Carbon Sequestration & Biodiversity.

*EAF supported implementation of biodiversity objectives that can contribute to emission reduction aims.*
Project Details

FINAL REPORT of project EUCC's Contribution to EU Marine Policy and EU Climate Change Policy / Carbon Sequestration and Biodiversity

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References
I. Summary

The start of this EUCC project has been stimulated by the current lack of recognition and not enough knowledge on the role of biodiversity conservation in Europe for saving carbon sinks. The project aims to demonstrate, when working under the umbrella of EECONET Action Fund (EAF), what are the possibilities to link carbon sequestration to biodiversity conservation. The project focuses on wetlands and grasslands, as these ecosystems are given the highest priority in the objectives of EAF to contribute to stop biodiversity decline in Europe. The project results demonstrate that EAF supported actions on strategic land purchase and restoration measures for biodiversity conservation contribute for saving carbon sinks. The most important impact of EAF projects is that protection and restoration of small areas can ensure avoidance of degradation and sustainable management of much larger areas. The case studies conducted at Tarkhankut Peninsula (Ukraine) and River Mesta (Bulgaria) for linking of biodiversity with carbon sequestration objectives, can be further used as demonstration projects for the development of a carbon sequestration programme under the umbrella of EAF. The case study at Dragoman marsh (Bulgaria) contributes to increased knowledge on carbon sequestration in post restored fresh water marshes and can be further used also for studies in other wetland areas. For the further development of a Carbon Sequestration Programme, we need to identify projects at areas larger than the EAF sites: for this purpose we should use already achieved results within EAF supported projects for the protection of large nature areas or include new threatened areas. When developing and realizing carbon projects at nature conservation areas, knowledge on carbon sequestration needs to be „translated“ into needs of nature conservation. European environmental policies should consider inclusion of carbon funding in biodiversity conservation projects. Restoration and sustainable nature management are both important in order to combine the purposes of biodiversity and carbon sequestration. Therefore, it is substantial that sustainable management and improved management are included in carbon-funded projects.
II. Executive Summary

The start of this EUCC project has been stimulated by the current lack of recognition and not enough knowledge on the role of biodiversity conservation in Europe for saving carbon sinks. The project aims to demonstrate, when working under the umbrella of EECONET Action Fund (EAF), what are the possibilities to link carbon sequestration to biodiversity conservation. To construct this report we focused on wetlands and grasslands, as these ecosystems are given the highest priority in the objectives of EAF to contribute to stop biodiversity decline in Europe. On the longer term the project aims at the development of a Carbon Sequestration Programme under the umbrella of EECONET Action Fund.

The project specific objectives have been as follows:

- Organize a workshop aiming to increase the knowledge and expertise among our EAF-partner NGOs in C&EE on the possibilities to combine biodiversity objectives with carbon sequestration objectives.
- Evaluate the potential for carbon storage in grassland and wetland ecosystems, as these ecosystems have the highest priority in the EAF work and describe measures that contribute as to biodiversity objectives as to emission reduction.
- Estimate the carbon sequestration potential of three pilot sites and propose the development of demonstration projects serving biodiversity and carbon sequestration objectives.
- Describe different EAF conservation sites where there are good opportunities for combining biodiversity conservation goals with improved carbon storage and sequestration capacity.
- Make recommendation for the development of a carbon sequestration demonstration programme and policy recommendations.

For the project purposes we have used local knowledge and worked together with EAF-partner NGOs and scientific experts from C&EE. Desk research and filed research have been applied.

An international workshop on carbon dioxide sequestration and biodiversity was organized by EUCC in cooperation with the Slovakian NGO BROZ. It was held at 9-10 November 2009 in Bratislava. Thirty participants took part, including representatives of EAF partner NGOs from C&EE and also other nature protection and environmental organizations, scientists and authorities. Presentations and discussions were given on the potential of carbon biosequestration for mitigating climate change and the related current policies, funding opportunities for projects on managing carbon in biological systems and carbon sequestration in different ecosystems, representing wetlands, peatlands, grasslands and forests. (The presentations made at the workshop are published on the EAF website – www.eeconet.org - Climate & Biodiversity). Preliminary results made on the identified case studies at Dragoman marsh in Bulgaria and Danube floodplain in Slovakia were presented and further development of demonstration projects was discussed. A particular focus has been put on wetlands, as wetlands restoration and conservation is an important part of the EAF work and although concerning carbon
sequestration they are generally less studied, it is important to understand their role in climate mitigation. Wetlands are difficult for estimating carbon capture and storage; and in particular, there is little known about carbon stock changes of flooded areas. The meeting acknowledged the need for more investigations about changes in carbon capture and storage at restored wetlands. In terms of biodiversity – getting wetlands where they were historically will also increase biodiversity. Conclusions and recommendations were made in regard to developing future projects including carbon and biodiversity components. The general recognition is that in these projects biodiversity should be the core benefit and carbon sequestration should be regarded as a co-benefit.

A general literature overview has been prepared on the potential for carbon storage in grassland and wetland ecosystems, as these ecosystems have received the highest priority in the EAF work. Based on the results of the literature overview, the evaluations during the workshop, and further consultations with local experts of EAF partner NGOs, three pilot sites were identified to carry case studies for estimating the carbon sequestration potential and propose the development of demonstration projects serving biodiversity and carbon sequestration objectives. The following three case studies were carried out:

- Adoption of Sustainable Agriculture Land Management by Farmers at Tarkhankut Peninsula in Crimea Ukraine.
- Carbon Sequestration Potential of Dragoman Marsh (Bulgaria)
- Riparian Forest Restoration and Carbon Sequestration Potential along the Mesta River (Bulgaria)

The 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006) provide tiered methodologies for estimating and reporting of carbon emissions and removals in grasslands and croplands. Within the case study Adoption of Sustainable Agriculture Land Management by Farmers at Tarkhankut Peninsula in Crimea Ukraine, carbon stocks changes are calculated according the methodologies provided in the 2006 IPCC Guidelines.

In wetlands, there are techniques available for detailed carbon studies, but future efforts must address the need for simple and rapid assessment of the carbon stores in wetland ecosystems and the changes in those stores over time. This is an important challenge for the wetlands scientific community. Within the project case study Carbon Sequestration Potential of Dragoman Marsh (Bulgaria), carbon storage and GHG emissions are estimated on base of filed measurements and literature data. Within the project case study Riparian Forests restoration along the River Mesta in Bulgaria, a rough assessment of the sequestration capacity of the riparian forests is made, based on the hypothesis of the net primary production as an indicator for carbon sequestration; species composition and average age of the riparian habitats were determined by experts in the region and also according to the respective forestry plans.

Detailed descriptions of the methods and technics used for carbon stocks calculations are provided within the case studies.

Summary results of evaluation of sites for carbon projects development

The pilot site at Tarkhankut Peninsula in Crimea, Ukraine provides a good example on the impact of EAF supported biodiversity conservation action for achieving of emissions reduction aims. At this site, the EAF supported lease of 200 ha natural steppe area enables the Ukrainian nature conservation NGO USPB to make agreements with local
farmers to manage surrounding agricultural areas of ca 4000 ha in a sustainable way, which contributes to restoration of habitats at depleted agricultural soils. The case study conducted at this site on Adoption of Sustainable Agriculture Land Management by Farmers in Crimea shows decreased GHG emission and increased C sequestration in soil as a result of the restoration of steppe pasture on depleted agricultural lands. The annual GHG emission from the project area is estimated as follows: reduction of GHG emission C equivalent from 9,328.84 tonnes of C equivalent year\(^{-1}\) (baseline scenario) from total area 3,989 ha under current land use to 937.35 tonnes of C equivalent year\(^{-1}\); C sequestration in soil (mainly) over 1,068 tonnes of C equivalent year\(^{-1}\). The total GHG emission balance of the pilot area (3,989 ha) after the project implementation is estimated to be 9,459 tonnes of C equivalent year\(^{-1}\) (e.g. sum emission reduction (9,328.84 – 937.35 tonnes) and carbon sequestration (1,068 tonnes). Carbon sequestration is a co-benefit to the core benefit of biodiversity conservation. The changed land use regime for the carbon project implementation leads to the restoration of rare steppe habitats with up to 70% of steppe pasture similarity of the virgin steppe plant associations and the steppe habitats will be enlarged with 1,024 ha. Steppe habitat restoration leads also to important benefits for the local communities, as increased productivity of the steppe pasture, food safety and others.

At different wetland sites, EAF supported strategic land purchase enabled restoration of the hydrological system of much larger wetland areas. In this way realised restoration and avoidance of degradation of wetlands areas on the longer term ensures protection of their carbon stocks (examples are Slano Kopovo site, Hortobagy National Park, Oder delta Nature Park, Danube Floodplain site and others.) EAF has supported projects on restoration and conservation of different wetland ecosystems, mainly including fresh water marshes, floodplains and peatlands. Therefore we conducted studies to investigate the potential for carbon sequestration at a post-restored fresh water marsh (Dragoman marsh, EAF supported site) and at forested floodplains (Danube floodplain forests, EAF supported site). Seeing the importance of floodplain/riparian forests for carbon storage and sequestration a case study is carried out also at a newly identified site: River Mesta riparian forests in Bulgaria.

The case study at Dragoman marsh in Bulgaria (331 ha) demonstrates the potential of post-restored wetlands to sequester carbon. The estimated carbon sequestration of 147 gC/m\(^2\)/y corresponds to a total of 487 tones of C annually or 1,782 tones of CO\(_2\) annually. If carbon storage in emergent vegetation in the wetland is taken into account, an additional carbon storage benefit of approximately 900 tons would be associated with the vegetative standing crop. Based on these projections, it appears that substantial atmospheric carbon can be stored in the emergent vegetation of restored wetlands. Although carbon stored in vegetation is often viewed as not being permanent and susceptible to loss from disturbances such as fire, vegetative communities quickly re-establish following fire. Given the resilient nature of wetland plant communities, carbon storage in wetland vegetation is an almost immediate and rather constant form of carbon storage. Future research should be conducted to better quantify atmospheric carbon storage in standing crops of plants in restored wetlands.

The case study on riparian forest restoration and carbon sequestration potential along the Mesta River in Bulgaria was selected because riparian forests, with their fast growth rate, provide a sink for atmospheric carbon. Riparian forests are also among the most deteriorated habitats in Europe and Bulgaria.. The study proposes restoration measures for riparian forest habitats from Annex 1 of the Habitats Directive 92/43/EEC: 91E0, 92A0
and 92C0, which are represented along the Mesta and its tributaries and are presently in unfavourable conservation status. The case study shows that the proposed habitat restoration leads to increased carbon sequestration capacity. It is estimated that by year 2020 total carbon sequestration for the whole area (510 ha) will be at least 1,036 t C/y which is 200 t more than in the current situation. Converted into CO₂ sequestration this gives us a sum of 3,797 tones CO₂ annually. But considering the young age of the restored forest growing on stands of improved soil conditions, annual carbon sequestration will increase up to year 2040-2045 when sustainable harvesting of autochthonous tree species could begin. In the process of habitat restoration, carbon sequestration is only a co-benefit along with other ecological and socioeconomic benefits. And the restoration of the riparian habitats should be only one part of the whole strategy for improved river management.

For EAF supported restoration and conservation projects we make an evaluation of practices that contribute as to biodiversity objectives as to emission reduction. This evaluation shows that EAF supported areas are interesting from a carbon perspective due to the conservation practices enhancing sequestration, like converting farm land to natural or semi-natural habitats and introduction of sustainable management practices at areas larger than the EAF sites. Apart of it, several EAF sites, including important for carbon storage wetland types, such as: floodplains, peatlands, salty grounds are briefly evaluated regarding opportunities for carbon projects development. Further research in such areas is needed in order to establish values of carbon sequestration and the management measures that ensure optimal conditions to preserve carbon stores.

Conclusions and Recommendations

The EAF has supported actions on strategic land purchase and restoration measures for biodiversity conservation which contribute also to protect carbon storage. The most important impact of EAF projects is that protection and restoration of relatively small areas can ensure avoidance of degradation and sustainable management of much larger areas.

The case studies at Tarkhankut Peninsula (UA) and River Mesta (BG) can be used as demonstration projects for the development of a Carbon sequestration programme under the umbrella of EAF. The Tarkhankut Peninsula case study can be further used e.g. for the development of steppe restoration projects in Romania. The River Mesta case study treats the very important issue on improved river management and there is a big need of implementation of such projects. Steppe restoration and improved river management are also important issues in current EU environmental policies. The case study at Dragoman marsh contributes to increased knowledge on carbon sequestration in post restored fresh water marshes and can be further used also for studies in other areas, for which close cooperation with the scientific community is needed. In wetlands, future projects should be identified at peatlands, floodplains and salt marshes as these wetland ecosystems are already recognised to play crucial role for carbon storage.

For further development of a Carbon sequestration programme under the umbrella of EAF we need to identify projects at areas larger than the EAF sites, and where possible using already achieved results within EAF supported projects for the protection of larger nature areas and important for carbon storage ecosystems, or include new threatened areas. For our EAF partner NGOs which are managing nature sites, it is very important to get more knowledge and expertise about management practices which influence GHG
emission and carbon sequestration; exchange of expertise and experience are very important. Within new projects development, biodiversity conservation stays our core objective, and carbon sequestration should be considered as a co-benefit together with other socio-economic benefits. When developing and realizing carbon projects at nature conservation areas, knowledge on C sequestration needs to be „translated“ into needs of nature conservation. Apart of it, projects need to be put in a broader context, as community development and sustainable development in order to create incentives for participation and support.

The Carbon sequestration programme under the umbrella of EAF will include Europe-based projects, which will instil European customers with a greater sense of confidence than offsets gained from overseas projects.

European environmental policies should consider inclusion of carbon funding in biodiversity conservation projects. Although a part of a project budget, carbon funding can help that implementation of biodiversity objectives take place. It is also important to show to the public the value of biodiversity preservation for the provision of different ecological services, herewith included carbon storage. Restoration and sustainable nature management are both important in order to combine the purposes of biodiversity and C sequestration. Therefore, it is substantial that sustainable management and improved management are included in carbon-funded projects.

III. Theoretical background. The biological management of carbon in tackling climate: technical potential, international policies and carbon funding.

Carbon storage in terrestrial biological systems

Terrestrial ecosystems play an important role in regulating climate. They store about 2,100 Gt of C in living organisms, litter and soil organic matter; almost three times as much as it is currently present in the atmosphere. Different ecosystem types store different amounts of carbon depending on their species composition, soil types, climate and other features. Loss of or damage to ecosystems reduces their capacity to capture and store carbon. Therefore, maintaining of existing natural carbon reservoirs worldwide is essential if carbon capture and storage is to make a major contribution to climate mitigation. [Trumper, K. et al. 2009., European Commission 2009].

