of adaptation, regional and local-level analyses and risk assessment frameworks, linking adaptation knowledge and decision-making, and developing the means to monitor and evaluate adaptation efforts. Knowledge gaps are fed into the calls for research projects under the Horizon 2020 programme. Similarly, LIFE will be used as the ideal tool to test, pilot or demonstrate adaptation actions.

Adaptation has been successfully mainstreamed into a number of EU policies. Mainstreaming is one of the key elements in the national adaptation strategies of Member States. However, it is an ongoing process. We are now turning our attention to vulnerable sectors such as energy, transport, health, and measures such as 'green' and 'grey' infrastructure. Moreover, climate change impacts have to be taken into account to a greater extent in disaster insurance, a powerful tool to induce adaptation measures.

The role of LIFE

The LIFE Programme plays a crucial role in tackling climate adaptation. LIFE covered climate-related topics well before the creation of the sub-programme for Climate Action, funding projects in areas such as water, coastal management and adaptation planning. Cyprus, for instance, received financing to develop a national adaptation strategy (see pp.26-29). Under the new LIFE programme 2014-2020, funding is available in the form of both 'traditional' as well as newly introduced 'integrated' projects to tackle the priorities identified in the EU Adaptation Strategy.

As a new addition to our toolkit, integrated projects are designed to facilitate the implementation of adaptation strategies on a significant cross-sectoral and geographical scale.

In the current LIFE funding period, around €190 million is earmarked for increasing resilience to climate change up to 2017, with a similar amount expected for the period 2018-2020. Besides vulnerability assessments and adaptation strategies, the focus will be on vulnerable areas indicated in the EU Adaptation Strategy: cross-border flood and coastal management, urban environment, mountain and island areas, water management and drought-prone areas.

Moreover, urban adaptation and green infrastructure will increasingly be the centre of attention. For instance, part of the first LIFE call last year was successfully geared towards urban adaptation, reflecting the fact that 75% of European citizens live in urban areas. Many of the future LIFE projects may have this urban dimension, with several of them also including green approaches in the urban context. Nature-based approaches are not a 'silver bullet', but green infrastructure is often cost effective and delivering multiple benefits.

The recently launched Natural Capital Financing Facility (NCFF), within the LIFE Programme, illustrates DG CLIMA's wish to actively involve the private sector in adaptation efforts. This financial instrument, developed in collaboration with DG Environment and the European Investment Bank (EIB), supports ecosystem-based approaches to biodiversity conservation and climate change adaptation. Projects financed by the NCFF will combine a strong impact on resilience and adaptation capacity with innovative financing options, demonstrating that adaptation efforts can go hand-in-hand with creating revenues or cost savings. It will moreover leverage private financing to promote adaptation and biodiversity goals.

Photo: LIFE13 NAT/SE/000116/Länsstyrelsen i Jämtlands län

LIFE funding has helped mainstream climate change adaptation in the EU water policy

Strengthening the role of adaptation

All these tools are contributing to climate adaptation in the Member States and beyond. And hopefully, so will the United Nations Climate Change Conference in Paris later this year. Adaptation should play an increasingly important role, as all countries, rich or poor, need to adapt to the adverse effects of climate change.

The 2015 Conference represents an opportunity to strengthen and improve provisions for and the commitments of all parties to continue adaptation efforts, cooperate and share information, and further monitoring, evaluation and reporting. However, we need to keep in mind that adaptation measures are also being implemented outside the Convention, so that we do not duplicate existing efforts.

It goes without saying that adaptation is not an alternative to mitigation. In fact it can reinforce awareness of just how crucial mitigation is, since adaptation would be powerless to prevent catastrophic climate change if emissions targets are not implemented. The best way to adapt is to control climate change, first and foremost. Unfortunately, climate change is happening, and we need to tackle mitigation and adaptation together, to achieve the best possible outcome".

INTRODUCTION

Meeting adaptation challenges: **the EIB's perspective**

Nancy Saich is senior climate adviser at the European Investment Bank's Environment, Climate and Social Office. In this interview, she discusses the bank's role in climate change adaptation.

"The EIB finances climate adaptation through projects that provide adaptation benefits to cities, communities or businesses. We also finance adaptation in projects themselves, making them more resilient to climate change impacts. In addition, we are funding technical assistance support.

Financing adaptation and accounting for it is part of our job as a bank. We are at the beginning of a major transition: in five to ten years, this kind of thinking will be commonplace.

Mainstreaming adaptation

Mainstreaming climate adaptation really means thinking about the climate change impacts on our projects, on our promoters, on our internal processes and seeing how we can be proactive in trying to increase climate resilience. It also means making sure that we share best practices and knowledge with partners, such as DG CLIMA, and with our colleagues in other EU finance institutions. To this end, we participate in a working group on climate adaptation involving all EU finance institutions.

After a public consultation, which included numerous questions on adaptation, the EIB is planning to publish its new Climate Action Strategy later this year. This will give us a much more specific work plan, which will be rolled out across all parts of the bank.

Screening of projects is an important part of the mainstreaming process. One of the challenges is

Photo: EIB Photolibrary, Graphic Team

Nancy Saich - senior climate adviser in the EIB

how to deal with current projects that have not incorporated climate change impacts into their thinking. As well as helping those projects adapt, we will help promoters, authorities and clients take climate change adaptation into account in the planning of future projects.

We also need to do upstream work. Often the best way to do that is with Commission and EU funding. A good pipeline of projects from another programme, for example, could benefit from blending financing options, perhaps using some of the grant money from the Commission to cover any extra adaptation costs or measures included in the project.

Managing uncertainty

Uncertainty is often cited as a reason for inaction. Climate adaptation is not something that can be left to the future. We have to learn how to make decision pathways that incorporate uncertainty. Take sea-level rise, for instance: we know it will happen, but not how fast. There are many examples in coastal defence where some decisions have to be taken now, but others can be left for the future, provided that the possibility to adjust the project is built in. This flexibility avoids the danger of channelling all adaptation efforts into one type of activity that may not be the right solution in the future.

Although climate data has become much more useable, it still needs to be translated in a way that decision-makers can understand. In this context, it can be useful to show that there are likely going to be changes, which will make weather events more extreme and more frequent, explaining what some of those scenarios might look like.

There is still an enormous need for knowledge and capacity building. The European Climate Adaptation Platform Climate-ADAPT is a great basis for this, and we have to promote this knowledge sharing through Climate-ADAPT here in the bank, in other organisations, in the consultancy industry, climate services, and the data-providing industry to close knowledge gaps.

Strategic goals

At €1.4 billion over the last two years, climate adaptation accounts for a small portion of the EIB's lending. We know more needs to be done: increasing adaptation lending and advice services inside and outside the EU will be a main pillar of the new climate strategy.

So far our financing efforts have largely focused on water resource management and land use. Other projects have dealt with forestry and flood protection. There has also been a small amount of adaptation in infrastructure projects, such as counting the extra measures to make a road climate resilient.

The EIB and DG CLIMA have had many discussions about ways of supporting SMEs to become climate resilient through our financial intermediaries. This is absolutely critical: small businesses are highly vulnerable to extreme weather events.

We also need to finance adaptation in major sectors such as energy, transport, industry and R&D, including addressing cross-sectoral issues. This is where the urban dimension comes in. By building out from sectors where we have already done a lot of work, we should have a clearer picture of how to address cross-sectoral climate vulnerabilities.

In future, mainstreaming adaptation into water resource management, land use, food production, and urban projects will be important. We would like to see more projects being put forward which truly take climate risk and vulnerability assessment into account or where the EIB can provide the support necessary to incorporate that into projects, regardless of the sector."

NCFF: a new tool in the EIB's arsenal

Photo: EIB Photolibrary, Graphic Team

"The Natural Capital Financing Facility (NCFF) has been designed to go into smaller and riskier projects than the EIB would traditionally fund. The NCFF focuses exclusively on bankable nature-based projects for climate adaptation that can either create revenue or save costs. For instance, instead of building grey infrastructure for flood protection, the NCFF would finance a nature-based solution. Using market-based instruments, this innovative approach works in a different way to project grants, although the possibility to blend funding options could still apply.

Clearly, when something is based on nature, thinking has to be long term, patience is required. There are numerous other benefits that may or may not be monetised. All of this will make these kinds of projects a little more complex to appraise. The aim with nature-based solutions is to think about certain business models that will provide revenues, such as ecotourism, for example.

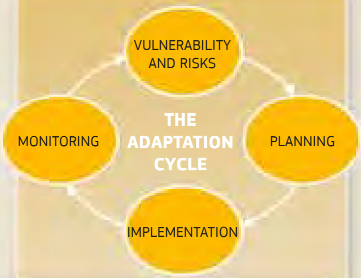
Once a demonstration has been successful in one place or sector, we will catalyse third-party – mainly private – investments. The main focus is on replicability, catalytic effect and the idea that, after three years, there will be numerous projects which have already demonstrated their value and in which third parties can invest."

James Ranaivoson, managerial advisor – Structured Finance for Climate Action & Environment, EIB

LIFE's impact on adaptation

ADAPTATION STRATEGIES & PLANS

TOTAL BUDGET	EU CONTRIBUTION
16 million	8 million



LIFE funding has:
- Helped Cyprus adopt its National Adaptation Plan
- Helped authorities in Italy, Poland and Finland develop local strategies and plans
- Helped projects develop modelling tools for decision-makers

All projects have helped build decision makers' capacity to deal with adaptation

BENEFICIARIES

- Local authority
- NGO-Foundation
- Public enterprise
- Regional authority
- Research institute
- SME Small and medium-sized enterprise
- University

COUNTRIES BENEFITTING

CY	1	IT	2
FI	4	PO	2

URBAN RESILIENCE

TOTAL BUDGET	EU CONTRIBUTION
44 million	20 million

LIFE projects implemented green roofs and lowered the urban heat-island (UHI) effect in Belgian, Swedish, Maltese, Spanish and UK cities

LIFE has spent 27 million euros on blue infrastructure such as: SUDS, open storm water systems, rain gardens

Green and blue infrastructure has featured in all urban and peri-urban resilience projects. These projects have helped boost biodiversity and ecosystem services

COUNTRIES BENEFITTING

BE	1	IT	5
ES	7	MT	1
FI	1	SE	2
FR	3	UK	2

AGRICULTURE

TOTAL BUDGET	EU CONTRIBUTION
54 million	26 million

More than 25 projects have demonstrated farming techniques that have helped EU farms adapt to climate change

22 million euros have been invested to make irrigation more efficient

32 million euros have been used to train farmers on adaptive cultivation practices

LIFE projects have influenced policy; measures have been included in Rural Development Programmes

Future funding through NCFF and traditional LIFE projects

COUNTRIES BENEFITTING

ES	13	IT	4
FR	3	LT	1
GR	3	SE	1

FORESTS

TOTAL BUDGET	EU CONTRIBUTION
38 million	20 million

LIFE has reduced the incidence of forest fires in the EU through mapping and modelling, training, knowledge transfer and awareness raising. It has funded 12 projects with a combined budget of nearly 16 million euros.

LIFE projects have developed forest monitoring systems to track changes in species distribution, taking bioclimatic region and local factors into account

21 million euros has been used to finance forest management tools. Projects have trained forest managers and given them guidelines

Forest projects have made EU forests more resilient to otbreaks of pests and pathogens

COUNTRIES BENEFITTING

EE	1	HU	1
ES	6	IT	1
FI	2	PL	3
FR	1	SI	1
GR	4		

WATER

TOTAL BUDGET	EU CONTRIBUTION
95 million	45 million

LIFE has developed modelling tools to assess and respond to water scarcity
LIFE has explored different managed aquifer recharge methods

Through multinational partnerships, LIFE is fostering a water-saving culture in the EU, getting citizens involved

63 million euros has been spent on 26 projects that focused on reducing flooding using natural water retention measures.
LIFE has helped map flood risks, and provide early flood warnings

COUNTRIES BENEFITTING

AT	6	NL	2
BE	1	RO	1
DE	4	SE	1
DK	2	SK	2
ES	5	UK	3
GR	2	FI	1
HU	1	FR	1
IT	8	MT	1
LV	1		

COASTAL

TOTAL BUDGET	EU CONTRIBUTION
35 million	19 million

LIFE is one of the main EU financial instruments supporting the adoption and implementation of Integrated Coastal Zone Management (ICZM).
It is developing best practices in managing coastal zones

Projects have addressed sea level rise by tackling biodiversity loss and saltwater intrusion

30 million euros have been spent combating coastal erosion through innovative beach and dune management and restoration measures, making dunes more resilient to climate change

COUNTRIES BENEFITTING

BG	1	IT	4
DE	1	LV	1
ES	4	UK	4
FIN	1		

BIODIVERSITY

TOTAL BUDGET	EU CONTRIBUTION
44 million	20 million

41 LIFE nature projects have targeted climate adaptation

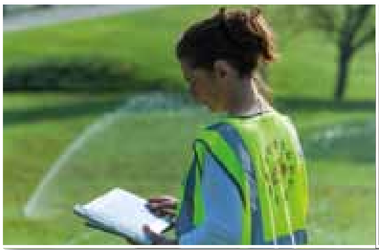
Projects have increased spatial connectivity by linking the habitats of threatened species (e.g. brown bears, European mink, migratory fish and amphibians) to strengthen populations through genetic exchange

Projects have reconnected prime core habitats such as rivers with floodplains; continuous grasslands; coastal meadows; networks of bogs and mires; and boreal forests

COUNTRIES BENEFITTING

BE	1	IT	1
CY	1	PT	1
ES	2	SE	3
FI	1	SI	1
GR	1	UK	1

PLANNING



LIFE **helps roll out adaptation plans and strategies**

The LIFE programme is contributing to the process of drafting climate change adaptation strategies and helping plan effective responses at regional and local levels.

The EEA's 2012 report, *Urban adaptation to climate change in Europe*, notes that "taking a place-based approach to adaptation policies is a way to further policy integration and coherence... Urban adaptation to climate change is a task that concerns all government levels - from local to European. While municipalities and regions focus on the implementation of place-based adaptation measures, national and European governments should have a supporting role."[1]

1 http://www.eea.europa.eu/publications/urban-adaptation-to-climate-change

Stakeholders working on a peer review of climate reports

Photo: LIFE07 ENV/FIN/000138/Union of the Baltic Cities

The EEA report notes that "regional governments play an important role when adaptation issues exceed municipal boundaries". However, there are also limitations to regional governance – regions lack resources and influence in a number of Member States. Thus, the EEA report stresses the fact that "national governments provide the crucial link between EU priorities and local adaptation action".

National governments can provide a strategic framework. They can climate-proof national legislation and policy and mainstream adaptation into different areas whilst ensuring that national policies are also coherent and supportive for local adaptation. They also play a crucial role as supporters and enablers of local and regional strategies and action.

EU Member States are encouraged to adopt, implement and review adaptation strategies. As Figure 1 shows, they are at different stages in the process of adoption and implementation. As of June 2015, some 20 EU Member States had successfully adopted a climate change adaptation strategy.

What makes a good strategy?

In 2013, the European Commission produced a set of Guidelines on developing adaptation strategies[2] as a first response to the barriers to the uptake of

2 http://ec.europa.eu/clima/policies/adaptation/what/docs/swd_2013_134_en.pdf adaptation strategies at national level. The guidelines build on and aim to make more operational the Adaptation Support Tool, a key feature of the Climate-ADAPT portal.

The Commission, together with the adaptation steering group composed of Member State officials and a diverse range of stakeholders identified aspects of good adaptation and limiting factors that can impede successful adaptation (see Table 1).

These were taken into consideration in the six steps to drafting a national adaptation strategy detailed in the 2013 guidelines (see Figure 1).

Table 1: **Current efforts in adaptation policy-making**

Aspects of good adaptation	Limiting factors
Sectoral focus	Lack of consideration of cross-border impacts
Mainstreaming	Need for detailed risk and vulnerability assessments
Stakeholder involvement	Lack of concrete national adaptation plans
Communication and awareness-raising	Lack of monitoring and evaluation
An evolving process (review and update strategies)	Lack of funding

Figure 1: **Six steps to drafting a national adaptation strategy**

1 PREPARING THE GROUND FOR ADAPTATION	• Obtain high-level support • Set up the process (establish a core team for adaptation; liaise with other relevant administrative bodies; identify affected stakeholders and involve them in the adaptation process) • Estimate human and financial resources needed and identify potential sources of funding for the long term • Collect information (get a first overview on actual and potential future climate change-related effects; identify ongoing activities with relevance for adaptation; explore good practices within or outside the country) • Communicate and raise awareness (clarify the terminology; communicate climate change and the need for adaptation)
2 ASSESSING RISKS AND VULNERABILITIES TO CLIMATE CHANGE	• Analyse how past weather events have affected your country • Undertake a climate change risks and vulnerability assessment • Take transboundary issues into account • Develop an approach for addressing knowledge gaps and for dealing with uncertainties • Select your country's main concerns and set your strategic direction
3 IDENTIFYING ADAPTATION OPTIONS	• Collect appropriate adaptation options given your country's main concerns • Explore good practices and existing measures • Describe adaptation options in detail
4 CHOOSING ADAPTATION OPTIONS	• Assess possible options in terms of time, cost, benefits and efforts • Assess cross-cutting issues, trade-offs and synergies of adaptation options • Prioritise adaptation options and select preferred ones • Prepare a strategy document and get political approval
5 IMPLEMENTATION	• Identify and make use of entry points for adaptation into existing instruments and/or create new instruments for adaptation (mainstreaming) (identify key instruments for integrating adaptation; determine the need for action with respect to modifying existing instruments; establish new instruments) • Seek agreements with stakeholders responsible for implementation • Develop an action plan
6 MONITORING AND EVALUATION	• Develop appropriate M&E provisions for both adaptation policy objectives and selected adaptation options • Identify indicators

Photo: LIFE07 ENV/FIN/000141/University of Helsinki/Juh Aalto

Vaccia carried out vulnerability assessments of key ecosystem goods and services

The LIFE programme has supported fewer projects to develop climate change adaptation strategies and plans than their climate change mitigation equivalents. This is in part because the concept of mitigation has been established in public discourse for longer; and partly because it is less straightforward to quantify an increase or decrease in vulnerability than it is to monitor CO_2 emissions.

Those LIFE projects that have been funded in this area have, however, made a significant contribution to the development of adaptation strategies and their subsequent implementation. Of particular note is the CYPADAPT project in Cyprus, the only occasion on which LIFE co-funding has been used to draft a national adaptation strategy (see pages 26-29).

Finnish pioneers

Finland was the first country in the European Union to adopt a national strategy for adaptation to climate change, back in 2005, as an independent element of the wider National Energy and Climate Strategy. Highlighting the value of sectoral focus, the strategy was developed by several ministries in partnership and indeed, the Ministry of the Environment and Ministry of Agriculture and Forestry also have their own sector-specific strategies as a subset of the national strategy.

In 2007, Finland secured funding for four LIFE projects that in different ways contributed to the implementation of the strategy. According to Pekka Hänninen, external monitor for each of the four projects, "One can say that the projects VACCIA, Julia 2030 and CCCRP were more or less around the implementation of this strategy." The Finnish part of the fourth project, CHAMP, "also had something to do with the national strategy, but the main focus was more of a European dimension, involving partners from Germany, Italy and Hungary," he adds. CHAMP set out to develop integrated management systems (IMS) to improve local and regional competence to deal with climate change and, in particular, to improve cross-sectoral coordination at local and regional level. The project established training hubs in eight countries and representatives from 58 local and sub-regional authorities were trained to use the IMS. The revision of the NAS, the National Adaptation Plan for Climate Change 2022, has recently resulted in the publication of a new NAS in November 2014, known as the National Adaptation Programme.

VACCIA provides useful models for planners

Finland's climate change strategy "describes the impacts of climate change and potential adaptation measures for each sector for a period extending until 2080," explains Irina Bergström of the Finnish Environment Institute (SYKE), who was responsible for the synthesis and dissemination of the VACCIA project. The experts from SYKE who helped develop the national strategy were also involved in VACCIA, thus ensuring that this LIFE project incorporated the basic principles of the strategy and was designed so that results could be used in further strategic planning.

The project team developed several mathematical modelling systems for the assessment of changes, thresholds, and adaptation measures for different ecosystems, including forestry, agriculture, watersheds and fisheries. The modelling systems were used to provide regional and national impact scenarios and predictions for each ecosystem.

The scenarios and modelling tools were presented and discussed with local and regional authorities and citizens at a series of workshops and seminars. The events were an opportunity for planning officers and local communities to consider the merits of different adaptation options and solutions e.g. for urban planning, northern tourism, fisheries, forestry and agriculture. "The researchers and the audience were thus able to have immediate feedback on each other´s suggestions," says Ms Bergström.

VACCIA's results have been used in administrative planning and in subsequent projects. It was mentioned and used as background in the updated adaptation (2011-2012) action plan for implementing Finland's adaptation strategy. Findings of VACCIA's synthesis report of Finland's climate change adaptation research were included in the national ISTO programme, whilst the project's results were used in the revision of the sector specific strategies for agriculture and forestry in 2013. The Finnish-Chinese cooperation project CLIMES (2012-2014) had its roots partly in VACCIA and was conducted partly in the same study areas. This project looked at landscape-scale processes and adaptation options for two key ecosystem services/sectors - water services and soil/carbon sequestration.

In addition, local and national media coverage of the project helped raise public awareness of the future changes demanding adaptation. Results of the VACCIA project are included in Climateguide.fi, the web portal on climate change for Finnish citizens.

LIFE builds a climate portal for Finland

"The importance of communication was recognised in Finland's National Strategy for Adaptation to Climate Change, but at that time (2005) there were no plans to develop a national climate portal," explains Sanna Luhtala, who coordinated the Climate Change Community Response Portal (CCCRP) project. The value of such a tool soon became clear, however, and LIFE co-funding was secured in the 2007 call by three research organisations: the Finnish Meteorological Institute (FMI), the Finnish Environment Institute (SYKE), and Aalto University to develop climateguide.fi. Launched in June 2012, the portal aims "to provide scientific background information on all aspects of climate change (climate change as a phenomenon, Finland's changing climate, impacts, mitigation, and adaptation) as well as the tangible means for mitigation and adaptation," says Ms Luhtala (see box - Impact of Finland's climate portal).

The portal is more than just an awareness-raising tool; it gives local and regional authorities all the baseline information they need to decide which measures are most needed to counteract the predicted impacts of climate change within their jurisdiction. The portal includes a Community Response

Impact of Finland's climate portal

According to CCCRP project coordinator, Hanna Luhtala, "the number of users of the Climateguide.fi portal has steadily increased since the launch, especially in the past year. In spring 2015 Climateguide.fi had approximately 3 000 weekly users with 9 000 weekly page views. Since the CCCRP project, the Climateguide.fi portal has been continuously updated and developed." New elements include infographics, videos and climate news.

Ms Luhtala says that although the project did not measure the impact of its awareness-raising activities,"the impact can be seen in the increasing number of users and the positive feedback received from users directly, through a user survey (in 2014) and user workshop."

Significantly, three regional climate and energy strategies developed in Finland since the launch of the portal - those of Southern Ostrobothnia, Pirkanmaa and Savonia - have referenced climateguide.fi. The portal is also mentioned in the 2014 National Adaptation Plan for Finland. Indeed, climateguide.fi "is identified as the key method of communication of the Plan," says Ms Luhtala.

Photo: LIFE07 INF/FIN/000152/Finnish Meteorological Institute/Studio Halas

Wizard which helps local decision-makers (and citizens) understand the main impacts of climate change in different sectors, understand the possibilities for adaptation in municipalities, find the most suitable set of actions and find case studies and best practices.

Developing a plan for Helsinki region

The Julia 2030 project was mainly concerned with climate change mitigation through plans and actions to reduce CO_2 emissions in the Helsinki metropolitan area. However, one part of the project focused on the development of a climate change adaptation strategy for the city region.

"The first Finnish National Strategy for Adaptation to Climate Change (2005) had few if any policies or targets for the local or regional level adaptation. Therefore all the local/regional level adaptation actions and efforts in Finland so far have happened on a voluntary basis and from the initiative of the local/regional level actors themselves," says Julia 2030 project coordinator, Susanna Kankaanpää, climate specialist with the Helsinki Region Environmental Services Authority (HSY). "This was also the case of the Helsinki Metropolitan Area adaptation strategy," she adds.

"The renewed (2014) national adaptation plan[3] now has also acknowledged the local/regional level adaptation but this has happened in my opinion because of a bottom-up effect," says Ms Kankaanpää, who adds: "much of the adaptation action has happened at the local level so in many cases or sectors you could say that the local level has been driving the national level adaptation and not vice versa (this is the case in other European countries as well, for example Denmark). But now we have legislation concerning adaptation so the situation is changing."

She notes that the project had 'few challenges' carrying out its data analysis because Finland's knowledge base regarding climate change, scenarios and impacts was already strong. The project also drew on the know-how of urban planners regarding potential impacts of climate change on technical infrastructure and buildings (see box - Julia 2030).

Local and regional experiences from Poland

Poland adopted its national climate change adaptation strategy in 2013. To date LIFE has co-funded two projects in the country to support the development of adaptation planning at county and municipal level.

The first of these was DOKLIP, which ran from 2010 to 2015. "We wanted to raise the awareness of

Julia 2030

The Julia 2030 team used climate change scenarios developed by the Finnish meteorological institute to underpin adaptation planning work. Increased precipitation and storm events, increased mean temperature, more hot days and sea level rise were identified as the most likely climate change impacts for the Helsinki region. In response to these, "policies (about 30 in all), were developed for seven sectors," says Ms Kankaanpää. These sectors were land use, building and climate-proof local environment, transport and technical networks, water and waste management, rescue services and safety, health care and social services, and co-operation in the production and distribution of information.

The cities, region and other actors used workshops as a means of defining adaptation actions. Each actor then developed a number of actions. "Currently there are about 80 adaptation actions being implemented," explains Ms Kankaanpää, who notes that "economic impacts of the policies or actions have not been assessed yet: HSY is monitoring the implementation and state of the policies (first report published this year) and is currently developing indicators to monitor adaptation. This will take some time however, since it is pioneering work on monitoring and evaluation systems."

Photo: LIFE07 ENV/FIN/000145

3 The 2014 revision of the National Adaptation Strategy was referred to as a National Adaptation Plan

local leaders and decision-makers and help them to take actions that will lead to a larger number of investments in climate change and more public initiatives," explains Per Markus Törnberg, President of the Foundation Institute for Sustainable Development and coordinator of the LIFE project. "We also wanted to have an impact on the attitude of the general public towards climate change issues."

To this end the LIFE Information & Communication project organised a series of conferences, debates, seminars and workshops for the various target audiences and produced analytical reports that were distributed to the counties and other stakeholders.

A key element of the project focused on building capacity amongst local decision-makers to enable them to take practical local measures. Mr Törnberg says that local leaders participating in the project's debates, workshops, conferences and study trip have "received all the appropriate knowledge and capacity needed to be better prepared for the adaptive measures...they might not have all the tools and knowledge necessary to select the appropriate measures themselves, but they will know how to gain further tools, experience and knowledge and to some extent even to select measures themselves."

Also in Poland, Dr Wojciech Szymalski of the ISD is coordinating the ongoing project LIFE_ADAPTCITY_PL , which is developing a climate change adaptation strategy for the city of Warsaw. The Polish capital hopes to draw on lessons from Stuttgart's experience. "Stuttgart has been picked as a best case scenario because it already has an adaptation plan, one of the first in Europe," explains Dr Szymalski. "The plan is also proposed on a very operational level, so quite good recommendations can be taken out for the cities in Poland. We hope to learn more about Stuttgart's city climate atlas and about the city planning measures that resulted from the spatial planning processes," he adds.

LIFE_ADAPTCITY_PL will prepare a climate map for Warsaw, assess the state of the city's ecosystem and prepare an intensive public consultation of the strategy. Round tables will be held to coordinate the works of the many institutions that will need to cooperate to prepare the adaptation strategy. "Through district and special meetings we aim to involve citizens as much as possible, as well as various relevant groups within the city (e.g. fire fighters, health care, small businesses)," notes Dr Szymalski.

Photo: LIFE13 INF/PL/000039

Dr. Wojciech Szymalskl presenting LIFE_ADAPTCITY_PL at an event

The project is also inviting citizens to propose local initiatives, large and small, related to water management and air quality, such as local water tanks or the creation of 'fresh air' corridors that connect local parks and squares.

To build the city administration's capacity to implement the strategy, the project is planning study visits to Helsinki (Finland), Ancona (Italy) and Malmö (Sweden).

The project has proposed that two of the adaptation actions it develops will be included in the city budget. Dr Szymalski says it is too early to say if there will be a cost-benefit analysis of the adaptation measures: "First we need to find out what kind of measures and then we will decide."

He adds that the LIFE project is crucial to the realisation of Poland's climate change adaptation strategy. "Warsaw is the first city to prepare an adaptation strategy and serves as the pilot ground for methodology and approach for other Polish cities."

In this way, Poland is providing a tangible demonstration of one of the observations of the 2012 EEA report, namely that: "Supporting local adaptation measures provides national governments the opportunity for policy learning. Neighbourhoods can be seen as testing grounds for policy providing valuable lessons on the performance of policy measures in different local contexts."

Developing municipal strategies in Mediterranean countries

In Member States that have yet to devise or implement a national adaptation strategy, the importance of bottom-up adaptation planning cannot be overstated. In Italy, LIFE co-funding helped municipalities take the lead well before the national adaptation strategy was adopted in 2015.

ACT - Adapting to Climate change in Time - sought to develop a process for creating an effective municipal strategy for local climate adaptation measures. The Italian-led project worked with three Mediterranean municipalities – Ancona (Italy), Patras (Greece) and Bullas (Spain). The project, which ran from 2010 to 2013, applied many of the principles that would subsequently be enshrined in the Commission's 2013 guidelines for drafting a climate change adaptation strategy, namely data collection, creating the baseline scenario, assessing vulnerabilities and risks, identifying the adaptive measures, implementing them and monitoring and evaluating their impact.

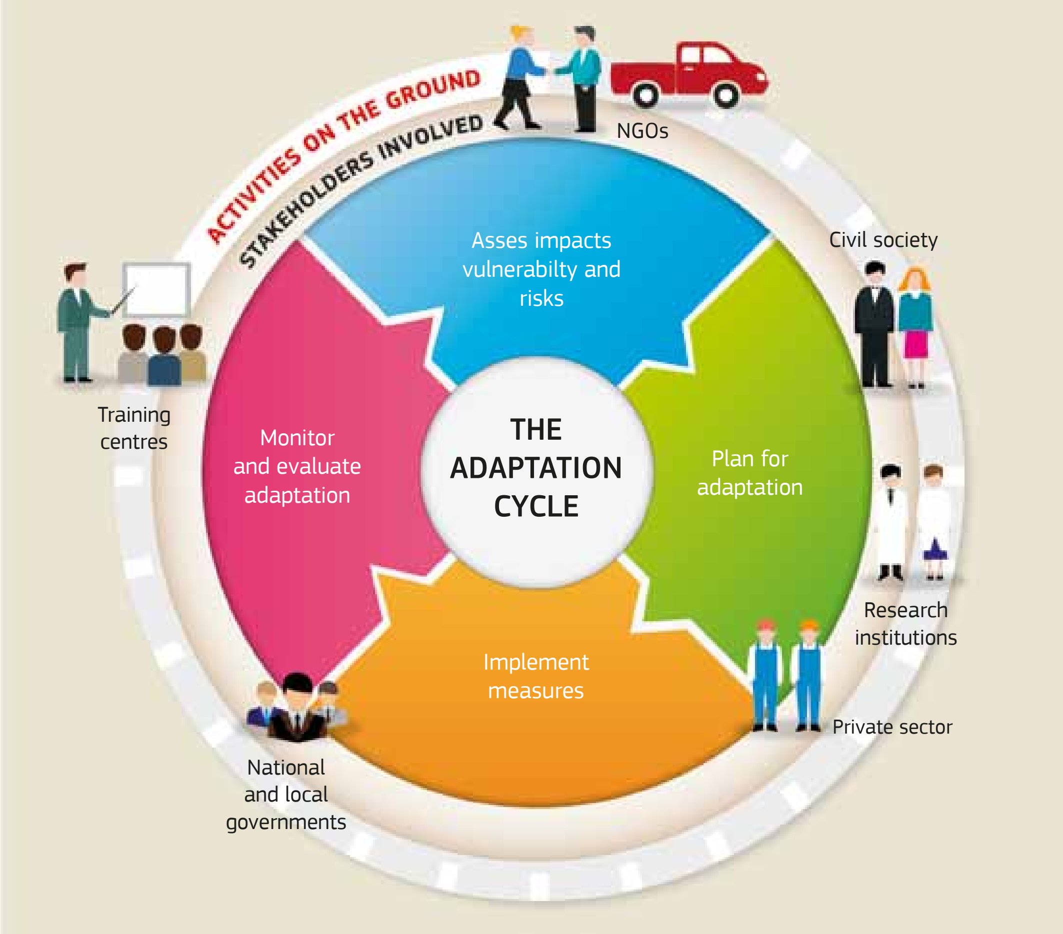
The project trialled a participatory approach to development of the adaptation plans, channeled through a Local Adaptation Board (LAB) in each of the three cities. Each LAB was essentially a multidisciplinary working group that included representatives of a number of relevant sectors, including environmental protection, soil and water management, civil protection, utilities, industry, commerce and tourism.