The biological management of carbon in tackling climate change has essentially two components:
• The reduction in emissions resulting from damage of natural ecosystems or unsustainable management practices of human-dominated ecosystems
• The increase of carbon storage in biological systems

The reduction in emissions from biological systems and the increase in their storage of carbon can be achieved in three ways:
• Existing stores could be protected and the current high rate of loss reduced.
• Historically depleted stores could be replenished by restoring ecosystems and soils,
•Potentially, new stores could be created by encouraging greater C storage in areas that currently have little.

There is significant potential for cutting future emissions of greenhouse gases through maintaining healthy ecosystems and restoring degraded environments, in particular by restoring peatlands and wetlands, replanting forests and conservation of natural forests, and reducing other pressures on nature. In addition, semi-natural ecosystems, which are mainly grasslands and managed ecosystems, including those used for agriculture, offer many opportunities for active C sequestration and reduction of emissions. A biological approach to C management offers also different other benefits, as: biodiversity conservation, soil stabilization, water and nutrient availability, reversal of land degradation, etc which in turn will have positive impact on livelihoods of local people.

**International Policies in regard mitigating climate change through biological C management**

Realization of the large technical potential for mitigating climate change through biological carbon management depends on having a suitable policy framework to enable it. The potential of ecosystem carbon management is recognized in the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto protocol through the Land Use Land Use Change and Forestry Sector (LULUCF). Under the LULUCF developed countries must report on carbon stock changes from afforestation, reforestation and deforestation (since 1990) and can also elect to report on additional activities of forest management, cropland and grazing land management and re-vegetation [Robledo, C and Blaser, J. 2008, Trumper, K. et al. 2009.]. But the current land use based mitigation policies do not provide the kind of framework that is required to deliver the necessary incentive mechanisms. Among the shortcomings of the current policy framework are incomplete coverage of carbon sources and sinks as Parties are only required to account for forestry activities. All other activities are voluntary and there is no option for wetland accounting. Other shortcomings are: the requirement to account for managed land only, complex monitoring and reporting requirements and difficulties in factoring out anthropogenic from natural disturbances. Another point is that emissions reductions from the land use sector are not taken into account in the formulation of targets for developed countries, but still can be used to meet them. It is recognized that reducing emissions from deforestation and forest degradation (REDD) is important in all forest biomes – boreal, tropical and temperate – and in economically developed as well as developing countries, but the current international negotiations are focused on reducing emissions from deforestation and forest degradation in developing countries only. This has led many to see LULUCEF as an offset mechanism, rather than one that achieves overall emissions reductions. The creation of a more effective policy framework mainly depends on factors as: a) inclusion of “all lands”, and b) whether the perception of LULUCF can be changed from an offset mechanism to a sector capable of bringing about real reductions in emissions. [Trumper, K. et al. 2009.]

The Council of the European Union recognises the potential role of biodiversity, agriculture and forestry in increasing ecosystem resilience at climate change by providing green infrastructure; it also recognises the role of sustainable forest management in reducing vulnerability of forests [Council of the European Union, Conclusions on Climate change: Towards a comprehensive EU adaptation strategy, 25 June 2009].
The European Commission recognises that amongst the measures to reduce emissions and increase carbon storage in biological systems there are priority “low-cost co-benefit” options that simultaneously contribute to conservation and sustainable use of biodiversity. These options include preservation and restoration of degraded land, forests, peatlands, organic soils, wetlands, reduction in conversion of pastureland, less slash and burn practices and improved grassland management. [European Commission, 2009].

A number of Governments are now introducing legislation to tackle climate change. In the UK, for example, the Climate Change Act sets out a statutory responsibility to quantify natural carbon sinks as a part of the overall carbon accounting process. [Laffoley, D. d’A. & Grimsditch, G. . 2009, Thompson, D. 2008]

Carbon Funding

Financial incentives include non-market instruments such as an international fund and the carbon market. The carbon offset market is split between: compliance markets, and voluntary markets. Compliance offset markets are regulated by mandatory carbon reduction regimes such as: the Kyoto Protocol’s Clean Development Mechanism (CDM), or the EU Emissions Trading Scheme.

To date the Kyoto Protocol allows credits for carbon sequestration solely in forests. The Kyoto protocol requires signatory nations to include emissions and sequestration from afforestation, reforestation and deforestation within their greenhouse gas commitment (Article 3.3.) There are therefore approved methodologies in place for verifying carbon emission and sequestration from forestry. As such, forestry projects are viable in the Kyoto mechanisms, although in the case of Clean Development Mechanism (CDM) there are caps to limit afforestation and reforestation projects. Forestry is not included in the EU Emissions Trading Scheme (EUETS). [Thompson D. 2008, Trumper, K. et al. 2009]

The Kyoto Protocol does not currently allow credits for carbon sequestration in agricultural soils or wetlands. The IPCC (Intergovernmental Panel on Climate Change) have developed methodologies for accounting for emissions and sequestration from cropland and grassland management, which all UNFCCC countries have to include in their annual GHG Inventories. However, inclusion of these measures is currently optional under Article 3.4. of Kyoto. Improved agricultural soil management practices are not eligible in the international compliance C market: The Clean Development Mechanism (CDM)/ and the Joint Implementation (JI) project -based mechanisms/, which are laid down in the Kyoto Protocol.

The voluntary offset markets, not associated with any mandatory regimes, offer companies and individuals the opportunity to purchase carbon offsets on a voluntary basis as a means to compensate for their greenhouse gas (GHG) emissions.

In order to strengthen the credibility of the C offset market, a number of different standards have been developed. Main existing standard systems for carbon offset are:

- CDM Clean Development Mechanism
- VCS The Voluntary Carbon Standard
- GS The Gold Standard
- CCB The Climate, Community and Biodiversity standards
Forestry projects have been central to the voluntary C market from the outset and, until fairly recently, made up the majority of all voluntary projects. However there have been credibility issues relating to the permanence of sequestration, due to fire, pests, disease and land use change. Leakage is also a potential barrier to forestry projects, particularly afforestation on agricultural land, which could displace production elsewhere. There have also been concerns, that some forestry projects have had adverse biodiversity and social impacts. [Thompson, D. 2008]. More recently, standards for forestry projects in the voluntary market have improved through schemes like the GS and CCB which sets higher environmental and sustainability benchmarks. The VCS also includes independently approved methodologies for afforestation and reforestation projects.

Soil management offset projects. Some voluntary schemes allow for the inclusion of soil management offset projects and have developed methodologies for verifying their carbon savings. One international example is the VCS, which includes guidance for Agricultural, Forestry and Other Land Use Projects (AFOLU) [VCS 2007]. If a methodology that can verify carbon savings from the above practices has been approved by the VCS board, then those projects are eligible for VCS credits. The issue of leakage is clearly an important one, which requires full consideration and analysis when contemplating GHG reduction options. It is often cited as a reason to discount any mitigation options, which require land to be taken out of intensive agricultural production [Thompson D. 2008]. As with forestry and peat restoration projects, another key issue is permanency which would need to be addressed through some form of insurance scheme.

Peatlands. Wetlands International operates a Global Peatland Fund for investing in peatland restoration and conservation projects with associated socioeconomic development goals. The Global Peatland Fund supports projects that prevent large quantities of carbon dioxide (CO₂) emissions by protecting and restoring peatlands. Furthermore, it promotes sustainable development through micro-credit and small grants to peatland inhabitants. These projects are designed to generate Voluntary Emission Reductions (VERs), validated by the Voluntary Carbon Standard (VCS) and to also meet the Climate, Community and Biodiversity (CCB) Standards.

IV. Project objectives

Project goal: Under the umbrella of EECONET Action Fund (EAF) we want to demonstrate what are the possibilities to link carbon sequestration to biodiversity conservation, when focusing on grassland and wetland ecosystems.

We focus on wetland and grassland ecosystems as these are given the highest priority in the work of EAF.

(A brief description of the goals and achievements of the EAF is given at point IV of the report)

On the longer term the project aims at the development of a Carbon Sequestration Programme of EECONET Action Fund
Project specific objectives:

1) Organize a workshop aiming to increase the knowledge and expertise among our EAF-partner NGOs in C&EE on the possibilities to combine biodiversity objectives with carbon sequestration objectives.

2) Evaluate the potential for carbon storage in grassland and wetland ecosystems, as these ecosystems have the highest priority in the EAF work and describe measures that contribute as to biodiversity objectives as to emission reduction.

3) Estimate the carbon sequestration potential of three pilot sites and propose the development of demonstration projects serving biodiversity and carbon sequestration objectives.

4) Describe different EAF conservation sites where there are good opportunities for combining biodiversity conservation goals with improved carbon storage and sequestration capacity.

5) Make recommendation for the development of a carbon sequestration demonstration programme.

For the project purposes we tend to use local knowledge and work together with EAF-partner NGOs and scientific experts from C&EE.

V. Project implementation.

*EAF supported implementation of biodiversity objectives that can contribute to emission reduction aims.*

1. Overview on the role of EAF for the protection of European nature heritage. *Restoration and conservation of internationally and nationally important wetland and dry grassland areas in C&EE.*

The EECONET Action Fund (EAF) was established in 1995 with the goal to fund third parties in Central and Eastern Europe to buy or lease important natural sites and undertake urgent actions, as a means of securing biodiversity and landscape protection in order to contribute to the Pan European Ecological Network. After the political changes in C&EE in the 90 ties, agriculture decline on the one hand and intensification of economical activities on the other hand have led to the deterioration of nature areas. Following the restitution of land to small private owners, which are not able or not interested to manage the land, many areas have become abandoned. Hence vegetation succession appeared and led to destruction of wetland and grassland habitats. On the other hand economical changes, as development of intensive agriculture, uncontrolled tourism, etc. negatively affect the natural areas.

Restoration and conservation of internationally and nationally important wetland and dry grassland areas, which are especially important for breeding and migrating birds is the most important contribution of EAF to stop biodiversity decline. Thanks to the strong commitment of the EAF and our local partners, many biodiversity hotspots have been
conserved at the Baltic Sea coast, the Black Sea coast, the Danube basin, in Polesia and other regions in C&EE.

The 15 years operation of EAF has resulted in the protection of more than 160,000 ha of land, in 15 countries. The added value of the EAF work is the important contribution it has provided to the realization of key objectives of the European nature conservation policy, as the establishment of the Pan-European Ecological Network (PEEN) and of Natura 2000 network, creation of new protected areas, stop of biodiversity decline and initiation of local sustainable development (www.eeconet.org).

2. Carbon storage and sequestration in grassland and wetland ecosystems. A general overview.

We focus at the potential for carbon storage in grasslands and wetland ecosystems (including peatlands and floodplain forests) as these are the main ecosystems represented in the work of EAF.

GRASSLANDS

Much of the original area of temperate grasslands has been cleared for agriculture. In Europe, natural grasslands still occur in the Eastern part. Semi-natural grasslands occur throughout Europe and are sustainable ecosystems that have contributed to maintain a high concentration of biodiversity. European grasslands encompass a wide range of habitats that vary greatly in terms of their management, agricultural productivity, socio-economic value and nature conservation status, reflecting local differences in physical environment and economy, the effects of traditional practices and impacts of recent management. Widespread loss of biodiversity, as well as other environmental problems have resulted from agricultural intensification or abandonment. Policies that have contributed to this have been progressively revised, initially by agri-environment schemes, and subsequently through changes in farm support payments and stricter regulatory frameworks, though many threats remain. Grassland biodiversity is both an externality of particular environments and farming systems and also contributes to objectives of multi-functional land-use systems. In addition to meeting species conservation and habitat protection, grassland biodiversity can contribute to enhanced value of agricultural products, as well as to improved ecosystem functions linked to soil and water quality, and resilience to environmental perturbation. [Hopkins, A. and Holz, B., 2006]

Grasslands are a major terrestrial carbon stock which can be increased by appropriate management. Overall, temperate grasslands have low levels of plant biomass compared with forest or shrubland ecosystems. However, soil C sequestration in grasslands is significant, and its effects with respect to climate mitigation are measurable and verifiable. Soil organic C (SOC) of temperate grasslands tends to be higher than those of temperate forests: ca 133 t C /ha. [Fan et al 2008, Amundson, R. 2001] . Locally soil organic carbon composition differs.
Practices that can enhance CO2 sequestration in grasslands

There is clearly a significant anthropogenic component with respect to both current levels of sequestration and emissions of grasslands. Land use change, particularly conversion to agricultural ecosystems, depletes the soil C stock. And land use change which involves taking land out of agricultural production generally results in an increase in the amount of carbon stored in soil and vegetation until a new equilibrium is reached. Large mitigation potential lies also in improved agricultural management: improved grazing land management and the restoration of cultivated organic soils and degraded lands. Traditional models of sustainable management contribute to the preservation of the high ecological value of grasslands, including also preservation of their role as Carbon sinks. [Trumper, K. et al. 2009, Thompson D. 2008]

Sequestration in restored agricultural lands is associated with a high level of uncertainty. There are major concerns with respect to leakage and permanence of sequestration. The issue of leakage connected with creation of agricultural land elsewhere or intensifying of agricultural production elsewhere is of less relevance in relation to land of marginal productivity or where production is in decline anyway for other socio-economic reasons. The concerns about permanence of sequestration can best be addressed through a combination of long term incentives to retain sequestered carbon in the ecosystem combined with capacity building towards management changes that in themselves have sustained benefits without long-term financial gains specifically linked to carbon sequestration. [Trumper, K. et al. 2009, Thompson D. 2008]

Grassland management practices that enhance soil carbon sequestration can also result in enhanced food production, greater biodiversity, improved water management both with respect to quantity (flood control) and quality (reduced pollution of waterway), restoration of degradation. However, more studies and research are required in different agro-ecological zones to quantify such multiple benefits. [FAO, 2009]

The 2006 IPCC Guidelines provide tiered methodologies for estimating and reporting of carbon emissions and removals in grasslands and croplands.

WETLANDS

Wetlands deliver a wide range of critical services. These include food, fiber, biodiversity, water supply, water purification, regulation of water flows, coast protection, carbon storage, regulation of sediment, tourism, recreation and cultural services. Their benefits to people are essential for the future security of humankind, and this depends on maintenance of their extent, natural functioning and ecological character. The degradation and loss of wetlands is more rapid than rates for other ecosystems (Ramsar STRP, 2005). These trends have primarily been driven by land conversion and infrastructure development, water abstraction, eutrophication, pollution and over-exploitation.

Wetlands are different from other biomes in their ability to sequester large amounts of carbon, as a consequence of high primary production and then deposition of decaying matter in the anaerobic areas of their waterlogged soil. In general, the conditions in wetlands lead to the accumulation of organic matter in the soil and sediment, which makes wetlands one of the most effective eco-systems for storing soil carbon. However,
it is very complicated to estimate the actual quantity of carbon stored in wetlands worldwide, because carbon fluxes and pools vary widely in different wetlands. The balance between carbon input (organic matter production) and output (decomposition, methanogenesis, etc.) and the resulting storage of carbon in wetlands depends on several factors such as the topography and the geological position of wetland, the hydrological regime, the type of vegetation, the temperature and moisture of the soil, pH and the morphology. The influence of many factors on the accumulation of carbon in wetlands makes this process a very complex one [Adhikari, S. et al. 2009]. The differences in the carbon storage capacity of different types of wetlands, depending on their morphology, climatic regions and management practices have not yet been studied adequately.

Wetlands may affect the atmospheric carbon cycle in four ways. Firstly, many wetlands especially boreal and tropical peatlands have highly labile carbon and these wetlands may release carbon if water level is lowered or management practices result in oxidation of soils. Secondly, the entrance of CO$_2$ into a wetland system is via photosynthesis by wetland plants giving it the ability to alter its concentration in the atmosphere by sequestering this carbon in the soil. Thirdly, wetlands are prone to trap carbon rich sediments from watershed sources and may also release dissolved carbon into adjacent ecosystems. This in turn affects both sequestration and emission rates of carbon. And lastly, wetlands also release CH$_4$, which has a higher Global Warming Potential than CO$_2$. It is considered, that the overall long-term negative effect of methane emissions is lower than the positive effect of CO$_2$ sequestration [Pritchard, D. 2009]. The complex nature of carbon dynamics in wetlands requires further research, as the role of wetland flux of carbon in the global carbon cycle is still poorly understood.

Wetlands encompass a broad range of ecosystems. Article 1.1 of the Ramsar Convention (Convention on Wetlands, Ramsar, Iran, 1971) defines them as “areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres”. Many wetlands are e.g. forested.

In this section we further look at peatlands, marshes and floodplain forests because of the crucial importance of these ecosystems for the global carbon cycle and also because the conservation of these ecosystems has been widely supported by the EAF work.

**Peatlands.**

Peatlands are the most important long-term carbon store in the terrestrial biosphere. In a pristine state, peat usually remains wet at the surface all year round and will continually accumulate organic matter, sequestering between 0.1-0.5 t C/ha/year (Dawson J. & Smith P., 2007). This is a relatively small amount when compared with carbon sequestration rates in other ecosystems, but due to the anaerobic character and low nutrient availability within peat lands the carbon stocks increase continuously. Peatlands capacity for storage is huge; with estimates suggesting that ~550 Gt of C is stored globally in peat soils [Sabine, C.I. et al. 2004], which is ca 30% of global soil carbon. The worldwide average of carbon stored in peatlands is estimated at ca 1,450 t C per ha [Parish, F. et al. 2008], but there is a wide variability of the characteristics of peatlands at different locations. Peat land areas are globally widespread: in temperate, boreal and tropical climates, but cover a tiny proportion of land area (only 3% of the Earth’s land area), which makes peat land among the most space effective carbon stores (Parish F. et al, 2008, ). Intact peatlands can store up to 1,300 t C per ha, compared to 500-700 t C per
ha in old-growth forests (Pena, 2008). European peatlands alone are estimated to store about 41 billions tonnes of carbon (Byrne et al. 2004). As well as acting as a globally important CO_2 sink and carbon store, peatlands are also a source of GHG.

The wet conditions that enable peat accumulation to occur, also encourage the formation of CH_4 (methane). Many long-term studies of overall CO_2 and CH_4 exchange in temperate and northern peatlands highlight the complex nature of the interaction between the various plant and soil components at work. This complexity and range of variation will complicate any general predictions [Pritchard, D. 2009].

When peatlands are drained, mineralization generates considerable emissions. Great quantities of carbon are currently being lost from drained peatlands and unless urgent action is taken this loss will increase further as the area of drained peatlands (as they are converted for agriculture, plantations and bioenergy) is steadily increasing worldwide. There is uncertainty over the degree of carbon losses from drained peatlands world wide, but in all probability losses are already significant: 0,5-0,8 Gt C per year, which forms a significant fraction of anthropogenic emissions of GHG. (Parish et al. 2008; Verwer et al. 2008)

Marshes.
Salt marshes and tidal marshes play a crucial role in the global carbon cycle. By difference of fresh water wetlands, salt marshes release “negligible amounts of greenhouse gases and store much more carbon per unit area” (Chmura, G. L, 2003) due to salt water soil processes. All tidal marshes are generally net sinks for atmospheric CO_2 through burial of organic matter in sediment; some portion of this carbon is recycled and consequently emitted as CO_2 to the water column and directly to the atmosphere at low tide [Abril G, Borges AV. 2004, PWA 2009]. Thus, the benefits of salt marshes and tidal marshes restoration for carbon sequestration are great and numerous investigations are going on about carbon sequestration in salt marshes and tidal marshes.

Many fresh water marshes often release significant amounts of CH_4, which reduces there role as carbon sinks or they can be a GHG source; but investigations on the influence of different conditions at freshwater marshes on carbon fluxes are limited.

Floodplain/ riparian forests.
Trees grow rapidly in riparian zones due to favourable moisture and nutrient conditions, therefore riparian forests play a significant role in sequestering of carbon. However there is very limited data on carbon sequestration in the specific conditions of floodplain/riparian forests.

In general, temperate forests are active carbon sinks. The overall C store for temperate forests has been estimated at 150 and 320 t/ha, of which plant biomass accounts for ca 60% and soil C - for the remainder. The IPCC default values for temperate forests are a carbon stock of 217 t C/ha of total C, 96 t C/ha of biomass C, and a NPP of 7 t C/ha/year. The IPCC has identified the need for forest-based mitigation analyses that account for natural variability, that use primary data and that provide reliable baseline carbon accounts.

Floodplain soils play a crucial role in the storage of carbon, and thus for the mitigation of climate change, as indicated by the IPCC 2000. Recent studies prove the relevance of floodplains as possible C sinks, which should be increasingly taken into account for river
management (Cierjacks et al. 2010). However, little data are available on C stocks of floodplains in comparison to other terrestrial ecosystems. Remote sensing data have been used for quite some time for the detection of soil characteristics. However, there is still no scientific basis for the generation of large-scale soil maps showing the distribution of organic carbon in floodplain soils which are based on remote sensing and additional data. Suchenwirth, L. et al. (2010), e.g. are currently developing a knowledge-based method to model the spatial distribution of organic carbon stocks in floodplain soils, using very high resolution remote sensing data and the auxiliary information, intended to support large-scale mapping of organic carbon stocks in floodplain soils.

Influence of wetland use and management practices on their GHG emissions or ability to sequester carbon.

Wetland land-use, and discharge, treatment and re-use of wastewater can all have profound effects on emissions and hence on the success of mitigation and adaptation strategies. The most robust generalisation is that degradation and disturbance of naturally-functioning wetlands can be (and already is) a major cause of increased carbon emissions [Ramsar Secretariat, 2007]. When wetlands are drained the once anaerobic soils become exposed to the air. Increased rates of aerobic decomposition in these drained soils will release stored carbon back into the atmosphere as CO$_2$. One of the best documented dimensions of this relates to peatlands, where the delicate balance between anaerobic production and aerobic decay causes them readily to switch from carbon sinks to sources following human interventions.

The Intergovernmental Panel on Climate Change specifically discusses restoration of former wetlands as a strategy to sequester carbon from the atmosphere. The Panel states that restoration of former wetlands will remove CO$_2$ from the air and increase storage in soils. Thus, they recommend wetland restoration as a carbon sequestration strategy. Wetland ecosystems can be restored, but over variable periods of time and with variable resemblance to natural wetland ecosystems One concern with wetland restoration is that many freshwater wetlands emit CH$_4$, which is a powerful greenhouse gas. Peatland restoration is best documented to deliver benefits for carbon storage. Carbon sequestration benefits should result from restoration of areas of other wetland types too, but there are as yet few documented case experiences relating to these.

Peatland degradation is now a major and growing cause of loss of global carbon storage capacity. Any action that would avoid degradation of these wetlands would therefore be a beneficial mitigation option. Peatland restoration and mitigation programmes are beginning in Europe and north America. Studies show e.g. switching of the carbon balance of Finnish cutover peatlands from sources to sinks within a few years of restoration [Pritchard, D. 2009, Erwin, K. 2009]. A UNDP/GEF Project is being implemented on 'Renaturalization and Sustainable Management of Peatlands in Belarus to Combat Land Degradation, Ensure Conservation of Globally Valuable Biodiversity and Mitigate Climate Change’ (www. peatlands.by).

Peatland GHG fluxes tend to have high variability between and within sites and between different management practices, which makes it difficult to produce standard emission factors that are widely applicable. Peat type (nutrient status), disturbances from management and climate are key parameters for estimating and understanding peatland GHG fluxes [Byrne et al, 2004, Thompson D. 2008 ].
The 2006 IPCC Guidelines provide methodologies for estimating and reporting GHG emissions only from certain types of managed wetlands, which include: i) peatlands cleared and drained for production of peat for energy, horticultural and other uses and ii) reservoirs or impoundments, for energy production, irrigation, navigation or recreation. (Emissions from unmanaged wetlands are not estimated). Further, the 2006 IPCC Guidelines indicate where to find the guidance relative for wetlands managed for other uses such as forest and grassland management, or croplands. Some uses of wetlands are not covered, because adequate methodologies are not available; these include among others rewetting of previously drained wetlands or wetland restoration.

3. Project workshop on Carbon Sequestration & Biodiversity

An international workshop on $CO_2$ sequestration and biodiversity was organized by EUCC in cooperation with the Slovakian NGO BROZ. It was held at 9-10 November 2009 in Bratislava. Thirty participants took part, including representatives of EAF partner NGOs from C&EE and also other nature protection and environmental organizations, scientists and authorities.

Presentations and discussions were given on the potential of carbon biosequestration for mitigating climate change and the related current policies, funding opportunities for projects on managing carbon in biological systems and carbon sequestration in different ecosystems, representing wetlands, peat lands, grasslands and forests. Preliminary results made on the indentified case studies at Dragoman marsh in Bulgaria and Danube floodplain in Slovakia were presented and further development of demonstration projects was discussed.

The full report of the workshop is attached to this report. The presentations made at the workshop are published at the EAF website – www.econet.org - Climate & Biodiversity.

A particular focus has been put on wetlands, as wetlands restoration and conservation is an important part of the EAF work and although concerning carbon sequestration they are generally less studied, it is important to understand their role in climate mitigation. Wetlands are difficult for estimating carbon capture and storage; and in particular, there is little known about carbon stock changes of flooded areas. The meeting acknowledged the need for more investigations about changes in carbon capture and storage during restoration of wetlands and at post restored wetlands. In terms of biodiversity – getting wetlands where they were historically will also increase biodiversity.

Conclusions and recommendations were made in regard to developing future projects including a carbon and biodiversity component. The general recognition is that in these projects biodiversity should be the core benefit and carbon sequestration should be regarded as a co-benefit.

- The economic value that can be attached to nature via C sequestration is of great interest for conservation area managers: the issue is important as for getting financing as well as for raising public awareness on the value of biodiversity.
- When developing and realizing carbon projects at nature conservation areas, knowledge on carbon sequestration needs to be „translated“ into needs of nature.
conservation. Apart from that, projects need to be put in a broader context – as community development and sustainable development in order to create incentives for participation and support.

- Restoration and sustainable nature management are both important in order to combine the purposes of biodiversity and carbon sequestration. Therefore, it is essential that sustainable management and improved management are included in carbon funded projects.
- More knowledge and expertise is needed about area management practices in order to store and increase carbon stocks. Tools to assess the sites are needed. Exchange of expertise and experience are very important. - how far are we with knowledge on C sequestration issues and how can we use these knowledge.

4. Evaluation of sites for the development of demonstration projects serving biodiversity and carbon sequestration objectives.

4.1. Case studies at pilot sites

The EAF supported project at Tarkhankut Peninsula, Crimea (Ukraine).

Case study on Adoption of Sustainable Agriculture land Management by Farmers.

The EAF supported project at Tarkhankut Peninsula.

Tarkhankut Peninsula in the Crimea has a rich and unique biodiversity with a high level of endemism. It represents a most biologically important part of the steppe coastal zone. The Peninsula has surface area of 1500 sq.km. The Climate on the area is steppe moderately warm with hot dry summers and soft wet winters. Tarkhankut Peninsula is considered a globally and locally important centre of biodiversity, from the 16 Important Bird Areas (IBAs ) in Crimea, 2 are located on Tarkhankut peninsula. On the whole, more than 100 species of birds live here. This region is significant not only as a nesting ground for many large colonizing and non-colonizing species, but also for migrating, wintering, and moulting birds. During the migration period, the total number of birds can reach 1.5-2 million. The list of rare (globally threatened and near threatened) bird species nesting, wintering and occurring on migration in Crimea includes red-breasted goose, Saker falcon, lesser kestrel, white-tailed eagle, great bustard, Imperial eagle etc.

Currently, main threats for local environment are posed by unsustainable and often illegal farming practices. Intensive cultivation causes fragmentation of natural ecosystems and a continuing decline in species diversity, changes in hydrological processes and decline in the quality of surface and ground water and soil. Digging in some steppe parts is a primary threat factor posing the highest risk and causing irreversible losses of steppe biodiversity. The level of conservation activities in the area does not meet current requirements for sustainable functioning of natural ecosystems in the region. Existing
protected areas cannot assure effective conservation of key rare species and important habitats. It is necessary to extend conservation practices beyond the boundaries of protected areas.

At Tarkhankut Peninsula EAF supports a project on long term lease of a target area of 200 ha. The process of land lease is now ongoing. The Ukrainian Society for Protection of Birds (USPB) is the responsible organisation. The target area is located close to the villages Mezhvodnoe, Vodopoynoe and Zaitsevo /Tarkhankut Peninsula. The sites for lease are located in a region, which is considered as unprofitable agricultural land because local soils are mostly inappropriate for farming, and there is scarcity of fresh water. The lands for lease are categorised as agricultural with low category: accordingly to the Ukrainian system they are categorised as “reserved land” or “land for grazing” and are partially abandoned. The land around Mezhvodnoe is considered as a zone of semi-desert steppe and saline lands. The sites for lease are mostly presented by pristine natural and semi-natural ecosystems, uninhabited area with very little influence from urbanization, transport, intensive agriculture and tourism. The surrounding area contains salt- and brackish lakes (Yarylgach with depth up to 1m, Dzharyylgach with depth up to 0.5m) and areas of natural steppe or semi natural steppe between agriculture lands, which are partly abandoned.