In the first phase, the members of the LAB analysed the issues, evaluated impacts and proposed measures. During the second phase, participation allowed the creation of a consensus and strengthened the capacity for territorial governance on climate change.

As a result of the project, the city of Bullas has signed up to the Mayors Adapt Initiative, whilst Ancona is in the process of joining.

An Italian signatory city of Mayors Adapt, Bologna, has used LIFE funding to pilot a participatory approach to the adoption of a Local Adaptation Plan through the BLUE AP project. Coordinator Giovanni

The adaptation cycle



Fini says that Bologna has drawn inspiration from the experiences of outputs of northern European cities, Copenhagen, Rotterdam, Stockholm, London and The Hague ("whose representatives have been part of the scientific board of the project)." Mr Fini explains that, "coming from a very different political and climatic background, the biggest challenge [for Bologna] has been to suit their approach to the local context, especially with regards to the administrative organisation and citizens' awareness."

Stakeholder involvement has been essential to achieving BLUE AP's goals (see box, Bologna participates).

The project developed an Adaptation Plan for Bologna that has defined measures to deal with potential drought and water shortages, urban heat waves, and excessive rain and hydrogeological risk. It also identified a series of 'green' and 'blue' best practices that could be implemented in Bologna and other Italian cities. "The 'green' measures are: peri-urban parks, green and cool roofs and green walls; the 'blue' measures are: permeable pavements, Sustainable Urban Drainage Systems (SUDS), rainwater harvesting, wastewater treatment by greywater separation and water savings," says Mr Fini.

"Bologna is a vulnerable territory even though it may not seem so," says Mr Fini. "We are very happy with the project results that allowed us to build up an integrated approach to urban resilience. The Bologna Adaptation Plan outlines the strategies capable of confronting the critical situations highlighted in the Local Climate Profile and identifies a series of good practice actions." The Adaptation Plan envisages that all these actions will be completed by 2025.

"The Plan is concerned not only with what to do but also how to do it, and pays particular attention to the interaction between different levels of government in the territory and private individuals who will be directly involved in implementing the plan's steps," says Mr Fini. This is particularly so with regards to measures addressing hydrogeological instability and water supply. "The implementation of the steps outlined in the Adaptation Plan will also occur through upgrading the territory's regulation and planning tools," adds Mr Fini.

Conclusions

The project examples in this chapter show the usefulness of LIFE as a tool for sub-national and municipal adaptation planning. However, it is important to synchronise the impacts of bottom-up initiatives with the top-down imperatives of national adaptation strategies and also ensure strong linkages across sectors. The following pages highlight the ongoing work in Cyprus to develop a national strategy that can be effectively implemented at the local level.

Bologna participates

"The Adaptation Plan has been built with a participatory collaboration, in which individuals and organisations are also actors of the plan," says Giovanni Fini of the City of Bologna. A map of local stakeholders was created at the start of the process to facilitate their input into the local climate profile, good adaptation practices and strategy documents. Meetings with stakeholders took place at each phase of implementation of the Adaptation Plan.

Mr Fini explains that it was important to guide stakeholders through the process without overwhelming them with complex climate science. Participants were asked to complete a questionnaire divided into two parts: the first gathered information about the interviewee; the second focused on general awareness of resilience and climate change, with three questions specifically relating to matching adaptation measures to economic needs. "This gives us clear information about how both small businesses and large companies view the topic," says Mr Fini. Some 84% of the 125 companies surveyed said they worry about the effect climate change may have on their business. BLUEAP has produced a report on the survey's results, which will help Bologna achieve the project's goal of offering "start up" support to local stakeholders, with the aim of designing and launching some of the measures and actions defined by the Local Adaptation Plan.

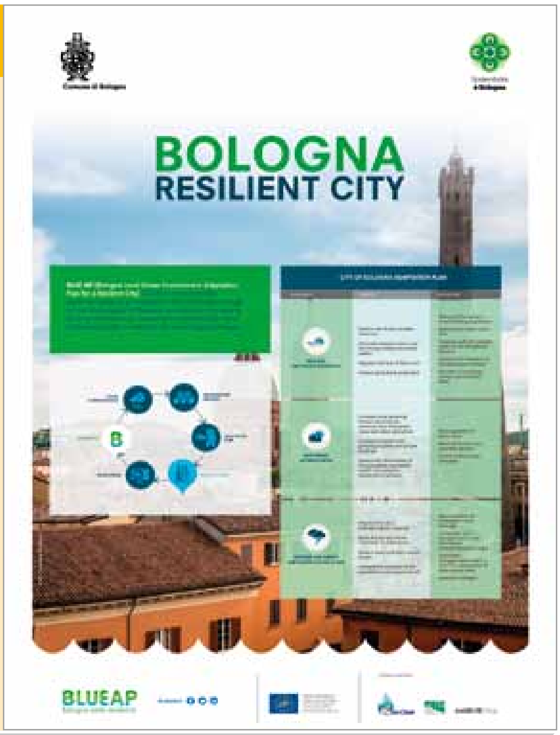


Photo: LIFE11 ENV/IT/000119

PLANNING

Developing an **adaptation strategy** for Cyprus

Cyprus is so far the only EU Member State to have developed a national adaptation strategy with the support of the LIFE programme. The process has proved extremely valuable.

"In 2007, Cyprus was short of drinking water [because of drought]. It was a very, very difficult time. To solve this problem we had to bring water from Greece," recalls Theodoulous Mesimeris, Senior Environment Officer, Environment Department, Republic of Cyprus. "After this, we took the decision that we have to plan and we have to develop appropriate policies and measures. Not only for drinking water, not only for water shortages, but for all sectors that will be affected by climate change."

As head of the climate unit within the Environment Department, Mr Mesimeris was placed in charge of the planning process. "We asked about financial tools and the Commission suggested to us that one good tool is LIFE." With partners at the National Technical University of Athens (NTUA) and the National Observatory of Athens (NOA) on board, LIFE funding was secured for the CYPADAPT project, the first use of the mechanism to enable a Member State to develop a national adaptation strategy.

The project had six stages - a current vulnerability assessment; future vulnerability assessment; identification of adaptation measures; evaluation of adaptation measures; development of an adaptation strategy (known as the National Adaptation Plan - NAP); and monitoring and evaluation. Each stage was accompanied by active stakeholder engagement and public awareness raising.

"It was very, very important to try to have from the beginning all stakeholders involved. We had people from the academic sector, from the public sector,

Table 1: **The 11 adaptation sectors of Cyprus**	
Agriculture	Infrastructure
Public health	Tourism
Energy	Fisheries
Coasts	Forests
Soil resources	Biodiversity
Water resources	

the private sector, from local authorities," explains Mr Mesimeris, who managed the CYPADAPT project.

The EEA report on *Urban adaptation to climate change in Europe* notes that "without flexible and cross-sectoral coordinated measures, adaptation efforts may be hampered by sectoral thinking." The role of the Cypriot climate unit is to act as the 'co-ordinating team' for all government departments. "It's a horizontal issue," says Mr Mesimeris. "We had a frank discussion, an open communication with all stakeholders and we decided to create 11 different committees."

These committees corresponded to 11 sectors for which a climate change and vulnerability assessment and subsequent adaptation strategy would be produced (see Table 1).

The climate change vulnerability assessment involved a review of EU and international policies, plans and measures and the creation of a database of more than 790 adaptation measures being applied worldwide.

The assessment found that in the last 20 years, precipitation on Cyprus had been reduced by 1 mm/yr and the average mean temperature had risen by 0.5 °C , compared to the period 1960-1990. Other observed climate change impacts for the country include an increase in the annual maximum and minimum air temperature, as well as in the number of days below freezing and above 40 °C each year. Whilst overall precipitation has decreased, the number of heavy rainfall events has increased. There has also been an increase in the average sea surface temperature and evapotranspiration rate.

A total of 56 climate change impacts were identified for the 11 sectors. Vulnerability was then assessed for each impact using the equation:

- Vulnerability = impact - adaptive capacity (where impact = sensitivity x exposure)

The PRECIS regional climate model was used to project future climate change in Cyprus. By combining these forecasts and other socio-economic projections with the current vulnerability assessment, the CYPADAPT team was able to determine Cyprus's future vulnerability to climate change (in 2020, 2050 and 2080).

Priorities for action

Sixteen climate change impacts were identified as presenting 'moderate' to 'very high' vulnerability, requiring appropriate adaptation actions and were prioritised in line with the recommendations of the stakeholder committees (see Table 2).

"Gathering information was not the major issue," says Mr Mesimeris. "The complexity of this new, horizontal issue...this was the major challenge: to link the impacts with climate change: impacts in the forest, impacts in agriculture, impacts in health."

Highlighting the need for a cross-sectoral approach says Mr Mesimeris is the fact that "the energy sector is one of the major sectors that is affected by climate change. If we have long periods of high temperatures that means that we will need more energy to adapt to these extreme weather conditions. If you need desalination units you need energy, you need extra power plants, more CO_2 emissions - everything is connected."

The MCA tool

"It was very important for us to choose the appropriate measures, to prioritise them and to give the opportunity to different sectors to participate in

Table 2: **CYPADAPT ranking of 'moderate' to 'very high' vulnerability climate change impacts**	
1st priority	Drinking water availability in mountain areas; water availability for irrigation in mountain areas; desertification
2nd priority	Drought; dieback of tree species, insect attacks and diseases; forest fires; water availability for irrigation in plain and coastal areas
3rd priority	Crop productivity
4th priority	Biodiversity of terrestrial ecosystems; biodiversity of wetland ecosystems
5th priority	Biodiversity of marine ecosystems
6th priority	Mortality and morbidity related to heat waves and high temperatures; damage to crops caused by extreme weather events; soil erosion; water availability for irrigation in tourism

this decision-making procedure," recounts Mr Mesimeris. To this end, CYPADAPT created the Multi-Criteria Analysis (MCA) Tool for Cyprus, "a kind of supporting tool, using the knowledge of the stakeholders," he explains. "It's a tool that can be modified according to the different priorities and different scenarios that you may choose."

The MCA tool enables users to select the most appropriate set of adaptation options for Cyprus.

The NAP for Cyprus contains the adaptation measures prioritised by the MCA tool and provides suggestions for their integration into national sectoral policies, strategies, plans and legislative texts.

The initial list of adaptation measures was subject to evaluation and revision during the course of the LIFE project. "When we ran the multi-criteria analysis in the beginning we saw that the stakeholders didn't agree with some of the results, so then we went back and adjusted the weighting," explains Christina Pitta, Agricultural Research Officer in the Environment Department's climate unit.

The end result is a more accurate and responsive MCA software tool, one that generates alternative adaptation scenarios based on selection criteria and the system's degree of vulnerability to climate change. Some 250 measures addressing climate change impacts in the 11 selected sectors have been included in the NAP.

Theodoulous Mesiimeris (right) coordinated the CYPADAPT project. His colleague Christina Pitta is now developing a climate change risk assessment for Cyprus

Assessing risks and costs

The NAP has been approved by the Committee of Audit and the Competent Authority (Ministry of Agriculture, Rural Development and Environment). The Department of Environment is planning to submit to the Council of Ministers the adaptation strategy together with a climate change risk assessment and cost/benefit analysis.

"The risk assessment is an *ex ante* conditionality under the multi-annnual financial framework. That means that without this Cyprus is not eligible to receive support from the Cohesion funds. It was very, very useful for Cyprus to have in place the adaptation strategy because without this it would be difficult for us to develop the risk assessment," believes Mr Mesimeris.

"In order to have support and financing, it was very important to present the cost of not doing anything. This is why we are doing this risk assessment," says Ms Pitta, who is in charge of drafting this document. "The cost of not doing something has a value. It is important to show why we have to do something, why we have to spend something - and to show also the benefits of action, the social benefits and the potential to create economic opportunities from climate resilience measures."

The risk assessment is due to be completed in mid-2016. "When we get the results from that we will do the cost-benefit analysis, and hopefully by the end of 2016, beginning of 2017, gather all of this together to present to the Council of Ministers," Ms Pitta adds.

To demonstrate popular support for the strategy, Mr Mesimeris says that the Department of Environment is also "assessing the possibility of developing a framework legislation for parliamentary approval including both adaptation and mitigation measures."

Once the strategy is adopted, implementation will be the responsibility not of the Department of Environment, but of the various ministries, departments and local authorities, in line with their sectoral and geographical competences. "Having the adaptation strategy and having also the risk analysis and the cost-benefit analysis, we will proceed then to the implementation phase having a timeline and a specific budget for the implementation of the measures, which will be done based on the budget of each implementing body," explains Mr Mesimeris. "For example, we have a long list of measures in the water sector. After the submission and approval of the measures and the budget then we will link this list to the budget and the scope and policy of the water development department and they will be the implementation body. And we will monitor the implementation of these measures."

The NAP developed by the CYPADAPT project includes a monitoring and evaluation strategy with step-by-step guidelines to assess the success of each measure implemented. The climate unit is working to link measures that are already being implemented as part of sector-specific EU directives and policies, e.g. the Water Framework Directive - such as desalination of water - with the climate change adaptation strategy and risk assessment.

The monitoring team will also be responsible for periodically re-evaluating the level of impact, adaptive capacity and vulnerability of Cyprus to climate change. "Definitely the adaptation strategy will need revision according to the monitoring we are going to be doing. Whether that revision comes in two years or five years depends on how the implementation goes," says Ms Pitta. "We will propose some indicators, but it's difficult to say now what they will be. The lesson from other countries is that indicators are different from one country to another," she notes.

The CYPADAPT project has useful outcomes for climate change adaptation planning across Europe. "The MCA tool can readily be applied in other EU Member States," believes Mr Mesimeris. To aid transferability, the CYPADAPT team produced a user manual, walk-through video and guidelines showing how to use the tool in climate change adaptation planning. "We are receiving many requests to exchange information and to support other countries, other units within the Cypriot government and academic bodies to develop their own strategy or to evaluate the impacts or to use the MCA tool," he says.

Photo: LIFE08 ENV/CY/L000460/NEEMO EEIG/Cristina Marouli

The Kalo Horio river basin, Cyprus. CYPADAPT developed measures for the water sector as part of its cross-sectoral approach to climate adaptation planning.

"CYPADAPT was not about a study for the office, it was about a study that will give solutions to many problems," believes Mr Mesimeris. "It was very useful for Cyprus to have the opportunity to use the LIFE financial tool to support the initiative to develop our national strategy. It was the basis for the preparation of one of the major *ex ante* conditionalities under the new financial framework, the climate change risk assessment."

Another significant impact of the project was linked to the Cyprus Presidency of the European Council in July-December 2012: "[The Cypriot government] decided that the main issue for discussion in the informal council for environment was adaptation. This was the first time [the EU] had a discussion about adaptation at ministerial level. The CYPADAPT project supported the preparation of material for those discussions. It was very important not only from the technical angle, but also from the political one," concludes Mr Mesimeris.

Project number: LIFE10 ENV/CY/000723

Title: CYPADAPT - Development of a national strategy for adaptation to climate change adverse impacts in Cyprus

Beneficiary: The Department of the Environment within the Ministry of Agriculture, Natural Resources and Environment of Cyprus (MANRE)

Contact: Theodoulos Mesimeris

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Period: 01-Sept-2011 to 31-Mar-2014

Total budget: €1 359 000

LIFE contribution: €678 000

URBAN

Making **cities** and **towns** **more climate resilient**

The LIFE programme has successfully demonstrated how green and blue infrastructure can increase urban resilience to climate change impacts, such as water scarcity, flooding and heat island effects.

Cities are the cornerstone of Europe's economic strength and wealth and the key to its future prosperity. Three-quarters of Europe's population lives in urban areas and the proportion is expected to increase. The potential impacts of climate change on people and assets (such as emergency services and essential infrastructure) are amplified in these densely populated areas. It is therefore essential to target climate adaptation actions at urban areas.

Climate change is likely to exacerbate existing pressures facing European cities, such as overcrowding, aging infrastructure and increasing pollution from transport and industry. These problems impact upon energy demand, waste management and water resources far beyond the administrative boundaries of cities.

Climate change is strongly intertwined with socio-economic change, through its effects on people,

R-Urban implemented a participative strategy to increase the ecological resilience of the town of Colombes

Photo: LIFE10 ENV/FR/000215/NEEMO EEIG/Carlos de la Paz

Designing resilience in urban areas

COLLABORATIVE PROCESS
1 Collaborative appoach to funding green and grey infrastructure

SPECIES SELECTION CRITERIA
1 Resilience to pests and diseases

DESIGNING WITH TREES – POSITIVE RESULTS
1 Enhanced walking environment
2 Attractive retail environment
3 Supporting mental health
4 Cooling and sheltering
5 Air quality

TECHNICAL DESIGN SOLUTIONS
1 Integration of trees and sustainable drainage systems
2 Adequate substrate for root development eg crates
3 Load bearing and environment eg rafts

property and ecosystems. Some sectors of the economy, such as agriculture, forestry and tourism, are directly dependent on climatic conditions, and are already experiencing the impacts of climate change. Urban areas compete for water with agriculture and outlying industry, which can lead to regional water scarcity.

Although climate change impacts will be widespread, urban areas are subject to localised effects (e.g. reduced air quality) that are different to those in surrounding areas. Urban areas in different regions will also experience different intensities and types of change, with cities and towns located in vulnerable areas, such as coastal zones or river floodplains, experiencing additional site-specific impacts. Higher temperatures will intensify forest fires where they threaten cities, for example, whilst sea level rise increases the risk of coastal flooding. Climate change impacts can exacerbate water scarcity. Conversely, with most of Europe's large cities located along major rivers, increases in rainfall, storms and melting snows in upstream areas bring a greater risk of flooding.

Urban areas are affected by city-specific climate change impacts that are generated by the process of urbanisation itself. Built-up areas create unique microclimates, for instance, due to the replacement of natural vegetation with artificial surfaces. This affects air temperature, wind speed and direction, and precipitation patterns. For example, soil sealing increases the absorption of energy from the sun and leads to higher urban temperatures (the 'urban heat island effect'). Heatwaves can compromise public health (particularly in cities with vulnerable, aging populations); reduce people's ability to work; and put infrastructure at risk. Urbanisation also reduces the area available for natural flood management.

Poor urban design can aggravate the impacts of climate change. The impermeability of sealed areas reduces natural drainage and increases runoff, for instance, which during heavy rains can lead to urban floods. As climate change modifies the whole hydrological cycle, this can lead to more frequent and intense rainfall that affects urban infrastructure, especially water supply, wastewater and storm water systems.

Urban design and spatial planning therefore can play an important role in reducing the impacts of climate change. Furthermore, investing in green infrastructure not only increases resilience, but also provides numerous co-benefits including improved air quality, protection for biodiversity and enhanced quality of life.

Action for EU urban areas

Within the EU Adaptation Strategy and in coordination with other EU policy areas, the Mayors Adapt initiative, now integrated into the New Covenant of Mayors (see box), supports cities that voluntarily commit to adopting local adaptation strategies.

The challenge for policy-makers is to understand climate change impacts sufficiently to develop and implement policies that ensure an optimal level of adaptation. For example, strategies focused on managing and conserving water, land and biological resources to maintain and restore healthy, effectively functioning and climate change-resilient ecosystems are one way to deal with the impact and can also contribute to the prevention of disaster. Cities need to act, because delaying adaptation action will likely increase costs at a later stage or the measures will come too late to prevent costly damage. Furthermore, adaptation to climate change offers the opportunity to attract business, develop new jobs promote innovation and increase citizens' quality of life.

City authorities are therefore adopting long-term spatial planning measures to ensure effective - and affordable - adaptation. Working with nature's capacity to absorb or control impacts can be a more efficient way of adapting than simply focusing on grey[1] infrastructure. Green[2] and blue[3] infrastructure can play a crucial role in adaptation, especially under extreme climatic conditions. Examples include improving the soil's carbon and water storage capacity, and conserving water in natural systems to alleviate the effect of droughts or prevent floods.

A combination of these infrastructure measures has the potential to deliver robust and flexible solutions, whilst delivering co-benefits such as increased

1 Grey infrastructure measures involve man-made assets, such as ensuring sewage systems can cope with heavier precipitation, reviewing building designs to better insulate against heat, and adapting energy and transport systems to cope with higher temperatures, low water availability or flooding.
2 Green infrastructure measures such as the creation of parks, forests, wetlands, green walls and roofs provide a cooling effect and play a role in managing floods.
3 Blue infrastructure is a type of green infrastructure focused on alleviating water scarcity or flooding.

Table 1: **Climate change impacts and responses to increase resilience in urban areas**

Vulnerability	Factors	Response
Heatwave	Soil sealing Insufficient building insulation Lack of green urban areas Heat generation by production, transport, heating Population density	Decrease in soil sealing Green infrastructure (green spaces, green belts, green roofs-facades) Education and awareness raising
Water scarcity and droughts	Temperature rise and dry spells Soil sealing Water stress in the region - high water abstraction compared to limited resources Low water availability (surface and underground) Water intense industry, tourism, agriculture in the region	Green and blue infrastructure (green roofs-facades, green spaces, SUDS, water harvesting, water recycling) Availability of organisational measures such as water use restrictions Education and awareness raising
Urban floods	High share of low-lying urban areas, potentially prone to flooding High and increasing degree of soil sealing Lack of green urban areas Increase of frequency and intensity of heavy precipitation Sea level rise in combination with storm surges Snow melt	Green infrastructure (SUDS, green spaces, green belts green roofs-facades) Availability of flood defences and retention areas Effective sewage systems Education and raising awareness
Forest fires	High share of urban areas in forest fire risk zones High share of population in forest fire risk zones Drought Increased temperature Increased wind speed	Effective forest fire management Training for forest managers Capacity building for forest planners Education and raising awareness

Mayors Adapt and the New Covenant of Mayors

Launched in March 2014 in the context of the EU Adaptation Strategy, Mayors Adapt is the Covenant of Mayors Initiative on Climate Change Adaptation. It informs, mobilises and supports local authorities to take adaptation action.

Currently more than 150 cities from 21 EU Member States, as well as from European Free Trade Association (EFTA) and candidate countries, have officially signed the Mayors Adapt initiative.

Signatories voluntarily commit to a series of steps and agree to have their actions monitored. They are obliged to prepare a risk and vulnerability assessment, develop a local adaptation strategy or mainstream adaptation into the relevant plans within two years of signing the Commitment. They must also submit an Implementation Progress Report every second year. In return, the cities gain visibility on their commitment, wide-ranging support, networking and capacity-building opportunities, through regular events, an online platform, and via synergies with relevant stakeholders and other EU initiatives and funds. A web-based Urban Adaptation Support Tool has been developed to aid adaptation practitioners in urban municipalities to plan and implement adaptation actions. The tool makes it easy to access information and knowledge resources specifically designed for urban conditions.

Mayors Adapt builds upon the success of the previous European Commission (DG CLIMA) pilot project, EU Cities Adapt, and links with the existing European Environment Agency (EEA) online platform, Climate-ADAPT.

In October 2015, the Commission launched the New Covenant of Mayors for integrated climate and energy action. It builds on the following three pillars:

1. It features a new target of at least 40% reduction in CO_2 emissions by 2030;
2. It includes both mitigation and adaptation through the integration of the Covenant of Mayors and the Mayors Adapt initiatives;
3. It reaches a global scope, opening up participation to local authorities worldwide.

energy efficiency and the creation of attractive areas for nature and recreation. This can be complemented by 'soft' measures that often can be implemented at a lower cost. Such measures include behavioural change, emergency systems and the adequate provision of information to vulnerable groups in society.

Urban climate change adaptation requires coordinated action at regional and national levels, as events outside cities can have major effects in urban areas. Inappropriate land use and flood management in upstream areas, for example, can cause flooding in cities. Therefore, to build resilience, a joint and multi-level approach within regions, combining dialogue and multi-sectoral partnerships, is required.

Planning integrated climate change mitigation (i.e. reduction of gas' emissions causing climate change) and adaptation action is efficient and leads to synergies. For instance, better insulated buildings reduce both energy consumption and the impact of climate change induced heat waves; green areas contribute to store carbon while reducing the impacts of floods and heat waves.

LIFE and urban resilience

The LIFE programme has funded over 20 projects that have demonstrated adaptation measures based on green and blue infrastructure, spatial planning and natural resource management, with the aim of reducing the vulnerability of urban and peri-urban areas to climate change. A wide range of measures have been implemented at various governance levels. This chapter gives an overview of the technological, informational, organisational, behavioural and ecosystem-based approaches that LIFE projects have implemented and the positive results they have achieved, including co-benefits and improved local economic development.

Green and blue infrastructure has been identified as 'best practice' at local level for achieving greater urban sustainability and resilience, although on occasion this is combined with grey infrastructure, such as expanding storm sewers. The climate adaptation benefits of green infrastructure are generally related to its ability to moderate the impacts of extreme precipitation or high temperatures. These benefits include: better management of storm-water runoff; fewer incidents of combined storm and sewer overflows; water capture and conservation; flood prevention; storm-surge protection; defence against sea-level rise; accommodation of natural hazards (e.g. relocation out of floodplains); and reduced ambient temperatures and urban heat island effects.

Green infrastructure is also a contributor to improving human health and air quality, lowering energy demand, increasing carbon storage and creating additional wildlife habitat and recreational space.

Examples of green infrastructure include green roofs, permeable surfaces, green alleys and streets, urban forestry, green open spaces such as parks and wetlands, and adapted buildings to better cope with floods and coastal storm surges.

Green technologies and infrastructure solutions are often implemented with a single goal in mind, such as managing storm water or reducing local ambient heat, with the costs and benefits being evaluated in the same way. However, the full net-benefit of green infrastructure developments can only be realised by a comprehensive accounting of their multiple benefits, such as water filtering, slower runoff, cooler urban heat islands, and cleaner air. Green infrastructure approaches range in scale from individual buildings and neighbourhoods, to entire cities and metropolitan regions, with benefits that range in scale accordingly.

Spatial planning and green belts

Management practices for climate change adaptation may include planning, urban design, and smart growth approaches that incorporate green infrastructure into the urban landscape. Examples include higher density housing that accommodates green open spaces, large-scale urban forestry projects, green belts around cities, or wetlands that buffer against river flooding or storm surges in coastal areas.

LIFE has played an important role in establishing new ways of integrating spatial planning to enable the development of green infrastructure. For instance, LIFE projects have demonstrated how green belts, created around metropolitan areas to control urban sprawl, have produced an array of co-benefits, such as reduced forest fire risk, increased biodiversity, reduced soil sealing, and the creation of recreational areas that bring human health benefits.

A LIFE project from 2001-2004, Green Belt, used spatial planning to restore land degraded by diffuse development in peri-urban areas on the outskirts of Barcelona. Three areas (each 8-10 ha) were restored and converted into a green belt. The project team also forested areas with tree and plant species known to increase soil moisture, to help prevent fires spreading easily, and reintroduced traditional

LIFE Housing Landsapes has reduced urban vulnerability by adopting green and blue infrastructure measures

Photo: LIFE12 ENV/UK/001133

Photo: LIFE10 ENV/IT/000399

LIFE has funded large-scale urban forestry projects and created green belts around cities

URBAN

varieties of fruit trees to create a green business in an Agricultural Park. This measure also helps safeguard local biodiversity.

Another Spanish project, Gallecs, increased the resilience of urban and peri-urban areas by creating a green belt accompanied by other green infrastructure measures. This helped protect agricultural activity, with farmers adopting green infrastructure measures, and has also limited the fragmentation of natural habitats and reduced soil sealing. A set of integrated measures was introduced, such as the creation of a wetland to regulate heavy torrents of water and avoid the floods that are common in the region after intense precipitation. River banks were strengthened, degraded areas re-planted with indigenous species, and water-efficient irrigation systems installed to avoid water scarcity incidents. The green infrastructure aspects of the project demonstrated obvious environmental benefits that are being integrated into urban-planning decisions affecting the region today.

The ongoing LIFE ZARAGOZA NATURAL project is using green and blue infrastructure to increase resilience and biodiversity in urban and peri-urban areas. The aim is to restore eight natural areas, through forestation and the recovery of natural steppe vegetation, and to create continuity between them through peri-urban areas. The project

Green measures for grey areas

Grey infrastructure elements have made Flanders (Belgium), the most fragmented and second most sealed region of the EU. Projections indicate that urban sprawl and grey infrastructure expansion in Flanders is likely to increase by 17% by 2030.

"Due to a combination of surface sealing and climate change effects, flooding will occur more frequently in the future in peri-urban and urban areas such as in Flanders. This will damage buildings and infrastructure, with high costs for society," says LIFE-GREEN4GREY project manager, Pieter De Corte. "We are implementing natural water retention measures such as renaturalising artificial streams and creating wadis, which will have the effect of creating natural flooding areas, and water retention bodies to capture water from rainfall during peak showers." Land use is also being changed from intensive agriculture to grasslands, increasing the soil's water infiltration capacity.

In periods of heavy rainfall, these blue and green infrastructure elements capture water upstream. "Given the amount of soil sealing, these measures are of crucial importance to prevent urban flooding," explains Mr De Corte. "These green areas are also used for recreational purposes, such as walking, biking or jogging, and so create co-benefits for health. They act as green landscapes, which is positive for mental health and for social interaction," he concludes.

Photo: LIFE13 ENV/BE/000212

will also provide a 'blue matrix' of infrastructure, through river and wetland restoration, that will enhance the inter-connectivity between blue and green infrastructure to provide a multifunctional resource for the local community.

The presence of grey infrastructure can reduce the adaptation benefits of green infrastructure, a situation addressed by the LIFE-GREEN4GREY project (see box).

Urban forests

Planting and maintaining trees in urban settings is considered a quintessential green infrastructure practice, with multiple benefits including increased resilience in terms of both climate change adaptation and mitigation. Trees contribute to climate change adaptation by intercepting and filtering storm water runoff to prevent flooding and improve water quality, by absorbing air pollutants, protecting buildings from wind damage, and by regulating heat island effects through shading and evaporation. Simultaneously, trees contribute to climate change mitigation by lowering demand for electricity, as they cool urban areas, and sequester carbon. They also provide wildlife habitats and ecosystem services, and can increase property values.

However, although urban and peri-urban forests are exposed to the same climate change impacts as other forests, they are less adaptable than their more natural counterparts. Climate change affects eco-physiological mechanisms, especially under drought stress, for example, making trees more susceptible to pathogens. Urban areas tend to be more polluted and have higher temperatures, further increasing physiological stress, whilst urban forest stands are usually smaller and therefore do not have the structure that determines optimal ecological resilience.