On the longer term, the EAF supported project aims at restoration and conservation of the coastal zone steppe on the Tarkhankut Peninsula. It is essential to save this area as a buffer zone within the future Tarkhankut National Park, protect its steppe and wetlands biodiversity, and create conditions for sustainable use of its resources, as well as development of conditions when local communities are taking benefits, including indirect and direct profit of the area. It is important to use synergic resource management of the area, including the site leased and also the surrounding agricultural lands and wetlands, when widely involving rural communities. In this order, USPB is planning to contract local farmers to manage their agricultural lands in a sustainable way, that is favourable for conserving the rare steppe biodiversity. The total area, at which USPB will in this way introduce sustainable agriculture land management practices is ca 4000 ha.

At this site of ca 4000 ha we have conducted a pilot study to demonstrate how restoration of steppe pasture on depleted arable lands influences GHG emission and carbon storage.

It is important to note the EU funded project on Sustainable Integrated Land Use of the Eurasian Steppe, implemented in Ukraine, www.steppe.org.ua, which explores the opportunities to apply carbon land use change projects as a tool for steppe restoration.

Adoption of Sustainable Agriculture Land Management by Farmers.

Action Aims of the Carbon project
- To demonstrate potential of the carbon market financing for nature conservation activities funding
- To contribute greenhouse gasses emission reduction by the establishing of “green” infrastructure (restore steppe pasture on depleted arable lands)
- To contribute to climate change mitigation and risk reduction by the adoption of land use practices by local farmers with respect of the biodiversity conservation needs (e.g. crops rotation with respect to support wintering populations of geese and great bustard)
- To contribute to steppe biodiversity preservation by improving the quality of existing habitats and the restoration of habitats on depleted arable lands (e.g. steppe pasture proper management, including rotation grazing, haymaking and controlled burning).

Case Study Assumptions

The following assumptions have been used for this case study:

- The case study used default factors for GHG emission reduction evaluation. The country and project specific factors value have to be developed in the future for each carbon & biodiversity project;

- The default factor values were used for a period of 20 years and all calculations are made for that period;

- The case study is not evaluating the following parameters, which have to be evaluated within carbon projects: (1) \( \text{N}_2\text{O} \) and \( \text{N}_2\text{O-N} \) emissions from the crops, (2) C stocks in litter and biomass;

- The case study is not evaluating cropland converted to grassland (which principally has to be evaluated for carbon projects)

- The case study is not defining leakage and additionality, which also has to be defined in each carbon project;

- The case study is not evaluating associated GHG emissions from fossil fuel combusting.

GHG Emission Reduction Evaluation

Applicability Conditions with Respect of C Emission Reduction

The project introduces sustainable agriculture land management practices into an agricultural landscape with respect of GHG emission reduction and biodiversity conservation needs, accordingly to the following conditions:

The project conservatively assumes that the lands of a given land use type would degrade in the absence of the project. Specifically it is likely that:

- If the land is cropland, then it will remain cropland in the absence of the project; otherwise
- The land is grassland that will remain grassland or be converted to croplands in absence of the project.
Applicability conditions ensures that, in absence of the project, the land would likely not have been:
- Abandoned and allowed to naturally regenerate, or
- Afforested or reforested.

With these applicability conditions the project can assume that the soil organic carbon would remain constant or decrease with time in absence of the project.

Applicability conditions mean that there is no increase in methane and nitrous oxide emissions from grazing animal as a result of the project.

Displacement of biomass from outside the project boundary to within the project boundary may cause the loss of carbon stocks outside the project boundary (if this biomass would not be burnt in absence of the project). This is a potential source of leakage.

Displacement of manure from outside the project boundary to within the project boundary may cause the loss of carbon stocks and/or increased used of nitrogen based fertilizers outside the project boundary. These are potential sources of leakage.

**Baseline Scenario**

The project area is located at Tarkhankut Peninsula, in Chornomorskyi rayon, Crimea, Ukraine (Map 1). The project area includes 52 sites (Map 2). It is located in warm dry climate zone. The sites area, types of management regimes, types of soil are presented in table 1 below and at Map 3.

The Google Earth image is used for fields’ boundaries and type of land use determination. Field data is used for the verification of the type of land use for each field and to define current crops structure of the pilot area. ArcGIS software is used to digitalize fields’ boundaries and to calculate the area of each plot. The existing soil map (inventory 1970) is used to prepare the soil map of the pilot area.

The calculations and equations used for the purpose of this case study are presented in an separate file in Excel format (see Annex 2a-c).

The key assumptions made for the case study calculations are as follows:
- The initial amount of organic carbon in mineral soil is 38 tones C ha⁻¹, in 0-30 cm depth;
- Use default value of management, input and land use factors for baseline scenario;
- Use default value of management, input and land use factors for project scenario;
- No evaluation of carbon stocks on cropland converted to grassland
Map 1. Case Study Area, Crimea, Ukraine. Legend: “green plots” – Cropland Remaining Cropland; “grey plots” – Grassland Remaining Grassland; “brown plots” – Cropland Converted Grassland; yellow line – boundaries of plots; figures - # of plot (see Table 1.)

Map 2. Case Study Representative Areas, Crimea, Ukraine. Legend: read line – boundary of each plot; figures – area of plot in ha (see Table 1.)
Table 1. Current land use, management and input status of the project site(s) (default period – 20 years).

<table>
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<tr>
<th># of site</th>
<th>Area, ha</th>
<th>Type of soil, IPCC 2006</th>
<th>Management regime, default IPCC 2006</th>
<th>F_{LU}</th>
<th>F_{MG}</th>
<th>F_{I}</th>
<th>Soil Organic C Stocks for mineral Soils (tones C ha^{-1}, in 0-30 cm depth)</th>
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1 See Soil Maps attached for project area.
2 CRC set aside – arable land currently neglected/abundant.
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<td>HAC soils</td>
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</tbody>
</table>
Table 2. Annual C stocks in the project area: baseline scenario (use default factors value for period 20 years).

<table>
<thead>
<tr>
<th>Sources of GHG emission</th>
<th>Sites total area, ha</th>
<th>Type of GHG</th>
<th>C stocks in different pools [tonnes ha(^{-1})]</th>
<th>Subtotal C stocks, [tonnes ha(^{-1})]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cropland Remaining Cropland</td>
<td>2248.018</td>
<td>CO(_2)</td>
<td>1.5576 Not evaluated - - 0.3770</td>
<td>1.9346</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CH(_4)</td>
<td>0.0028 - - -</td>
<td>0.0588(^3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N(_2)O</td>
<td>0.000072 Not evaluated - Not evaluated</td>
<td>0.02232(^4)</td>
</tr>
<tr>
<td>TOTAL for Cropland Remaining Cropland</td>
<td>2248.018</td>
<td>CO(_2)</td>
<td>2.1816 Not evaluated Not evaluated 0.5700</td>
<td>2.7516</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CH(_4)</td>
<td>0.0039 - - -</td>
<td>0.0039</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N(_2)O</td>
<td>0.0001 Not evaluated -</td>
<td>0.0001</td>
</tr>
<tr>
<td>TOTAL for Grassland Remaining Grassland</td>
<td>1741.122</td>
<td>CO(_2)</td>
<td>Not evaluated Not evaluated 0.5700</td>
<td>2.7556</td>
</tr>
</tbody>
</table>

Note: AG – above-ground biomass (burning); BG – below-ground biomass; GHG – greenhouse gas;

**Baseline scenario**: the annual GHG emission from the project area can be estimated in 9,328.84 tonnes of C equivalent year\(^{-1}\) from total area 3,989 ha under the current land use.

\(^3\) CH\(_4\)/CO\(_2\) factor = 21  
\(^4\) N\(_2\)O/CO\(_2\) factor = 310
**Project Scenario**

Table 3. Annual C stocks in the project area: project scenario (use default factors value for period 20 of years).

<table>
<thead>
<tr>
<th>Sources of GHG emission</th>
<th>Sites total area, ha</th>
<th>Type of GHG</th>
<th>C stocks in different pools, tonnes ha⁻¹</th>
<th>Subtotal C stocks tonnes ha⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cropland Remaining Cropland</td>
<td>1 207.39</td>
<td>CO₂</td>
<td>0 Not evaluated Not evaluated</td>
<td>0,7766</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CH₄</td>
<td>0 - - -</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N₂O</td>
<td>0 Not evaluated - Not evaluated</td>
<td>0</td>
</tr>
<tr>
<td><strong>TOTAL for Cropland Remaining Cropland</strong></td>
<td></td>
<td></td>
<td></td>
<td>0,7766</td>
</tr>
<tr>
<td>Cropland Converted Grassland</td>
<td>1 024,14</td>
<td>CO₂</td>
<td>Not evaluated Not evaluated Not evaluated</td>
<td>- 0,3866²</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CH₄</td>
<td>Not evaluated Not evaluated Not evaluated Not evaluated</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N₂O</td>
<td>Not evaluated Not evaluated Not evaluated Not evaluated</td>
<td>-</td>
</tr>
<tr>
<td><strong>TOTAL for Cropland Converted to Grassland</strong></td>
<td></td>
<td></td>
<td></td>
<td>-0,3866</td>
</tr>
<tr>
<td>Grassland Remaining Grassland</td>
<td>1 741,12</td>
<td>CO₂</td>
<td>0 Not evaluated Not evaluated</td>
<td>-0,3866</td>
</tr>
<tr>
<td></td>
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<td>CH₄</td>
<td>0 - - -</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N₂O</td>
<td>0 Not evaluated - Not evaluated</td>
<td>0</td>
</tr>
<tr>
<td><strong>TOTAL for Grassland Remaining Grassland</strong></td>
<td></td>
<td></td>
<td></td>
<td>-0,3866</td>
</tr>
</tbody>
</table>

Note: AG – above-ground biomass (burning); BG – below-ground biomass; GHG – greenhouse gas;

**GHG Emission Project Balance**

The annual GHG emission from the project area can be estimated as follows:
- Reduction of GHG emission C equivalent from 9,328.84 tonnes of C equivalent year⁻¹ (baseline scenario) from total area 3,989 ha under current land use to 937.35 tonnes of C equivalent year⁻¹;
- C sequestration in soil (mainly) over 1,068 tonnes of C equivalent year⁻¹.

The total GHG emission balance of the pilot area (3,989 ha) after the project implementation is estimated to be 9,459 tonnes of C equivalent year⁻¹ (e.g. sum emission reduction (9,328.84 – 937.35 tonnes) and carbon sequestration (1,068 tonnes)).

This GHG emission reduction estimation is based on default factors value. The project’s specific factors value have to be determined in order to have more accurate estimation of the GHG emission reduction.

The detailed calculations are given as Annexes 2a-c.

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² By the end of 20 years period (value use only for this case study as an assumption, that cropland will have grassland parameters by the end of 20 years period.)
Benefits for Biodiversity Conservation

The following benefits can be defined for biodiversity conservation due to the land use change in the frame of a carbon project implementation:

- **Funding**: sale of ERUs (Emission Reduction Units) can be a source of sustainable investment for nature conservation activities and implementation of the site management plans. Current price of 1 tonne of CO$_2$ equivalent is up to 11 Euro (e.g. potential annual income from carbon trade can be up to 50 Euro per ha over long period of time – 20 years and more);

- **Site management**: changed land use regime for the carbon project implementation purpose is complementary with nature conservation site management, e.g. site management for climate change mitigation will serve as site management plan for biodiversity (improvement of steppe pasture, optimization of crops rotation, improve site quality of wintering (great bustard, geese) and breeding populations of birds due to enlarging habitats mosaic etc);

- **Steppe habitats restoration**: the changed land use regime for the carbon project implementation will lead to the restoration of rare steppe habitats with up to 70% of steppe pasture similarity of the virgin steppe plant associations (for this case study). For example, in this case study the steppe habitats will be enlarged for 1,024 ha.

Benefits for local communities

The following benefits for local communities can be defined:

- Increased productivity of pasture (steppe pasture for this case study) at least for 2 - 4 tonnes per ha, which will lead to increasing the amount of ERUs for sale;

- Improved quality of depleted soils for future food safety and cost of the land due to depleted arable lands converted to grassland;

- Increased number of livestock and their productivity due to improved pasture;

- Increased pasture resistance to the dry years or seasons, which give additional benefits for livestock farming.
CARBON SEQUESTRATION POTENTIAL OF DRAGOMAN MARSH

As EAF plays an important role for restoration of fresh water wetlands, we have considered research to assess carbon removals and emissions at a recently restored freshwater marsh: Dragoman marsh in Bulgaria. The EAF support for the restoration of Dragoman marsh started in year 2000. It included support for land purchase and for restoration measures. The Bulgarian NGO responsible is Balkani Wildlife Society (BWS). Now Dragoman marsh area is one of the few restored wetlands in Bulgaria and it is a Natura 2000 site. Dragoman marsh site is characterized with rich biodiversity: wet meadows with specific boreal flora as – Salix rosmarinifolia, Plantago maxima, Viola Pumila, Fritilaria meleagroides; a unique steppe sub-mediterranean flora at Chepan Hill; 226 species of birds, 126 breeding.
The goal of this study was to estimate the potential of restored, previously farmed wetland, as a means to sequester atmospheric carbon.

Site description
The Dragoman Marsh is the biggest karst marsh in Bulgaria (A= 331 ha). It is an endoreic basin situated at mid altitude (705 m.a.s.l.) and is characterized with mean alkalinity (4.1 µeq/l) levels. The marsh was partly drained in the 1930s, with a complete transition to arable land in the 1950s. The drainage canals remained the only permanent waters in the region, and acted as a refuge for the remaining flora and fauna. Restoration actions have started since the end of the 1990s.

Methods

Net aerial primary productivity (NAPP) of *Phragmites australis* (Cav.) Trin ex Stend. and *Ceratophylum submersum* L. was estimated by harvesting the biomass at the end of the growing season (mid of October 2009) at selected stations in the two associations. At each sampling, the above-ground biomass of green shoots was determined, 30 stems were cut, oven-dried at 85 °C for 48h to constant mass and weighed. The average shoot biomass was calculated by dividing the total weight of the shoots to the shoot number. The product of the average shoot number and average shoot biomass per square meter is taken to be the estimated peak biomass and hence annual above-ground productivity.

The Productivity of *Thypha latifolia* L., *Typha angustifolia* (L.), *Scoenoplectus lacustris* agg and *Carex* spp. (Cyperaceae) is assessed on the basis of data cited in the literature and the area of the associations in the marsh.

The phytoplankton primary production is assessed according to the oxygen “light and dark” enclosures method [Winberg, 1960; Chromov & Semin 1975]. The bottles were incubated “in situ” at depth of 20cm.

The Net Community Metabolism is estimated according to the diurnal oxygen curve method. The oxygen dynamics are followed at 5 depth intervals in the drainage canals (0.1m, 0.25m, 0.5m, 0.8m and 1m), as well as at 0.2m in the open waters with submerged macrophyta vegetation. A coefficient of 0.375 is used for conversion from oxygen to carbon units. We take the average carbon content of plant material to be 46% (2.15 mg organic matter / mg organic carbon) as recommended by Winberg & Lavrentieva, (1984). The concentration of chlorophyll-a is determined according to ISO 10260.

In the canals draining the marsh, gas bubble formation was quantified with subsurface bubble collectors (area 0.03 m²) fastened to the canal-lock. The gas collections lasted 4 days and the volume of trapped gas was checked from the displacement of water in a measuring cylinder. Methane and carbon dioxide concentrations of bubble gas was determined with Dräger X-am 7000 gas detector.
on 24 October 2009 from gas trapped in bubble collectors after disturbing the sediment.

Results and discussion

Net aerial primary productivity

Restoration of wetlands and re-establishment of their hydrology and vegetation restores the wetlands functions in time and space. One of those functions is the net primary productivity (NPP) of a wetland macrophyte community. Productivity reflects the general health of the wetland community and its trophic status.

The assessment of the vegetation in a newly created wetland through the measurement of NPP – and not only the estimation of plant structure such as diversity and cover – provides essential data on the functional capacity of a site.

The producers of organic matter, in the Dragoman Marsh, could be divided to three main groups: emergent and submergent vegetation and phytoplankton. The emergent vegetation is the most important, with dominant associations of Phragmites australis (Cav.) Trin ex Stend., Thypha angustifolia (L.)/ Thypha latifolia (L.) and Schoenoplectus lacustris (L.) Palla 1888, among others.

The net productivity of Phragmites australis, which spreads approximately to 13% of the area of the marsh, or 43 ha, is $1100 \pm 141 \, \text{g DM/m}^2/\text{y}$ (or $601 \pm 64 \, \text{g C/m}^2/\text{y}$). We have estimated only the above ground production of the Phragmites association. If we assume, that approximately 40% of the produced organic matter is stored as below ground structures (in the perennial rhizomes) and that another 20% are used to meet the energy requirements of the plants (Alimov, 1989), then, the gross primary production of the reeds in the marsh reaches $\approx 1760 \, \text{g DM/m}^2/\text{y}$ (or $802 \, \text{g C/m}^2/\text{y}$). Net aerial primary productivity of reeds is estimated to be $755 \pm 97$ tones organic matter ($345 \pm 44$ tones organic carbon) annually. The estimated primary productivity of reed beds is by 43% lower, compared to the estimates of Baeva (1994) for “Srebarna” reserve, and half of the assessed by Kochev (1983) and Kochev & Yordanov (1981) in a marsh close to Batin village. This is probably due to the early stages of formation of the reeds in Dragoman Marsh, as well as to the altitudinal difference between the investigated areas (both mentioned sites are situated at the Danube River at approximately 80 m a.s.l.).

The associations of Thypha latifolia and Thypha angustifolia have similar productivity to the beds of Phragmites australis – the annual production of the above ground biomass is on average $1310 \, \text{g DM/m}^2/\text{y}$ (or $597 \, \text{g C/m}^2/\text{y}$). The gross primary production of the association accounts for $2100 \, \text{g DM/m}^2/\text{y}$ (or $955 \, \text{g C/m}^2/\text{y}$). The net aerial primary productivity of cattail is $1446$ tones organic matter (or $659$ tones organic carbon) annually (taking into account the aerial extend of cattail – 69ha). The assessment of the primary production is based on average productivity sited in the literature [Dykyjova et al. 1971; Dykyjova et al. 1972; Kochev, 1983; Baeva, 1994]. The results are approximately 60% of the annual productivity of a mature marsh (Aldomirovci) located close to Dragoman site [Kochev, 1983; Kochev & Yurukova,
Taking into account the observed differences in the productivity of *Phragmites australis* and the short time passed after the restoration of the marsh, we suppose that these figures are adequate representation of the average *Thypha* sp. productivity.

The area of Dragoman Marsh overgrown by *Schoenoplectus lacustris* is assessed at approximately 60 ha, with average production into the above ground parts of 1220 g DM/m²/y (or 556 g C/m²/y). The gross primary production of the species accounts for 1952 g DM/m²/y (or 890 g C/m²/y). The net aerial primary productivity of club-rush is 1170 tones organic matter (or 534 tones organic carbon) annually. This production is approximately 80% of the sited by Kochev (1983) for the Aldomirovci Marsh.

The area of Dragoman Marsh overgrown by different species of family *Cyperaceae* is approximately 42 ha, with annual production of 118 g DM/m²/y (or 54 g C/m²/y). The gross primary production of the species accounts for 189 g DM/m²/y (or 86 g C/m²/y). The net aerial primary productivity of the sedges is 79 tones organic matter (or 36 tones organic carbon) annually.

The production of the submerged aquatic vegetation plays secondary role to the production of the emergent vegetation. Despite this fact, the small depth of the water in the marsh and the favorable light regime promote the development of dense submerged macrophyta beds. The development of the submerged aquatic plants is limited only in the deepest parts of the marsh and mainly in the drainage canals. The area of the marsh occupied by the *Ceratophyllum submersum* association is 117 ha, with annual production of 485 ± 177 g DM/m²/y (or 221 ± 81 g C/m²/y). The gross primary production of the submerged aquatic vegetation is 776 ± 284 g DM/m²/y (or 354 ± 129 g C/m²/y). The net aerial primary productivity of submerged macrophytes in the marsh is assessed at 908 ± 332 tones organic matter (or 414 ±151 tones organic carbon) annually.

In this study we have not determined the productivity of peri- and metaphyton, but their overall impact should be included into the productivity of submerged vegetation and phytoplankton. Another group of producers, with significant impact to the overall productivity of the marsh is the phytoplankton. We have assessed the gross primary production of phytoplankton (GPP) in the drainage canals at 3.45 g organic C/m²/d, and the average community respiration for the whole depth profile (CR) is 3.46, giving a ratio of GPP/CR = 0.99. A comparison between the net phytoplankton production, assessed according to the light and dark enclosures method (L-D), community metabolism (CM) and corrected for diffusion community metabolism (CMcor) is presented at fig. 1.
Figure 1. Comparison between the net phytoplankton production: light and dark enclosures method (L-D), community metabolism (CM) and corrected for diffusion community metabolism (CMcor).

The net primary production (NPP = 0.75 gO2/m3/h) of the phytoplankton represents 98% of the total community metabolism and 104% of the corrected CM. Apparently, we have overestimated the role of diffusion, as we used fixed tabular values of the diffusivity constant. Based on these results, we can say that the estimated value for the net primary production in the deep canals is defined mainly by the production of the phytoplankton and in much lesser extent by the submerged vegetation. The estimated NPP corresponds to 39.8 ± 11.7 mg/m³ Chl-a in the phytoplankton, while the amount in the interior of the marsh is 5.33 ± 1.4 mg/m³ chlorophyll-a Chl-a. If we assume, that similar to other studied communities (Vassilev et al., 2001), the amount of oxygen produced per amount of Chl-a is constant, then the PP of phytoplankton among the submerged aquatic plants in the lake should be 0.08 gO2/m³/h. The later value corresponds to 5.8% of the estimated CM value (1.38 ± 0.33 gO2/m³/h) in these biotopes.

The average area of open water in the marsh is 117 ha, of which the area of the drainage canals is 1%. Thus, if we assume that the rate of production does not change significantly throughout the year, the net primary production of the phytoplankton in the open waters should be approximately 44 tones organic carbon (or 117.8 tones organic matter) annually, and in the drainage canals − 5.5 and 14 tones respectively. This assumption probably underestimates the summer development of the phytoplankton in the marsh and, consequently, the annual production of the phytoplankton.

Assessment of the green house gases emissions

In the deep waters of the draining canals, the gas emissions by ebullition were measured (Table 1). No values for plant-mediated CH₄ emissions were obtained, but according to the findings of Kankaala et al. (2004) this emissions could even exceed the ebullition rate. The maximum ebullition rate is during the active growth season.
The proportion of CH$_4$ released in winter is usually < 10% of annual emissions from temperate lakes [Kankaala et al., 2004].

Table 1: Assessment of the daily rate of gas emissions by ebullition in the deep canals of the marsh.

<table>
<thead>
<tr>
<th>Avrg</th>
<th>CH$_4$</th>
<th>CO$_2$</th>
<th>O$_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>117.5</td>
<td>6.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Stdev</td>
<td>12.6</td>
<td>0.7</td>
<td>0.1</td>
</tr>
</tbody>
</table>

The estimated open-water period emission of methane from the Dragoman marsh is ca. 95295 kg/y, or 287 kg/ha/y. If we assumed equal share between plant mediated and ebullition rate, and a 10% of winter release of CH4, then the annual methane emissions would be ca. 633 kg/ha/y. This figure is comparable to the 701 kg/ha/y found by Kankaala et al., (2004) for total annual emission of methane from the littoral zone of lakes.

The estimated open-water period emission of carbon dioxide from the Dragoman marsh is ca. 5 070 kg/y, i.e., 15.3 kg/ha/y.

Storage of carbon

The primary production of macrophyte communities can be diverted to: consumption by herbivores, accumulation biomass with subsequent transition to the degradable detrital compartment over the plant life span (Cebrian, 1999). Most of the detritus undergoes decomposition within the community, with a small fraction of recalcitrant detritus escaping from further degradation and entering the refractory compartment (Schlesinger, 1997). The accumulation of refractory organics form the sediment organic carbon (SOC), which reflects the amount of carbon sequestered by the wetland over long term scale.

In addition to replenishment of SOC stocks, the vegetative community that rapidly develops in restored wetlands represents an additional pool of sequestered carbon (Euliss et al., 2006). Wetlands are highly productive, and the standing biomass of aquatic plants in Dragoman Marsh varies between 1.8 and 20 t/ha, depending on the species. In Table 2 we have presented the annual values of production and decomposition of the major associations in the marsh. Based on the work of Cebrian (1999) we have calculated the decomposition of biomass and the accumulation of refractory detritus in the marsh. The percentage of primary production channelled as refractory detritus is taken to be 35% of the emergent macrophyte species, 2% of the submerged species and 0.5% of the phytoplankton production. These figures reflect the amount of coarse material and the turnover rate of the biomass.
Table 2. Production (P), decomposition (D) and accumulation of refractory carbon (R) in Dragoman marsh. Phytoplankton 1 – rates of the phytoplankton community in the drainage canals; Phytoplankton 2 – rates of the phytoplankton community in the open waters/aquatic macrophyte beds.

<table>
<thead>
<tr>
<th>communities</th>
<th>P gC/m²/y</th>
<th>D gC/m²/y</th>
<th>R gC/m²/y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phragmites</td>
<td>802</td>
<td>521,3</td>
<td>280,7</td>
</tr>
<tr>
<td>Typha</td>
<td>955</td>
<td>620,75</td>
<td>334,25</td>
</tr>
<tr>
<td>Schoenoplectus</td>
<td>890</td>
<td>578,5</td>
<td>311,5</td>
</tr>
<tr>
<td>Cyperacea</td>
<td>86</td>
<td>55,9</td>
<td>30,1</td>
</tr>
<tr>
<td>Ceratophillum</td>
<td>354</td>
<td>346,92</td>
<td>7,08</td>
</tr>
<tr>
<td>Phytoplankton 1</td>
<td>0,28</td>
<td>0,2786</td>
<td>0,0014</td>
</tr>
<tr>
<td>Phytoplankton 2</td>
<td>3,45</td>
<td>3,43275</td>
<td>0,01725</td>
</tr>
</tbody>
</table>

Most of the production of the different communities is channeled as detrital production, which is consistent with previous results in different communities [Schlesinger, 1977; Mann, 1998; Cebrian and Duarte, 1998]. Our results show that the biomass with coarse structure stores more refractory carbon in the sediments. This indicates that deep lakes and marshes with big areas of open waters are smaller carbon sinks because they favor the development of submerged and planktonic communities, which biomass is more palatable for herbivores and decomposers [Enriquez et al. 1993].

In order to assess the overall carbon storage in Dragoman Marsh, we have weighted the production, decomposition and accumulation of refractory carbon according to the area of the marsh that each community occupies. The weighted values are given in Table 3.

Table 3. Area weighted values for production (P), decomposition (D) and accumulation of refractory carbon (R) in Dragoman Marsh. Phytoplankton 1 – area weighted rates of the phytoplankton community in the drainage canals; Phytoplankton 2 – area weighted rates of the phytoplankton community in the open waters/aquatic macrophyte beds. C ebullition – represents both CH₄ and CO₂ ebullition expressed as CO₂-carbon. C sequestration – the difference between total refractory carbon and C ebullition.

<table>
<thead>
<tr>
<th></th>
<th>P gC/m²/y</th>
<th>D gC/m²/y</th>
<th>R gC/m²/y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phragmites</td>
<td>104,26</td>
<td>67,769</td>
<td>36,491</td>
</tr>
<tr>
<td>Typha</td>
<td>200,55</td>
<td>130,3575</td>
<td>70,1925</td>
</tr>
<tr>
<td>Schoenoplectus</td>
<td>160,2</td>
<td>104,13</td>
<td>56,07</td>
</tr>
<tr>
<td>Cyperacea</td>
<td>11,18</td>
<td>7,267</td>
<td>3,913</td>
</tr>
<tr>
<td>Ceratophillum</td>
<td>123,9</td>
<td>123,2805</td>
<td>0,6195</td>
</tr>
<tr>
<td>Phytoplankton 1</td>
<td>0,09492</td>
<td>0,0930216</td>
<td>0,0018984</td>
</tr>
<tr>
<td>Phytoplankton 2</td>
<td>0,0345</td>
<td>0,03381</td>
<td>0,00069</td>
</tr>
<tr>
<td>Total</td>
<td>600</td>
<td>433</td>
<td>167</td>
</tr>
<tr>
<td>C ebullition</td>
<td></td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>C sequestration</td>
<td></td>
<td></td>
<td>147</td>
</tr>
</tbody>
</table>
The estimated carbon sequestration of 147 gC/m²/y corresponds to a total of 487 tones of C annually or **1,782 tones of CO₂ annually**. If we take into account the carbon storage in emergent vegetation in the wetland, an additional carbon storage benefit of approximately 900 tons would be associated with the vegetative standing crop. Based on these projections, it appears that substantial atmospheric carbon can be stored in the emergent vegetation of restored wetlands. Although carbon stored in vegetation is often viewed as not being permanent and susceptible to loss from disturbances such as fire, vegetative communities quickly re-establish following fire. Given the resilient nature of wetland plant communities, carbon storage in wetland vegetation is an almost immediate and rather constant form of carbon storage.