The LIFE programme has funded several projects that show positive effects of forests in increasing urban resilience. For instance, EMoNFUr is establishing a monitoring network to assess adaption in urban forests (see box). Also in Italy, the GAIA project produced both climate change mitigation and adaptation outcomes through urban forestry. It fostered public-private partnerships involving 18 companies to pay for the planting of 1 320 trees within the city of Bologna, with the companies using the scheme to offset part of their CO_2 emissions. The trees are helping to improve air quality and to reduce the heat island effect in the city. The project also monitored the effects that climate change and air pollution have on urban trees, especially effects related to decreased resilience to extreme climatic events and biotic disturbance.

Monitoring the adaptability of urban and peri-urban forests

Climate change is affecting the ability of urban forests to produce ecosystem services, according to Enrico Calvo, project manager of EMoNFUr, a LIFE project that is setting up a permanent monitoring network for urban and peri-urban forests in Lombardy (Italy) and Slovenia to measure the adaptability of new lowland forests to climate change.

"We aim to provide parameters of ecological and environmental relevance, such as plant and animal biodiversity, carbon dioxide sequestration capacity, and how the forests are evolving and adapting in an urban environment," says Mr Calvo. "We will use a monitoring protocol for each site to explore climate impacts, soil quality, dendrometric parameters, biomass, health, and biodiversity. We are also carrying out an inventory for forestry land indices, geometric structure and forest categories, and investigating the health status of the urban and peri-urban forests," he explains. "We are analysing the growing rates of the trees in relationship with climate impacts, species composition, incidence of diseases and microclimatic improvement."

The project is measuring a wide range of biological and climatic parameters in 18 sampling areas in the two countries, including humidity and evaporation from foliage, soil moisture and tree growth rates in relation to climate impacts, species composition, incidence of diseases and microclimatic improvement. Among the key findings are the positive results of urban forests on the heat island effect. "By comparing the data obtained from the weather stations of the project with the data of 2002, we measured a decrease in temperatures," recalls Mr Calvo. "The cooling effect is greater at night (-0.7°C). This is very important as Milan in the last decades has undergone an average annual temperature increase of 1.5°C."

Photo: LIFE10 ENV/IT/000399

In Spain, the LIFE-QUF project is demonstrating the effectiveness of water retainers and fungal mycorrhiza for enabling tree growth without any additional water infrastructure in a water scarce Mediterranean area. The project team is planting 30 000 trees in four groups to test the benefits of afforestation techniques with the aim of increasing by 95% the survival rate for trees planted without water infrastructure; and to study the benefits of soil quality improvements. The project seeks to gain 1% more organic matter in soil.

Green roofs and facades

In terms of climate adaptation, green roofs are generally installed to respond to two primary climate drivers: extreme precipitation and temperature. Extreme precipitation accompanied by soil sealing can overwhelm the capacity of drainage and sewage systems, and lead to urban flooding. Green roofs can reduce annual storm water run-off by 50-60% on average. They also delay the time at which runoff occurs, resulting in decreased stress on sewage systems at peak flow times.

Urban environments have large areas of hard reflective surfaces. In combination with increased temperatures, they exacerbate the Urban Heat Island (UHI) effect[4]. By increasing solar radiation reflectivity (albedo) and evapotranspiration, green roofs help to cool buildings. By decreasing surface temperatures, they reduce the UHI effect in urban areas[5]. Other co-benefits are reductions in air and noise pollution, increased biodiversity, improved thermal performance of buildings (with decreased CO_2 emissions), carbon capture (also with climate mitigation potential), new recreational areas and health improvements.

Several LIFE projects have demonstrated the benefits of green roofing. The Roof Greening project encouraged the wider application of green roofing techniques in Sweden, at a time (1998-2003) when they were still in the experimental stage. It demonstrated reduced storm water runoff, water regulation, energy saving through better insulation and noise reduction.

More recently, GreenClimeAdapt tested green facades and roofs in Malmö. Green facades were shown to cool external facades by 8 °C, and by 1-1.5 °C for indoor temperatures (relative to the outdoor temperature), reduce ground-level ozone readings near the green facades, and increase biodiversity in their vicinity. Testing different low-cost and lightweight green roofs built using different substrates, the project showed that the roofs with the best overall plant coverage and plant germination rates were those with hemp as a bottom layer; biochar and crushed bricks were also found to be good green roof substrate components. This project also suggested that well-maintained green facades might have a positive impact on the productivity of solar panels. The project's economic analysis showed that such green infrastructure solutions were less expensive to construct and maintain than conventional drainage systems.

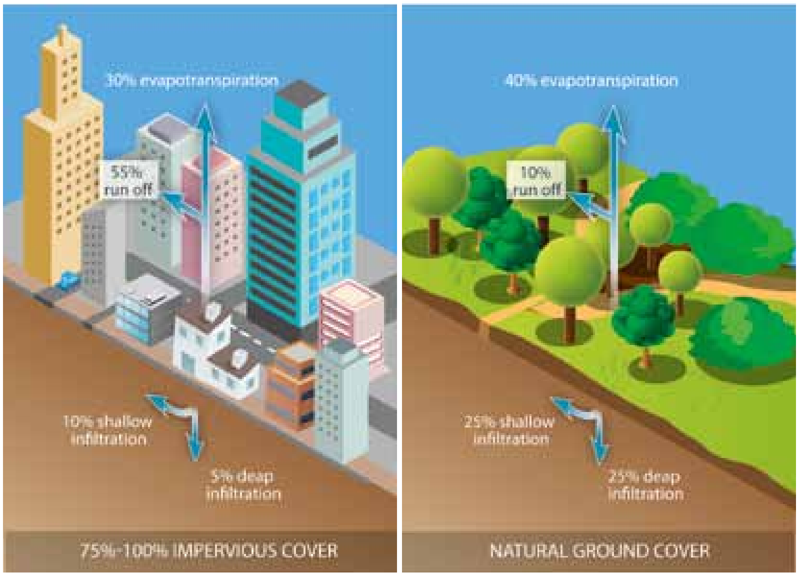
A current project dealing with the economics of green roofs is LifeMedGreenRoof, which is conducting a study to identify the economic barriers to their implementation, and suggesting technological and economically viable solutions for the large-scale introduction of green roofs in Malta. The GRACC project improved understanding of the different options for building green roofs and produced a 'Green Roof Code of Best Practice' for use in the UK, which provides designers, specifiers, installers and maintainers of green roofs with information and guidelines

Biodiversity in urban areas increases thanks to green infrastructure

Photo: LIFE12 ENV/MT/000732/Vince Morris/Antoine Gatt

4 Cities are known to be hotter than the rural areas that surround them; this phenomenon is called an 'urban heat island' (UHI). UHIs are caused by many factors including the extensive use of man-made materials such as asphalt and concrete in urban areas, which results in the reduction of evapotranspiration and in greater heat storage capacity.
5 Green roofs in some cases reduce surface temperature by 30-60°C and ambient temperature by 5°C, compared to conventional black roofs.

Blue versus grey infrastructure



to make better-informed decisions. Also in the UK, the LIFE Housing Landscapes project is retrofitting houses with green roofs and other green infrastructure (see box).

Blue infrastructure

Sealed surfaces tend to generate surface runoff. Runoff water in urban environments is thus usually collected, channelled and treated in wastewater treatment plants. However, with increased precipitation the capacity of sewage systems may be exceeded, resulting in urban flooding. There are different ways to mitigate this phenomenon, such as increasing the amount of open soil (de-sealing) or through the implementation of blue infrastructure measures such as Sustainable Urban Drainage Systems (SUDS). Runoff can also affect the quality of surface waters as the cleaning function of soil is lost.

Since 2008, three LIFE projects have focused on mitigating the effects of runoff water by adopting SUDS, including the previously mentioned LIFE Housing Landscapes (see box), which is demonstrating sustainable urban drainage as part of a holistic package of blue measures that also includes rain gardens[6], drought-resilient plants, and rainwater harvesting. Benefits will include a reduction in flooding risk, use of rainwater for garden irrigation and less wastewater to be treated.

In the Province of Valencia in Spain, AQUAVAL used SUDS to solve the problem of sewer overflow discharges into rivers and to mitigate urban flooding. As part of an ambitious plan to create Europe's first industrial estate based on sustainable development principles, another Spanish project PLATAFORMA CENTRAL IBERUM aims to control the whole water cycle through rainwater harvesting and re-use, creation of permeable structures to avoid sealing, construction of canals and reservoirs to allow water to be collected for distribution, and the use of SUDS and the creation of storm ponds to maintain surface aquifers.

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

Engaging residents in climate-proof social housing

The LIFE Housing Landscapes project is retrofitting blue and green infrastructure to climate-proof existing social housing in the UK, with a focus on increasing local stakeholder engagement. "Alongside the adaptation solutions listed we are working closely with residents and our partnering local authority to deliver a series of training events, to support long-term resident engagement," says project manager, Hannah Clay. "The training programme will ensure that participants understand the principles through which measures such as green roofs, permeable paving, rain gardens, filter strips and swales have been designed, and how to maintain them to support their functionality."

The project will provide 2 790 m^2 of enhanced green infrastructure within three high-density housing estates in West London, with a monitoring programme managed by the University of East London. "We are expecting the measures to result in heat amelioration, reduced flood risk, improved air and water quality and sustainable drainage across the three estates," says Ms Clay.

"We have created synergies between climate-proofing social housing landscapes and increasing the adaptive capacity of their resident communities. People of all ages are getting involved in practical activities as part of implementing and maintaining the blue and green infrastructure measures, such as growing food or monitoring rainfall and weather conditions to contribute to the technical performance monitoring of this project," explains Ms Clay. "The improvements themselves will deliver social benefit in the extent to which they provide increased opportunities for physical activity and improved health. We are also using the Social Return on Investment approach to support calculations around social benefits on health, well-being and community cohesion."

Photo: LIFE07 ENV/SE/000908

Green facades and roofs tested by GreenClimeAdapt were shown to cool indoor temperatures by 1-1.5 °C

Open storm water management is another blue measure that can reduce the risk of flooding. It has been successfully demonstrated by the GreenClimeAdapt project in Sweden, which built a catchment area capable of retaining 90% of the water of a 10-year rain event.

In neighbouring Finland, the ongoing project Urban Oases is creating storm water swales in areas around Helsinki that are used to convey, infiltrate and clean storm water as well as to dissipate flow energy and store snow. In this project, four swales of varying design will be prototyped and implemented in sites having small urbanised watersheds with intermittent water flow. They are also being used to monitor the mitigation impact of constructed wetlands.

Conclusions

LIFE projects have provided valuable examples of adaptive measures that can be used to increase resilience in urban areas; this despite comprising only a very small part of overall LIFE funding. The majority of these projects have focused on a couple of practices (i.e. green roofs and forested area), whereas the most recent have taken a broader view on increasing urban resilience, for example, by integrating green and blue infrastructure, creating collective participation and a sense of responsibility, or getting businesses on board.

The LIFE programme has helped develop and promote green infrastructure and ecosystem-based approaches to climate change adaptation in cities across Europe. Green roofs or networks of green space, acting as ventilation areas, have alleviated the UHI effect, for instance, whilst multi-use water retention areas have reduced flood risks.

However, more needs to be done to improve the resilience of urban areas, such as developing and deploying innovative adaptation technologies within the water, energy and construction sectors, and increasing the focus on health-related issues. This will require massive investments, especially when implementing grey and green infrastructure measures. Large financial resources are needed and at least 20% of the entire European Union budget 2014-2020 is foreseen for climate-related projects, including both climate change mitigation and adaptation. Particularly relevant for climate change adaptation in cities are the European Regional Development Funds (ERDF)[7], the Horizon 2020 research programme, the European Investment Bank (EIB) through the Jessica programme[8], and the LIFE programme. As of 2014, calls for proposals for the LIFE programme include urban adaptation as one of the policy priorities for the sub-programme for climate action, which alongside the EU's Mayors Adapt initiative, is part of the EU Adaptation Strategy's contribution towards a more climate-resilient Europe.

7 The European Regional Development Funds (ERDF) offer ample opportunities for supporting interventions in urban areas. Climate change adaptation is one of the priorities of the ERDF, and the fund additionally foresees that a minimum of 5% of the resources of the Partnership Agreements shall be allocated at the national level to sustainable urban development. Please see http://ec.europa.eu/regional_policy/en/funding/erdf
8 http://ec.europa.eu/regional_policy/en/funding/special-support-instruments/jessica/

URBAN

Benefits of urban resilience

ECONOMIC BENEFITS

- Increased retail sales
- Tourist and recreational facilities
- Income generation
- Property prices
  Faster property sales
  Land value
- Reduced energy costs
- Chance of gaining planning permission

SOCIO AND ENVIRONMENTAL BENEFITS

- Social cohesion
- Well-being
- Reducing flood damage
- Work place productivity
- Physical and mental health
- Heat-island effect reduced
  Improved air quality

URBAN

Developing eco-corridors for improved environmental resilience

The SeineCityPark project is building up green and blue infrastructure to increase the resilience of the Chanteloup loop, a peri-urban area near Paris. Actions will also boost biodiversity and the local economy.

Surrounded on three sides by the river Seine, the Chanteloup loop is an area of residential districts, uncultivated wasteland and brownfield sites in the Ile-de-France region. Many sites have been identified for further urban development, which since the 1950s has significantly increased the area's population. Such development, however, along with the emergence of river quarries, has greatly altered the landscape of the area, and the loss of natural spaces and the fragmentation of natural habitats are having a negative impact on quality of life.

The challenge for urban planners is to show that development can be combined with environmental protection – the main aim of the SeineCityPark project, which focused on a 1 700 ha development site. The LIFE project, in fact, is one of several projects that are being carried out in the area within a framework of coherent spatial planning. Its focus is to create a "resilient urban area and peri-urban territory, recover biodiversity and boost the local economy," says project manager Isabelle Chatoux of the Conseil départemental des Yvelines.

Specifically, the aim is to link up ecological infrastructure in the target site with the Seine to the south and the green areas to the north, i.e. the Hautil Massif. Such improved connectivity will aid the free movement of land animals, birds, insects, amphibians and dragonflies across the urban territory. This objective is being achieved through the use of natural clean-up techniques for tackling water and soil pollution and through the removal of invasive aquatic and terrestrial plant species. Thus the resilience of urban areas is being built up through the development of blue and green infrastructure.

The Ecopole Seine Aval will build a sustainable green business district that will blend in with the ecological corridors

Furthermore, the health and well-being of the local population will benefit from greater contact with the natural environment, emphasises Ms Chatoux. "We are creating recreational areas – picnic areas and bicycle/walking trails – and organising excursions."

The Coeur Vert

One aspect of the project was to plant native trees and vegetation on a degraded and polluted brownfield site known as the *Coeur Vert* ("Green Heart"). Furthermore, for around 100 years, these areas were irrigated with untreated water from Paris and its suburbs, polluting the soil with lead and cadmium. Market gardening was brought to a halt here in 1999 by a ban on growing vegetables or aromatic plants.

Nevertheless, the project team recognised the area's potential as a green corridor and took measures to put an end to its days as a site for fly-tipping and squatting. "We wanted to maintain the Coeur Vert as an area rich in biodiversity. This corridor will allow the transition between the town and the river," says Ms Chatoux.

Half of the site's total surface area has been set aside for growing miscanthus, "a plant for depolluting the contaminated soil," explains Ms Chatoux. It is also a plant that can be used in eco-construction and bioplastics or biomass production. "We can say that our adaptive measures, along with other environmental benefits, are also creating a biomaterial eco-business, thus giving a little boost to the local economy," she adds.

The project has also planted a number of other species, "to establish a link with the neighbouring urban areas and create a true patchwork of plant species," says Ms Chatoux: "The peripheral areas were sown with grasses and other plants, and the entire plain is now crisscrossed with hedges, small woods and former orchards."

Parc du Peuple de l'herbe

The town of Carrières-sous-Poissy is separated from the Seine by around 100 ha of farming and aggregate land that has largely been abandoned. The project sought to recover this land, developing a multi-purpose park, the *Parc du Peuple de l'herbe*. The park is made up of picnic areas, trails for biking or trekking, playgrounds and an educational insectarium that also doubles as a conference centre.

SeineCityPark is developing an ecological corridor, covering nearly 113 ha that will boost biodiversity and increase resilience

Photo: Agence TER

The aim was to reconnect the town with the Seine by improving the "continuity between the green urban areas and the open natural area on the banks of the Seine," explains Ms Chatoux. This continuity is guaranteed by the development of "an ecological corridor covering nearly 113 ha that reconnects the town to the broader Seine loop landscape." The development of such green infrastructure represents a boost to biodiversity and the ecosystem services provided by the area. "Through sustainable land and water management [green infrastructure] creates a more resilient landscape that can respond to the pressures of a changing climate," underlines Ms Sylvaine Baudoux, project partner from Communauté d'Agglomération 2 Rives de Seine (CA2RS), the organisation responsible for implementing the revitalisation of the Chanteloup loop as a whole, of which the SeineCityPark project is just one part.

The new park moreover hosts a series of grassland habitats such as couch grass (*Elytrigia repens*), orchard grass (*Dactylis glomerata*), perennial ryegrass (*Lolium perenne*) and ribwort plantain (*Plantago lanceolata*). Part of this aspect of the project was to restore these habitats and the species that they host. For example, the threatened native flower, the smallflower buttercup (*Ranunculus parviflorus*) will benefit from the continued mowing of the grasslands. The habitats also host more than 50 migratory birds (11 of which are of Community importance).

River restoration

Another key project action involves the renaturalisation of a 3 km stretch of the Seine. Channelling of the river has led to the increased incidence of flooding, so the project team was eager to restore its natural geomorphological functioning by eliminating barriers and remodelling the river banks. In addition, it has replaced the poplar trees that were planted on the bankside at the end of the 19th century with native riverine vegetation. Reedbed habitats and small islands along this stretch have been restored with the effect of boosting biodiversity. Furthermore, restoring the wetland adjacent to the riverbank will allow it to play a greater role in flood management.

Photo: CD78

River renaturalisation lessens the impact of flooding events

Renaturalising the river has also involved removing grey infrastructure: some 30 000 m^3 of gravel has been taken from manmade sections of the riverbank and used to replenish natural features of the banks, such as shoals, chutes and new riffles. "We have also created a large backwater to act as a fish nursery and refuge for wildlife especially birds and amphibians. Amphibians had basically disappeared from the area but through these interventions, they are managing to recover," says Ms Chatoux.

Eutrophication presents another challenge for the Chanteloup loop area. Due to increases in pollution and temperature, this problem has worsened in recent years, resulting in severe algal blooms throughout the summer seasons. Following the renaturalisation of the river banks and the replanting of aquatic plants, this phenomenon has diminished and water quality is steadily improving.

The natural ecosystems of the project area are also affected by invasive alien plant species, another problem that is exacerbated by climate change which can increase colonisation. In order to bolster the resilience of the territory, the project is removing invasive aquatic and terrestrial plant species, including Japanese knotweed (*Fallopia japonica*), the black locust tree (*Robinia pseudoacacia*) and species of the genus Ludwigia. To date, the project has achieved a 70% decrease in the presence of Ludwigia and a 10-30% decrease in Japanese knotweed and black locust.

Sustainable development

The SeineCityPark project represents an important part of the development of the Chanteloup loop. "We have managed to requalify whole areas and transform them into green corridors. This has not only made our territory more resilient to flooding and other climate-related impacts, but by making this ecological transition between park, the Seine and the city, we are protecting the environment and supporting the sustainable economic development of this area while improving the health and well-being of our citizens," summarises Ms Chatoux.

Local residents and students have taken part in field visits to understand more about the park's planning principles and the environmental challenges the area is facing. They have also already benefited from the recreational facilities and the newly created solarium is expected to be a hit when it opens shortly. In the remaining two years of the project, the SeineCityPark team will establish a 24 ha "area of ecological interest" at the Ecopôle Seine Aval, a 200 ha business park located between the Seine and the Coeur Vert site. "The main actions will be to requalify 300 ha area which is full of quarries that have been filled and abandoned; the last operating quarry is scheduled for closure in 2018 and to transform it into the area of ecological interest. Work to recreate a wetland, a dry prairie and wooded areas "will extend the ecological network and provide a home for the region's many breeding avifauna," explains Ms Chatoux.

Project number: LIFE11 ENV/FR/000746

Title: SeineCityPark - Development of an urban green infrastructure in the Chanteloup loop

Beneficiary: Conseil général des Yvelines

Contact: Isabelle Chatoux

Email: ichatoux@yvelines.fr

Website: http://www.seinecitypark.fr/

Period: 01-Feb-2012 to 31-Jul-2017

Total budget: €3 473 000

LIFE contribution: €1 729 000

URBAN

AGRICULTURE

Adapting **agriculture for a sustainable future**

Agricultural practices have adapted over millennia to regional and local variations in weather conditions. But as the effects of climate change become more noticeable, further adaptation becomes essential to ensure food security in Europe.

Though patterns of climate change vary across the continent, the basic principle applies: farmers must manage their land in ways that improve its resilience to the impacts of a changing climate. Agronomic techniques and farming practices have already been adapted in some areas, but if global temperatures and precipitation levels continue to rise at current rates, climate change could outstrip agriculture's capacity to adapt.

LIFE has demonstrated how adaptive farming practices can increase resilience

Photo: LIFE13 ENV/ES/000541

The effects of climate change on agricultural production are wide ranging[1]. The increased frequency of extreme weather events threatens the stability of food production (since extreme heat and deluges damage crops). In addition, steadily rising atmospheric CO_2 concentration, higher average temperatures, changes in intensity and frequency of weather events, changing wind patterns, and changes in annual rainfall across Europe as a whole also have a long-term negative impact on crop yields and livestock farming.

In general, the agricultural sector will be most affected in south and south-east European countries where increased temperatures, greater risk of drought and declining rainfall and availability of water will reduce yields and suitable areas for crops. In extreme cases, degradation of ecosystems through prolonged dry periods could lead to desertification and a subsequent loss of agricultural production.

In northern Europe wetter winters and hotter summers could increase crop yields – although in the long term potential gains are likely to be outweighed by the impact of rising sea levels (higher soil salinity lowers productivity), increased incidence of pests and more ground-level ozone. In

1 Adapting to climate change: the challenge for European agriculture and rural areas

Farming practices for adaptation

HEALTHY FARM PRACTICE

1 Landscape approach
2 Integrating crops and livestock
3 Crop diversity and rotation
4 Cover crops

HEALTHY FARM BENEFITS

5 Soil health
6 Biodiversity
7 Resource efficiency
8 Economic health
9 Environmental health

central Europe the decline in summer precipitation increases the risk of soil erosion, whilst the warming of colder climes reduces snowfall in favour of rain, leading to a greater risk of waterlogging and a consequent rise in the incidence of pests and diseases. Increased need for pesticides and subsequent runoff of water could additionally lead to more polluted water sources.

The impact on farming will also be determined by the type of crop being harvested: certain vegetables are sensitive to temperature fluctuations outside their normal range and fruit crops can easily be damaged by extreme weather events. Furthermore, the economic impact for farmers will not only depend on regional variation, but also on the size of the farm, intensity of land use, the diversity of agricultural practices employed, and moreover, the farmers' ability to access the latest climate-resilient technologies and adaptation knowhow. Increased competition for water and potentially higher prices could also harm the agricultural sector in some places, whilst rural areas as a whole are threatened by the wider implications of extreme weather events for forestry, infrastructure and local businesses.

EU action

The EU, however, is responding to the challenge to agriculture. The European Commission's White Paper of 2009 outlined a framework for action for improving Europe's resilience to climate change, while recent revisions to the Common Agricultural Policy (CAP) place a greater emphasis on supporting farming practices that sustain resilience. Under reformed CAP rules, 30% of direct payments to farmers are linked to improving environmental performance and 30% of rural development funds are aimed at measures related to land management and the fight against climate change[2].

The LIFE programme has demonstrated and developed many practices and protocols necessary for adapting agriculture to changing climatic conditions. It has long co-funded actions to improve soil, air and water quality that are themselves examples of good adaptation practice in agriculture (i.e. Humedales Sostenibles, HydroSense, IRRIGESTLIFE). More recently, LIFE has supported projects that are directly

2 http://ec.europa.eu/clima/publications/docs/06-climate_mainstreaming_fact_sheet-eafrd_en.pdf demonstrating technological solutions and adjustments in farm management that increase resilience, such as cover crops, no-till farming, crop rotation and buffer zones. When applied in combination, these methods can boost soil's resilience to climate change (see box). Before many of these adaptation strategies can be implemented, however, it is often necessary to develop the right policy frameworks, access to knowhow and financial models – another area in which LIFE can play a vital role.

Sustainable crop management

LIFE projects have trialled organic and precision farming methods in a range of circumstances. For example, the project Crops for better soil set out to demonstrate that the cultivation of semi-arid land in Spain can be made economically viable by applying organic farming techniques. It encouraged organic farmers to introduce legumes and oilseeds in a crop rotation system. Egbert Sonneveld, the project's technical coordinator, explains that these types of crop have "good value" on the market and benefit the soil because "their roots go deeper into the lower layers and the legumes fix nitrogen for themselves and for the following crop".

Ways to help agriculture adapt

A common method is to cultivate a fast-growing cover crop (in addition to the main crop) that reduces the risk of soil degradation by providing temporary or permanent surface cover. Benefits include reduced soil erosion, improved soil structure and nitrogen fixation, weed suppression and the provision of insect habitat.
Another method is to reduce the intensity of tillage (or practice 'no-till farming') in order to increase the storage of soil organic carbon (SOC) and reduce soil erosion through the development of a litter layer that offers protection against the impact of rain. This method has been shown to help keep water in the soil and thus avoid the runoff associated with conventional practice. The organic content in soils can also be increased by manure and residue management.

Crop rotation also helps to reduce runoff and erosion, as well as increase organic matter moisture in soils and improve pest control. Furthermore, intercropping (growing two or more crops in proximity) can improve yield, fertility and increase resistance to pests and diseases, whilst organic and precision agriculture (assessing variations in crop yields from field to field) apply management practices that improve the land's resilience to climate change.

Maintenance of grasslands and reduced grazing have the positive effect of contributing to soil conservation and the regulation of water flows, helping to reduce flash flooding from heavy rains by maintaining indigenous vegetation.

Another effective measure demonstrated by LIFE has been to create buffer zones, which act as a shield against overland flow from agricultural fields and reduce the amount of runoff reaching watercourses. Buffer zones thus help combat soil erosion and prevent pollutants entering water sources.

Photo: LIFE10 ENV/ES/000471

Crops for better soil trained farmers in the use of sustainable techniques such as crop rotation

Other crops that have performed well in trials include lentils, chick peas, dry peas and some very old legumes such as bitter vetch, grass pea and broad bean – but controlling weeds is a problem for farmers. For this reason, the project bought a tilling machine to remove them, and due to its demonstrated success, Mr Sonneveld believes that every farmer should own one. Oilseeds are also not without their difficulties, given that they are a summer crop and thus dependent on unreliable spring rains.

The project has also tried alternatives to wheat and barley – namely durum wheat, oats and rye – as well as crops in combination such as lentils with wheat, which have yielded "very positive" results, according to Mr Sonneveld. Moreover, crop rotation has an economic advantage for farmers. "Instead of getting return on the land once every two years, by rotating only cereals with set aside, now they get return every year," he says.

Mr Sonneveld is also lending his expertise to another Spanish project, Operation CO_2, which is being led by the University of Valladolid. This project is targeting microorganisms in the soil and reintroducing the use of an old type of plough on ridges (the "Roman plough") that enables the crop roots to penetrate deeper into the soil and thus increase its fertility and resilience to climate change. "Once these [deeper] layers are penetrated by roots the next crop makes use of these channels, so we see a soil of 20 centimetres deep turning into a soil of more than a metre deep in just a few years. And by avoiding heavy turning movements of the soil the essential and beneficial microorganisms colonise these deeper layers as well," he explains.

The project is able to make these measurements by digging holes after each plant and following the roots – the impact on yields is considerable. "The plough is the perfect tool to obtain aeration of the soil and this of course helps with the fixing of nitrogen. Even in a very dry year, the yield of vetches on our plot in Zamora is higher than the irrigated crop in the same area."

Rising temperatures may be opening up new wine-growing areas in the north of Europe but in more established wine regions, climate change adaptation is essential for continued production. The ongoing French project, LIFE ADVICLIM has selected vineyards in four climatic regions across Europe in order to develop different adaptation models based on local observable data (e.g. slope, orientation, type of soils, climatic variability). Adaptation models will also include the results of in-depth surveys with winemakers "in order to integrate crop and working calendars specific to each European wine region". Its main aim is to then transfer this technical knowledge to winegrowers and policy-makers.

Improving soil fertility

Greece's oLIVE-CLIMA project is pioneering organic farming to improve soil organic matter (SOM) and soil fertility, as well as increase water and nutrient retention. The project is introducing new cultivation practices for tree crops, particularly olives, in Greece. Programme manager Chrysostomos Makrakis–Karachalios says that it is important to improve soil biodiversity by "feeding organic matter to soil micro-organisms." The practice aims to "decrease agrochemical inputs so as to least disturb the in-soil flora and fauna, and hence improve ecosystem sustainability." Seed mixtures are used to enhance poor areas, such as the 'empty spaces' within olive groves.

oLIVE-CLIMA is also a good example of a project that shows how crop residues can be returned to the soil to improve fertility and reduce degradation. It is testing a range of material from pruned wood and olive mill sludge to leaves and composted matter. Another way to improve soil fertility is to plant perennial crops - especially grasses - that store a higher proportion of carbon underground. LIFE RegaDIOX is testing this approach in Spain.

Combating soil degradation was also an objective of the Almond PRO-SOIL project. It set out to demonstrate the benefits of applying compost and growing almond trees to restore semi-arid and arid soils. According to Jorge García Gómez of project partner EuroVértice Consultores, the project showed that a 50% increase in plant biomass yield can be achieved in arid or semi-arid sites in Italy and Spain when organic waste matter is applied to the soil to improve its carbon content. "Our project offered integral and definitive strategies for using organic wastes that follow both present-day and foreseeable European guidelines," he says.

LIFE ADVICLIM has selected vineyards in four climatic regions in order to develop different adaptation models

Photo: LIFE13 ENV/FR/001512/Neethling

The Agricarbon and ClimAgri projects, both led by the Asociación Española Agricultura de Conservación Suelos Vivos, have applied conservation agriculture practices that have increased the carbon content of soil by up to 56% in comparison with conventional farming. Adaptation methods being demonstrated by the ongoing project, ClimAgri, include modifying crop cycles in order to avoid critical crop development stages coinciding with periods of high temperatures and encouraging the use of plant species that are resistant to droughts and extreme heat.

The two projects also introduced no-till farming, a technique in which at least 30% of the agricultural area is covered by plant residues "and crops are sown using machinery able to place seeds through the plant residues of previous crops", explains Emilio González Sánchez of the coordinating beneficiary: "Stubble and covers kept over the soil prevent water evaporation whilst increasing its infiltration."

Photo: LIFE08 ENV/E/000129

Covers and stubble are kept to avoid water evaporation and increase infiltration

Adapting to water shortages also means improving irrigation practices. The ClimAgri project is focusing on reducing distribution network losses, run offs and deep percolation, as well as adapting irrigation schedules to the specific conditions of the region. According to Mr González Sánchez, the structural improvements facilitated by conservation agriculture have increased the water content of soil up to 18%.

Furthermore, as with the Crops for better soil project, increased yields are adding weight to the economic argument for good environmental practice. "The global average production for the four agricultural seasons with a full rotation is 5% greater with conservation agriculture than with conventional techniques," says Mr González Sánchez. Leguminous crop production is up 7.9% and wheat, 7.3%, he notes.

The Italian project LIFE HelpSoil has also introduced conservation agriculture practices such as cover crops, crop rotation and no-till farming on the plain of the River Po. According to Stefano Brenna, the project's technical manager, these practices have already increased the vitality and fertility of the soil, increasing its SOM and biodiversity (i.e. more earthworms, microarthropods)

REAGRITECH built a hybrid wetland system using shipping containers and implementing hydraulic controls for recirculating water

Photo: LIFE11 ENV/ES/000579

and reducing erosion. In the medium term, fewer pesticides and fertilisers will be required and less energy consumed (lowering the cost of yields). The project is also testing subsurface drip irrigation, which has proved to be "particularly suitable for no tillage soil management," says Mr Brenna. It is also desirable as an adaptation practice, given that the reduction of evapotranspiration means that less water is used.

The HelpSoil project has promoted livestock manure management through the application of trailing-shoe, shallow injection and 'fertigation' systems. These techniques are expected to increase manure and slurry efficiency, and the project will adapt them to prevent the soil becoming compacted. "Agronomic and ecological data will be collected to assess the extent that all these conservation agriculture techniques can deal with the impact of climate change," says Mr Brenna.

Creating buffer strips

According to Andrea Lorito of the REWETLAND project, the actions it has taken to improve the quality of surface waters in the Pontine Plain, south of Rome, "can be considered direct and immediate measures for increasing the area's resilience to climate change." As well as carrying out actions on pilot sites to improve ecosystem functioning and flood management, the project was a trailblazer for buffer strip management using phytoremediation (the process of decontaminating soil or water by using plants and trees to absorb or break down pollutants). Since nitrates and phosphates enter water courses from croplands in many places, creating buffers (on two of the four pilot sites) was an "appropriate and cheap solution. Among the best plant species to use in this context is common reed *(Phragmites australis)*," says Mr Lorito.

Another project to have created buffer strips was CONCERT'EAU. Through cooperation with stakeholders and administrators, the project was able to implement crop rotation and buffer strips throughout the Adour-Garonne river basin territory in France, techniques designed to reduce nitrate and pesticide levels in surface waters.

One of the specific aims of the REAGRITECH project has been to assess the potential of buffer strips as an ecosystem-based adaptation approach. The project's overall goal is to reduce the volume of water used in agriculture and to limit the impact of nitrogen-rich runoff water. Its solution was to build a hybrid wetland system using large shipping containers and implementing hydraulic controls for recirculating water. "The system offers the possibility that certain desired flows of treated effluents can be recirculated to any of the constructed wetlands," says Prof Jordi Morató, the project manager. The system was installed at an irrigated plantation crop in Lleida (Catalonia). Here, water for the constructed wetland is taken from the infiltrated water by means of well pumps and treated using a two-chambered sedimentation tank. Water quality is being continually monitored in order to optimise the system.

Testing adaptive farming techniques

The 12 farms participating in the Swedish project, SOLMACC were selected to demonstrate four practices relevant to climate change adaptation: optimised on-farm nutrient recycling (such as composting, cooperation on manure/forage and biogas fermentation); optimised crop rotations with legume-grass leys (the grass-legume is harvested as hay or silage); optimised tillage system (i.e. reduced tillage in combination with forage-legumes and cover crops in an organic farming system); and agroforestry. The latter is the practice of combining trees, crops and livestock as a whole production unit. "The adaptation potential of this technique relies on the presence of trees in the cropping system which helps to protect the soil and the crop against soil erosion and severe climate conditions such as long droughts," explains Ann-Kathrin Trappenberg of International Federation of Organic Agriculture Movements Regional EU Group, the project beneficiary.

The project has developed a monitoring protocol for each farming practice that includes a yearly visit to each participating farm and the taking of soil samples for analysis. Soil structures, in particular, are expected to be strengthened by better tillage systems and the application of compost. The farms practising crop rotations are also better adapted to changing climatic conditions "since soils with higher SOC due to grass-legume cropping are more resilient," adds Ms Trappenberg.

Photo: LIFE12 ENV/SE/000800/Pfänder Hof GbR

AGRICULTURE

Increasing the resilience of grasslands

Species-rich, semi-natural permanent grasslands provide many functions and ecosystem services but this functioning is lost when they are converted to agricultural land. Such land use change not only threatens biodiversity it also diminishes resilience. Permanent grasslands also mitigate flood threats because of their capacity to store water. Wet grasslands can serve as a buffer zone for agricultural run off and help reduce erosion. The reconversion of former arable land to grassland can improve the land's adaptive capacity, but the process is not straightforward.

LIFE and the Rural Development Programme have financed agri-environmental measures that are beneficial for the conservation of European grasslands. Since 1992, more than 450 projects have focused on grassland conservation, demonstrating such practices as grazing and cutting. Overgrazing, however, can have a negative impact on soil's capacity to retain water as well as increasing soil erosion and runoff. Reversing this tendency will result in improved soil quality and better regulated water flows that lower the incidence of flash flooding following heavy rainfall.

A good example of a LIFE project helping to improve the resilience of grassland is the ongoing project PTD LIFE. It is testing on 120 cattle farms a Dynamic Rotational Grazing management system that controls grazing according to the growth phases of the grassland. Anne Porchet from CAVEB, the project beneficiary, explains that, "the animals are only allowed to graze a patch of land for a very short period of time so as not to exhaust its value as forage." By maximising the productivity of the grass in this way and allowing the meadows to self-fertilise, the use of mineral fertilisers can be limited.

Furthermore, the project is analysing the carbon content of the soil to show the improved resilience achieved by the PTD system and assessing potential economic benefits.

The natural and semi-natural grasslands in Lithuania targeted by LIFE Viva Grass are complex ecosystems that provide a range of ecosystem services – for example, the Silute grasslands are habitats for many birds and attract budding birdwatchers to the region. These sites, however, have suffered as the result of intensive agriculture in productive areas and marginalisation or land abandonment in more remote areas. The LIFE project aims to tackle this problem. "This is a policy project, where we would like to develop the tool to increase integrated planning efficiency," says Kęstutis Navickas of the Baltic Environmental Forum (BEF) Lithuania, the project beneficiary. He explains that the project

LIFE Viva Grass is training farmers to use a combination of grazing and mowing to maintain alvar meadows

Photo: LIFE13 ENV/LT/000189/Zymantas Morkvenas

Photo: LIFE08 ENV/IT/000406

Buffer strips improved the quality of surface waters polluted by agricultural run-off in the Pontine Plain

could lead to the development of recommendations that highlight the role that grasslands have in regulating water availability.

One of the project's partners is the Kurese farm and it is applying a more 'natural' approach to farming. The farmer, Urmas Vahur, uses a combination of grazing and mowing to maintain aluvar meadows and wooden pasture. The cows, which he rents from a neighbouring farmer, are used as a means of land management and not a direct source of income.

Efficient water use

Combating water scarcity and droughts – two noticeable impacts of climate change – is the driving force behind the adoption of more efficient irrigation practices. Such efforts are in line with EU water policy, notably the Water Framework Directive (2000/60/EC), and LIFE projects are demonstrating how greater efficiencies can be achieved, including the advantages of adopting drip or sprinkler irrigation systems (see boxes).

Another means of reducing water consumption is through more selective irrigation. For example, the AG_UAS LIFE project employed airborne sensors on drones to identify the specific irrigation needs of the crops in the Navarra area of Spain. The project tested two different sensors: an IR sensor that measures soil moisture and a multispectral sensor that allows the vegetation index to be calculated. "With these sensors you are able to obtain a spatial representation (image) of the soil moisture and therefore the spatial irrigation needs of the crop. In this way you can save water," explains project manager Teo Vitoria.

A further problem relating to water security is the rise in sea levels as global temperatures increase. The intrusion of seawater can lead to freshwater sources become saline, and thus soil can also become saline when this water is used for irrigation. To combat this problem, the Italian project, WSTORE2 is introducing an innovative water management system in the Vallevecchia river basin that channels and discharges poor quality water into the sea, but stores excess water, which has sufficiently low salinity, in canals and basins.

"When the data from the automatic system show that there are the suitable conditions, we release good quality water from the basin to the drainage network (the canals, channels and ditches) so that slowly a sweet water table forms above the saline one," explains Lorenzo Furlan from the project beneficiary. The success of this method has made

Photo: LIFE09 ENV/ES/000456

AG_UAS is using airborne sensors on drones to identify crop irrigation needs in Navarra

it possible to introduce several cash crops as well as improving the yield and quality of staple crops such as maize and soybean.

Irrigation can also be made more efficient by improving scheduling times. The IES ('Irrigation Expert Simulator') project in Spain has devised a tool that creates irrigation schedules based on the user's plot details and the meteorological conditions.

Registered users of the IES tool can also receive recommendations based on how an expert would have irrigated the same plot. "By comparing the results with the help of a trainer during face-to-face sessions or [by consulting] the manual in on-line sessions, farmers identify the best irrigation practices to apply in their fields," explains Josep Pijuan of project partner, Eurecat.

Through these sessions, the project has already reached more than 100 farmers and students and expects resulting water savings to be considerable. Financial savings will depend on regional variations in water prices and energy prices relating to pumping.

More efficient irrigation

The POWER project developed a model for improving crop irrigation efficiency in Zaragoza, Spain. It demonstrated water-efficient sprinkler irrigation on a small, 1 ha plot of corn crop, and a drip irrigation system on a larger, 3 ha plot. According to Nieves Zubalez, the project manager, the sprinkler system incorporated several innovations: remote control devices, humidity sensors, fault and leak detection and usability across a range of scales. The project also experimented with the use of drip irrigation on crops normally irrigated using sprinkler systems as a means of improving efficiency in water use.

The project's model combines such water efficiency with the use of renewable energy – for example, photovoltaic panels at the pumping station. Water and energy savings offer farmers and land mangers a competitive edge and the project was well received by stakeholders. A total of 10 irrigation communities have voluntarily adopted the project's good water governance models, including the national association of irrigation communities. "Economic savings vary depending on the irrigation task and the objective price of water," says Ms Zubalez.

Photo: LIFE08 ENV/E/000114

The MEDACC project is implementing aspects of the Catalan Strategy for Adapting to Climate Change as they relate to a number of areas, including irrigation. It is testing two types of irrigation systems (drip and gravity), "because both have interesting positive characteristics in terms of water sources (amount and quality), crop needs, energy costs and economic feasibility," says Dr Robert Savé of IRTA, a project partner. The project is also improving the efficiency of water use by sharing knowledge of crops' water needs with farmers, by avoiding water evaporation from the soil and by developing crops in less dry areas.

Improving cultivation

The need to improve cultivation techniques is perhaps more apparent in dry areas where the impact of climate change is already visible. As its name suggests, the Green Deserts project aimed to apply new planting techniques in desertified areas of Spain. By combining these techniques with an innovative water box technology (Twinboxx), it showed that even unpromising land could be made productive. The boxes, which hold 25 litres of water, offer a novel way of planting trees that avoids the need for irrigation. A wick below the box 'leaks' the water slowly to the plant's roots. "It basically restores the capillary function and forces the plant to grow deep roots anchored in the soil," explains project manager Sven Kallen.

Survival rates of around 80% were achieved without irrigation since the box captures rainwater and dew. "After one or two summers the box can be taken off for re-use in another plantation as the roots will have grown deep and wide into the soil where it will further develop thanks to the restored capillary action," Mr Kallen adds. Restoring desertified areas is particularly effective for tackling the problem of climate change. The restored areas serve as "green barriers" to further erosion and allow more rainwater (especially from extreme rainstorms) to be absorbed.

Trials with cash crops (trees for timber, cherries, almonds, pistachios etc.) showed the economic viability of the project's method. Tomatoes, cucumbers and peppers also have been successfully cultivated in very arid areas in this way.

The MEDDAC project, mentioned earlier, is not only focusing on irrigation, but also how farming management practices and plant breeding techniques could allow for the sustainable intensification of crop production in Mediterranean regions. Results show that in some cases the solution is to plant native species that are better adapted to changing environmental conditions – e.g. native grapes have the potential to help both increase the range of wines produced and reduce the amount of pesticide and fertiliser required. Such an approach, however, does not work for all types of produce. Certain native tomato species, for instance, adapt well to new environmental conditions but produce lower yields or have properties that lower their market value.

Climate-resilient durum wheat

The Italian project LIFE SEMENte parTEcipata is seeking to improve the resource-efficiency of commercial plant breeding activities by creating composite cross population of durum wheat germplasm (*Triticum turgidum subsp durum L.*) and other Triticum species using genetic improvement technology. The end result will be the promotion of agricultural systems that are more resistant to climate change. To this effect, the project has asked several germplasm banks for access to old varieties of durum wheat that have been subjected to breeding before the introduction of chemical fertilisation.

Professor Concetta Vazzana, the project manager, explains that these varieties have "retained the useful genetic characteristics for organic crop production." For example, they are more competitive in relation to weeds, have better nutritional qualities and have a greater potential to respond to climate change. The project is carrying out evaluations on organic farms in the different project regions.

Organic farming is a "low-input system", says Prof Vazzana, and requires less fertiliser and soil tillage. The project is building on these benefits through a three-year crop rotation cycle that consists of sunflower or maize; chickpea, bean or multi-essence green manure; and durum wheat. The legume crop reduces external nitrogen inputs, while the green manure increases organic matter, resulting in soil structure improvements, better weed control and less need for mechanical intervention. "The introduction of a wide genetic variability within the material obtained makes the crops more resilient, enabling them to respond successfully to climate variability," concludes the professor.

Photo: LIFE13 ENV/IT/001258

AGRICULTURE

Controlling pests

Rising temperatures increase the number of pests and diseases, as organisms expand their ranges to warming climates. Milder winters also result in an increased survival rate of many frost-sensitive insects. Higher rainfall and CO_2 levels also help spread crop diseases. Despite these challenges, it is possible to manage pests without more pesticides. Integrated pest management is a multidisciplinary, ecologically based pest management system that allows growers to minimise pesticide use and the risk of chemical run off and water pollution. It can, moreover, facilitate responses to this increasing risk of pests and disease.

LIFE's Ecopest project demonstrated such an approach to pest management and thus shows how the Directive on the Sustainable Use of Pesticides (Directive 2009/128/EC) can be implemented. It carried out pilot activities on an intensely cultivated area north of Athens: "The challenge was to protect the aquatic ecosystems and soils from the impacts of high concentrations of toxic substances due to excessive use of pesticides and fertilisers," explains project manager Kiki Machera.

The Ecopest project met this challenge by developing a 'Low Input Crop Management (LCM) System' and agro-environmental safety principles for human health and the environment. Soil maps and a hydrogeological map of the Viotikos Kifissos basin were used to determine where on the pilot area to locate

Photo: LIFE07 ENV/GR/000266/NEEMO EEIG/Gabriella Camarsa

Ecopest used pheromone traps to monitor the presence of pests

the sampling and monitoring sites. The participating farmers then implemented suitable systems incorporating new technologies that included a weed seeker, spray drift control nozzles, a prototype for controlling spraying machinery, a 'heliosec' system for collecting liquid waste, and environmental modelling and predicting models.

Such innovations led to a 30% reduction in the amount of pesticide used in crop production. Less pesticide helps make soil more resilient by reducing pollution and increasing its organic content. The project designed and operated a rolling programme

Farmers were trained to apply Low Input Crop Management systems on cotton, maize and plum tomatoes

Photo: LIFE07 ENV/GR/000266/BPI/Chachalis 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 key impact of the project was training farmers in these methods. Some 220 farmers (63% of all of those on the pilot site) were trained to use LCM systems for cotton, maize and plum tomato, enabling them to implement non-chemical and alternative control methods for weeds, pests and diseases. A further 50 agronomists were taught how to better advise farmers on regional pest types, when to spray and what pesticides to use.

Spreading the word

Cooperating with stakeholders, such as farmers, has been central to the success of the LIFE programme. Moreover, LIFE projects have specifically aimed to inform the agricultural sector of best practices and the latest technologies. The CHANGING THE CHANGE project in Spain, for example, gave Galicia's agroforestry sector information on activities to improve climate change adaptation. Technicians at the 37 agrarian offices in the region attended four-day training workshops and received daily bulletins to enable them to offer the best environmental advice to farmers.

The engagement of farmers and other stakeholders has been one of the LIFE programme's strengths in relation to climate change adaptation. Encouraging farmers to actively engage with new techniques (often overcoming initial concern about the impact on yields and incomes), is helping improve resilience. The fact that many farmers have adopted climate-friendly techniques and continued to use them after projects end illustrates that such practices can be environmentally and economically viable. 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 local and regional authorities 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.

Conclusions

LIFE projects have focused, in particular, on improving irrigation practices and on the introduction of adaptation strategies such as no tillage and cover crops. Some projects have even helped influence policy (AgriClimateChange - see pp. 56-57) and the incorporation of techniques into the measures foreseen by the Rural Development Programme. Despite these successes, more can be done in other areas of agricultural practice. Few LIFE projects have explored intercropping, the use of adapted crops and improving the genetic traits of crops, for example. Moreover, LIFE projects have yet to focus on animal rearing conditions or livestock diversification in the context of climate change adaptation.

LIFE has promoted stakeholder involvement, creating a dialogue between farmers, agronomists and local planners all over the EU

Photo: LIFE13 ENV/ES/000541/Rafael Navarro

AGRICULTURE

AGRICULTURE

Demonstrating **good practice to farmers and policy-makers**

The AgriClimateChange project not only implemented good adaptation practices on the ground. It also met Commission officials and MEPs and submitted proposals that have informed policy-making at EU level

AgriClimateChange assessed the climate change-related environmental performance of farms in four countries, an international scope that adding weight to its proposals. Of those farms, 24 were in France (mostly in the south-west), 48 in Spain (Valencia, the Canary Islands and Murcia), 24 in Italy (Umbria) and 24 in Germany (Baden-Württemberg).

The project developed a software tool to make its farm-performance assessments drawing on the experience of the project partners, especially Solagro, the French agriculture and environment association.

Experts from the project partners then used the assessment data to develop action plans with the participating farmers. Many of the measures encouraged and assessed by the project can be classed as adaptation measures – alongside those that reduce greenhouse gas emissions and energy consumption.

Assessing alfalfa cover crop: Jordi Domingo (left) with farmer Alfons Domínguez

Moreover, "some mitigation options have a close relationship with adaptation problems that farmers are beginning to address," says Jordi Domingo of the Fundación Global Nature, the coordinating beneficiary. These options include cover crops, irrigation efficiency, development of ecological infrastructure, integrated pest management and self-sufficiency of food for livestock. Farmers are increasingly aware of climate-related problems, such as heat waves and erosion caused by heavy rainfall, and are implementing these measures to tackle them.

Mr Domingo was especially involved in working with farmers in his native Valencia region of Spain. He emphasises that it was important to trial as many different farming systems as possible – 27 in total. "Once you have this pool then the conclusions that you can reach are really powerful," he says.

Diverse measures

At one particular farm in the region, this diversification of measures is apparent. The organic citrus fruit farmer, Alfons Domínguez, has planted species-rich hedgerows to afford his orange, lemon and avocado groves better protection against the increasingly hot summers and to nurture natural pest killers (preventing the need for pesticides). He is also using a range of cover crops, including alfalfa that can be used as animal fodder. This leguminous plant helps to retain moisture and fix atmospheric nitrogen in the soil.

The hedgerows also have the benefit of mitigating the soil erosion that is a common problem for the conventional farmers that are not practicing conservation measures. With the increased incidence of sudden weather events – such as torrential rains – the hedges and cover crops serve to retain some of the runoff in the fields. Indeed, the rich ochre of the soil on Mr Dominguez's farm stands in contrast to the paler soil found on neighbouring farms and is an immediate visual clue to the fertility of his land.

For farmers such as Mr Dominguez the impact of climate change is already evident. In short, rainfall is down (wells half full) and temperatures are up to the extent that he is now adding to his output more 'tropical fruit' (namely, mango, lime and papaya), which were previously grown in Spain only farther south in warmer parts. Such diversification has the commercial advantage of allowing him to harvest produce all the year round.

Mr Dominguez has met with other farmers eager to understand the approach that he is taking on his farm. Such word-of-mouth communication is essential if widespread change is to occur. Nevertheless, one of the goals of the project was to work "side by side" with the farmers, he says. "Climate change is a trend and some farmers are not interested in what 'may' happen in the future. 99.9% of them don't really understand the link between their agriculture and the climate."

Explaining this link isn't easy, but he emphasises that making the demonstrable business case for adapting to a changing climate is the way to go. The approach also needs to be adapted to local economic conditions. For example, technically difficult solutions and those that require large investments, such as biogas plants, may not be the priority for Spain and, in particular, his region where farmers own small plots.

One such local solution employed to good effect on Mr Dominguez's land is the use of manure as a fertiliser that significantly improves the structure and fertility of the soil in the long term and, moreover, has a low carbon footprint. He was able to share these experiences with farmers from other regions at the project's European Conference on Farming and Climate Change in Toulouse.

But, as mentioned, it was not only within the agricultural sector that the LIFE project focused its efforts. It also called on EU policy-makers to include climate change actions in European legislation. In order to support this goal, the project team organised two meetings with Commission officials and two breakfast meetings at the European Parliament. These meetings resulted in a request for policy proposals and advice on how to present them in the correct format, says Mr Domingo.

In spite of the comprehensive analysis of results that the project had been able to perform, he was initially "quite pessimistic" about the impact that the results would have on the EU. "But we were welcomed," he says. "The project's report to the European Parliament included a set of measures for achieving realistic climate change mitigation and adaptation at farm level, including a short description of each measure, the expected impact at the EU level, the constraints to be overcome and a proposal for including the measures in different regulations." In this way, the report's authors detailed the different possibilities, such as improving the greening of CAP Pillar I or including agri-environmental measures in Pillar II.

The project was also invited to the 4th Meeting of the Expert Group for Sustainability and Quality of Agriculture and Rural Development. Furthermore, it carried out lobbying activities in the four countries where it was active to influence regional and national governments – for example, it held meetings with the Spanish Ministry of Agriculture, Food and Environment, the French Environment & Energy Management Agency [ADEME], the Italian Agricultural Ministry and the government of Baden-Württemberg (Germany). "Some of the measures promoted and tested during the project were sent to the Spanish Ministry to be considered in the Diffuse Sectors Roadmap for Climate Change in Spain," adds Mr Domingo.

Project number: LIFE09 ENV/ES/000441

Title: AgriClimateChange - Combating climate change through farming: application of a common evaluation system in the 4 largest agricultural economies of the EU

Beneficiary: Fundación Global Nature

Contact: Eduardo de Miguel

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Period: 01-Dec-2006 to 30-Jun-2010

Total budget: €1 589 000

LIFE contribution: €794 000

FORESTS

Looking after the long-term future of EU forest resources

LIFE is at the forefront of developing knowhow and transferable best practices that help EU forests to adapt to climate change and thereby safeguard their multifunctional benefits for future generations.

Europe is home to more than 70 different forest types, which between them support a huge range of flora and fauna as well as act as popular recreational resources. The forestry and forest products industries employ 3.5 million people, with some 450 000 forest-based businesses representing 7% of EU manufacturing GDP.

Forests prevent soil erosion and desertification, especially in mountains or semi-arid areas. They do this mostly by limiting runoff and lowering wind speed in their immediate surroundings. Tree roots enrich soil, contributing to soil fertility, productivity and carbon sequestration. Forests also play a major role in the storage, purification and release of water to surface water bodies and subsurface aquifers and help in conserving biodiversity.

Like other ecosystems, forests are susceptible to changing climate patterns. Climate adaptation measures for forests are therefore a high priority for the EU and its Member States.

LIFEGENMON is conducting the genetic monitoring of beech canopy in Slovenia

Photo: LIFE13 ENV/SI/000148/Boris Rantaša

Photo: LIFE13 ENV/PL/000048/K Pilch

LIFE+ ForBioSensing PL is identifying changes in forest structure and tree species composition caused by climate change

Adapting forest policies

"Climate change is projected to strongly affect forests in Europe," says Dr Marcus Lindner, Head of the Forest Ecology and Management Programme at the European Forest Institute. "Forest management will have to adapt to changes in mean climate but also to increased variability with greater risk of extreme weather events, such as prolonged drought, storms and floods," he explains.

The EU's new Forest Strategy notes the importance of both policy and practical actions that maintain and enhance the resilience and adaptive capacity of forests.

Special attention in this respect is paid to building on actions proposed by the EU Strategy on Adaptation to Climate Change[1], as well as the Green Paper on Forest Protection and Information[2]. A key challenge is to adapt existing forest management to take proper account of climate factors.

Trees' long growth cycles (100 years or more for some softwood plantation species) mean that adaptation policy measures for forestry need to be planned well in advance of expected changes in growing conditions.

Member States are directing their strategic priorities towards bridging knowledge gaps and mainstreaming adaptation action through national forest plans, forest inventories and action plans under the Convention for Biological Diversity (CBD) or United Nations Convention to Combat Desertification (UNCCD).

Protecting forestry

Climate change will impact forests through a number of factors: atmospheric CO_2 increase; changes in temperature; changes in precipitation and hydrology; changes in tree species composition; abiotic disturbances; and biotic disturbances.

Forests in different parts of Europe are affected differently by these impacts. Flooding incidents are increasing in some Member States, whilst droughts are becoming more acute and frequent in other countries. Varying concentrations of atmospheric gases can also affect the natural dynamics of tree growth.

A rise in 'abiotic' disturbances including fire incidents and storm damage has different implications for different EU forests ecosystems (see Figure 1). These ecosystems also face so-called biotic problems linked

1 COM(2013)216.
2 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0066:FIN:EN:PDF

FORESTS

Bioclimatic Map of Europe (Rivas-Martínez et al., 2004)

to the consequences of pests or diseases that extend their range and move (often northwards) in response to shifts in climate patterns.

A one-size-fits-all approach is therefore not suitable for stakeholders involved in adapting EU forests – forest management strategies need to be flexible.

The LIFE programme is an important source of support for implementing forest adaptation actions. It has been involved in co-financing some of the EU's earliest forest adaptation work (around 20 projects in all). Already funded LIFE projects have tackled the impacts of warmer temperatures and atmospheric pollution, changes in tree species composition, forest fires and the spread of pests and pathogens. They have also helped build capacity to adapt to climate change and raised awareness of issues.

LIFE projects "have provided valuable input, helping Member States to continue sustainable forest management through a time of changing climate," says Jerzy Plewa, Director General for the European Commission's Directorate of Agriculture and Rural Development. He adds that "the new LIFE 2014-2020 Programme provides additional opportunities for forests, with extra attention for climate change. This programme complements well the forest-related measures carried out under [EU] rural development policy in support of sustainable forest management." As well as climate action grants for adaptation actions, the programme now has the potential to increase its impact via the Natural Capital Financing Facility (NCFF) (see pp. 14-15).

Warmer temperatures and atmospheric pollution

Higher temperatures have different impacts in different locations. In northern climes they can extend the growing season of forests, potentially increasing pressure on water resources. In Mediterranean countries, a warming climate could stunt tree growth as hotter conditions reduce precipitation and photosynthesis. Temperature increases also impact productivity and change species distribution patterns, causing potential conflicts between species (see biodiversity chapter – pp. 100-106).

Many forest projects tackling adaptation issues have worked to clarify the extent of impacts of temperature increases and to test the validity of practical actions to help forests adapt to hotter, drier conditions.

Photo: LIFE13 NAT/ES/000724

Life+ Pinassa will adopt silvicultural techniques that will improve the biodiversity, stability and resilience of intensively exploited dense stands of forest

LIFE's potential for building knowledge bases about how forests can be adapted to better cope with warming temperatures is seen in the Italian project, RESILFORMED, which is mapping Sicily's forests to identify the areas at greatest risk of desertification and where urgent application of forest management techniques aimed at increasing resilience is needed.

"In general silvicultural techniques aimed at increasing forest resilience are of two types: when the forest has been degraded due to fires, overgrazing or erosion, the measures aim to increase foliage coverage and the stock of above-ground biomass, reduce erosion, and restore the vegetative parts of damaged topsoil," says project manager Luciano Saporito. "In forests in a normal state, resilience is increased by promoting the internal dynamic ecosystem through interventions that promote arboreal biodiversity, reduce the level of structural simplification, and improve the natural potential in forests of artificial origin," he explains.

Increasing resilience in Mediterranean forests

Photo: LIFE11 ENV/IT/000215

RESILFORMED has developed a number of management models for forest resilience. It used cane mats and increased tree density with native tree species to enhance hydrogeological civil engineering; artificial stands have been naturalised by selective thinning and planting of native trees and shrubs; degraded areas have been restored using native shrub species; and the project has developed the structural complexity of stands. The projects methods will be included in a set of forest management guidelines that will enable the implementation of a forest management plan for Sicily. "It is essential to involve the government authorities and their planning tools," believes Mr Saporito. "In addition, it is important to reduce risks due to human action," he says. To this end, RESILFORMED is involving local communities in forest protection measures and establishing indicators to define the role of communities and ecosystems in adapting to climate change. "Local authorities should aim to increase local community awareness of the importance of improved forest resilience to safeguard the ecosystem services forests provide," says Mr Saporito.

As mentioned previously, varying concentrations of atmospheric gases can affect the natural dynamics of tree growth. The FO3REST project studied the impact of ozone (O_3) levels on growth levels to enable new pollution benchmarks to be established (see box).

Photo: LIFE10 ENV/FR/000208/G.I.E.F.S.

Ozone-induced injury to the leaves of the European hornbeam

Changes in tree species composition

Climate change is expected to lead to competition between tree species and changes in species distribution, differing according to the bioclimatic region and local factors. To understand the nature of such changes, there is a need for systems for forest genetic monitoring that can give an early warning of species' response to environmental change on a long-term temporal scale. LIFE is helping here through actions such as those being developed by the LIFEGENMON project (see box).

The Polish project LIFE+ ForBioSensing PL is identifying changes in forest structure and tree species

Thresholds for ozone levels

The FO3REST project studied how changes in ozone (O_3) levels can affect the growth of forests. Mediterranean forests will be especially vulnerable to the negative effects of this atmospheric pollutant in a context of global warming. The current European benchmark for measuring O_3 levels is the AOT40 index, based on concentrations in the air exceeding 40 ppb over the daylight hours of the growing season. However, studies have shown that vegetation is also affected by ozone uptake through the stomata into leaves or needles, leading to impaired cell functioning and death. An index, based on the stomatal ozone flux, called phytotoxic ozone dose above a threshold Y of uptake (PODY), has been proposed as a new standard. However, in order to be considered suitable as a new EU benchmark, the PODY index needs to be validated in field conditions.

FO3REST compared the performance of AOT40, total stomatal ozone uptake (POD0) and threshold-based phytotoxic ozone dose (POD1) for eight Mediterranean forest species in a large-scale field investigation on some 80 plots in Italy and south-east France.

Results showed that there was a greater correlation between POD0 and observed ozone-induced injuries in the field, confirming the findings of earlier lab studies. The LIFE project team defined critical levels of POD0 for six tree species (*Pinus cembra, Pinus halepensis, Pinus sylvestris, Pinus pinea, Pinus pinaster and Fagus sylvatica*) in cases where 5-15% of needle or leaf area shows signs of ozone-induced damage. In doing so, it has made a significant contribution to the development of methods for quantifying ozone effects on vegetation at the regional scale, particularly in a context of climate change.

Project results have been widely disseminated to the scientific community which will enable the results to be taken into consideration in future updates to legislation on forest protection against ozone (e.g. EC directive 2008/50).

The beneficiary established strong links with national ministries, regional forestry authorities and local forest managers, facilitating direct application of the results through adapted and sustainable forest management.

composition that occur in the forest stands caused by spruce and ash dieback, and hornbeam expansion. "We will be able to confirm which changes are caused by climate change," says Krzysztof Stereńczak from the project. LIFE+ ForBioSensing PL is carrying out airborne laser scanning of the Polish part of the Białowieża Forest to produce a new baseline of maps and other key data (e.g. growing stock, canopy cover, location of ash dieback, large-scale spatial distribution of forest stands). Knowledge of different climatic parameters can be used later in modelling and to understand the different factors influencing the forest's ecosystems. This in turn will help national park and forest district managers implement relevant protection activities.