Future research should be conducted to better quantify atmospheric carbon storage in standing crops of plants in restored wetlands.

To put this into perspective, Dragoman wetland has the potential to sequester (as refractory carbon only) transportation-related CO₂ emissions equivalent to 10.8 million kilometres annually. If we assume an average of 15000 km/y/car, this represents sequestration of CO₂ released by 720 cars!

Here we demonstrated the potential of restored wetlands to sequester carbon. It is important to remember that the restoration of wetlands provides more ecosystem services ancillary to carbon sequestration, such as reduction in soil erosion, improved water quality, floodwater storage, and wildlife habitat and recreation [Knutsen and Euliss, 2001]. Given the strong environmental concerns of modern society, Gleason et al. (2005) (suggest) suggests that the best approaches to carbon sequestration in wetland settings should be those that would store carbon without negatively impacting any of the other ecosystem services provided by restored wetlands.
The site is not an EAF supported one, and the study has been a part of our strategy to identify new areas, which are threatened and where pilot carbon projects can take place. For the developing of this case study we cooperated with Balkani Wildlife Society, which is an EAF partner NGO. The site has been selected as riparian forests are assumed to play a crucial role in the global carbon cycle.

The goal of this study is to estimate the potential for carbon sequestration of restored riparian forests along the Mesta River and its tributaries in Bulgaria.

Theoretical background

With their fast growth rate, riparian forests provide a sink for atmospheric carbon. Riparian forests are also among the most deteriorated habitats in Europe and Bulgaria. Restoration of riparian forests has been identified as a priority area for action in international and regional policies, derived from both:

- the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC or FCCC), aimed at fighting global warming and

Identifying optimal measurements for habitat restoration demands an ecosystem approach for monitoring and sustainable maintenance (meaning balance between effective carbon sequestration and biodiversity conservation for a long period of time). Every component of the system takes its part in carbon cycle which is the basis for calculating the sequestration capacity of the forest. Moreover, the riparian habitat is characterized with specific microclimate and soil conditions of higher humidity and is influenced by near surface groundwater dynamics [Kutsch et al, 2001]. The ecosystem approach presumes establishing the carbon pools and paths between the different components of the system. Generally, carbon is fixed in photosynthesis and switched in the phytomass (this is the primary production of the ecosystem) on one hand, and stored into the soil humus on the other. According to Odum (1986) in the forests of the temperate latitudes almost half of the organic carbon in the whole system is hold in the soil humus. The quantity of carbon in wood is similar and much smaller part is that of tree leafs and mould ($A_0$ soil horizon). The respiration of the system is the second important parameter (first is CO$_2$ fixation) that refers to C sequestration.

Site description

Mesta (Bulgarian: Места) or Nestos (Greek: Νέστος) is a river in Bulgaria and Greece. It rises in the Rila Mountains and flows into the Aegean Sea near the island
of Thasos. The length of the river is 230 km, of which 126 km in Bulgaria and the rest in Greece. It forms some gorges in Rila and Pirin mountains. The total catchment area of the river is 5,613 km² (2,770 km² located in Bulgaria). The flow of the Nestos river is used by both countries for municipal water supply, irrigation and hydroelectric power production. The past estimated mean runoff of the Nestos River is 20 to 30 m³/s and the annual discharge 1,120 mio. m³.

Two NATURA 2000 sites according to the Habitats Directive (pSCI Reka Mesta and pSCI Dolna Mesta) and 1 according to the Birds Directive (SPA Mesta) are proposed around the Mesta River and its tributaries in Bulgaria.

Picture 1: Mesta River

Riparian forests of Mesta and its tributaries

Three riparian forest habitats from Annex 1 of the Habitats Directive 92/43/EEC are represented along the Mesta and its tributaries:

- **91E0** Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*)
- **92A0** *Salix alba* and *Populus alba* galleries
- **92C0** *Platanus orientalis* and *Liquidambar orientalis* woods (*Platanion orientalis*)

Habitat 91E0 is still in favourable conservation status only along the upper courses of Mesta and especially along its tributaries. In the middle courses of Mesta it is deteriorated, cut down and replaced by hybrid poplar plantations.
Habitat 92C0 is represented only along the lower course of the tributary Kanina river. Single *Platanus orientalis* trees are found along some smaller rivers flowing to the Gotse Delchev Plane.

Habitat 92A0 is only found in the lowest course of Mesta close to the Greek border. It is deteriorated and represented by poor *Salix sp.* galleries without *Populus alba* or *Populus nigra*.

In general all riparian habitats are in unfavourable conservation status and restoration is needed. Large areas in the middle course of Mesta, especially in the Gotse Delchev Plane, are available for restoration of habitats 91E0, 92A0 and 92C0.

**Literature review**

There are no investigations of productivity and carbon cycles in Bulgarian riparian habitats (particularly riparian forests of Mesta River). Little data is available on carbon stocks of floodplains in comparison to other terrestrial ecosystems (Cierjacks et al, 2009). Kutsch et al (2001) have investigated a 60-years old *Alnetum glutinosae* habitat of Bornhöved Lake District and found out a net ecosystem balance of about 3.5 t C/ha/y that remained in the system. This is a minimum possible sequestration capacity because of the higher age of the trees, relatively unfavorable habitat conditions (too much moist and coolness during the years of investigation) and high value of the total system respiration (above 80% of carbon input) in the investigation cited. The aboveground net primary production in the investigation cited is **5.38 t C/ha/y**. Carbon is included mainly in wood increment and for this reason net primary production (NPP) is a proper indicator for carbon sequestration, functional status of the ecosystem and subsequently habitat conditions. Since measuring and calculating root growth is rather labour-consuming and expensive, especially in forests, aboveground NPP is more applicable and informative for the productivity potential of the system.

Resting on the hypothesis of the net primary production as an indicator for carbon sequestration a very rough assessment of the present sequestration capacity of the riparian habitats in Gotse Delchev Plane could be made. According to the Forestry Plans of Gotse Delchev and Garmen State Forestry Units (from 1996 and 2000 respectively) the following information for the tree species, areas, average age and other functional parameters is available:
### Tabl. 1. Biometric characteristics of the trees in the riparian forests of G. Delchev and Garmen Forestry Units

<table>
<thead>
<tr>
<th>Forestry Unit</th>
<th>Tree species</th>
<th>Habitat</th>
<th>Area</th>
<th>Age</th>
<th>Wood stock (only stem)</th>
<th>Wood stock (with branch)</th>
<th>Total wood stock</th>
<th>Relative weight</th>
<th>Total weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hybrid poplars (I-214, etc.)</td>
<td>none</td>
<td>211</td>
<td>12</td>
<td>140</td>
<td>150</td>
<td>31650</td>
<td>0.45</td>
<td>14243</td>
</tr>
<tr>
<td></td>
<td>Alnus glutinosa</td>
<td>91E0</td>
<td>17.7</td>
<td>30</td>
<td>170</td>
<td>178</td>
<td>3151</td>
<td>0.55</td>
<td>1733</td>
</tr>
<tr>
<td></td>
<td>Populus nigra, P. alba</td>
<td>92A0</td>
<td>none</td>
<td></td>
<td></td>
<td></td>
<td>0.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Salix sp.</td>
<td>92A0</td>
<td>3.3</td>
<td>35</td>
<td>210</td>
<td>230</td>
<td>759</td>
<td>0.56</td>
<td>425</td>
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<tr>
<td></td>
<td>Platanus orientalis</td>
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<td></td>
<td></td>
<td></td>
<td>0.61</td>
<td></td>
<td></td>
</tr>
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<td></td>
<td><strong>TOTAL</strong></td>
<td></td>
<td>232</td>
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<td></td>
<td></td>
<td>35560</td>
<td></td>
<td>16400</td>
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<table>
<thead>
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<th>Habitat</th>
<th>Area</th>
<th>Age</th>
<th>Average growth</th>
<th>Average growth (NPP)</th>
<th>C sequestration*</th>
<th>Total C sequestration</th>
<th>Total CO₂ sequestration**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hybrid poplars (I-214, etc.)</td>
<td>none</td>
<td>211</td>
<td>12</td>
<td>12.5</td>
<td>5.6</td>
<td>2.8</td>
<td>593.4</td>
<td>2174.4</td>
</tr>
<tr>
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<td>Alnus glutinosa</td>
<td>91E0</td>
<td>17.7</td>
<td>30</td>
<td>5.9</td>
<td>3.3</td>
<td>1.6</td>
<td>28.9</td>
<td>105.8</td>
</tr>
<tr>
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<td>92A0</td>
<td>1.9</td>
<td>41</td>
<td>8.1</td>
<td>3.6</td>
<td>1.8</td>
<td>1.1</td>
<td>4.1</td>
</tr>
<tr>
<td></td>
<td>Salix sp.</td>
<td>92A0</td>
<td>0.8</td>
<td>39</td>
<td>6.6</td>
<td>3.7</td>
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<td>6.1</td>
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<td>Platanus orientalis</td>
<td>92C0</td>
<td>1.1</td>
<td>71</td>
<td>8.1</td>
<td>4.9</td>
<td>2.5</td>
<td>2.7</td>
<td>9.9</td>
</tr>
<tr>
<td></td>
<td><strong>TOTAL</strong></td>
<td></td>
<td>70.9</td>
<td></td>
<td>12.5</td>
<td>5.6</td>
<td>2.8</td>
<td>682.4</td>
<td>2302.4</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Forestry Unit</th>
<th>Tree species</th>
<th>Habitat</th>
<th>Area</th>
<th>Age</th>
<th>Average growth</th>
<th>Average growth (NPP)</th>
<th>C sequestration*</th>
<th>Total C sequestration</th>
<th>Total CO₂ sequestration**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hybrid poplars (I-214, etc.)</td>
<td>none</td>
<td>66.3</td>
<td>12</td>
<td>12.5</td>
<td>5.6</td>
<td>2.8</td>
<td>186.5</td>
<td>683.2</td>
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<tr>
<td></td>
<td>Alnus glutinosa</td>
<td>91E0</td>
<td>0.8</td>
<td>34</td>
<td>5.0</td>
<td>2.8</td>
<td>1.4</td>
<td>1.1</td>
<td>4.1</td>
</tr>
<tr>
<td></td>
<td>Populus nigra, P. alba</td>
<td>92A0</td>
<td>1.9</td>
<td>41</td>
<td>8.1</td>
<td>3.6</td>
<td>1.8</td>
<td>3.5</td>
<td>12.6</td>
</tr>
<tr>
<td></td>
<td>Salix sp.</td>
<td>92A0</td>
<td>0.8</td>
<td>39</td>
<td>6.6</td>
<td>3.7</td>
<td>1.8</td>
<td>1.4</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>Platanus orientalis</td>
<td>92C0</td>
<td>1.1</td>
<td>71</td>
<td>8.1</td>
<td>4.9</td>
<td>2.5</td>
<td>2.7</td>
<td>9.9</td>
</tr>
<tr>
<td></td>
<td><strong>TOTAL</strong></td>
<td></td>
<td>70.9</td>
<td></td>
<td>12.5</td>
<td>5.6</td>
<td>2.8</td>
<td>195.1</td>
<td>714.8</td>
</tr>
</tbody>
</table>

**As a general rule one-half the dry weight of wood is carbon** ([http://www.forestinfo.org/products/eco-links/16-2ClimateChange.pdf](http://www.forestinfo.org/products/eco-links/16-2ClimateChange.pdf))

** According to Carbon Dioxide Information Analysis Center ([http://cdiac.ornl.gov](http://cdiac.ornl.gov)) 1 g C = 3.664 g CO₂
Tree species composition and average age of the riparian habitats (table 1 and table 1a) are determined by experts in the region of this investigation and also according to the respective forestry plans. Most of the species occur along the river Mesta and its tributaries. The data for wood stock (m$^3$) and relative weight (m$^3$/t) of the different tree species pointed in Tabl. 1 is taken from the Directory of Dendrobiometry (http://www.bulprofor.org).

**Discussion**

As it is seen from the tables, the riparian forests in the Gotse Delchev and Garmen Forestry Units are in unfavorable condition. According to the information from the forestry plans and description from local people about 20 years ago the existing forest was put under clear felling. Thus space was opened for agricultural land. This activity was followed by afforestation but mainly with hybrid poplars (table above) aiming to grow up wood for industry. Soils in the region are normally alluvial, clay-sandy, deep and well-moist with level groundwater surface of about 1 – 1.5 (according to Gotse Delchev Forestry Plan). Because of some unfavorable activities – building dikes very close to the river banks, extraction of aggregates and the deforestation mentioned above, soils conditions worsened. Soil moist and groundwater surface decreased. That made native species suffer. Only poplar trees feel relatively well at such altered stands, but in terms of wood use they are felled regularly each 10 years and used mainly in paper industry. Soon however (several years ahead) average growth of even hybrid poplar plantations will decrease because of continuing soil deterioration.

The present situation in the discussed site is worsened alluvial forest habitat. According to the aboveground net primary production values of the forests **carbon sequestration for both forestry units and the total area of 303 ha is 2.06 t/ha/y, which corresponds to total annual C sequestration of 823 t (Tabl. 1a).** In this example native species are only the alder (*Alnus glutinosa*) and *Salix sp.* which however cover only a small area. The alder trees taking about 6% of the total stand area now loose vitality because of the decrease of groundwater surface. The optimum of its growth is with comparatively high level of groundwater surface.

This result is not representative enough because we have no information about other important parameters referring to the forest structure. But it is informative for the necessity and use of habitat restoration on which basis we can assume that a restored forest of mixed composition will sequester **at least 4 tC/ha/y.**
On the basis of the data we used for this general estimation the following measures could be proposed for initial habitat restoration:

1. Assessing the condition of hybrid *Populus sp.* cultivations and gradual removal of exhausted plantations is necessary. We consider their area to be about 50% of all poplar plantations in 10 years.

2. Putting the alder and willow trees under observation (monitoring). Often alders grow under hybrid poplars as a process of natural resumption of the forests. After felling the hybrid poplars *Alnus sp.* natural communities renew. This is a long process in time and habitat conditions are of great importance.

3. Carefully considering the forestry activities (mainly felling activities) in this habitat restoration with the “naturalness” of species composition of the habitat. It is essential to restore natural riparian habitats (91E0, 92A0, 92C0) in order to achieve the goals of the respective NATURA 2000 sites.

4. In terms of carbon sequestration capacity paying also special attention should be given to wood quality. As a rule, the thicker and qualitative the wood is the bigger amount of CO$_2$ the forest will sequester. Criteria for wood quality are thickness, texture, color. As it seen from Tabl. 1 *Platanus orientalis, Alnus glutinosa, Salix sp.* have thicker wood that could be used in the production of furniture an thus the C will be removed from the atmosphere for much longer period. So these species are preferred in habitat restoration activities not only in terms of biodiversity but also regarding carbon sequestration capacity!