In addition to tree species composition, LIFE funding has been mobilised to increase understanding of the future development of carbon and water balances and their relationship to climate change in boreal forests. To this end, the MONIMET project in Finland is building a comprehensive platform for analysing climate change effects on seasonal dynamics of various phenomena. To do so, it is collating data spread across a number of institutes and from existing monitoring mechanisms (such as Earth Observation – EO (satellite) – data), as well as a new webcam network that is being established by the project to monitor the seasonal cycle in boreal ecosystem carbon exchange. The project's actions will establish links between climate change indicators and their effects and create climate change vulnerability maps that can be used by Finnish municipalities situated in the boreal zone.

Monitoring genetic changes

Led by a Slovenian beneficiary, the LIFEGENMON project is working on guidelines for forest managers and a decision-support system that will help predict when climate change may pose particular types of risks to tree species and appropriate responses, including for early stage prevention. The project team is developing indicators that can be used to monitor changes in genetic diversity across a transect from Bavaria to Greece for two selected target species (the common beech, *Fagus sylvatica* and silver fir, *Abies alba*). "The indicators include demographic and genetic verifiers, on which the selection processes, changes in genetic variability and mating system can be assessed," says project manager, Tjaša Baloh.

"LIFE is helping us to determine the most cost-effective measurement methods and our results will be used in at least three countries (Germany, Slovenia and Greece). Such outcomes can be very useful for informing policy-makers. The project has strong strategic legislative goals," says Ms Baloh.

The guidelines produced by the project aim to feed into the preparation of common forest adaptation and strategies and recommendations at national, regional and European scale.

Photo: LIFE13 ENV/SI/000148

Abiotic disturbances: forest fires

Climate change is forecast to cause more droughts, higher temperatures and more high winds, raising the likelihood and severity of fires. Some 500 000 ha of forest is destroyed by fire every year in the EU[3]. Negative impacts include loss of life, damage to property, emissions of greenhouse gases and other particles, reduced soil fertility and loss of species and habitats. Active forest management can help reduce fire risks.

Forest fire prevention was an explicit aim of the LIFE+ Information & Communication strand (2007-13), and the LIFE programme as a whole has supported a cluster of projects that have tackled forest fires through mapping and modelling, training, knowledge transfer and awareness raising. By contrast, there have been no LIFE projects that address the impact of another type of abiotic disturbance, destructive storms.

Removing the biomass that feeds fires is one of the goals of the Greek project, Flire. The project has produced a forest fuel map based on the vegetation structure that will allow forest managers to reduce the risk of fires starting and spreading. The project's online decision-support system includes fire risk assessment and fire propagation modules and weather forecasts. The system is designed to be used by local authorities and other key responders who need early warnings of (potential) fires and floods.

3 Green Paper On Forest Protection and Information in the EU: Preparing forests for climate change COM(2010)66 final

ENERBIOSCRUB is a good example of how project outcomes can contribute to climate mitigation policy as well as adaptation agendas. The project is mapping an entire forested area in Castilla-Leon and Galicia to determine the amount of flammable scrub biomass that can be converted into solid biofuel. The mapping process will enable selection of plots, types of biomass and management methods (optimal season per plot and number of clearing operations). Collaboration with landowners and land managers will enable scrub clearance to take place in line with the identified approaches.

In Catalonia, CPF, the autonomous public body responsible for the administration of private forests, is coordinating two projects (LIFE+ DEMORGEST and Life+ Pinassa) that are having complementary impacts. "Our LIFE Environment project (DEMORGEST) is increasing awareness about fire prevention via production-oriented measures and the LIFE Nature project (Pinassa) is reinforcing the resilience of species' habitats that have come under increased fire threat," explains Teresa Cervera, the coordinator of both projects.

DEMORGEST aims to provide a practical demonstration that Catalonia's ORGEST silvicultural models (launched in 2004) are a viable means of sustainably managing forests and protecting them from megafires. The project is applying the models in two pilot areas with high fire risk but with different socio-economic characteristics. Demonstration sites are also being set up in seven different forest typologies spread across Catalonia with the eventual goal of transferring the models to other Mediterranean countries. "For areas with high fire risk, these models have two primary management objectives: production of goods (wood, cork and pine nut) and fire prevention. The tools help to identify site quality and vulnerability to canopy fires," says Ms Cervera. Noting that only 30% of private forest owners in Catalonia have forest plans, she adds that "the main aim [of DEMORGEST] is to advise on the practical application of specialised knowledge of forestry and promote forestry practices and technology transfer in the sector."

According to Ms Cervera, Life+ Pinassa "will adopt recovery actions and silvicultural treatments that will improve the biodiversity, heterogeneity, stability and resilience of intensively exploited mature and young dense stands of forest." Actions will be tailored to individual stands based on ecological inventories made by the project (see pp. 100-106).

Protecting biodiversity of high conservation value at the same time as increasing the resilience of forests to wildfires is the goal of both the LIFE MONTSERRAT and LIFE+BOSCOS projects, also from Spain. The two projects are working at landscape level to create a mosaic of habitats, including recovering abandoned farmland to restore connectivity between ecosystems.

In the case of LIFE MONTSERRAT, EU funding is testing the viability of ecosystem-based measures on small to medium-sized farms, implementing grazing management and forest restoration plans as tools to foster ecosystem services and multifunctionality. Project manager Leire Miñambres says "the long-term effectiveness of this strategy may depend on paying small and medium-sized farms for providing services beyond their productive activity."

Improving the vitality of Catalonia's cork forests

"Cork forests in Catalonia have started to suffer from lower vitality and productivity," says Roser Mundet from the LIFE+ SUBER project. Pests such as the cork beetle (*Coraebus undatus*) are causing worsening problems and the scale and frequency of fires have increased.

The project is aiming to increase the long-term vitality of cork trees by decreasing risks from fire and enhancing natural regeneration potential. "We are testing large-scale threat-control techniques that have not been tried before on such a scale," says Ms Mundet. Techniques include removal of 90-100% of shrub cover and development of open stands structures to ensure discontinuity of combustible material at strategic management points.

Results will be integrated in Catalonian's ORGEST guidelines and disseminated by networks in France, Italy and Portugal.

Photo: LIFE13 ENV/ES/000255

LIFE+BOSCOS has demonstrated sustainable forestry management practice in the context of climate change on Menorca. "We have restored natural pastures that are adjacent to or within forests. These will be maintained by livestock grazing," says project officer Agnès Canals. In addition to removing dense undergrowth to limit fire risks, the project has produced guidelines on how to increase genetic diversity in order to make Menorca's forests more resistant and resilient to climate change. "Our guidelines can be useful for other parts of Europe that need to reduce water stress and limit competition between trees," says Ms Canals.

Biotic disturbances

Climate change can increase the levels of damage caused by domestic forest pathogens and pests. It can also bring new exotic infestations, whether introduced by people or natural migration. Biotic disturbance agents are influenced by atmospheric CO_2 increase, changes in temperature, changes in precipitation and changes in abiotic disturbances. Climate change will affect herbivores and pathogens directly and indirectly through changes in plant nutritional quality and plant resistance or through community interactions. This could lead to an increase in the frequency and consequences (intensity and scale) of pest outbreaks.

The following feature article on Greece's Adaptfor project (pp. 67-70) shows how LIFE co-funding can be used to assess the extent of threats from pathogen pests in a changing climate.

In Finland, the Climforisk project explored the interaction between abiotic (drought) and biotic threats (pests/pathogens). "Pest problems start earlier in the year in warmer temperatures and we have also seen for the first time two generations of a pest swarm in the same year," explains Dr Mikko Peltoniemi from the Climforisk team. "For example, there were two generations of the European bark beetle in southern Finland in 2010. The likelihood of such years happening is expected to increase in future."

Dr Peltoniemi also notes that higher winter temperatures may increase the risk of damage to forests in eastern and northern Finland from the European pine sawfly, as well as heightening the risk of outbreaks of autumnal and winter moths in birch forests in Lapland. "Moisture conditions are also important for some fungal pathogens."

Photo: LIFE08 ENV/GR/000553

Forest Cities is establishing a national network of local authorities for forest fire prevention

Increased abiotic disturbances have consequences for forest management: "winter harvests and storm damaged trees must be collected from forests earlier, as bark beetles quickly colonise fresh dead wood and damage risks to nearby forests dramatically increase," says Dr Peltoniemi.

The Climforisk project explored relationships between soils, climate and pests. "The simple general hypothesis is that trees suffer physiologically from drought and cannot defend effectively against pests. The mechanisms of this are, however, complex and vary by pest species," explains Dr Peltoniemi. The LIFE project analysed the impact of drought on specific tree species in different soil types across a number of

Forest manager carrying out ground-based measurements to analyse the dynamics of the forest stands

Photo: LIFE13 ENV/PL/000048/K.Pilch

FORESTS

Photo: LIFE08 INF/PL/000523

LIFE projects have trained foresters to reduce fire risks

permanent sample plots, finding that areas of bare rock and hill summits may act as epidemic centres for certain pests, such as pine sawflies, whilst scleroderris cancer benefitted from rainfall and moist sites. "These two examples show that one cannot capture any general trends across damage types under climate change," he concludes.

"One of the key challenges regarding forests is to predict if there are critical changes in the damage regime," says Dr Peltoniemi. "Present information is not sufficient to make such conclusions. We think it would be beneficial to develop forest inventory frameworks in order to be able to monitor the damage and provide material for climate responses for various biotic damage agents."

The Climforisk project has enabled the beneficiary to provide online forecasts of potential pest development status. However, Dr Peltoniemi says more tools are necessary to support foresters, private landowners and public bodies in managing biotic disturbances. "We need to develop climate scenarios and see how all of these factors interact with one another."

Building capacity in Estonia

As temperatures increase, Estonia's forests are becoming more prone to fires. The FFPE project trained 179 firefighters (including volunteers) on how to prevent forest fires in the context of Estonia's vegetation, topography and other local factors. "Controlling forest fires is difficult in the Vihterpalu region due to large, dry and sandy forest areas and low technical capacity," says Mart Kelk, NGO manager from the Estonian Forest Society, who took part in a "useful" study trip to the region organised by the LIFE project.

As an added value of the project, the Tallinn Forest Owners Society was inspired to organise another seminar on forest fire prevention with its own resources.

FFPE also initiated ongoing networking amongst specialists from the Ministry of Environment, The Centre of Forest Protection and Silviculture, Rescue Service, Ministry of the Interior, State Forest Service and Environmental Board. This was the first time these organisations with responsibility for forest management had come together to discuss fire prevention. Proposals emerging from these meetings were recorded and submitted to the relevant higher authorities.

Capacity building

Capacity building within LIFE forest projects linked to climate change adaptation comes in two forms: projects have either developed monitoring and modelling tools that can be used to produce vulnerability maps and adopt measures to increase forest resilience; or they have trained foresters to implement specific techniques and methods that increase resilience, reduce biotic disturbances or reduce fire risks.

As an example of the former, the Forest Cities project introduced a collaborative approach to fire prevention for municipalities within the Greek region of Attica, boosting their collective ability for rapid reaction to outbreaks of fire through simplified shared information systems and local action plans.

Examples of the second type of capacity-building project include FFPE from Estonia (see box).

Capacity building was an important element of the previously mentioned Flire project, with its risk assessment models and improved decision-making systems. LIFE+BOSCOS is also putting management theory into practice, implementing actions recommended by its own good practice guidelines.

Future funding

As this article shows, LIFE funding has been used to address a broad range of forest adaptation issues already. Other issues that the new generation of LIFE projects could address include:

- Promoting adapted tree species compositions within forests;
- Increasing overall diversity to strengthen forest resilience;
- Increasing management intensity to decrease threats and improve responses; and
- Landscape-scale management measures that extend adaptation coverage.

FORESTS

LIFE helps **Greek forests to cope in a changing climate**

LIFE's AdaptFor project has improved understanding about the vulnerability of Greek forest ecosystems to climate change and informed national plans to develop and implement appropriate adaptation strategies.

As one of the Mediterranean basin Member States, Greece is projected to be among the EU countries most vulnerable to the effects of climate change. Forest adaptation strategies and associated woodland management plans are urgently needed to address these challenges, enhance biodiversity and enable the conservation of healthy, productive Greek forests.

The LIFE AdaptFor project has made a valuable contribution to this adaptation action by exploring problems and solutions in four different Greek forest ecosystems.

"Climate change appears to have affected the health of Greek forests. In particular, dieback and decline of conifer species such as Scots pine and Greek fir caused by fungi and insect pests have been observed during the last decades as well as intrusion of conifers into broadleaved forests," says Vasiliki Chrysopolitou, who led the AdaptFor project.

Unless climate change impacts are taken into consideration in forestry management, the ecosystem services that Greek forests provide will be degraded.

To provide a cohesive set of results that could benefit a large proportion of the national forest sector the project analysed four different types of forest ecosystem in four locations: Mount Pieria – which hosts the southernmost distribution limit of Scots pine in Europe; Aspropotamos and Kalampaka – representing some of the country's most productive and intensively managed forests (dominant species: fir, chestnut, oak etc.); Mount Taygetos - where Greek fir is at its southern distribution limit in Greece; and Parnitha - a National Park focused on biodiversity conservation where Greek fir is the dominant tree species. All four

Greek firs have declined due to an increase of pests and pathogens, which has been exacerbated by climate change

Photo: EKBY Photo Archive/L. Logothetis

Forest Directorate of Pieria

"From now on, the main concern of our Directorate is the study and monitoring of Scots pine regeneration rates and its adaptation to climate change, using field data from permanent sampling plots, a meteorological plot and pheromone traps established by the LIFE project. The ultimate aim is to fully restore this important forest ecosystem and protect its biodiversity." **Mr Pantelis Klapanis, Forester**.

areas overlap with Natura 2000 network sites. Quotes from project partners at the four sites are presented in boxes.

AdaptFor's adaptive management

AdaptFor employed an 'adaptive management' approach, says Vasiliki Tsiaoussi, head of biotic resources and management of protected areas at EKBY. This began with "a vulnerability assessment that provided significant information about the forest status and trends, under the effects of climate change. Localised adaptation measures were then drafted along with new management objectives for the forests," he explains.

Assessing vulnerability was constrained by gaps in meteorological, soil, tree growth, vegetation, forest fire and tree disease data, says Panagiotis Drougas, head of unit for planning and assessment of forest policy and development at the Ministry of Reconstruction, Production, Environment and Energy. However, Mr Drougas notes that "the collective actions of ministry staff and forest services, as well as the project's scientific experts helped overcome this weakness."

The project employed a range of adaptation techniques. "In general, the first step was to set the specific management objectives for each study area," explains Dr Argyro Zerva, forester at Directorate for Planning and Forest Policy in Greece's Ministry of Reconstruction, Production, Environment and Energy. To achieve these objectives, the project drafted three types of adaptation measures for forest management:

1. Short-term adaptation measures for immediate implementation.
2. Medium and long-term adaptation measures to enhance forest ecosystems.
3. Supplementary measures to enable the adaptation measures to succeed and to protect forests against biotic and abiotic factors.

Assessing the presence of diseases and pests from sampling plots

Photo: EKBY Photo Archive/L. Logothetis

Measures were targeted at specific phenomena. For instance, at the Ritini–Vria Forest on Mount Pieria, "project work focused on the conservation of Scots pine forest through prevention of tree dieback," says Dr Zerva. All dead, dying and infected trees were logged immediately to limit the spread of this disease (so-called 'sanitary logging'). To preserve and enhance the genetic diversity of Scots pine the project established a seed bank and seed orchards and erected fencing to encourage forest regeneration.

In the Kalampaka-Aspropotamos forest, "the project focused on halting intrusion of conifer species into stands where broadleaved species normally prevail," explains Dr Zerva. The goal was to prevent firs extending beyond their lower thermal tolerance limits into mixed oak woodlands and chestnut forest areas. Firs in these areas become vulnerable to insect attacks and affect the quality of the broadleaved stands.

These areas will be enhanced "through the cessation of clear cuts to broadleaved forests and the extension of the logging rotation period," notes Dr Zerva. "This will convert coppice forest to woodlands (high forest) with a higher sequestration rate and storage capacity of CO_2," he adds. These actions, are expected to improve the quality and volume of wood products, enhance soil productivity, and reduce soil erosion and degradation risks in forests that have been intensively managed for timber for many decades.

Highlighting the individual nature of the adaptation measures at good quality sites such as the Aspropotamos Forest, the project favoured the presence of invasive fir species in order to create a mixed deciduous and coniferous forest structure.

Multi-level support

Mr Tsiaoussi of the project's coordinating beneficiary, EKBY, says that the great achievement of AdaptFor was its ability to operate at different levels: "The project demonstrated the approach of adapting forest management to climate change at local level and then integrated the findings to provide guidance and training at regional and national levels."

Adaptation measures trialled by the project have been incorporated into the Forest Management Plans of the four pilot sites, following consultation with the competent authorities. In addition, says Mr Tsiaoussi, "permanent monitoring plots and telemetric meteorological stations have been established in each of the pilot sites, in order to assess forest status and success of adaptation measures.

"Knowledge and experience gained at local level was subsequently used to deliver guidance to Greek Forest Services personnel at regional and national levels, through capacity building guidelines and training activities on how to adapt forest management to climate change in Greece."

Forest Service of Kalampaka

"It is really important that we were given the opportunity to participate in a European project, with significant environmental impact for our region. We anticipate the evaluation of the application of the adaptation measures (through monitoring activities) after their implementation." **Mr Christos Pissias, head of Forest Service and Mr Panagiotis Poulianidis, forester**.

No regrets

Although the Management Plans for each pilot site combine silvicultural techniques and practices in a totally new context, the skills required are based on solid forest science so they are not completely new to the foresters.

AdaptFor also considered the implementation costs and social acceptability of adaptation measures. "The proposed measures are mainly 'no or low regret measures', addressing a wide range of possible climate changes and being beneficial for forests and local communities, under any circumstances," explains Ms Chrysopolitou. Their implementation should enhance the productivity of forests and the

FORESTS

Forest Service of Parnitha

"This forest is the biggest oxygen production factory for the capital of Greece and also the biggest carbon sink, contributing to climate change mitigation. This suburban ecosystem, so important for the residents of Athens, will be managed from now on whilst taking into consideration climate change impacts, and using modern technologies and methodologies. Causes of problems such as dieback of Greek fir, effects of the 2007 forest fire, and expansion of red deer damage have been thoroughly investigated and appropriate measures proposed." **Mr Georgios Zareifis, head of Forest Service and Mr Ilias Doufas, Forester**.


Photo: EKBY Photo Archive/L. Logothetis

services they provide, whilst having wider biodiversity and ecosystem benefits.

A lengthy and exhaustive consultation process was another success factor for the project. "Forest stands affected by the project's adaptation measures are going to be treated in a different manner from now on, or even excluded from forest management - at least from the traditional forest management used for timber production," "says Mr Tryfonas Daskalakis, director for planning and forest policy from the Ministry of Reconstruction, Production, Environment and Energy.

"This is expected to have a direct impact on the local, forest-dependent communities. All stakeholders hence had to be informed on the matter and agree to the proposals. Stakeholders' reactions have been reflected in the adaptation measures. For example, regarding the removal of fir and Black pine from Aspropotamos-Kalampaka Forest, the local community insisted on only gradual logging of conifers. In all cases, forest services were able to convince stakeholders about the long-term benefits of the measures' implementation for both the environment and society – the ecosystems will be strengthened and timber will be improved in terms of size, volume and quality."

Forest Service of Sparti

"Cooperation [with stakeholders] was strengthened through consultations and this was the most important success factor of the project, enabling an assessment of the vulnerability of Mount Taygetos Forest in correlation with climate change data. Consequently, new management plans were drafted with integrated adaptation measures to combat climate change impacts. These plans also integrate the continuous assessment (monitoring) of these measures and are necessary for the enhancement and sustainable management of Mount Taygetos Forest." **Mr Georgios Zakkas, head of Forest Service**.

Innovative actions

The AdaptFor project has pioneered adaptation of forest management to climate change within the Greek Forest Service. On the International Day of Forests 2015, Ioannis Tsironis, deputy Minister of Reconstruction of Production, Environment and Energy described AdaptFor as, "the inaugural effort of the Forest Service to meet the challenge of climate change, while developing synergies with other EU policies such as the conservation of biodiversity."

There is great potential for replicability within Greece thanks to the *Guidelines for the adaptation of Greek forest management to climate change* produced by the project. "[These] provide a clear and specific reference to measures that can be adopted to tackle the threats arising due to climate change," says Konstantinos Dimopoulos, director general for the development and protection of forests and rural environment at the Ministry of Reconstruction, Production, Environment and Energy.

Project number: LIFE08 ENV/GR/000554

Title: AdaptFor - Adaptation of forest management to climate change in Greece

Beneficiary: Section of Biotic Resources and Management of protected areas/ Greek Biotope Wetland Centre (EKBY)

Contact: Vasiliki Chrysopolitou

Email: vasiliki@ekby.gr

Website: www.life-adaptfor.gr.

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

Total budget: €1 719 000

LIFE contribution: €833 000

WATER
POLICY

An introduction to water and climate change adaptation

LIFE is supporting the efforts of policy-makers and planners to reduce the adverse impacts of climate change on water systems. Projects are helping mainstream adaptation measures and achieve the goals of EU water policy.

Climate change will impact the whole hydrological cycle. Predicted temperature increases will shift patterns of yearly and seasonal precipitation, alter groundwater levels, soil moisture, and snow cover, change river flows, raise sea levels, and increase rates of evaporation and transpiration. Results will vary from place to place, but may include water scarcity, flooding, reduced water quality, coastal erosion, salinisation, degraded ecosystem services and changes in biodiversity and the distribution of species.

This section of *LIFE and climate change adaptation* focuses on three major climate change impacts at the river basin level: water scarcity, water quality and flooding. In particular, it looks at how the LIFE programme helps EU Member States implement water policy, and how LIFE projects have demonstrated adaptation measures for reducing the environmental and socio-economic consequences of climate change impacts. The first two river basin level impacts will be addressed together in a chapter on water management; this will be followed by a chapter on flood control and natural water retention measures.

Mainstreaming climate adaptation into water policy

The Water Framework Directive (WFD - 2000/60/EC) was the first legal framework for protecting and restoring clean water across Europe. Given the nature of catchment areas and river flows, the WFD considers river basins as a logical unit of administration.

Photo: LIFE06 NAT/A/000127/AKL8-Tichy

LIFE has demonstrated how NWRM can reduce the vulnerability of water resources to climate change

Therefore, transboundary cooperation is vitally important for sustainable water management. Each EU Member State is obliged under the WFD to draw up River Basin Management Plans (RBMPs) and to achieve 'good status' for all waters in their national territory, including lakes, rivers, canals, groundwater, wetlands and estuaries.

WATER POLICY

Although the first iteration of the WFD does not explicitly mention climate change, the step-by-step and cyclical nature of its river basin management process makes the directive well suited to addressing this issue.

The WFD is complemented by the Water Scarcity and Droughts Policy (COM (2007) 414). The Policy identifies the importance of moving towards a water-saving economy, and recommends measures such as water pricing and land-use planning to incentivise efficient water use. The Floods Directive (2007/60/EC) requires Member States to assess all river basins and coastlines at risk of flooding, to map flood hazards, produce Flood Risk Management Plans (FRMPs), and to set adequate objectives to reduce flood risk, measures to achieve which will be reported to the European Commission by March 2016. In the flood risk management plans that Member States are required to draft, climate change should be taken into account.

In a white paper published in April 2009[1], the European Commission presented a framework for policy and adaptation measures to reduce Europe's vulnerability to the impacts of climate change. The white paper identified improvements in water resource and ecosystem management as a key strategy for building resilience. It was accompanied by an impact assessment and a policy paper on water, coasts and marine issues. These stress the crucial role that green infrastructure and ecosystem-based adaptation approaches can play in protecting biodiversity and ecosystem services, for example, the restoration of wetlands to improve water quality and to reduce downstream flooding. As part of the actions instigated by the white paper, the Water Directors of Member States adopted a guidance document[2] with the aim of climate-proofing RBMPs. The document provides 11 guiding principles that align WFD and climate adaptation objectives.

1 *Adapting to climate change: Towards a European framework for action (COM/2009/147)*

Photo: LIFE10 ENV/IT/000380

A European Environment Agency (EEA) report[3] found that only half of Europe's freshwater lakes and rivers will be of good ecological status by 2015, and will require mitigation or restoration measures to meet WFD objectives. The report noted the "indications that water bodies already under stress from pressures are highly susceptible to climate change impacts, and that climate change may hinder attempts to restore some water bodies to good status. Here the establishment of good ecological and healthy ecosystem conditions are extremely important."

Europe's Water Blueprint

As a result of such findings, in November 2012, the European Commission adopted a Water Blueprint[4], which was based on an extensive evaluation of existing water policy, reports and public consultation. The aim of the Blueprint was to identify obstacles to the implementation of EU water policy and the means to overcome them. It has helped to mainstream climate change adaptation into water policy areas and intensified actions to reach WFD goals within the next cycle of RBMPs (2015-2027).

The Blueprint's impact assessment showed a trend of increasing flood- and drought-related impacts in recent decades. The implementation of green infrastructure, particularly Natural Water Retention Measures (NWRMs), was again noted as a key priority for building resilience. The Blueprint stressed the need for green growth to promote climate change adaptation measures, noting that this could also lead to significant economic benefits.

2 *Common Implementation Strategy for the WFD: Guidance Document no. 24 – River basin management in a changing climate (WFD Technical Report 2009-040)*
3 *European waters – assessment of status and pressures, EEA Report no 8/2012*
4 *A Blueprint to Safeguard Europe's Water Resources (COM/2012/673)*

WATER MANAGEMENT

Implementing adaptive water management

The LIFE programme has demonstrated the implementation of adaptation measures that can reduce the severity of potential impacts on water abundance and water quality resulting from climate change.

Photo: LIFE04 ENV/IT/000500/Mauro Caffau

The CAMI project developed a model to help planners quantify groundwater stress for the Tagliamento river basin

Droughts are temporary deviations from the average natural water cycle, whilst water scarcity represents a long-term imbalance between water supply and demand. LIFE projects have not directly addressed drought situations – unlike the comparable work on climate change adaptation planning, support to drought management planning has been a notable gap in the programme. Many LIFE projects have however focused on water scarcity issues which, whilst not as extreme in their short-term consequences as drought, over time can have significant economic and environmental impacts.

At regional level, water scarcity is often a consequence of demand exceeding recharge capacity in abstraction areas. Climate change is predicted to reduce summer rainfall and diminish snow reservoirs, leading to lower river flows in southern Europe and exacerbating water scarcity.

LIFE projects have addressed water scarcity by demonstrating measures to increase supply and measures to reduce demand. The former include

Did you know?

At least 11% of Europe's population and 17% of its territory have been affected by water scarcity to date. Recent trends show a significant increase in water scarcity across Europe. *Source: COM/2009/147* improved water infrastructure and natural water retention measures such as aquifer recharge and river restoration. Demand reduction has focused on raising awareness and establishing incentives (e.g. water pricing) for efficient water use.

Models improve water management

The LIFE programme has funded a cluster of projects that have improved data collection methods and developed modelling tools in support of water management. These projects have provided valuable inputs for achieving the objectives of River Basin Management Plans (RBMPs), and have contributed to water scarcity management plans. Although developed for specific river basins, modelling tools developed by LIFE projects are readily transferable across Europe.

The CAMI project collected and analysed data for the whole hydrographic district of the Tagliamento river basin in north-east Italy. The project pioneered an integrated approach that combined data on aquifers and groundwater flows, including non-invasive geophysical methodologies. Data fed into a Regional Geohydrological Information System (REGIS). This river basin model supports planners in developing future scenarios for a more rational use of water resources, and, in support of the requirements of the Water Framework Directive it can be used to predict the effects of further groundwater extraction for civil, agricultural and industrial uses on water resources.

The LIFE projects WATER CHANGE and Trust developed models for water managers that take into account climate change scenarios. WATER CHANGE linked hydrological and water management models to predict available water resources for a range of climate change scenarios in the Llobregat river basin in Spain, which is greatly affected by scarcity issues.

"Topographic and geological data, as well as information about climate scenarios, aquifers, and water uses and quality were all entered in the custom-created Water Change Modelling System database," says Suzy McEnnis of project beneficiary CETaqua. The modelling system was used to test 65 global change scenarios (i.e. climate change, land use change, and water demand as affected by population changes) to evaluate the vulnerability of water resources for three time horizons (2030, 2050 and 2100) and to propose different adaptation strategies in each case. With the results in hand, CETaqua assessed which adaptation strategies could be best applied to the Llobregat river basin in order to avoid future water shortages.

Climate change and the water cycle in the EU

Winter rainfall (floods) Sea levels Hotter and drier summers Crop yields, range	↑
Temperature, annual rainfall, Water availability	↕
Drought risk, heat stress	↑
Crop yields Suitable crop areas	↓
Sea/Lake levels Storms, floods Hotter and drier summers Growing seasons, crop potential Pests Permafrost thaw	↑
Winter rainfall (floods) Drought risks Soil erosion risk Length of growing season Crop yields and range	↑
Summer rainfall	↓

Increasing resilience to water scarcity

The LIFE SEGURA RIVERLINK project is demonstrating the implementation of green infrastructure to restore ecosystems and increase connectivity in the Segura river basin (Spain). "Water scarcity is a constant threat in this river basin, with significant decreases in water resources over the past 30 years, and the foreseen impact of climate change will make the situation worse," says project manager Eduardo Lafuente. He explains that the project's measures will have clear benefits both for the resilience of the river and for climate change adaptation. For instance, one of the main effects of eliminating giant cane (*Arundo donax*) beds is a reduction in evapotranspiration: "These plants have an impressively rapid growth, several centimetres per day, and a huge evapotranspiration rate. In comparison, native riparian forest not only has very positive environmental effects, in terms of filtering pollutants and enhancing biodiversity, it also has an evapotranspiration rate four or five times lower. Therefore, replacing the giant reed beds with riparian forest could increase the available water resources by between 2 and 5%," says Mr Lafuente.

Photo: LIFE12 ENV/ES/001140/Javier Murcia/Francisco Almansa

The beneficiary carried out a cost-benefit analysis (CBA) of the many temporary and permanent adaptation measures available and proposed not simply measures but three adaptation strategies: "packages of measures that offer feasible solutions avoiding deficits in the basin whilst optimising investments and costs," explains CETaqua researcher Mónica Reyes.

The high-, medium- and low-adaptation strategies proposed respectively covered 70%, 50% and 30% of the monthly water deficits. In the case study done by the LIFE project, the medium-adaptation strategy was identified as having the best ratio of benefits to costs. In the real world, the CBA tool will allow river basin authorities and water companies to combine different economic values with the impact indicators and select different strategies. The tool will thus help them in their medium- and long-term planning activities and decision-making processes, in particular, by supporting the implementation of environmental policies associated with the WFD.

The Trust project developed a modelling tool to forecast the effects of climate change on water availability in the Veneto plain and Friuli in north-east Italy. "Monitoring data for the area going back 30 to 40 years showed a slow but significant and ongoing decline of the water table," says project coordinator, Matteo Bisaglia. "We wanted to investigate the likely future effects of climate change and land use on the availability of groundwater, to include these aspects in successful water management planning," explains Andrea Scarinci, an engineer at project partner SGI Studio Galli. The Trust team developed a hydrological model that showed how climate change scenarios exacerbate this trend by altering the flows of rivers feeding aquifers in the river basin. These flows are predicted to increase in the winter and decrease in the summer, spring and autumn: information that helps water managers estimate future groundwater levels over time for each of the 30 aquifers in the project area. "The modelling showed that 8% of the groundwater volume will decrease in the next 30 years due to climate change alone. By the end of the 21st Century the annual aquifer recharge could be reduced by 7% in Veneto and 11% in Friuli," notes Mr Bisaglia.

Avoiding unnecessary water loss

With climate change likely to increase the severity of water scarcity, it is essential to minimise losses of water caused by leaky pipes and other water infrastructure problems. Leaks cause over-abstraction of groundwater, with valuable drinking water being lost before it can even reach consumers. Repairing water supply infrastructure reduces abstraction, which allows the piezometric pressure within aquifers to increase. This enables aquifers to regain equilibrium and also helps reduce the risk of pollution and salinity intrusion into groundwater.

LIFE has targeted losses from leaky infrastructure through both the A.S.A.P. and MAC Eau projects. The former implemented an action plan to reduce hidden leaks, by developing models for an aquifer and a water supply network in Italy's Arno river plain. The project team installed a continuous monitoring system, based on applied dynamic flow/pressure regulation, which promptly detected and prioritised leaks for repair. This also enabled water pressure to be maintained at the minimum level necessary - higher pressures increase the amount of water escaping through leaks. The project cut water abstraction by 8.3% during the project, whilst also reducing infrastructure maintenance costs.

MAC Eau is reducing pressure within an urban water supply system in the Gironde province of France. A system check enabled the identification of sections where modulating pressure valves should be installed. In one case, it was noted that night-flow pressure could be decreased by as much as 55%. The company's first data analysis in 2015 showed water savings of some 100 000 m^3/year, or 20% of the volumes lost by the water company, and a 4.5% reduction in the volume withdrawn from a groundwater aquifer. As with the A.S.A.P. project, a reduction in the need for system maintenance has been reported.

Recharging aquifers

Aquifers are layers of permeable rock that contain or transmit groundwater: an underground water supply that can be extracted. Climate change is projected to shorten the seasonal recharge period for aquifers, exacerbating what may already be reduced water levels. A cluster of LIFE projects, including AQUOR, Trust and WARBO, has demonstrated artificial recharge techniques. These counterbalance water loss in aquifers to tackle water scarcity and water quality problems. AQUOR, for instance, assessed techniques such as infiltration wells and channels as part of a climate change adaptation strategy. This strategy is supported by the project's integrated knowledge structure for the hydrogeological system, which enables precise recommendations to be made regarding the siting of aquifer recharge systems.

In addition to its abovementioned tools for modelling the effects of climate change on water availability, the Trust project used hydrological models to assess the effectiveness of Managed Aquifer Recharge (MAR) techniques in three demonstration areas. Digging trenches and planting fast-growing trees increased the water entering an aquifer in a wooded area, whilst filling channels resulted in more water seeping into aquifers on agricultural land. "The hydrological model evaluated that MAR techniques could restore groundwater by 25% and 70% of the groundwater deficit induced by climate changes in the Veneto and Friuli regions, respectively," says Andrea Scarinci from the project team. Even taking into account the future negative impacts of climate change, MAR techniques could help replenish over two-thirds of the groundwater reserve in these regions. "Concrete measures to improve the water balance identified by the project will be included in the revised river basin management plans from 2015," notes project coordinator Matteo Bisaglia.

One of the barriers to wider implementation of MAR techniques has been a relative lack of legislation, an issue addressed by the WARBO project in Friuli-Venezia Giulia, north-east Italy. The project developed a model to assess aquifer response to recharge and protocols for managing recharge that do not harm the environment. The project's three demonstration sites, all located in ecosystems of Community interest with severe water scarcity problems, showed how abandoned excavations and neglected ponds could

ENSAT designed a Soil Aquifer Treatment (SAT) method to improve groundwater quality and quantity

Photo: LIFE08 ENV/E/000117

be transformed into MAR infrastructure, which acts to increase aquifer recharge capacity and to improve surface water quality. MAR structures like these can be used for contingency planning against high levels of salinity or pollution (e.g. accidental groundwater contamination), which will be exacerbated with lower river flows caused by climate change. Water can be poured into MAR structures to dilute contaminated outflow to safeguard water quantity for consumers and to protect biodiversity.

Aquifer recharge is not the only option in terms of rainwater retention and the replenishment of groundwater sources. The Hydro-climate Recovery project in eastern Slovakia is using new water harvesting techniques in the construction of retention ponds, rainwater gardens, flow control barriers in streams, and the re-cultivation of old logging roads. These methods will enable rainwater to be used where it falls to fill groundwater sources and feed vegetation, so revitalising the local hydrological cycle and contributing to the maintenance of a stable climate.

Fostering a water-saving culture

EU Member States are implementing many awareness-raising activities to promote water-saving and, working in partnership, they have developed the European Water Stewardship (EWS) scheme to promote water-efficient practices using a certification system linked to WFD objectives. The LIFE programme has funded many projects that raise awareness about water conservation, an important component of climate change adaptation strategies. The focus in this particular article is mainly on LIFE's efforts in educating citizens to conserve water.

To this end, the RENEW, AQUOR and MAC Eau projects combined awareness-raising with the distribution of water-saving devices in the UK, Italy and France, respectively; whilst Investing in Water helped implement best practice across a number of sectors (see box). The approaches in these projects are readily scaled up and transferable.

RENEW targeted both mitigation of and adaptation to climate change in demonstrating an innovative approach to improve consumer understanding of the link between hot water and energy usage. The project used a number of engaging ways of showing people how they can save money, conserve water and reduce carbon emissions, including through surveys, demonstration of a mobile shower simulator and distribution of free shower timers and water-efficient shower heads. AQUOR, on the other hand, targeted awareness-raising activities at schools and installed 196 water flow limiters on farms.

As well as improving the efficiency of water infrastructure in the Gironde, the MAC Eau team is working with 392 local authorities to distribute some 80 000 water-saving kits and 70 rainwater tanks to local households. Project manager Anne-Claire González says the project, which runs to the end of 2016, is also installing water-saving

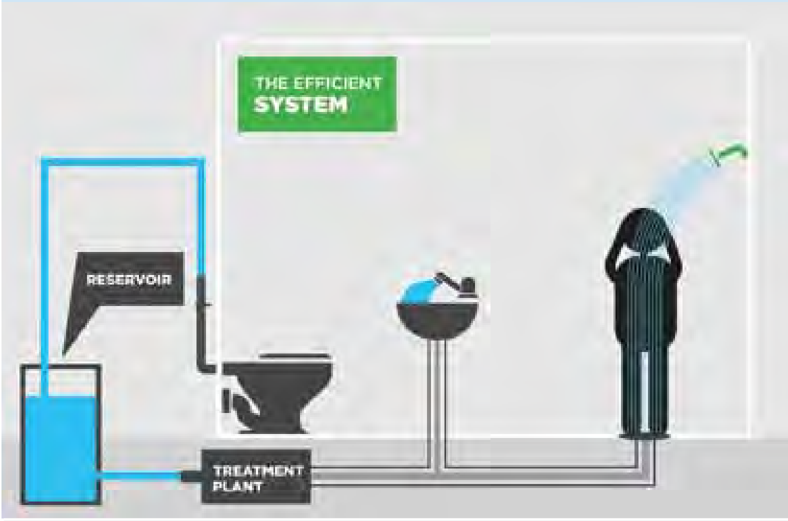
Investing in Water

This project is raising awareness about water scarcity in Malta, where rainfall seeping through porous rocks forms sea-level aquifers - the country's only naturally occurring freshwater source. Malta extracts nearly 50% more groundwater than is naturally recharged on an annual basis, and climate change predictions suggest annual rainfall could decrease by around 15%. "If this scenario comes to pass, Malta will become even more water scarce," says Joe Tanti, project leader and CEO of beneficiary Malta Business Bureau (MBB). This could force the islands to become increasingly reliant on energy-intensive seawater desalination, with the production of more greenhouse gases.

The main water consumers in Malta are the agriculture, domestic and commercial sectors, including tourist hotels. "Industry is playing a role in water conservation – over the past few years enterprises have collectively saved enough water for the savings to be reflected in national statistics," explains Mr Tanti. Measures they have adopted "range from flow rate regulation on showers and hand basins, to water recycling systems and wastewater treatment plants. It is critical that all stakeholders do their part," he adds.

MBB used the LIFE project to help enterprises implement best practice in water saving. "This was done by identifying the best-performing enterprises, and the opportunities they saw and the measures they used to fulfil their water savings potential," recalls Mr Tanti. "The most effective action has been water audits carried out by engineers engaged by the project, working closely with enterprise staff."

Photo: LIFE10 INF/MT/000091



WATER MANAGEMENT

equipment in public buildings in the Bordeaux area to demonstrate how much water can be saved.

The environmental costs of water abstraction are rarely taken into account when billing customers, even in water scarce areas. However, economic tools for addressing water scarcity are outlined in the WFD, especially metering and water pricing that reflect the true cost of maintaining the water supply. A couple of LIFE projects have put the economic theory into practice.

Water Agenda introduced financial mechanisms as a means of reducing consumption in the Anthemountas river basin (Greece). “It was clear that a more coherent water policy was required, including a more widespread use of metering and a more effective and transparent system of water pricing,” says Sokratis Famellos, co-manager of the project. The project developed a model for water use and availability, which generated different water management scenarios. These were used to develop water pricing schemes that take into account usage and environmental costs. The system is cost-effective, because the municipality recovers the full financial cost of water supply and network maintenance.

Similarly, in Italy, the WATACLIC project recommended that a fair price be paid for water to reduce water abstraction, with tariff schemes being adopted to discourage irresponsible water use. A key goal was to find ways to achieve full cost recovery whilst ensuring social equity and the financial sustainability of water services. The project suggested a two-part tariff with a fixed charge (ultimately calculated according to the consumer’s wealth) and a volumetric part with a sharply increasing marginal fee above the quantities that are regarded as a target threshold.

Did you know?

Higher water temperatures and extreme weather events such as flooding and droughts also impact upon water quality and exacerbate existing problems of pollution.
Source: COM/2009/147

Improving water quality

Climate change negatively impacts water quality in rivers and lakes, mainly as a result of changes in temperature and precipitation. Increasing temperatures in European rivers and lakes (recorded as being up 1-3º C during the last century) reduce available oxygen content, whilst flooding and water scarcity can increase pollutant levels, for example, by overflowing treatment plants and a process of concentration, respectively.

The WFD requires EU Member States to achieve a good status for groundwater. This is best achieved when there is a balance between water abstraction and the natural recharge of groundwater, as over-exploitation of water can reduce drinking water quality. Water balance can be improved by artificial aquifer recharge, so LIFE projects already mentioned in this context also contribute to improving water quality.

The natural filtration capacity of soil can be compromised by changes in water flow resulting from climate change. With aquifer recharge, additional measures can be taken to clean up infiltration water. This has been demonstrated by LIFE’s ENSAT project, which focused on an aquifer remediation technique called Soil Aquifer Treatment (SAT), designed to improve groundwater quality. The project

The Trust project used an Acoustic Doppler Current Profiler (ADCP) to measure river flow

Photo: LIFE07 ENV/IT/000475

Addressing climate change impacts on Vienna's 'urban lake'

The 'Alte Donau', formerly the Danube's main course through Vienna, is now one of Europe's largest urban lakes and is an important recreational resource. The objective of the LIFE Urban Lake project is to safeguard its water quality over the long term, by reducing its vulnerability to the impacts of climate change. The project is implementing management plans aimed at enhancing the lake's hydrological balance; a key measure being the construction of a soil filter: "a large pool filled with mineral material, through which inflowing water is conveyed," explains Thomas Ofenböck of Vienna's Department of Water Management: "The filter system enables an additional water supply from the nearby Neue Donau to be used to compensate for high evaporation rates during hot periods in summer and to increase water exchange with groundwater in the shallow Alte Donau," says Mr Ofenböck. This also helps maintain favourable nutrient and mineral balances, and contributes to a slight lowering of water temperature.

The project's practical experiences are being converted into guidelines for climate change adaptation measures, including measures to increase biodiversity that will promote ecosystem resilience. "The aquatic macrophytes, which are extremely important for the water quality in this lake, are highly dominated by just one species, *Myriophyllum spicatum*," says Mr Ofenböck. "Changes in water temperature or consequential effects of climate change might lead to a sudden extinction of this plant species, which would have serious consequences for the entire system. Therefore we are trying to establish a number of other macrophyte species to lower this risk."

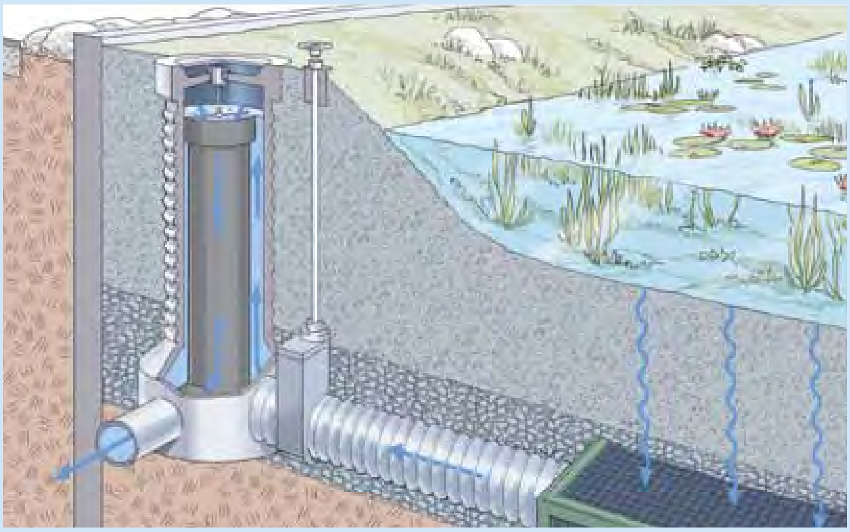


Photo: LIFE12 ENV/AT/000128

team installed a reactive organic layer in the bottom of an infiltration pond that feeds an aquifer in Spain's Llobregat river delta. This reactive barrier was shown to improve the quality of groundwater by enhancing the biological degradation of organic compounds and promoting the removal of micro-pollutants. LIFE Urban Lake used a soil filtering system to safeguard water quality in a different context (see box).

Eutrophication

Reduced oxygen content and altered nutrient cycling processes, arising from climate change, will make water bodies more susceptible to eutrophication, especially where high nutrient loads already occur (e.g. areas of agricultural fertiliser run off).

The GisBloom project constructed a cost-efficient integrated model for the monitoring of water quality, which was demonstrated in seven river basins in Finland. This helps integrate climate change into RBMPs, for instance, by predicting the impacts of different climate change adaptation scenarios on eutrophication and algal blooms.

"Our models can be used to estimate effects of nutrient load and runoff on algal blooms in all Finnish rivers, lakes and coastal areas," says project manager Olli Malve. He notes that although algal blooms are quite random by nature, the model is able to predict their occurrence with enough accuracy to enable cost-efficiency analysis of adaptation measures.

The project's results are accessible through two interactive web portals: the information platform Vesinetti and the mapping service JarviWiki. These support the decision-making process for the management of eutrophication, and provide real-time and forecast information on algal blooms for water managers and the public. Dr Malve explains that the project's operations model and tools have, with the participation of the public and all relevant stakeholders, been used to plan a programme of measures to improve water quality for recreation, households, fisheries and industrial uses.

WATER MANAGEMENT

Here comes the flood

LIFE has helped map flood risks, provide early flood warnings and reduce the impact of inundations through river restoration and natural water retention measures. In so doing, projects have demonstrated ways of cost-effectively implementing the Water Framework and Floods directives.

Between 1998 and 2009 floods in Europe caused some 700 deaths, the displacement of about half a million people and at least €25 billion in insured economic losses[1]. Floods threaten housing, transport and other essential infrastructure, commercial and industrial property and agricultural land. They can cause ill-health through disease outbreaks, destroy wetlands, harm biodiversity and affect water quality.

1 http://www.emdat.be/

More than 30 LIFE projects have restored natural river and floodplain dynamics over hundreds of kilometres of the Danube

Photo: LIFE06 NAT/A/000127/AKL8-Tichy

Some European rivers have been more prone to flooding in recent years than previously, but it has not been possible to detect general climate-induced trends in the occurrence and intensity of floods. This is partly due to the impact of changes in land use and water management – it is difficult to distinguish climate-related changes from these concurrent factors. Nonetheless, future changes in the intensity and frequency of extreme precipitation events combined with different land use policies are likely to cause an increase in flood hazard across much of Europe.[2]

The Water Framework Directive (WFD) and the Floods Directive (2007/60/EC) provide the policy framework for managing flooding at river basin level in Europe (see box). The need for EU and Member State action to ensure that climate change is taken into account in the implementation of the Floods Directive was emphasised in the EC white paper on adaptation (see pp.71-72 – water intro). As a consequence, the Floods Directive requires that Member States take into account climate change throughout the full flood risk management cycle, along with other hazards.

The Floods Directive states that the preliminary flood risk assessment (Article 4) shall be based on, amongst other things, the "impact of climate change on the occurrence of floods" from the first cycle, and article 14.4 states that the "likely impact on climate change on the occurrence of floods

2 Common implementation strategy for the water framework directive (2000/60/EC) - Guidance document No. 24 RIVER BASIN MANAGEMENT IN A CHANGING CLIMATE Technical Report - 2009 – 040 (European Commission)

shall be taken into account in the reviews [of the preliminary flood risk assessment and the flood risk management plans].”

LIFE’s role in flood protection

The LIFE programme has funded flood protection projects of different kinds. Some projects have helped develop flood risk maps and flood alert systems. Other projects have attempted to reduce the likelihood of flooding through the restoration of natural river hydrology and functions (including ecological functions in the case of LIFE Nature projects). This has often involved ‘re-naturalising’ waterways that have been channelised and otherwise modified for transportation purposes.

The feature article on the following pages (HydroClimateStrategyRiga – see pp. 87-89) developed models to generate flood risk maps in Latvia. That was also the aim of the FLOODSCAN project in Germany. There, the project team updated flood maps for Bavaria using state-of-the-art aerial laser scanning technology. “Because this technology is much cheaper and can map in more detail, it can be much more extensive,” says project manager Dieter Rieger. “It can include small water bodies, which can also cause flooding, but which were not previously mapped.” The new data were fed into a bespoke web-based flood mapping service which allows users to see the potential impact of different flood intensities (e.g. 30 year floods, 100 year floods etc.). Mr Rieger believes the increased information base enables better zoning, enabling municipalities to take more effective planning decisions: “The FLOODSCAN project is very much in the spirit of flood risk management – of enabling people to take precautions because they have the information.”

RiverWiki contains information on over 500 river restoration case studies, such as the Danube

Photo: LIFE09 INF/UK/000032/Environment Agency (UK)/Franz Kovacs

Floods policy

The Floods Directive required Member States to carry out a preliminary assessment by 2011 to identify the river basins and associated coastal areas at risk of flooding. For such zones they needed to draw up flood risk maps by 2013 and establish flood risk management plans focused on prevention, protection and preparedness by 2015. The Directive is to be carried out in coordination with the WFD, meaning that the flood risk management plans and river basin management plans are to be coordinated, with the coordination of the public participation procedures in the preparation of these plans. Member States are also obliged to coordinate their flood risk management practices in shared river basins, including with third countries, and shall in solidarity not undertake measures that would increase flood risks in neighbouring countries.

Photo: LIFE09 INF/UK/000032/Olli Toivonen

LIFE projects that have developed flood early warning systems (FEWS) include Stream of Usserød in Denmark (see box) and the Greek project Flire, which was featured in the forests chapter for its work combatting forest fires. The flood-related aspect of this project focused on developing and implementing a flood alert hierarchy for the Rafina catchment. “The FEWS produces Smart Alerts at three different levels,” explains project manager Maria Mimikou. These alerts - based on rainfall forecasts (level one); storm activity (level two); and real-time reports from flow gauges (level three) – can help relevant authorities prepare for and minimise the impact of flash flooding. Users can also access daily flood hazard maps based on the rainfall forecasts. The project has developed a planning tool that will help stakeholders and local authorities to strategically plan their activities by suggesting optimum structural and non-structural measures for the area, in terms of different flood, urban development and fire scenarios associated with climate change, explains Professor Mimikou.

Stream of Usserød

This project is developing a climate change adaptation toolkit for the stream that flows through the municipalities of Rudersdal, Hørsholm and Fredensborg (Denmark). The toolkit comprises a computer model for the hydrodynamics of the Usserød water system, a dashboard providing information to water management professionals, and mechanisms for informing the public about current conditions and predicted flood risks. Input is continuously provided by automated measuring stations.

"Setting up a valid computer model for the entire Usserød water system is a complex task, as the river runs through highly urbanised areas with very dynamic effluents from rainwater and sewage discharges," says Klaus Pallesen of the coordinating Fredensborg Municipality; "As a result, the water level will rise to critical levels within a few hours after the start of heavy rainfall."

Mr Pallesen explains that the purpose of the flood forecast and warning system "is to provide people inhabiting flood risk areas with relevant and meaningful information that enables them to take their own protective actions when flood risk occurs."

In the event of major floods, the national emergency apparatus takes over. A Joint Emergency Plan developed within the LIFE project framework will be implemented in such cases. This will involve, for example, the operation of a sluice in Rudersdal and a new floodgate that is being demonstrated in Hørsholm, which will divert flood water to uninhabited areas rather than vulnerable housing areas downstream that were hit by severe flooding in 2007 and 2010.

Information generated by the project's toolkit facilitates joint planning between the three cities for immediate flood prevention actions, and provides the basis for future planning and the design of climate change adaptation measures. "The Usserød project has launched serious change-management effort at all levels," concludes Mr Pallesen. "We have established a feasible framework that achieves the desired results without establishing surplus, parallel bureaucracy."

Letting nature takes its course

Natural water retention measures (NWRMs) are methods used to safeguard and enhance the water storage potential of landscapes, soils and aquifers. They are a form of 'green' or 'blue' (i.e. land- or water-based) infrastructure that works with nature to reduce the vulnerability of water resources to climate change and other anthropogenic pressures.

Laser scanning and other remote sensing data enabled the project to create accurate models of Bavaria's water bodies

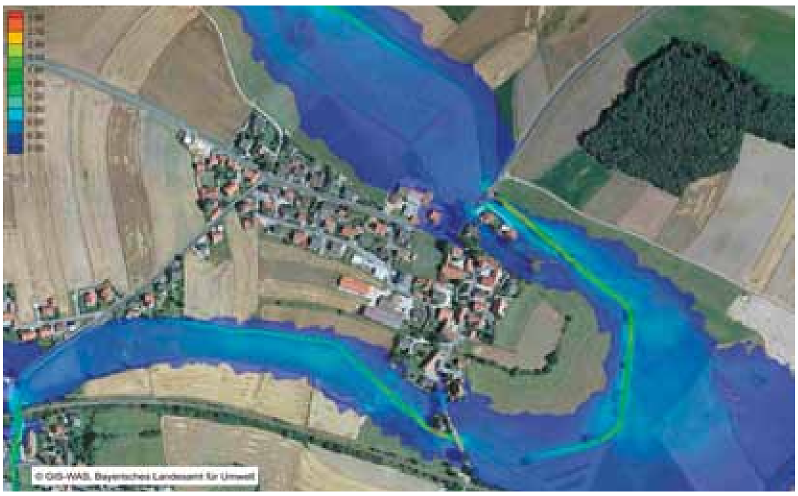


Photo: LIFE06 ENV/D/000461

This is achieved by restoring ecosystems, natural features and characteristics of water courses and using natural processes. Although they are primarily designed to regulate the water cycle these measures also improve connectivity between nature-rich areas and enhance landscape permeability. In addition, the areas benefiting from these measures will often be multifunctional, allowing farming, forestry, recreation and ecosystems conservation to operate together in the same space. NWRMs are adaptation measures that use nature to regulate the flow and transport of water so as to smooth peaks and moderate extreme events (floods, droughts, desertification, salinisation).

Measures may include sustainable forestry practices (afforestation, riparian forests), sustainable agriculture (e.g. buffer strips, cover crops etc. - see pp. 44-57), urban infrastructure (SUDS, green roofs – see pp. 30-43) and measures for increasing groundwater recharge (see previous chapter – pp. 76-77). In this chapter we will focus on measures of another kind: those designed to increase storage in catchments and alongside rivers. LIFE projects provide many examples of the use of hydromorphology measures such as floodplain and wetland restoration, re-meandering and natural bank stabilisation.

Floodplain restoration

Floodplains are areas bordering rivers that naturally provide space for the retention of storm waters. Within the EU, almost all major and many minor rivers have been separated from their floodplains by dikes, sluice gates and other structures designed to control water flow, or the floodplains have been drained for agriculture or development. A number of LIFE projects have restored floodplains to enhance biodiversity and to restore ecosystem functions, which build resilience against flooding and climate change impacts. By allowing streams to function naturally, with controlled flooding, floodplain restoration measures reduce the risk of flood damage.

In the case of the ongoing Dutch project, **Floodplain development**, the goal is to enlarge the floodplains of the River IJssel to increase their water storage capacity, thereby improving water safety and reducing the risk of flooding in more heavily populated areas. The use of buffer zones and storage infrastructure will slow water transfer between the floodplain and the river, thereby spreading the flow and thus decreasing flood intensity. The restoration work will also improve ecological connectivity between Natura 2000 network sites for species susceptible to climate change. This LIFE initiative is part of a more ambitious project, Rivierklimaatpark IJsselpoort, the aim of which is future-proof, climate change adapted spatial development in the upper floodplains of the IJssel.

Showing the variety of LIFE's work in this area, by contrast the LIFE RII project is restoring a floodplain in a largely urban area (see box).

Floodplains and afforestation

Afforestation is a natural water retention measure for floodplains that can reduce soil erosion, enhance water-holding capacity, and improve water quality in cases where precipitation infiltrates forest soils before flowing into reservoirs. The Emmericher Ward project in Germany is "establishing a new area of floodplain forest along a secondary river channel that is being reconnected with its floodplain," explains project manager Klaus Markgraf-Maué. This is being done to counteract flooding caused by changing precipitation patterns. Reconnecting the river to the floodplain will improve its ecological and hydrological functioning. Furthermore, the afforestation techniques will minimise the barrier effect of the forest in the event of flooding by integrating forest aisles with the side-channel and with an amphibian transition zone.

Also in Germany, the Elbauen bei Vockerode project is restoring a natural floodplain landscape in the middle Elbe using a range of different afforestation techniques, "depending on the local situation and taking into account the land users' objectives

Restoring an urbanised floodplain in Italy

The LIFE RII project is implementing large-scale floodplain restoration at the base of the Apennine mountains, where urbanisation makes interventions difficult. The goal is to increase the area's water retention capacity and its resilience to climate change. Project actions have focused on hydraulically-critical points within a network of canals and creeks.

The project is testing a number of novel management tools, such as 'flooding servitude' – payments to landowners for temporary, planned flooding of their fields to avoid more damaging floods in urban areas downstream. "This will allow substantial savings compared to more costly interventions such as creating temporary flood reservoir areas or compensating for damage after flood events," says project manager Alfredo Caggianelli.

Techniques being trialled include the use of vegetation-filled gabions to slow flood water flows, selective weirs to remove branches and other material that could stop water flowing smoothly, and maintaining embankments along some stretches of waterway.

"In the integrated approach of LIFE RII, the interventions for flood risk are simultaneously solutions to improve the ecological status of watersheds," says Mr Caggianelli. He notes that the first field surveys already indicate the start of a new dynamic in the waterways. A restoration programme is being implemented through a public agreement, signed by multiple public and private stakeholders, which will identify how shared objectives are to be achieved.

Photo: LIFE11 ENV/IT/000243/Bruno Boz

in the long term," says project manager Georg Rast of WWF Germany. He adds that "there is a clear trend over the last two decades for dry and very warm springs, which slows the natural rejuvenation of some species of the floodplain forest." To adapt to this, the LIFE project is aiming "to establish typical floodplain forests with a site specific mixture of native tree and shrub species. By that we expect high tolerance against flooding and a high resilience level, which is the best adaptation to climate change," says Mr Rast.

Wetland restoration

Wetland restoration and management can involve measures over a large spatial scale (including the installation of ditches for rewetting or the removal of dikes to enable flooding) or small-scale measures such as tree clearance, changes in land use and adapted cultivation practices. Wetlands can be used to store water (useful in areas prone to seasonal droughts) and they can slow the progress downstream of surface water run off, helping to reduce the impact of flooding.

An example of a project working at catchment scale is Anglesey and Lleyn Fens, which restored 84 ha of alkaline fen and 104 ha of calcareous fen found within a mosaic of wetland habitats in north Wales, UK. The project increased resilience to climate change to by restoring the natural hydrology, raising water levels in ditches to improve water quality and help reduce flooding.

Another type of wetland habitat, raised bogs, is the subject of the LIFE+GP project in the Netherlands. Restoration aims to increase resilience to extreme weather events and climate change, by elevating water levels, relocating a waterway and creating ecological 'stepping stones' to facilitate exchange between flora and fauna populations.

In Italy's Po floodplain, LIFE RINASCE is working to reduce flooding incidents by restoring a network of channels and sustainably managing vegetation. "Planned interventions will aim to restore the hydraulic functions of the floodplain, improve its ecology, and reduce the risk of flooding," says project officer Aronne Ruffini. As well as renovating some 7 km of channels, the project will create 2 ha of new wetland, thus helping to mitigate flood risks through water retention and improve water quality through natural filtration.

Re-naturalising rivers

A meandering river takes a natural winding form across a landscape. When a river is straightened by channelisation it cuts off meanders, leaving oxbow lakes and dried-out river bed, and speeds

The Anglesey and Lleyn Fens project restored alkaline fens and calcareous fens in north Wales, helping to recover their natural hydrology and reduce flooding

Photo: LIFE07 NAT/UK/000948

Photo: LIFE03 NAT/A/000009/Arbeitskreis Wachau/Haslinger

The WACHAU project restored gravel banks and islets in the Danube that serve as fish spawning grounds and as resting and breeding sites for aquatic birds

the flow of water and its drainage from wetland areas. When this higher flow speed combines with increased precipitation caused by climate change, the result is forecast to be an increase in flooding events.

Many LIFE projects (for example, WALPHY, GREENDANUBE and Nebenrinne Bislich-Vahnum) have re-naturalised rivers by recreating meanders, recovering oxbow lakes and seasonal streams, stabilising natural banks, returing river beds to a natural condition, reopening side channels and generally enhancing horizontal connectivity. The EU's longest river, the Danube, has benefitted in particular from such projects, which have introduced NWRMs all the way from Austria to the river delta in Romania.

One of the earliest projects to develop the Danube's green infrastructure was Donauauen (1998), which made the first practical application of a theory of flood defence for Vienna, based not on the conventional wisdom of building dams, strengthening dikes and straightening channels, but on lowering river banks and altering weirs to give the Danube more room to sprawl. The project team drew up detailed technical plans and made the first reconnections (at Orth and Untere Lobau) between the main river and former side channels in the floodplain. Later, the dike closest to the river was breached, allowing the old floodplain itself to become a retention basin. Increasing the "permeability" of the riparian forests for flood events led to noticeable and impressive results. Indeed, the subsequent self-restoration of floodplain dynamics exceeded all expectations.

The Donauaen project had an important demonstration value and conservation benefit, and side channel re-connection has subsequently been a feature of other river engineering projects along the Danube and its Austrian tributaries (see box). For instance, the WACHAU project recreated gravel banks and islets along one of the most picturesque and culturally important stretches of the river in Austria – the Wachau gorge, between Krems and Melk. The gravel used was recycled from the 400 000 m^3 dredged annually from the Danube's shipping channels and the project also drafted a 'gravel plan' for re-use in the river of all gravel excavated from the navigation channel between 2005 and 2020.