5. Assessing the condition and monitoring *Platanus orientalis* communities. The species forms galleries along the rivers, predominantly the Mesta tributaries, and has a great contribution to carbon sequestration per ha.

6. Studying some functional parameters of the riparian forests under restoration – productivity and nutrients cycle intensity. Such an investigation would give real current values for growth and carbon sequestration. Methods used will be according to the referred literature (Zianis et al, 2005; Bazilevich, Rodin, 1971; Lyubenova, 2005).

7. On the basis of 1 to 6 measures proposed a serious consideration should be given to improving the hydrological conditions and river management. That is of primary importance for improving the whole complex of habitat conditions. Some activities that should be applied include: raising the water levels with series of barrages and opening dikes in places that the high waters could enter the floodplains without economical or social risks.

If these measures are applied we can expect the following situation 10 years after the start of the restoration project.
Tabl. 2. Expected species composition, growth and carbon sequestration of the area subject to riparian habitats restoration

<table>
<thead>
<tr>
<th>Forestry Unit</th>
<th>Tree species</th>
<th>Habitat</th>
<th>Area</th>
<th>Age</th>
<th>Weight</th>
<th>Average growth, m</th>
<th>Average growth (NPP)</th>
<th>C sequestr.</th>
<th>Total C sequestr.</th>
<th>Total CO2 sequestr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gotse Delchev</td>
<td>Hybrid poplars (I-214,etc.)</td>
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<td>105</td>
<td>12</td>
<td>0.45</td>
<td>9.0</td>
<td>4.1</td>
<td>2.0</td>
<td>212.6</td>
<td>779.1</td>
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<td>2.1</td>
<td>206.3</td>
<td>755.7</td>
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<td>0.45</td>
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<td>3.6</td>
<td>1.8</td>
<td>54.7</td>
<td>200.3</td>
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<tr>
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<td>7.0</td>
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<td>2.0</td>
<td>166.6</td>
<td>610.4</td>
</tr>
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<td>92C0</td>
<td>15</td>
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<td>0.61</td>
<td>8.1</td>
<td>4.9</td>
<td>2.5</td>
<td>37.1</td>
<td>135.8</td>
</tr>
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<td></td>
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<td></td>
<td>677.2</td>
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<td>12</td>
<td>0.45</td>
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<td>4.1</td>
<td>2.0</td>
<td>60.8</td>
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<td>0.55</td>
<td>7.5</td>
<td>4.1</td>
<td>2.1</td>
<td>72.2</td>
<td>264.5</td>
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<td>14</td>
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<td>3.6</td>
<td>1.8</td>
<td>54.5</td>
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<tr>
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<td>2.0</td>
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<tr>
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<td>92C0</td>
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<td>0.61</td>
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<td>4.9</td>
<td>2.5</td>
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<td>TOTAL G. Delchev and Garmen</td>
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<td></td>
<td></td>
<td></td>
<td>1036</td>
<td>3797</td>
</tr>
</tbody>
</table>

We plan that after undertaking restoration measurements the total habitat area will increase to more than 500 ha. Half of the hybrid poplars will be replaced by native species through a process of natural resumption or reforestation. Additional 200 ha will be reclaimed from unused agricultural land in four different areas:

Thus the abundance of *Alnus glutinosa*, *Populus nigra*, *P. alba*, *Salix sp.*, *Platanus orientalis* and some other autochthonous species will increase. By year 2020 we expect total carbon sequestration for this whole area of at least 1036 t C/y which is 200 t more than in the current situation (Tabl. 1a). Converted into CO2 sequestration this gives us a sum of 3797 tones CO2 annually. This is equivalent to the emissions of 1534 middle-class cars with an annual performance of 15 000 km!

But considering the young age of the restored forest growing on stands of improved soil conditions annual, annual carbon sequestration will increase up to year 2040-2045 when sustainable harvesting of autochthonous tree species could begin.
Area 1: Mesta River close to Gotse Delchev town. Restoration of habitat 92A0 with Salix sp. and Populus sp.

Area 2: Kanina reka river close to Garmen and Ognynovo. Restoration of habitat 92C0 with Platanus orientalis.
Area 3: Mesta River between Gotse Delchev and Garmen. Restoration of habitats 91E0 (green), 92A0 (yellow), 92C0 (red).

Area 4: Mesta River and Musomishka River. Restoration of habitat 91E0.
Environmental, economic and social benefits from riparian forest restoration in the Mesta River valley

According to Knutsen and Euliss (2001), wetland restoration offers a broad suite of ecosystem services, such as reduction in soil erosion, improved water quality, floodwater storage, and wildlife habitat.

We expect the following benefits from riparian forests restoration in the Mesta River valley, besides carbon sequestration:

1. Restored spawning grounds for fishes in the Mesta floodplains. This will help the populations of rare (Balkan endemics) and economically important species: *Chodrostoma vardarensis, Barbus cyclolepis, Vimba melanops, Alburnoides bipunctatus, Leuciscus cephalus.*


3. Regulation of floods – the restored floodplains will ensure more space for the river when there is high water and will prevent many of the damages from floods that have been increasing the last 10 years.

4. Water purification – the riparian forests will improve the water quality of Mesta, which is contaminated from villages with no water-treatment plants and from the paper and wood industry.

5. Reduced soil erosion which is very serious and deepens the river.

6. Increased benefits for local people from fishing, hunting, forestry and agriculture.

Some general conclusions

No doubt habitat restoration is a long process in space and time which unifies complex measures and activities. Finding the most proper way of applying restoration measures is a matter of determination of priorities and finding the balance between biodiversity and resource usage. Thus optimal carbon sequestration would be achieved. Optimal, not maximal! In support to this concept the accent should be put on applying measures for river management and improving the water regime. The restoration of the riparian habitats, the aim of the present paper, should only be a part of the whole strategy (scenario, plan) for river management. There is enough experience from European polices and practices in this field [Scherer-Lorenzen et al, 2005; Cierjacks et al, 2010 and others]. Just then, concrete comments and conclusions about biodiversity, habitat conditions and the related carbon sequestration could be made.
4.2. Brief description of EAF supported nature sites and applied conservation and restoration measures that can enhance CO$_2$ sequestration and reduce emission.

Restoration of open habitats important for birds has been one of the main urgently applied conservation measures in different EAF supported project. As this measure is connected with trees and bushes removal, it is associated with reduction of carbon sequestration. On the other hand, at these sites traditional models of sustainable management have been applied, which contribute to the preservation of the high ecological value of grasslands as well as to preservation of their role as carbon sinks.

Changing land use from agricultural land to a grassland habitat can significantly increase soil carbon levels. Habitat restoration practices related to changing land use from agricultural land to a grassland habitat have taken place at different EAF supported projects. In most cases only small areas are taken out from agricultural use, and the most important impact of these practices at EAF supported sites is that they ensure natural habitat restoration at larger areas. (e.g. at Slano Kopovo proj. as described below). Habitat maintenance options do not have a similar impact to habitat creation and restoration as C storage is likely to be close to maximum. However the maintenance of natural or semi-natural grassland habitats, supported in different EAF projects is important from a carbon perspective too, because the conversion to a more intensively used agricultural land will result in the loss of carbon to the atmosphere and reduction of the soil carbon content.

Natural forests areas have been to a small degree included in EAF supported projects, nevertheless conservation of natural forests is an important objective for the EAF. The conservation of natural forests has crucial importance for climate mitigation and adaptation. Apart of higher biodiversity and ecosystem resilience, natural forests have also higher C residence time. The carbon stock of forests subject to commercial logging, and of monoculture plantations in particular, will always be significantly less on average (~40 to 60% depending on the intensity of land use and forest type) than the C stock of natural undisturbed forests.

Avoidance of degradation of wetlands is recognized to be of crucial importance for emission reduction aims. Many wetlands in Central and Eastern Europe have been restored and protected from degradation via the work of EAF. These include different wetland ecosystems: wet meadows, marshes, floodplains and peatlands.

EAF supported projects on land purchase and conservation measures have in many cases spin off effects that ensure protection of much larger areas, than the project areas. Therefore the contribution of EAF to emission reduction goals should be looked at the larger areas protected. From a carbon perspective, this is especially important for wetlands where land purchase and restoration measures have impact on the restoration and preservation of large wetland areas.
Several examples where large wetland areas are preserved with the contribution of EAF support are described below. These areas are interesting from a carbon perspective due to the conservation practices enhancing sequestration (like converting farm land to grassland habitats and avoiding intensive agricultural use) and for the preservation of large wetland areas including important for carbon storage wetland types, such as: floodplains, peatlands, salty grounds.

**Danube floodplain (Slovakia).**

**Carbon sequestration capacity of Danube floodplain habitats in Slovakia**

This site is described in more detail because of the importance of floodplains for carbon storage.

**Background information**

Floodplains play a crucial role in climate mitigation and regulation, but there is not enough data on carbon storage in flood plains that would allow easy assessment of carbon storage at different locations and conditions.

Accordingly to recent scientific investigations [Cierjacks *et al.* 2010], carbon stocks in the Danube floodplain soils are huge (up to 354 t C per ha within 1 m below surface) in comparison to other terrestrial ecosystems. In this study the researchers have quantified the carbon stocks of aboveground biomass and soils of riparian vegetation types at 76 sampling sites in the Donau-Auen National Park in Austria. Soils of different vegetation types show different texture with a higher percentage of sandy soils at the softwood sites, while loamy soils prevailed at hardwood sites. Total C stocks of vegetation types are significantly different, but reflect differences in woody plant biomass rather than in soil C stocks. Mature hardwood and cottonwood forests have significantly higher total C stocks (474 and 403 t ha\(^{-1}\), respectively) than young reforestations (217 t ha\(^{-1}\)) and meadows (212 t ha\(^{-1}\)). The C pools of softwood forests (356 t ha\(^{-1}\)) range between those of hardwood/cottonwood forests and of reforestations/meadows. This study proves the relevance of floodplains as possible carbon sinks, which should be increasingly taken into account for river management [Cierjacks *et al.* 2010].

Considering the information of Cierjacks *et al.* 2010 about huge carbon stocks in Danube floodplain soils and also significant carbon stocks in mature Danube floodplain forests, we can assume that the nature sites at Danube floodplain in Slovakia are generally important carbon sinks. But in these specific conditions, carbon sequestration has not yet been evaluated in Slovakia. And a few data is available on carbon sequestration and storage in floodplains in general, which makes
difficult to make predictions. Accurate estimation of the carbon stocks and sequestration at the EAF supported Danube floodplain sites will require extensive research.

Site description.

General description of the area.
The Danube river basin provides a platform for the development of a wide range of habitats along the main stream and his tributaries. This environment is often strongly influenced by the flood regimes of individual flows. The length of inundation has a significant impact on change in soil fabric flows and thus also on the speed of carbon sink in soils and biomass. Habitats that can be identified in the Slovak Danube floodplain differ mainly by hydrological conditions under which they have been created. They are: open water areas of flowing waters (rivers), open water surfaces of standing water (side arms), wetlands, occasionally flooded alluvial meadows, forest steppe communities of aggradations embankments, softwood floodplain forests and hardwood floodplain forests. Floodplain forests now comprise only fragments of its original size - about 2% of Slovakian forests are floodplain forests.

The EAF project site
At the Danube floodplain in Slovakia, the EAF has supported two land acquisition projects aiming to preserve the last fragments of natural floodplain forests and prevent from destruction other important habitats. The implementing organisation is the Slovakian nature conservation NGO Regional Association for Nature Conservation and Sustainable Development (BROZ). The EAF project site represents the Slovakian part of the large trans-border wetland along the Slovak-Hungarian section of the Danube River. Danube floodplains play a substantial hydrological, biological and ecological role of this section of the Danube River. BROZ has already leased and purchased a total area of 325,5 ha and purchase of other areas is in progress. All acquired lands are located in protected areas: Protected Landscape Area Danube Floodplains and Natura 2000. Purchase/lease of land allows to realize change of forest management, keeping natural forest without management, enlargement of the area covered with natural habitats, introduction of meadow management, implementation of wetland restoration, decrease of accessibility of selected sites. Following land acquisition, natural floodplain forests are being restored by implementing conservation management, continuous removal of non-native tree species and restoration of native trees. Conservation measures at the project sites have been funded via a LIFE project.

The biggest acquired area of ca 250 ha, covers the main part of a large Danube island - Velkolélsky island (total area of ca 330 ha). The island is Natura 2000 site. It is covered mostly by floodplain forests and partly by meadows, bushes and wetlands.
Carbon sequestration in conditions of Danube floodplain inundation

Carbon sequestration in conditions of Danube floodplain inundation has not yet been evaluated in Slovakia. Generally we can say that soil, together with other geological formations, is a stable reservoir of stored carbon. Organic carbon content is significantly greater in hydric soils than in non-hydric soils. Danube floodplain forests stand mostly on gravel-based mineral soils. Wetlands located on mineral soils - as in our conditions on the banks of the Danube, have typically higher productivity of biomass and volume of standing biomass (thus also higher carbon sequestration) than fens and wetlands on organic soils. [Kimble, J.M. 2002] From this perspective, it is very important to ensure the continuity of these natural processes - to avoid the increased collection of dead biomass from forests. In terms of floodplain forests, these processes are strongly influenced by water flow. The result is uneven distribution of places completely free of biomass on the surface and the accumulations of large quantities of biomass. The overall effect of these two opposing processes on carbon deposition was not yet evaluated in our conditions and would require several years to research. A prerequisite, however, is neutral to positive impact on the C sink in so affected habitats.
Carbon sequestration capacity of different types of habitats

Floodplain areas comprise a mosaic of habitats, thus carbon sequestration assessments are more complex than e.g. in steppe areas. We have looked at the different habitats of the largest purchased area - Velkolelsky island, as described above.