Another project on a Danube tributary, running almost concurrently with WACHAU, showed how it is possible to restore a heavily modified waterbody in an urban environment. LIFE LiRiLi redesigned a 5.5 km stretch of the river Liesing, turning a concrete

WATER MANAGEMENT

Re-naturalising the river Drava

Like many rivers in northern and western Europe, the Drava, a major tributary of the Danube, had been channelised in the name of 'development'. By the early 1990s, the outcome of river straightening was "catastrophic floods, erosion of the river bed and a falling groundwater level," explains Norbert Sereinig from the Carinthia regional government's flood control authority. At this time the authority began work to restore its stretch of the river to a semi-natural state, later accessing LIFE co-funding to support its efforts through the Obere Drau and Obere Drau II projects, the latter coordinated by Mr Sereinig. Obere Drau II involved widening the river, removing hydraulic structures and embankments at targeted local river reaches to allow river bank erosion to occur and the creation of new or restoration of old water meadows. An important aim of the second LIFE project was to solve management challenges thrown up by Obere Drau I, including stabilising the river bed and groundwater level (using bed load material), continuing habitat management measures and proposing cross-border strategies for water and ecological management of the Drava river basin (which takes in Italy, Austria, Slovenia, Croatia and Hungary).

Obere Drau II exceeded its aims, renaturalising 5 km of river and carrying out interventions at key points to reconnect side channels, oxbows and standing waters. Significantly, many of the restoration actions were designed to allow the river to further develop through natural processes rather than active management. Monitoring in July 2013 showed that the riverbed was stable and even rising in some places, whilst the increased water retention capacity was helping to protect downstream areas from floods and the stabilisation of the groundwater level had benefits for agriculture in the river valley.

channel into a semi-natural river that is still capable of meeting relevant flood protection requirements. The project capitalised on the demonstration value of its large-scale restoration works through significant media coverage and international networking with experts.

A number of LIFE Nature projects restoring rivers to conserve fish have also increased the resilience of river systems to floods and climate change. For example, HAPPYFISH in Estonia reconnected 10 oxbow lakes to a river system, and the HOUTING project reintroduced natural meandering to a 20 km stretch of river. The LIFE-TripleLakes project is restoring lakes in Sweden to conserve aquatic ecosystems and increase their resilience to climate change; with fish and other species in cold water habitats having low nutrient levels being particularly vulnerable to climate change.

Stabilising the river bed has enabled the LIFE Obere Drau II project team to improve flood protection in the Drau Valley

Photo: LIFE06 NAT/A/000127/Dapra

Water: a success story for LIFE

In conclusion, it should be noted that around one-third of LIFE Environment projects have worked to improve aspects of the hydrological cycle. These projects are helping overcome barriers to the implementation of EU water policy. LIFE was an early source of funding for projects demonstrating climate change adaptation measures for water systems. The programme continues to provide good examples of how to improve resilience in European river basins.

Did you know?

The RiverWiki developed by the Restore project to share best practice on river restoration includes, at the time of writing, 882 river restoration case studies from 31 European countries in its searchable database, many also with flood prevention objectives.

WATER MANAGEMENT

LIFE helps **Riga plan for increased flood risk**

The HydroClimateStrategyRiga project produced maps, models and guidance to help Riga City Council plan measures for safeguarding the Latvian capital against the increased risk of flooding predicted by climate change scenarios.

Climate change models predict an increased risk of flooding in northern Europe. In Latvia, more frequent and severe flash floods are a threat to the capital Riga, as well as surrounding Natura 2000 areas. Therefore, a LIFE project was initiated to develop the tools necessary for assessing how long-term climate change scenarios will change flood risk in Riga, so that adaptation measures can be incorporated into the city's planning system.

"We have an interesting hydrological system in Riga, with the River Daugava connecting to three lakes, and through these to other rivers," says Andris Locmanis, senior spatial development planner in the Strategic Planning Division of Riga City Council's City Development Department. "You cannot put one solution in the river mouth; it needs a more complicated set of solutions."

One of the first project actions was the development of a Riga City Relief Model, which provided the basis for all subsequent modelling and analysis. The scientific collaborators METRUM collected LiDAR data, and The Centre of Processes' Analysis and Research (PAIC) constructed the Relief Model, which can be updated as new information becomes available. The model helped establish the complex structure of the water bodies that comprise up to 16% of the Riga City area. "The relief model is the reason we have very good modelling results," notes Mr Locmanis.

Understanding water flows

PAIC produced a detailed study of the hydrological processes affecting Riga for the LIFE project. This involved modelling and assessing precipitation, flooding, coastal erosion, changes in groundwater levels, and other parameters with respect to the most reliable Intergovernmental Panel on Climate Change (IPCC) scenarios.

The project team then developed innovative modelling tools and software programmes, which were used to produce 60 scenario maps for three projected time frames. These showed how a series of bottlenecks (e.g. lake entrances) particularly affect flooding, and enabled the identification of the types of flooding that present the greatest threat to Riga in the future.

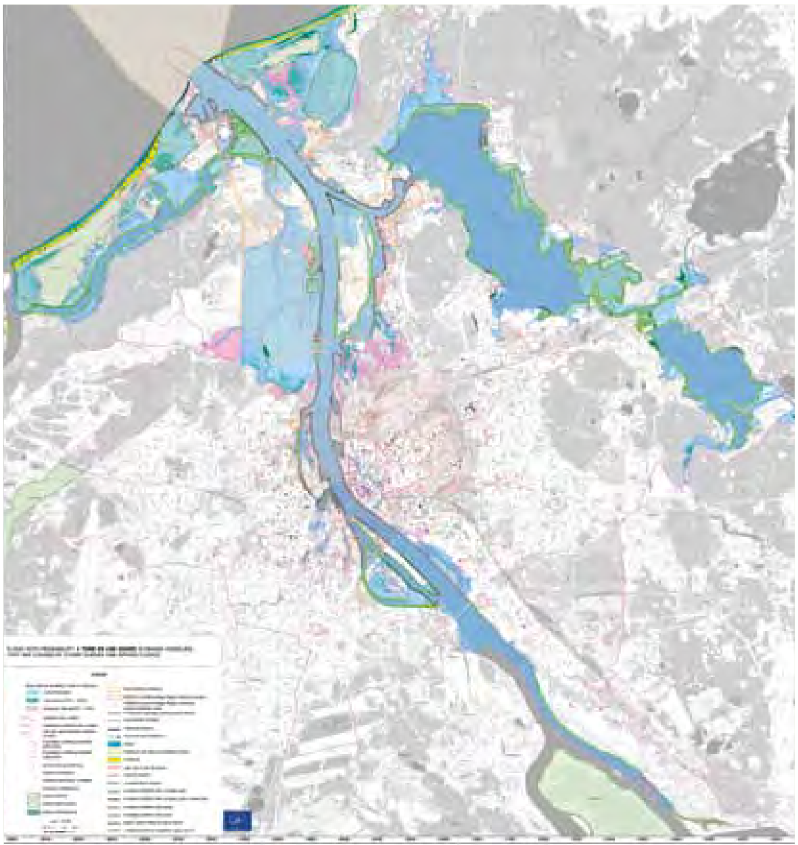
Aerial view of the River Daugava

WATER MANAGEMENT

"Flooding probability maps show that storm surges are the main priority," explains Mr Locmanis. Wind surges in Riga Bay during the autumn and winter can push water in the River Daugava, which is some 500-700 m wide and 12 m deep as it flows through Riga, back through the city. This represents the most serious long-term flood risk, but other threats were also identified. "Rainwater floods are not important yet, but looking long-term (e.g. 100 years) they become more frequent, as climate change models predict heavier and more frequent rainfall," he says.

The project's overlaid colour-coded scenario maps enable trends to be identified, and show the areas likely to flood at least once every 100 years for current (blue), near-future (green) and long-term future (pink) climate change projections. In the long-term, almost all river and coastal areas are liable to such flooding, while key roads not considered at risk of flooding today are revealed as being vulnerable. "It is important that we can see where the biggest differences are between today and the long-term future. In some places, there is not so much difference, but close to the city centre is an area where there will be a big difference," says Mr Locmanis.

Modelling tools were used to produce scenario maps for three projected time frames



This area includes densely populated residential areas and areas of historical importance. However, the scenarios suggest that there is time to implement adaptation measures to reduce the economic, social and environmental impacts of flooding.

The HydroClimateStrategyRiga team visited Antwerp (Belgium), Hamburg (Germany), and The Hague and Rotterdam (the Netherlands), to see how these cities are using long-term flood risk modelling to increase resilience to flooding. "We found these visits very useful for getting information on modelling periods, flood risk probabilities, and the variety of flood protection solutions and how to integrate them into public spaces," recalls Mr Locmanis. In Antwerp, the team were told that it is not possible just to keep building higher and higher dams; at some point you should look for other solutions. Antwerp has, for instance, left areas on river banks free of construction and allowed them to flood when water levels rise.

Flood Risk Management Plan

The Flood Risk Management Plan (FRMP) was the main outcome of the LIFE project. It was developed to manage flood risk in a way that balances environmental, social and economic needs, and it incorporates a process for periodic monitoring, evaluation and revision. The FRMP proposes a series of alternative climate change adaptation solutions for Riga and for six flood risk zones in areas surrounding the city. In each case, the FRMP includes an assessment of potential economic losses, a cost-benefit analysis, and technical parameters for the infrastructure solutions proposed, such as the height of dams or how much streets will need to be raised.

A priority within the FRMP is to ensure rescue roads are kept open, for example, by being made higher in cases where they connect to populations at risk of being cut off by rising flood waters. Another consideration is the management of Natura 2000 areas with habitats that require flooding during part of the year.

The project produced a series of Methodological Guidelines, in parallel with the FRMP. The guidelines included the lessons learned from the study visits and other best practice examples, with a focus on the most promising solutions and principles for the enhancement of flood prevention and adaptation in Riga.

The guidelines are already informing day-to-day planning decisions in the flood risk zones, and also the ‘Sustainable Strategy of Riga until 2030’ and the ‘Development Programme of Riga for 2014-2020’ that are currently being implemented by the City Development Department. For instance, regulations currently prevent building construction in areas where flooding probability is once every 10 years, but longer term flooding scenarios (e.g. once every 100 years) are now being considered as climate change becomes mainstreamed into the planning system.

“The Riga Waterfront Thematic Plan also started this year,” notes Mr Locmanis. “The guidelines were a good starting point for this, as they provide general best practice.” A riverside leisure area with a sandy beach recently has been constructed in a location where building is prohibited, for example, while streets close to the waterfront may be moved to create more public space between them and water bodies.

Photo: NEEMO EEIG/Stephen Nottingham

The project created a navigable gateway which allows to flood the Natura 2000 wetland areas

A choice of adaptation measures

On a drive outside the city, Mr Locmanis explains the alternative flood adaptation measures proposed in the FRMP for three flood risk zones. At the first site (Sarkandaugava), where urban areas are threatened by flooding in the long term, the project team recommend reconstructing and building new dams and raising the level of land in the neighbouring Free Port district. At the second site (Milgrāvis), where a bottleneck connects Lake Ķīšezers and the River Daugava, one solution is to build a navigable gateway below an existing bridge. “This measure will be expensive to build and maintain. The alternative is to make a lot of small solutions, which can be done using a step-by-step approach and will not require so large an investment at one time,” he says. “The next step is to do a more complex analysis, with indicators and public involvement.”

At the third site (Vecdaugava), a navigable gateway is also one of the alternative solutions proposed, but with a more complex system for opening to allow through sufficient water to flood Natura 2000 wetland areas. The other alternative comprises a series of measures involving dams and raising street levels; though where houses are close to the water and on both sides of streets these measures become more complicated. Finding a compromise between people and the environment is crucial; for example, high dams stop residents and visitors enjoying views in an area where water is considered an aesthetic resource.

These are the type of planning decisions being supported by the tools developed by the LIFE HydroClimateStrategyRiga project. “We are really happy about all the modelling processes,” concludes Mr Locmanis. “It was an example of very good cooperation between Riga City Council and scientists. There has been a lot of interest from other countries and cities, mostly from stakeholders wanting to use the modelling processes developed by the project in similar situations elsewhere. The scientists who were involved in the project, for instance, are now working on other Latvian projects involving flood risk modelling.”

Project number: LIFE08 ENV/LV/000451

Title: HydroClimateStrategyRiga – Integrated Strategy for Riga City to Adapt to the Hydrological Processes Intensified by Climate Change Phenomena

Beneficiary: Riga City Council

Contact: Andris Locmanis

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Period: 01-Feb-2010 to 30-Nov-2012

Total budget: €662 000

LIFE contribution: €329 000

COASTAL

Stepping up to **the climate change challenge**

Europe's coastal and marine areas are particularly vulnerable to climatic changes. LIFE has co-financed projects that address these threats and act to prevent or minimise damage, by building resilience and mapping risks related to land-sea interactions.

More than 52 million EU citizens live in low elevation coastal zones. These areas, which cover more than 480 000 km^2, are already experiencing the physical impacts of changing weather patterns, including flooding, erosion, saltwater intrusion and loss of ecosystems. Such climate-induced challenges are expected to become more prevalent in coming decades, with major socio-economic and ecological implications.

Key adverse impacts of climate change in coastal areas include: rising sea temperatures; rising sea

LIFE projects have been at the forefront of restoring coastal dunes and wetlands

Photo: LIFE05 NAT/IT/000037/Archive Park MSRM/L. Gorreri levels; coastal erosion; all of which lead to flooding and underground salt-water intrusion. These changes have had subsequent effects on ocean circulation and acidification, loss of biodiversity and ecosystems and socio-economic impacts. Climate change impacts exacerbate existing pressures on coastal zones and marine waters from urbanisation, drainage of coastal marshes for development, intensive agriculture and overfishing.

European action in coastal areas

The vulnerability of coastal areas has led to their identification by policy-makers as one of the key sectors for mainstreaming climate change adaptation. The challenge of climate change needs to be addressed through integrated and ecosystem-based approaches and instruments, such as integrated coastal management. These are crucial to build the foundations for sustainable coastal management and development, supporting socio-economic development, biodiversity and ecosystem services.

Integrated coastal management is an acknowledged tool to deal with current and long-term coastal challenges, including climate change and its impacts. As far back as 2002, an EU Recommendation on Integrated Coastal Zone Management (ICZM) referred to the threat to coastal zones posed by climate change as the basis for a strategic approach to coastal management.

The 2013 EU Climate Change Adaptation Strategy[1] proposes that ICZM and a second tool - Maritime Spatial Planning (MSP) [2] - be taken into account within the framework of the Integrated Maritime Policy (IMP), Marine Strategy Framework Directive (MSFD) and Common Fisheries Policy (CFP). The Strategy also includes a Staff Working Document that addresses adaptation, coastal and marine issues, as well as highlighting knowledge gaps and efforts that Member States need to take to overcome them.

In 2014, the EU adopted the Maritime Spatial Planning Directive as a means of achieving coherence between ICZM and MSP (see box).

1 Communication: "An EU Strategy on Adaptation to Climate Change», COM (2013) 216
2 ICZM involves a strategic, integrated and cross-sectoral approach that supports socio-economic development, biodiversity and ecosystem services. MSP is a tool for regulating human uses of the sea, whilst also protecting marine ecosystems and marine biodiversity.

Adapting to climate change: key policies and tools

The **Maritime Spatial Planning Directive** supports the implementation of the EU's Integrated Maritime Policy. The MSP Directive specifies **a need for climate change adaptation in coastal and marine areas**.

The **Marine Strategy Framework Directive** is the environmental pillar of IMP. It establishes a framework within which European countries need to take measures to achieve or maintain good environmental status in the marine environment by 2020. The MSFD specifies that Member States – in developing their respective national marine strategies – need to specify any evidence of climate change impacts.

Other policies relevant to climate change adaptation in coastal and marine areas include:

- The **Floods Directive** – this calls on EU countries to identify river basins and coastal areas at risk of flooding and to establish flood risk management plans;
- The **Water Framework Directive** (see previous chapter) – this requires that waters in coastal areas up to one nautical mile from a country's territorial baseline achieve 'good ecological status' and waters up to 12 nautical miles from the same baseline achieve 'good chemical status'; and
- **The Birds and Habitats Directives** and the **Natura 2000** network of protected areas – here the priority to protect marine ecosystems and their aquatic species has been reinforced by the EU Biodiversity Strategy to 2020. The Commission has also published guidelines[1] on climate change and Natura 2000 for site managers and policy-makers and commissioned a study promoting an 'ecosystem-based approach' to climate change adaptation and mitigation in Europe.

1 http://ec.europa.eu/environment/nature/climatechange/pdf/Guidance%20document.pdf

Photo: LIFE13 NAT/ES/001001

In addition to European-level initiatives, Member States are developing integrated coastal management strategies at national level to address the challenges climate change poses to coastal areas. These strategies need to take a long-term perspective, incorporate the precautionary principle and adaptive management, take account of the diversity of local conditions and work with natural processes to ensure coherence between planning and management.

Drawing from the well of LIFE

LIFE projects provide a font of learning and best practice about how to adapt to climate change in coastal zones. LIFE beneficiaries have addressed impacts including higher sea temperatures, sea level rise, coastal erosion and loss of ecosystem services. Projects have demonstrated risk mapping and modelling tools for assessing the full extent of those impacts and ways of increasing the resilience of Europe's coastal ecosystems.

LIFE's new sub-programme for Climate Action can build on the lessons from current and former projects, as well as tackling coastal and marine climate change impacts that LIFE has not yet addressed, such as ocean acidification and shrinking sea ice cover.

Dealing with rising sea temperatures

Global warming causes absorption of additional heat energy at the earth's surface, leading to higher sea surface temperatures. Thermal expansion is one of the factors causing sea-level rise; another is melting land-based ice.

Whilst there is considerable variability, the surface temperature of Europe's seas has risen significantly over the past century. According to the EEA[3], the greatest increases have been in the North Sea and Baltic Sea. Higher sea surface temperatures – together with changes in precipitation, wind and salinity – influence sea ice coverage, as well as the diversity and number of marine species.

In the eastern Baltic catchment, global warming poses an increasingly serious threat to an endangered seal species, the ringed seal (*Pusa hispida hispida*). The LIFE project Baltic MPAs has carried out inventories to better understand threats to the species including climate change (see box). Lessons from the project are being used to help the even rarer subspecies, the Saimaa ringed seal adapt to milder winters (see Biodiversity chapter - pp. 100-106).

Ice melt spells disaster for ringed seals

Ringed seals breed in ice lairs, an evolutionary adaptation designed to protect against polar bear attack. However, as Heidrun Fammler from the Baltic Environmental Forum Latvia, former project manager of Baltic MPAs, explains, because of global warming "for many years there has been insufficient ice coverage." When ice melts before seal pups have been weaned, they lack sufficient blubber to survive long in the cold water. They are also more vulnerable to predators (wolves, foxes, stray dogs, white-tailed eagles) and human disturbance.

The outlook is bleak for the southern Baltic ringed seal population, says Ivar Jussi, a project officer with the NGO Pro Mare, a partner in the Baltic MPAs project. "There are almost no measures that can be adopted to avoid the decline of the species in the event of warm winters continuing. Effort must be made to reduce human-caused mortality (by-catch in fisheries) and disturbance during the breeding season," he says.

Photo: LIFE05 NAT/LV/000100/I. Jussi

Adapting to rising sea levels

Thermal expansion of seawater and melting ice is accelerating the trend for sea levels to rise. In combination with storm surges, rising sea levels could increase flood risk, coastal erosion and saltwater intrusion into groundwater resources, rivers and estuaries. This intrusion will affect biodiversity and the quantity and quality of ecosystem services that coastal areas can provide.

As sea levels rise, many unique coastal wetland areas are being lost or degraded at an alarming rate, with significant impacts on biodiversity.

"Climate change is affecting our seas, causing sea level rise and an increase in extreme weather events which increase flooding events along our coasts. In the UK the projected relative sea level increases for 1990 to 2095 are approximately 21–68 cm for London. As little terns nest just above the high water mark on open, shallowly sloping sand and shingle beaches there is an obvious concern for the viability of current nesting sites," says Susan Rendell-Read, project manager of LIFE Little Terns, which is working with 29 colonies of the protected species across the UK. With hard coastal

3 EEA Report No 6/2006 *The changing faces of Europe's coastal areas*

Photo: LIFE12 NAT/UK/000869/Kevin Simmonds

Sea level rise and an increase in flooding events along coastal areas have brought a decline in the little tern's population

defences on the landward side, sea level rise also reduces the area of available beach habitat for little terns. The last full UK seabird census noted a decline in numbers from more than 2 500 breeding pairs (in the 1980s) to fewer than 2 000 (in the year 2000).

LIFE Little Terns is trialling the use of decoys and tape lures to encourage the species to breed on higher, safer areas of the beach. If tern nesting sites can be moved even short distances this may prevent nests being flooded out by high tides. An important adaptation to climate change will be the ability for little terns to colonise new sites or recolonise former sites, and so the project is supporting a number of habitat creation and habitat restoration actions, for example through shoreline management plans and coastal flood defence schemes. Such actions may involve high investment – such as creating nesting areas through shingle recharge and designing rafts as nesting platforms. Increasing our understanding at the micro-scale, such as nesting substrate preferences and whether the use of chick shelters on the beach afford effective protection, is also important. "Measures to increase productivity, and therefore resilience, could help mitigate some negative impacts of climate change," says Ms Rendell-Read.

One consequence of rising sea levels (and over-abstraction of water close to the coastline) is saltwater intrusion - the penetration of saline water into freshwater aquifers. LIFE SALT investigated the affect of saltwater intrusion in the Esino river basin of the Marche region of central Italy.

The project set out to get a clearer picture of the amount and quality of groundwater available in the river basin and, using this baseline data, simulated the impact of climatic changes on saline intrusion trends through a modelling tool that could also be used to develop a regional risk assessment procedure to support groundwater management in different scenarios.

The simulations indicated significant changes in temperature, precipitation and evapotranspiration in the project area between the reference period (1971-2000) and the end of the 21st Century. Average temperatures are projected to increase by four degrees Celsius and evapotranspiration is expected to rise by 10% in summer.

The project presented the main results in the form of maps of exposure, risk and damage. These maps will enable decision-makers to identify and prioritise risks and potential damage arising from climate change and assign priorities for intervention in adaptation plans for the Esino river basin. Risks related to saline intrusion, for instance, have been assessed as affecting a strip of land several hundred metres across throughout the territory.

There is high potential to replicate the project's methodology. The EEA notes that large areas of

Photo: LIFE05 NAT/D/000152/Hauke Drews

BALTCOAST restored a total of 34 coastal lagoons and meadows in five Baltic Sea countries (Denmark, Germany, Sweden, Estonia and Lithuania)

the coastal Mediterranean, especially in Italy, Spain and Turkey, are affected by saltwater intrusion.

LIFE and coastal erosion

Coastlines are variously subject to shoreline dynamics such as erosion and deposition of sediments depending on the nature of the coast (hard/rocky or softer sediments) and upon the coastal processes of sediment transport and water movements (waves and currents). Coastal erosion is a natural phenomenon that has been occurring for millions of years. However, the gradual natural erosion processes have become accelerated in recent years by human activities and by climate change-influenced factors such as rising sea-levels and heavier storms, higher waves and changes in prevalent wind and wave direction.

Approximately one-quarter of the European coastline for which data are available is eroding, with the coasts of Mediterranean, Atlantic and northern seas at highest risk. Erosion and coastal retreat pose serious problems for homes, infrastructure, communities and livelihoods – annual losses run into the tens of millions of euros. Wetlands and biodiversity are also affected.

Numerous interventions have failed to resolve coastal erosion. Indeed, some traditional 'heavy'

Junicoast installed sand stabilising fences for vegetation-free dunes subject to severe wind erosion on the Greek island of Chrysi

Photo: LIFE07 NAT/GR/000296/Remoundou Ilektra coastal defence solutions - i.e. building sea-walls or other hard structures - may actually have worsened the deterioration, especially in the long term, or simply shifted the problem elsewhere.

The challenge for policy-makers at the local, regional, national and international level is to devise and implement appropriate and ecologically responsible coastal protection measures that balance economic, social and environmental concerns. EU policies intended to address coastal erosion call for a coordinated and participatory approach, which is why Member States have been called upon to put in place national strategies towards ICZM.

Working to support the ICZM policy, LIFE projects have developed methods and implemented various practical actions to tackle the diverse problems associated with erosion of Europe's coastlines, such as Spain's Ebro delta, one of the most important wetland areas in the Mediterranean (see box).

Many examples of LIFE project actions to restore sand dunes, coastal lagoons and other coastal habitats are included in the LIFE Focus brochure, *LIFE and coastal management*[4]. This includes examples of projects that have prevented coastal erosion in highly developed areas through innovative beach and dune management measures.

More than 20 LIFE projects (such as SOSS DUNES LIFE and DuneTosca) have targeted Mediterranean dune habitats, carrying out a range of actions including restoration of dune morphology and dynamics and 'stabilisation' of the dunes using artificial barriers. The JUNICOAST project, for example, installed sand stabilising fences for 200 m of vegetation-free dunes subject to severe wind erosion on the Greek island of Chrysi. In other cases, dunes have been rehabilitated by controlling access to them or by eradicating non-native species.

More than 80% of the Laida beach dunes in Spain's Basque Country has been lost and with them important flora and fauna. Climate change is accelerating the speed of loss. The LIFE Dunas Laida project erected 'sand fences' made of willow branches or wicker facing into the prevailing winds. These act as barriers helping to trap the sand and enabling dune belts to build up over time. Once a sufficient volume of sand has been established, typical coastal dune species are planted such as European beach-grass (*Ammophila arenaria*) and sand couch (*Elymus farctus*), thus increasing the resilience of the whole dune system.

The project managed to gather precise information about the prevailing wind pattern at the beach, the sedimentary nature of the sand and the dynamics of the Urdaibai estuary. Since climate change can cause changes in wind direction that make erosion worse, the information on wind patterns will enable

4 http://ec.europa.eu/environment/life/publications/lifepublications/lifefocus/documents/coastal.pdf

EBRO-ADMICLIM's eco-engineering approach

Some 150 ha of wetland were lost from the mouth of the Ebro between 1957 and 2000. Upstream retention of river sediments (in reservoirs and behind dams) is responsible for this coastal regression, but the problem is being made worse by sea level rise and natural subsidence (each some 2-3 mm/year).

"It is predicted that around 50% of the delta's surface area (15 000 ha) could be affected by this phenomenon during this century," says Albert Rovira, technical coordinator of the LIFE EBRO-ADMICLIM project.

The Catalan government estimated that the traditional engineering solution – building dikes and artificially depositing sand – would cost around €300 million, excluding maintenance. It could also lead to further deterioration of the wetlands.

Both delta regression and subsidence can only be redressed in the long term by measures aimed at recovering the input of (inorganic) river sediments and the generation of organic matter in the wetlands and rice fields.

The EBRO-ADMICLIM project is applying new eco-engineering techniques to achieve this goal. The adaptation techniques will be subject to a modelling and a pilot phase during the project, which runs until June 2018. For the modelling phase, satellite radar imagery will be used to determine the distribution of sediment and historical and actual subsidence rates.

One of the techniques being tested is the use of 'flushing flows' that enable sediment trapped upstream to bypass blockages. Mr Rovira explains that these flows should be able to transport 2 million m^3 of sediment at a cost of only €1-2 million, "much less than traditional techniques."

Following the trials and consultations with the main socio-economic stakeholders, the project will produce a climate action plan for the delta (PACDE).

Photo: LIFE13 ENV/ES/001182

COASTAL

Photo: LIFE04 NAT/E/000031/NEEMO EEIG/Ainhoa Darquistade

Dunas Laida erected 'sand fences' made of willow branches that help trap the sand and enable dune belts to build up over time

more effective interventions to counteract erosion. Restoration of the dunes has increased the number of visitors to the area, with economic benefits for local businesses.

More recent LIFE projects have focused on developing ecosystem-based approaches and demonstrating soft measures to counteract coastal erosion such as beach nourishment, dune rebuilding, and coastal revegetation with native species that are adapted to sand, such as the umbrella pine (*Pinus pinea*).

Coastal erosion represents one of the main threats to ecosystems in the Sentina Reserve, a coastal wetland in the Marche region of Italy. LIFE's Re.S.C.We. project delivered a programme of bioengineering works in favour of dune recovery, creating windbreaks out of driftwood and planting bayberries to stabilise the dunes. It also created micro-habitats using dead trunks, excavated small ponds just behind the dune line and shaped new dune cordons using the excavated sand.

Coastal ecosystem services

Coastal ecosystems such as dunes and sandy barriers, mangroves and salt marshes deliver a wide range of services to people. They protect against storms and floods, control erosion, store carbon, provide habitats and are a source of food, income and wellbeing (e.g. through tourism and recreation).

In order to plan and deliver effective programmes of adaptation measures, it is necessary to assess the impact on ecosystem services of intensifying climate change. The influential LIFE project VACCIA did just that, feeding into the process of updating Finland's national climate change adaptation strategy (see strategies and planning chapter, pp. 20).

Increasing ecosystem resilience

Coastal wetlands (or tidal marshes) are saltwater and brackish water wetlands located in coastal areas. As well as being important habitats for fish, shellfish and birdlife, they provide natural defence against coastal flooding and storm surges. Tidal wetlands can serve to improve degraded waters by recycling nutrients, processing chemical and organic wastes and capturing sediment loads; the cleansed water helps maintain aquatic organisms.

The restoration of coastal wetlands and managed realignment are important tools for adaptation of coastal areas to climate change. There are several means of re-establishing the natural functions of degraded wetlands. One method is to add sediment to raise land above the water level and allow wetland plants to colonise, or modify, erosion processes that are degrading wetland areas. Alternatively, blocking ditches and reducing groundwater extraction is an effective restoration technique for (drained) brackish wetlands. A more resource intensive technique involves transplanting vegetation from healthy marshes or specialised nurseries.

LIFE Nature funding has been one of the main drivers of coastal wetland restoration across the EU, implementing ecosystem-based approaches that, as well as aiding protected flora and fauna, are making these habitats more resilient in the face of climate change impacts such as flooding, storms and sea level rise. One of the most ambitious projects of this kind has been BALTCOAST, which restored a total of 34 coastal lagoons and meadows in five Baltic Sea countries (Denmark, Germany, Sweden, Estonia and Lithuania).

"We restored the natural hydrology of lagoons by re-opening natural connections to the sea and by closing pipes draining the lagoons," explains project manager, Hauke Drews. The BALTCOAST team also removed excess vegetation and silt from natural depressions and prevented further eutrophication of lagoons by rerouting nutrient-rich runoff around the lagoons or by establishing nutrient retention ponds for drainage water.

In the UK, a key objective of the Alde-Ore project was to enhance the resilience of two sites rich in birdlife in East Anglia (at Orford Ness and Havergate Island) to changing climatic conditions, especially rising sea levels. At Orford Ness, new water management infrastructure has created an additional 3 ha of coastal lagoon habitat, along with 2.4 km of new ditches and a further 4 km of linear scrapes (foot drains).

Grant Lohoar, East Suffolk Coast & Countryside Manager for the National Trust, which led the LIFE project, explains that the deepened scrapes and new ditches increase the water carrying capacity of the site, allowing it to hold water for longer into the summer and early autumn. "The linked system allowed improved management of water at appropriate times of the year to maintain optimum water levels for key bird species," he says. During the winter months, a "new, more efficient pumping system" can evacuate

VACCIA identifies coastal changes

VACCIA investigated the impact of climate change on changes in chemical, physical and biological variables relating to coastal ecosystems. Results showed that increasing eutrophication has reduced the turbidity of water in the Gulf of Finland. VACCIA's models predict that "more frequent occurrence of floods and heavy rains is likely to increase the loads of nutrients and suspended matter even further," explains project manager Martin Forsius.

The project found a trend for decreasing salinity in coastal areas of the Gulf of Finland, which may be linked to climate change (the connection has not been verified). However, evidence does confirm that the combined impact of various changes in the Baltic Sea ecosystem has "caused clear changes in several marine species", says Prof Forsius. Predicted changes in the temperature of water bodies and ice cover will affect fish spawning times, hatching dominance of species and migration.

The project also found that a warmer climate is having an impact on shoreline species and vegetation, including the coastal meadows of the Bothnian Bay, where the critically endangered plant creeping alkaligrass (*Puccinellia phryganodes*) and the southern dunlin (*Calidris alpina schinzii*), a wading bird, are found. Climate warming has also resulted in earlier spring migration and later autumn migration of water birds. On an average, autumn migration is 0.37 days/year later.

Different adaptation measures are needed to address each of these impacts. For surface waters these could focus on reducing runoff, erosion and nutrient loads; for the fishing industry, it would mean adapting to changing fish stocks and an extended trawling season (because of shorter ice cover); for coastal areas, it would mean changes in agricultural practices (e.g. buffer zones, less fertiliser) to limit the impact of more rainfall and floods on runoff.

VACCIA assessed the potential impact of climate change on ecosystem services, such as food production

Photo: LIFE07 ENV/FIN/000141/METSÄHALLITUS/WESTERBOM Mats

COASTAL

excess rainfall into the estuary system. This also "proved its value" following a North Sea tidal surge in December 2013, which led to significant incursion of tidal water into the site.

At Havergate Island, the project fully restored saline lagoons and replaced six tidal sluices to ensure that water levels are favourable to target species. "The new sluices allow more efficient influx of river water to refresh the marshes and reduce salinity," says Mr Lohoar.

Other important wetlands in East Anglia are threatened by 'coastal squeeze', where intertidal habitats are prevented from migrating landwards due to the presence of sea walls. At Titchwell Marsh, tidal surges in 1994 and 1996 were an early warning that climate change was going to pose an increasing threat to this Natura 2000 network site. In the 1996 incident saltwater breached the northern sea bank, entering the freshwater marsh.

In 2007, the RSPB, which manages Titchwell Marsh, secured LIFE funding for TacTICS, a project which combined protective measures with managed realignment. "The measures that were adopted involved breaching the existing sea wall to allow a brackish marsh to be naturally converted to mostly tidal marsh, which now acts as a first line of defence in absorbing pressure from the sea," says senior site manager, Robert Coleman.

Further inland, the bank that previously separated the brackish from the freshwater marsh was rebuilt and strengthened to become the new sea wall. Behind this, the area of freshwater habitat was managed to ensure a mix of freshwater marsh, islands and reedbeds to provide for all the habitat needs of the local wildlife.

"Climate change will continue to impact on the North Norfolk coast, but LIFE project actions have helped to establish a natural protective infrastructure and a collective will among local stakeholders that should now ensure the survival of the Titchwell Marsh SPA and its rich diversity of coastal habitats," believes Mr Coleman.

Increasing the resilience of Spain's lagoons

Delta-Lagoon is a project working to increase the resilience of the Alfacada and Tancada coastal lagoons in Spain's Ebro Delta, an area, as we have already seen, that is particularly vulnerable to the effects of climate change. Project manager Carles Ibáñez explains that actions have focused on improving the hydrological status and connectivity of the lagoons. For instance, it has removed dikes to reconnect the Tancada lagoon with the Alfacs Bay, helping to restore salt marshes damaged by intensive fish farming. In the Alfacada lagoon, work is focusing on the restoration of original lagoon areas that have been converted to rice fields or which were formerly used for aquaculture.

Adaptation to rising sea levels involves "the re-establishment of hydrological connectivity between the lagoons and the sea, in order to increase the sediment inputs to the lagoons during marine storms," says Dr Ibáñez.

Sea level rise and sea storms are also affecting the La Pletera saltmarsh in the flood plain of the Ter estuary, near Girona. The site is of high ecological importance due to the presence of brackish and hypersaline coastal lagoons. The ongoing project, LIFE-PLETERA, is restoring all aspects of the coastal lagoon system – including foredune, mobile coastal dunes, a gradient zone of mixed sand and clay substrates, permanently-flooded lagoons and wetland flood belts – with the specific aim of enabling it to respond to predicted climate change impacts.

Photo: LIFE09 ENV/ES/000520/IRTA

Risk management and mapping

Improving knowledge and understanding of the effects of climate change in coastal areas is a prerequisite to developing effective adaptation strategies. By incorporating climate change data and scenarios into coastal risk mapping and long-term planning, local and regional authorities can take steps to divert new development away from areas of risk, and seek to modify or reduce risks in areas of existing development. The UK project, Response, provides a framework for understanding and better preparing for the impacts of climate change around Europe's coastline.

In partnership with nine organisations from the UK, France, Italy and Poland, it collected data on coastal behaviour systems in five study areas. Going beyond previous macro-scale classifications, the methodology allows for an assessment

IMAGINE all the 'at risk' coastal areas ...

'V-shaped' storm systems, once rare in the Mediterranean, are becoming more frequent due to the increase in the average temperature of the oceans. The terrain and morphology of Liguria and Tuscany, together with increased urbanisation and soil sealing, makes them particularly exposed to the impacts of extreme rainfall events, including landslides. There have been 13 floods in the two regions since 2000, causing extensive damage and loss of life.

The aim of the LIFE+ IMAGINE project is to be able to better predict extreme events in coastal zones and monitor and implement the changes required to optimise current and future developments," says project manager Giorgio Saio.

The project will provide managers of coastal areas in Liguria and Tuscany with applications that address relevant scenarios, including predictions of the impacts of soil sealing, flooding and landslides. The project will develop a means of harmonising heterogeneous spatial information (SEIS, INSPIRE, GMES) into a tool that can be used to produce vulnerability maps and indicators for coastal planning. By providing a cost-benefit analysis of different climate adaptation measures, the tool will enable users to incorporate the most appropriate measures into ICZM plans, thus reshaping the planning process and allowing for informed decisions based on spatial data and climate scenarios.

"We have identified two 'at risk' areas for pilot activities," says Mr Saio: in Liguria, the towns of Monterosso and Vernazza that were particularly severely hit in the 2011 landslides; and a 60 km-stretch along Tuscany's coast that regularly experiences landslides following heavy rains or storms."

of local coastlines to provide detailed forecasts of likely future scenarios. It was tested in five regional coastal study areas with a variety of coastal landforms: "This has tremendous potential", says the project, to improve local coastal planning around the world.

Meanwhile, in Italy's coastal zones – researchers say there has been a marked increase in the past 10 years of periods of heavy rainfall and flooding – as witnessed by the catastrophic landslides of October 2011 in the "Cinque Terre" district of Liguria – where coastal towns suffered loss of life and substantial damage to infrastructure and buildings. According to a new project, LIFE+IMAGINE (see box), "scenarios simulated for next 50 years demonstrate that the likelihood of such extreme weather events will increase over the next 50 years".

The Re.S.C.We. project restored pre-existing wetlands and dune formations which increases resilience to risks of sea level rise

Photo: LIFE09 NAT/IT/000608

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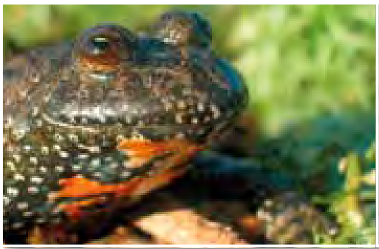

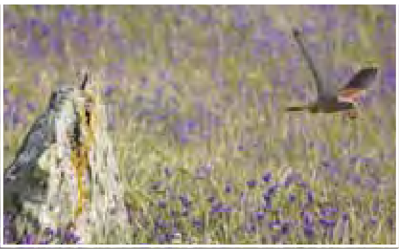

Enabling biodiversity to adapt

LIFE project actions have been improving the conservation status of Europe's protected species and habitats, boosting ecosystem resilience and thus making biodiversity more "fit" to adapt to climate change.

Photo: LIFE13 NAT/GR/000909/NCC

Climate change is affecting biodiversity, threatening the survival of species such as the Eleonora's Falcon

Climate change has both direct and indirect impacts on species and ecosystems. For species these include: increased population fluctuations and local extinctions, movement to higher altitudes and latitudes (upwards and northwards), changes in species relationships (e.g. mismatching in lifecycle events in food webs), loss of habitat, and local extinctions. In terms of habitats, negative impacts include: erosion, drought, flooding, changes to the nutrient balance/eutrophication, as well as increased frequency and severity of fire, flooding and storms.

Impacts of climate change will often interact with existing pressures: for example, eutrophication may be enhanced by increased fluctuations in water tables; changes in geographical distribution of species as a response to climate change will be limited by habitat fragmentation and the availability of habitat in new areas that are climatically suitable.

The Arctic fox provides a vivid illustration of how a species can be impacted by the need to adapt to climate change as well as existing pressures (see box).

The tale of the Arctic fox

In mainland Europe, the Arctic fox (*Vulpes lagopus syn. Alopex lagopus*) is found above the tree line in the mountain tundra of Fennoscandia. The species' population plummeted at the beginning of the 20th Century because of over-harvesting by the fur industry and remained low thereafter. In 1997, the adult population in Fennoscandia was estimated to be lower than 100 animals.

The LIFE SEFALO project was launched in 1998 as a joint conservation effort between Sweden and Finland aimed at halting the Arctic fox's decline and increasing its breeding population. Completed in 2002, the project helped stabilise the population but was unable to increase numbers. Consequently, a follow-up project was carried out during 2003-2008, SEFALO+, which also included Norway.

The manager for both projects, Anders Angerbjörn, says the key threats to the Arctic fox are low availability of food and competition from the larger red fox (*Vulpes vulpes*) for territory and den sites. To combat these, extra food in the form of commercial dog pellets was provided to dens with litters of Arctic foxes, and in winter reindeer carcasses were hidden nearby under the snow. In Sweden, this action was combined with culling of red foxes during winter.

These methods managed to stop the Arctic fox's decline and boost the number of litters born, in combination with an increase in the lemming population, one of its main food sources. Despite these improvements, the Arctic fox remains at risk. in particular, from climate change. "With a warmer climate we will have lower peaks of rodents and less pronounced cyclicity," says Mr Angerbjörn. Climate change also pushes the tree line northwards and hence the range of the red fox, resulting in more competition. The possibility of reintroducing the Arctic fox to Finland is made more difficult by changes to the landscape linked to a warming climate (e.g. tundra habitat being replaced by boreal forest).


Photo: LIFE03 NAT/S/000073

The EU aims to secure the long-term protection of biodiversity through the Birds Directive, Habitats Directive and the Natura 2000 network. In 2012, it also adopted the EU Biodiversity Strategy to 2020, which sets out the Union's long-term (2050) vision on biodiversity policy and a range of mid-term targets and actions, including some that address climate change. The headline mid-term target is "halting the loss of biodiversity and the degradation of ecosystem services in the EU by 2020, and restoring them in so far as feasible, while stepping up the EU contribution to averting global biodiversity loss."

Through nature-based approaches to adaptation and mitigation, opportunities exist to strengthen the resilience of ecosystems, and thus reduce impacts of climate change on biodiversity, whilst helping to mitigate climate change.

Nature-based approaches to adaptation and mitigation provide both adequate responses to climate change challenges and sustain ecosystem functions in the long term. Such approaches to adaptation are ready to use and are easily accessible. As highlighted by a 2011 report for the European Commission, *Assessment of the potential of ecosystem-based approaches to climate change adaptation and mitigation in Europe*[1], they often bring multiple benefits at comparatively low cost.

Guidelines for climate change adaptation

In 2013, the European Commission produced a set of guidelines on climate change and Natura 2000 network sites[2] aimed at the managers of these sites.

The guidelines seek to underline benefits from Natura 2000 sites in mitigating the impacts of climate change, reducing vulnerability and increasing resilience. A decision framework is included to help identify opportunities for sensible adaptive planning to protect target species and habitats whilst tackling the effects of climate change.

1 Report available at http://ec.europa.eu/environment/nature/climatechange/pdf/EbA_EBM_CC_FinalReport.pdf
2 Guidelines on Climate Change and Natura 2000: Dealing with the impact of climate change On the management of the Natura 2000 Network of areas of high biodiversity value [Technical Report - 2013 - 068; http://ec.europa.eu/environment/nature/climatechange/pdf/Guidance%20document.pdf

The guidelines include six main categories of adaptation measures, of which the five key ones are:

- To reduce existing pressures;
- To ensure ecosystem heterogeneity;
- To increase connectivity;
- To ensure abiotic conditions; and
- To manage impacts of extreme events.

As the main funding tool for Natura 2000 network conservation, the LIFE programme is already demonstrating how each of these categories of measures may be applied in practice.

Reducing existing pressures

Existing pressures on species and habitats may be reduced through restoration measures, development of buffer zones and the defragmentation of infrastructure (for example, through green tunnels and bridges).

The EC Guidelines on Climate Change and Natura 2000 cite the example of the LIFE project Dutch dune revival, which runs from 2010 until the end of 2015, and which is featured in the coastal chapter of this publication. Other projects that have developed buffer zones include SPIN4LIFE on Sicily, whilst projects such as LIFE + OZON in the Sonian Forest in and around Brussels and LIFE BEAR DEFRAGMENTATION, which is linking brown bear habitats in Spain's Cantabrian mountains, are addressing the problem of fragmentation. The latter project is building on the work of LIFE Corredores oso (2009-2011) by taking action to connect two isolated bear sub-populations along a 50 km transit corridor: improving connectivity between habitats, reducing the potential for harm in transit areas (i.e. road and rail crossing points), and raising awareness in the local community by working "with local people, with cattle breeders, beekeepers, landowners, stakeholders, hunters, trying to create a good social environment for the bear to come and to use these corridors," says project manager, Fernando Ballesteros.

Increasing ecosystem heterogeneity

The heterogeneity of ecosystems may be increased through enhancing structural gradients (mosaics of habitats) and by allowing natural processes to take effect. One example with positive adaptation impacts used by many LIFE projects is to increase shade along streams. As the Guidelines for Climate Change and Natura 2000 indicate, "Tree roots make banks stable and offer long-term protection against erosion. In general, recovery of stream shade (and therefore temperature) is expected within decades, and is accelerated by deliberate planting." Forest-ForWater, a Swedish LIFE Environment project that ran from 2003 to 2007 used riparian shade to reduce thermal stress on freshwater organisms and planted floodplains with woodland species to alleviate downstream flood risks. More than 120 LIFE projects have implemented actions for the restoration of riparian habitats.

The corridor that connects the two Cantabrian brown bear populations is dependent on habitat availability and connectivity

Photo: LIFE07 NAT/E/000735 - Fundación Oso Pardo

Photo: LIFE10 NAT/IT/000241

The TIB project is creating underpasses to allow species to cross roads

Increasing connectivity

Connectivity between Natura 2000 network sites and other green spaces may be increased by the development of corridors/stepping stones, wider landscape management, the creation of new nature areas and spatial planning.

LIFE has done much to connect nature across Europe. For instance, in Cyprus, the ICOSTACY project restored connectivity and mitigated the impacts of land-use change and climate change by improving the ecological coherence of the country's Natura 2000 network for various targeted species. The project, which ran from 2010 to 2014, carried out a climate change scenario analysis for those species, which include the Cyprus whip snake (*Coluber cypriensis*), Mediterranean horseshoe bat (*Rhinolophus euryale*) and Jersey tiger (*Euplagia quadripunctaria*). This showed, for instance, that habitats of the latter species, a type of day-flying moth, are not currently fragmented, but that "based on climate change scenarios, it is expected that suitable habitats will decline," says project manager Elena Stylianopoulou. The project also produced habitat suitability maps for species. "These could be used to advise and inform about conservation and protection of the species across their range and distribution," says Ms Stylianopoulou.

Ongoing projects such as TRANS INSUBRIA BIONET (TIB) in Italy and LIFE ElClimA in Greece are currently working to increase connectivity through nature-friendly adaptation solutions. TIB aims to combat the negative effects of climate change by facilitating the mobility of animal and plant species along an ecological corridor between Campo dei Fiori and the Ticino River Park, an area covering some 15 000 ha and including 14 Natura 2000 network sites. The project will improve habitats in the corridor and install underpasses to allow species to cross roads.

The LIFE ElClimA project is targeting actions at one keystone species, Eleonora's falcon (F*alco eleonorae*), with the goal of facilitating its adaptation to ongoing and future climate change. It plans to implement a series of targeted conservation actions to improve the species' breeding performance and the quality and availability of its foraging areas. These actions will include constructing 1 000 artificial nests, eradicating rats and planting fruit trees on migration routes. It will assess the bird's foraging behaviour and habitat quality, as well as the impact on these habitats of land-use changes and climate change.

The network level

Larger scale (network level) adaptation measures facilitate movement of species between different Natura 2000 sites, as well as between Natura 2000 sites and suitable habitat in their surroundings. Network level measures allow species to disperse into future suitable climate zones. As the Guidelines on Climate Change and Natura 2000 note, "facilitating range shifts will require well connected, green infrastructure over large distances."

The concept of Green Infrastructure describes ecological networks in their wider context. It emphasises the importance of maintaining and restoring the provision of ecosystem goods and services for society and the value of functionally and connected, healthy ecosystems.

Green infrastructure could contribute to the coherence of the Natura 2000 network by improving landscape permeability and thus adding to the resilience of ecological networks to climate change. Many implementation coalitions can be developed with other land uses and functions, such as agriculture, forestry and water management. The Commission issued a Communication on Green Infrastructure in 2013[3], which provides an enabling framework for nature-based adaptation solutions.

LIFE has begun to address the issue of network-level adaptation measures through recently funded projects such as EcoCo LIFE Scotland (see box) and LIFE-TripleLakes. The latter project is developing a model

3 (COM(2013) 249 final)

Improving Scotland's ecological coherence

The EcoCo LIFE Scotland project is implementing integrated habitat networks to improve ecological coherence across the Central Scotland Green Network. As project coordinator Alistair White of Scottish Natural Heritage explains, "the ecological coherence protocol will be a framework for determining the best places to carry out habitat management and creation within Central Scotland, to improve ecological coherence at a series of scales (site, local, regional) whilst also taking into account benefits to wider socio-economic benefits and ecosystem services."

The protocol is being developed through workshops involving experts, stakeholders and partner organisations. "These workshops refine and direct the use of habitat mapping and ecosystem services mapping to produce a framework which can be applied across the project area," says Mr White. The framework will be tested on selected sites during the project and also used to identify new sites for habitat restoration work.

Mr White explains that the protocol will help improve the resilience of habitats and species to changing climatic conditions, "in a number of ways. By improving ecological coherence at the site level, sites which have been identified as being suitable will become more ecologically robust and will display a range of variation in habitat structure, maximising opportunities for biodiversity resilience in the face of changing climatic conditions. Secondly, the focus on enhancing connectivity, and dispersal opportunities, will assist with improving the permeability of the landscape within the project area, affording species the opportunity to move in response to climate change. The protocol will allow 'pinch points' and potential corridors to be identified, and will enable work to be targeted towards areas which can contribute to enhancing and aiding the movement of species. Thirdly, the project's focus on catchment scale restoration will allow geomorphological opportunities to be identified and mapped, resulting in, for example, rivers being reconnected with their floodplains, natural flood management opportunities being developed, and areas of habitat being created in response to changing climate events."

Amongst other habitats, the project is targeting degraded lowland raised bogs with recovery potential. Work on these sites will provide connectivity and allow for dispersal, as well as ensuring that an important carbon sink is maintained.

Photo: LIFE13 BIO/UK/000428/East Ayrshire Coalfields Environmental Initiative

Fire protection in Spain's black pine forests

An ongoing project in Catalonia, Life+ Pinassa, is working to increase the resilience of black pine forest to large fires and climate change. According to project coordinator, Teresa Cervera Zaragoza, "for areas with high fire risk, we use the ORGEST ('Guidelines for Sustainable Forest Management') models, which have two primary management objectives: production of goods (wood, cork and pine nut) and fire prevention." In terms of the latter role, she explains that the models "have keys for identifying vulnerability to canopy fire in pine stands and some parameters - fire prevention requirements - to improve the type of structure for a forest stand."

Indicators used to assess the biodiversity of these forests will include "characteristics of tree, shrub and herbaceous cover; deadwood and suitable natural cavities for birds and bats; floristic composition; and bioindicators," adds Ms Cervera Zaragoza.

Photo: LIFE13 NAT/ES/000724

for adaptive catchment management for high conservation value aquatic ecosystems in Sweden that takes into account climate change. "To strengthen resilience we need to improve the conditions for typical species within the catchments and the habitat types to reduce stress. Therefore we need to work to diminish physical, chemical and biological impact to create high-quality habitats and a minimum of stress from different kinds of land use and human activities in general," says project manager, Malin Bernhardsson. Specific actions will include restoring watercourses and removing dams and other barriers to the free passage of species, creating and restoring spawning beds, conducting an inventory of wastewater treatment plants to reduce nutrient loads and demonstrating good water management practices in forestry and agriculture.

Ensuring abiotic conditions

Maintaining the hydrological integrity of a site is often key to delivering species and habitat objectives. Increased water scarcity and drought are expected and, as a secondary effect, this may lead to increased levels of nutrients (especially nitrogen) and pollutants. Higher temperatures in combination with more rainfall can also lead to an increase in biomass, requiring changes to management measures such as mowing regimes.

Many technical measures exist to ensure adequate water quality, water quantity or nutrient balance for Natura 2000 sites (see pp. 71-86). Furthermore, numerous LIFE projects have helped restore or maintain the hydrological integrity of Natura 2000 network sites. One notable example comes from England, where the Alde-Ore Estuary project enhanced the resilience of the sites on Orford Ness and Havergate Island to changing climatic conditions. The new water management infrastructure created an additional 3 ha of coastal lagoon habitat, along with 2.4 km of new ditches and a further 4 km of linear scrapes (foot drains) (see coastal chapter – pp. 84-93).

Slovenia's salt pans under threat

"Climate change is becoming one of our biggest management problems. The climate is changing so rapidly, in front of our eyes. We speak to our old salters and they say we never had rain in the summer; now this is very common. Biodiversity is really affected – so many eggs and chicks are lost because of the summer storms. Of course we have to adapt to that, so in our management plan and in our guidelines for reconstruction works, we are adding height. We know that the sea level is higher and we are trying to adapt to this yearly change of distribution of rain and storms. We are dredging out separate dikes and ditches so the excess water in summer really can drain down." **Andrej Sovinc, Project Manager, MANSALT, Slovenia**.

Photo: LIFE09 NAT/SI/000376/Davorin Tome

Managing impacts of extreme events

The increasing prevalence and severity of extreme events (fires, floods, storms, droughts) is one of the most apparent and most challenging impacts of climate change (see MANSALT box).

In terms of helping biodiversity to adapt, LIFE is showing the way through projects such as Life+ Pinassa (see box) and EstepÁrias. The latter project, which ran from 2009 to 2012, worked to conserve the great bustard, little bustard and lesser kestrel in Portugal's Baixo Alentejo cereal steppes. Potential climate change scenarios were examined by the project to evaluate their potential impact on these steppe birds. These scenarios were used to establish emergency intervention procedures, including drought mitigation measures, which were subsequently integrated into good practice manuals designed for use by those involved in agri-environment management.

As a 'last resort' for the most vulnerable species, the 2013 EC Guidelines propose relocation to new, suitable sites.

Where relocation is not feasible, LIFE has shown that there are other ways to help the most vulnerable species adapt, as shown by the case of the Saimaa ringed seal in Finland (see box).

LIFE Saimaa Seal

"The Saimaa ringed seal (*Phoca hispida saimensis*) is categorised as a critically endangered subspecies both nationally and internationally. It inhabits a freshwater lake in Finland [Lake Saimaa] and there are some 300 seals left, and around 60 pups are born annually," explains Raisa Tiilikainen, manager of the LIFE Saimaa Seal project, which runs from 2013 to 2018. "The major threats to the population are by-catch mortality, small and scattered population size, habitat deterioration and climate change," she says. One of the goals of the project is to help the seals adapt to climate change by developing a method of producing artificial snow drifts to improve their lairing conditions during mild winters.

"The breeding success of the Saimaa ringed seal, like other ringed seals, is dependent on sufficient ice and snow cover. The seals give birth to a single pup in a subnivean snow den (known as a lair) that is situated at snowdrift formed on shoreline of islands. The lair provides shelter against predators and harsh climate, and mother-pup pair use it over the nursing period," explains Dr Tiilikainen.

The LIFE project is implementing an artificial snowdrift method that was developed specifically for this purpose at the University of Eastern Finland. 'The drifts are piled up using snow shovels and pushers at the breeding sites of the seals. Snow used in the drifts is collected at the vicinity of the drift site," says Dr Tiilikainen.

During the mild winter of 2014, 240 artificial snowdrifts were piled up in the Saimaa ringed seal's breeding area. More than 90% of the pups born that year were born at lairs with artificial snowdrifts, highlighting the usefulness of the technique. In 2015, "around 70 man-made snowdrifts were constructed at the main breeding areas of the seals where snow conditions were not sufficient for breeding," adds Dr Tiilikainen.

Photo: LIFE12 NAT/FI/000367/Mervi Kunnasranta

LIFE & Climate change adaptation project list

Here is a complete list of LIFE projects that are featured in LIFE and Climate change adaptation. Arranged by theme, the list highlights more than 130 LIFE projects relevant to climate change adaptation. These are drawn from a total of 24 EU Member States. 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
		PLANNING	
LIFE07 ENV/FIN/000138	CHAMP	Climate Change Response through Managing Urban Europe-27 Platform	20
LIFE07 ENV/FIN/000141	VACCIA	Vulnerability assessment of ecosystem services for climate change impacts and adaptation	20, 21
LIFE07 INF/FIN/000152	CCCRP	Climate Change Community Response Portal	20, 21
LIFE07 ENV/FIN/000145	Julia 2030	Mitigation of and Adaptation to the Climate Change in the Helsinki Metropolitan Area - From Strategy to Implementation	20, 22, 23
LIFE09 INF/PL/000283	DOKLIP	A Good Climate For Counties	23
LIFE13 INF/PL/000039	LIFE_ADAPTCITY_PL	Preparation of a strategy of adaptation to climate change with use of city climate mapping and public participation	23
LIFE08 ENV/IT/000436	ACT	Adapting to climate change in Time	24
LIFE11 ENV/IT/000119	BLUE AP	Bologna Local Urban Environment Adaptation Plan for a Resilient City	24
LIFE10 ENV/CY/000723	CYPADAPT	Development of a national strategy for adaptation to climate change adverse impacts in Cyprus	26-29
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LIFE10 ENV/FR/000215	R-URBAN	R-URBAN / Participative strategy of development, practices and networks of local resilience for European cities	30
LIFE00 ENV/E/000415	GREEN BELT	A proposal for sustainable territorial planning	34
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	35
LIFE12 ENV/ES/000567	LIFE ZARAGOZA NATURAL	Creación, gestión y promoción de la Infraestructura Verde de Zaragoza	35
LIFE13 ENV/BE/000212	LIFE-GREEN4GREY	Innovative design & development of multifunctional green & blue infra-structure in Flanders grey peri-urban landscapes	35, 36
LIFE09 ENV/IT/000074	GAIA	Green Areas Inner-city Agreement "GAIA"	36
LIFE10 ENV/IT/000399	EMoNFUr	Establishing a monitoring network to assess lowland forest and urban plantation in Lombardy and urban forest in Slovenia	36

PROJECT REFERENCE	ACRONYM	TITLE	PAGE
LIFE12 ENV/SE/000800	SOLMACC Life	Strategies for Organic- and Low-input-farming to Mitigate and Adapt to Climate Change	49
LIFE13 ENV/FR/001315	PTD LIFE	Dynamic rotational grazing	50
LIFE13 ENV/LT/000189	LIFE Viva Grass	Integrated planning tool to ensure viability of grasslands	50
LIFE09 ENV/ES/000456	AG_UAS	Sustainable water management at regional scale through Airborne Remote Sensing based on Unmanned Aerial Systems (UAS)	51
LIFE11 ENV/IT/000035	WSTORE2	Reconciling agriculture with environment through a new water governance in coastal and saline areas	51
LIFE08 ENV/E/000114	POWER	Project for Optimisation of Water and Emissions Reduction	52
LIFE11 ENV/ES/000621	IES	Irrigation expert simulator	52
LIFE09 ENV/ES/000447	The Green Deserts	The Green Deserts: new planting techniques for tree cultivation in desertified environments to face Climate Change	53
LIFE12 ENV/ES/000536	LIFE MEDACC	Demonstration and validation of innovative methodology for regional climate change adaptation in the Mediterranean area	53
LIFE13 ENV/IT/001258	LIFE SEMENte parTEcipata	Modelli di selezione vegetale e di tecniche agronomiche adatti alle condizioni pedo-climatiche locali	53
LIFE07 ENV/GR/000266	EcoPest	'Strategic plan for the adaptation and application of the principles for the sustainable use of pesticides in a vulnerable ecosystem'	54
LIFE07 INF/E/000852	CHANGING THE CHANGE	LIFE+campaign 'Changing the change'. The Galician agriculture and forest sector facing climate change.	55
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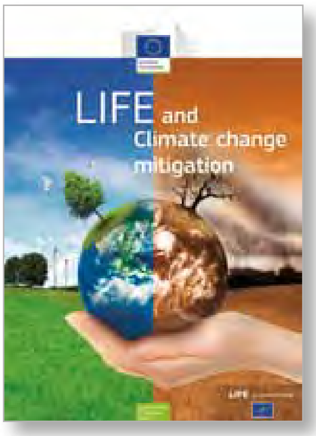

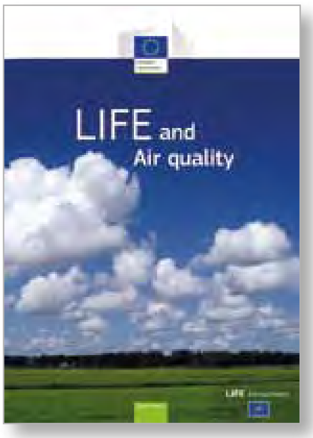

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KH-AJ-15-001-EN-N

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

The LIFE programme is the EU's funding instrument for the environment and climate action

Period covered 2014-2020

EU funding available approximately €3.46 billion

Allocation of funds Of the €3.46 billion allocated to LIFE, €2.59 billion are for the Environment sub-programme, and €0.86 billion are for the Climate Action sub-programme. At least €2.8 billion (81% of the total budget) are earmarked for LIFE projects financed through action grants or innovative financial instruments. About €0.7 billion will go to integrated projects. At least 55% of the budgetary resources allocated to projects supported through action grants under the sub-programme for Environment will be used for projects supporting the conservation of nature and biodiversity. A maximum of €0.62 billion will be used directly by DG Environment and DG Climate Action for policy development and operating grants.

Types of projects Action Grants for the Environment and Climate Action sub-programmes are available for the following:

> "Traditional" projects – these may be best-practice, demonstration, pilot or information, awareness and dissemination projects in any of the following priority areas: LIFE Nature & Biodiversity; LIFE Environment & Resource Efficiency; LIFE Environmental Governance & Information; LIFE Climate Change Mitigation; LIFE Climate Change Adaptation; LIFE Climate Governance and Information.

> Preparatory projects – these address specific needs for the development and implementation of Union environmental or climate policy and legislation.

> Integrated projects – these implement on a large territorial scale environmental or climate plans or strategies required by specific Union environmental or climate legislation.

> Technical assistance projects – these provide financial support to help applicants prepare integrated projects.

> Capacity building projects – these provide financial support to activities required to build the capacity of Member States, including LIFE national or regional contact points, with a view to enabling Member States to participate more effectively in the LIFE programme.

Further information More information on 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/life.htm

Contact

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European Commission – Directorate-General for Climate Action – B-1049 Brussels (clima-life@ec.europa.eu).
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doi:10.2779/429595