![Typical Danube hardwood floodplain forest (photo A. Kovarik)](image)

**Natural floodplain forests.** BROZ directs most of its forest management to the recovering of natural plantations. Keeping natural forest without management and enlargement of the area covered with natural habitats are conservation measures which on the longer term can significantly contribute to increasing the carbon storage. Unmanaged forests at a late stage of succession development are considered to be insignificant as carbon sinks, since in theory, assimilation is thought to be balanced by respiration. However, little experimental evidence for this hypothesis exists so far for forests at the ecosystem level. Unmanaged 250-year-old deciduous forest in central European conditions shows typical characteristics of an ‘advanced’ forest with large dead wood pools, a diverse stand structure and a wide tree age class distribution. Such forest is a large carbon sink up to 494 g C m\(^{-2}\). [Knohl, A. 2003]. This is about three times more than the main carbon sequestration rate in Slovakian mostly economically used forests. Flooded forest is much more complicated for carbon storage and sequestration assessments compared to other forests types. Therefore further research is needed to assess carbon storage values at the specific location of Danube floodplain forests.
Comparison with poplar plantations. Net primary production of aboveground biomass in young floodplain forests is rapidly catching up ahead of production in older forests and in forests near the climax stage. Chances of rotation plantations of fast-growing poplars for carbon capture are clear, but limited compared to the forest without management. Establishing and tending of plantations often results in early soil carbon loss, but soil carbon is significantly related (positively) to tree age. Increasing tree age eventually results in a net addition of soil carbon from plantations older than about 6 to 12 years of age. According to investigation of Hansen, E. A. (1993), on soil carbon sequestration beneath hybrid poplar plantations in the North Central United States, soil carbon loss under trees occurs most frequently within 30 cm from the surface early in the plantation history, what is evidence that the loss is due to mineralization. Soil carbon gain is most significant in the 30–50 cm layer and is attributed to tree root growth. Soil carbon accretion rate beneath 12- to 18-year-old poplar plantations exceeds that of adjacent agricultural crops. [Hansen, E. A. 1993].

The loss of carbon during the initial period of such plantation is cyclically repeated and therefore in comparison with the species composition of natural forests without management it is less effective way how to sequester carbon.

For accurate estimation of carbon sequestration and storage potential of the forest types that are found at Danube floodplain in Slovakia, separate investigations should be carried out for the softwood floodplain forests and hardwood floodplain forests and the monocultures in the specific conditions of Danube water regime and soil type.
Meadows. Alluvial meadows of Central Europe are probably among the most productive grasslands on earth, because according to research in the Morava floodplain the aboveground biomass production reached on average 973,683 g/m$^2$/year. Together with the underground biomass it is 1947,366 g/m$^2$/year [Šeffer, J. & Stanová, V., 1999] The proportion of C capture is therefore about 876,31 g/m$^2$/year. If we make a conservative estimation for e.g Veľkolélske island meadows, these will be able to capture about 700 g/m$^2$/year year what means 7 t C/ha. On the area of 100 ha is then captured about 700 t C per year.

For the accurate estimation of carbon storage and sequestration in grasslands at the specific locations of Danube floodplain, it would by needed to identify the different types (associations) of meadow communities that are found here and in the case of expected differences in biomass production, to set it for communities present here. Furthermore, it would be necessary to verify the content of dry biomass in these particular communities and the degree of similarity of carbon sequestration and biomass production in this particular case. If this similarity is confirmed, it might be easier to continue with works at other locations in Central Europe.

Wetlands and side arms. Restoration of wetlands is an important area of work of BROZ but it is difficult to make estimations for these habitats. Carbon sinks in wetlands and side arms could differ very much depending on the nutrient content of the water and the water regime of specific locations. Detailed studies are necessary to determine carbon storage potential of the wetlands.
River Narew floodplain (Poland).

This site is an example of floodplain restoration, where large areas are restored as a result of EAF project implementation. At the beginning of the eighties, parts of the floodplain were drained to convert the marshland to agricultural land. This resulted in degradation of bird habitats and increased danger of fire at dried out reed beds. As a result of the EAF supported project, land was purchased from private landowners in order that a seven kilometre long canal, converted from the original river, could have its water flow slowed down thus raising the water table and returning the wetland to its previous state. This site could be interesting from carbon perspective because of generally assumed high storage potential of floodplain soils; and a study at this site will also demonstrate carbon sequestration potential in restored wetland.

Hortobágy National Park

At Hortobágy National Park (15,000 ha) with EAF support were protected sensitive bog-land areas against the undesirable effects of intensive agriculture and privatisation of the surrounding areas. The area was threatened by changing ownership giving no guarantee of long-term protection and by the lack of buffer zones around the core area. Farming, including the use of chemicals, was carried out up to the edge of the National Park. Drainage had caused loss of wetland habitat and increased the risk of fire. Swamp, peat-bogs and fen-lands were purchased and urgent restoration measures taken including altering the hydrography and converting adjacent farmland to grassland. Preservation of the peatland areas is specially important for protecting carbon storage.

Oder Delta Nature Park.

The Polish part of the Oder delta is surrounded by large wetlands, including peatlands. Conservation of the natural values of the Polish part of Oder delta and the establishment of the Oder Delta Nature Park is one of the most important achievements of the EAF. During the last 13 years EUCC-Poland, with the support of EAF, has been able to purchase altogether about 1,000 ha of the valuable areas of coastal meadows located around Szczecin Lagoon. The land ownership in the area enabled the NGO to preserve the very rich biodiversity of much larger area. In 2005 was established the Oder Delta Nature Park which comprises ca 4000 ha and is the first NGO run nature park in Poland.
Preservation of the peatlands in the larger area around Oder delta Nature Park is specially important for protecting carbon storage. Herewith we provide a description of the peatlands particularly at Oder Delta Nature Park and surrounding areas connected with the east part of Szczecin Lagoon. These are known as Czarnocin Basin peatlands (characterized in the 1960s and 70s by Prof. Mieczyslaw Jasnowski). The areas occupied by various form of peat are estimated at about 350 – 400 ha. These include a peatland location in the area of Odra Delta Nature Park (about 75 – 85 ha) and adjacent parcels (some parcels just on the other part of the Park’s boundaries). The depth of the peat is not yet well known. Accordingly to general estimations it can vary between 0.5 and 6.0 m. The type of peat is not well known, but it can be assumed that blanket bog peat is prevailing. A new investigation has been initiated by the University of Wrocław and some preliminary results will be known at the end of 2010. (2010, Kazimir Rabski, personal communication)

The use of peatlands in this area started in XVI – XVII century with intensification in the XIX and beginning of XX century. After 1945, when these lands were included in the boundaries of Poland, mostly of the local peatland areas were changed to meadows or pastures by drainage. The current management of the peatland area belonging to Odra Delta Nature Park is focused on biodiversity preservation and includes improving of the hydrological system, removal of reeds and extensive grazing by horses and cows. Research is needed to establish optimal management of the peatland area in order to ensure preservation of carbon storage along biodiversity gains.

**Slano Kopovo**

Slano Kopovo site is a recent good example where EAF support for land purchase at relatively small area ensures the restoration and protection of much larger wetland site. Slano Kopovo is a Special Nature Reserve (950 ha). The area is a unique migration and breeding point for birds and is an Important Bird Area (IBA) and a Ramsar site. It contains one of the latest preserved ponds on salina ground in Serbia: salty lakes within paleomeanders, and types of salty habitats, that worldwide are endangered to disappear. The EAF support for the preservation of this Ramsar site started in 2006, with a grant for the purchase of 70 ha private land. The project includes purchase of agricultural lands and their conversion to the original state of pastures, meadows and reeds. This land purchase followed by land use change is impacting the whole core area of 500 ha as it makes possible the implementation of measures to improve the water regime of the reserve. Avoidance of further degradation of the wetland and practices for the restoration of natural habitats on depleted agricultural land contribute to enhanced carbon storage. Apart from that, this site is also very interesting from carbon perspective, because of the presence of salty habitats.
4.3. Summary results of evaluation of sites for carbon projects development

More detailed description of the results of the conducted case studies is given within the case studies.

The pilot site at Tarkhankut Peninsula in Crimea, Ukraine provides a good example on the impact of EAF supported biodiversity conservation action for achieving of emissions reduction aims. At this site, the EAF supported lease of 200 ha natural steppe area enables the Ukrainian Society for Protection of Birds (USPB) to make agreements with local farmers to manage surrounding agricultural areas of ca 4000 ha in a sustainable way, which contributes to restoration of habitats at depleted agricultural soils. The case study conducted at this site on Adoption of Sustainable Agriculture Land Management by Farmers in Crimea shows decreased GHG emission and increased carbon sequestration in soil as a result of the restoration of steppe pasture on depleted agricultural lands. The annual GHG emission from the project area is estimated as follows: reduction of GHG emission C equivalent from 9,328.84 tonnes of C equivalent year\(^{-1}\) (baseline scenario) from total area 3,989 ha under current land use to 937.35 tonnes of C equivalent year\(^{-1}\); C sequestration in soil (mainly) over 1,068 tonnes of C equivalent year\(^{-1}\). The total GHG emission balance of the pilot area (3,989 ha) after the project implementation is estimated to be 9,459 tonnes of C equivalent year\(^{-1}\) (e.g. sum emission reduction (9,328.84 – 937.35 tonnes) and carbon sequestration (1,068 tonnes). Carbon sequestration is a co-benefit to the core benefit of biodiversity conservation. The changed land use regime for the carbon project implementation leads to the restoration of rare steppe habitats with up to 70% of steppe pasture similarity of the virgin steppe plant associations and the steppe habitats will be enlarged with 1,024 ha. Steppe habitat restoration leads also to important benefits for the local communities, as increased productivity of the steppe pasture, food safety and others.

At different wetland sites, EAF supported strategic land purchase enabled restoration of the hydrological system of much larger wetland areas. In this way realised restoration and avoidance of degradation of wetlands areas on the longer term ensures protection of their carbon stocks (examples are Slano Kopovo site, Hortobagy National Park, Oder delta Nature Park, Danube Floodplain site and others.) EAF has supported projects on restoration and conservation of different wetland ecosystems, mainly including fresh water marshes, floodplains and peatlands. Therefore we conducted studies to investigate the potential for carbon sequestration at a post-restored fresh water marsh (Dragoman marsh, EAF supported site) and at forested floodplains (Danube floodplain forests, EAF supported site). Seeing the importance of floodplain/riparian forests for carbon storage and sequestration a case study is carried out also at a newly identified site: River Mesta riparian forests in Bulgaria.
The case study at Dragoman marsh in Bulgaria (331 ha) demonstrates the potential of post-restored wetlands to sequester carbon. The estimated carbon sequestration of 147 gC/m²/y corresponds to a total of 487 tones of C annually or 1,782 tones of CO₂ annually. If carbon storage in emergent vegetation in the wetland is taken into account, an additional carbon storage benefit of approximately 900 tons would be associated with the vegetative standing crop. Based on these projections, it appears that substantial atmospheric carbon can be stored in the emergent vegetation of restored wetlands. Although carbon stored in vegetation is often viewed as not being permanent and susceptible to loss from disturbances such as fire, vegetative communities quickly re-establish following fire. Given the resilient nature of wetland plant communities, carbon storage in wetland vegetation is an almost immediate and rather constant form of carbon storage. Future research should be conducted to better quantify atmospheric carbon storage in standing crops of plants in restored wetlands.

The case study on riparian forest restoration and carbon sequestration potential along the Mesta River in Bulgaria was selected because riparian forests, with their fast growth rate, provide a sink for atmospheric carbon. Riparian forests are also among the most deteriorated habitats in Europe and Bulgaria. The study proposes restoration measures for riparian forest habitats from Annex 1 of the Habitats Directive 92/43/EEC: 91E0, 92A0 and 92C0, which are represented along the Mesta and its tributaries and are presently in unfavourable conservation status. The case study shows that the proposed habitat restoration leads to increased carbon sequestration capacity. It is estimated that by year 2020 total carbon sequestration for the whole area (510 ha) will be at least 1,036 t C/y which is 200 t more than in the current situation. Converted into CO₂ sequestration this gives us a sum of 3,797 tones CO₂ annually. But considering the young age of the restored forest growing on stands of improved soil conditions, annual carbon sequestration will increase up to year 2040-2045 when sustainable harvesting of autochthonous tree species could begin. In the process of habitat restoration, carbon sequestration is only a co-benefit along with other ecological and socioeconomic benefits. And the restoration of the riparian habitats should be only one part of the whole strategy for improved river management.

For EAF supported restoration and conservation projects we make an evaluation of practices that contribute as to biodiversity objectives as to emission reduction. This evaluation shows that EAF supported areas are interesting from a carbon perspective due to the conservation practices enhancing sequestration, like converting farm land to natural or semi-natural habitats and introduction of sustainable management practices at areas larger than the EAF sites. Apart of it, several EAF supported sites, including important for carbon storage wetland types, such as: floodplains, peatlands, salty grounds are briefly evaluated regarding opportunities for carbon projects development. Further research in such areas is needed in order to establish values of carbon sequestration and the management measures that ensure optimal conditions to preserve carbon stores.
VI. Conclusions and Recommendations

The EAF has supported actions on strategic land purchase and restoration measures for biodiversity conservation which contribute also to protect carbon storage. The most important impact of EAF projects is that protection and restoration of relatively small areas can ensure avoidance of degradation and sustainable management of much larger areas.

The case studies at Tarkhankut Peninsula (Ukraine) and River Mesta (Bulgaria) can be used as demonstration projects for the development of a Carbon sequestration programme under the umbrella of EAF. The Tarkhankut Peninsula case study can be further used e.g. for the development of steppe restoration projects in Romania. The River Mesta case study treats the very important issue on improved river management and there is a big need for implementation of such projects. Steppe restoration and improved river management are also important issues in current EU environmental policies. The case study at Dragoman marsh contributes to increased knowledge on carbon sequestration in post restored fresh water marshes and can be further used also for studies in other areas, for which close cooperation with the scientific community is needed. In wetlands, future projects should be identified at peatlands, floodplains and salt marshes as these wetland ecosystems are already recognised to play crucial role for carbon storage.

For further development of a Carbon sequestration programme under the umbrella of EAF we need to identify projects at areas larger than the EAF sites, and where possible using already achieved results within EAF supported projects for the protection of larger nature areas and important for carbon storage ecosystems, or include new threatened areas. For our EAF partner NGOs which are managing nature sites, it is very important to get more knowledge and expertise about management practices which influence GHG emission and carbon sequestration; exchange of expertise and experience are very important. Within new projects development, biodiversity conservation stays our core objective, and carbon sequestration should be considered as a co-benefit together with other socio-economic benefits. When developing and realizing carbon projects at nature conservation areas, knowledge on C sequestration needs to be „translated“ into needs of nature conservation. Apart of it, projects need to be put in a broader context, as community development and sustainable development in order to create incentives for participation and support.

The Carbon sequestration programme under the umbrella of EAF will include Europe-based projects, which will instil European customers with a greater sense of confidence than offsets gained from overseas projects.

European environmental policies should consider inclusion of carbon funding in biodiversity conservation projects. Although a part of a project budget, carbon funding can help that implementation of biodiversity objectives take place. It is also important to show to the public the value of biodiversity preservation for the provision of different ecological services, herewith included carbon storage. Restoration and
sustainable nature management are both important in order to combine the purposes of biodiversity and C sequestration. Therefore, it is substantial that sustainable management and improved management are included in carbon-funded projects.

VII. ANNEXES


Annex 2 a-c. Case study area Tarkhankut Peninsula, Crimea, Ukraine. Carbon stock change in soil baseline and project scenarios. Estimation of GHG Emissions from Fire
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