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Maurizio Borin, Mario Malagoli, Michela Salvato, Benek Tanis

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PREFACE

During the last year SWS European meeting in Denmark, we were asked to organise the 8th SWS European Chapter Meeting in Italy. The idea of the SWS European Board was to give the opportunity to the meeting participants to experience for the first time a Mediterranean Country, since all the previous seven meetings have been held in Central or Northern Europe. Also, the choice of Italy aimed at attracting new members and involving practitioners in the group activities. Indeed, thanks to its geographical position, Italy is a hinge between Western and Eastern Europe, facilitating the meeting of researchers and technicians coming from both these areas.

We proudly accepted the invitation and decided to name the Conference "Wetland Systems: Ecology, Functioning and Management", hoping to stimulate the participation of scientists working on the different areas of the "wetland world". The programme of the meeting was divided in Pollution removal and geochemistry, Wetlands and global change, Wetlands vegetation, Wetland management. A further session was added as we were delighted to host the "Peatlands and Pollution Symposium", organised by the Peatbog research group.

The Conference programme includes a social event at the historical monumental pumping station Cà Bianca, belonging to the Consorzio di Bonifica Adige Euganeo, and a technical excursion at the Tenuta Civrana, a remarkable example of agro-environmental farm with a site of the Nature 2000 Network. Both the events are thought to give the meeting participants the opportunity to meet people involved in the water and wetland management.

The overall response to the Conference call for abstracts has been positive, considering that we received more than 80 contributions, with 80 registered attendees coming from 20 different countries.

We believe there are all the elements for a successful event. The programme will be intensive, but we are sure that the delegates will have many opportunities to interact each other and to grow the spirit of collaboration within the group.

By organizing this meeting in Italy, we hope to concretely contribute to the growth of the European Chapter of SWS.

We wish all the participants a pleasant stay in Padova and together with the organizing staff will do our best to make this meeting an unforgettable one.

Maurizio Borin and Mario Malagoli
Chairmen of the International Conference
"Wetland Systems: Ecology, Functioning and Management"
8th European SWS Chapter Meeting

Editors' foreword

This book of the Proceedings of the 8th European SWS Chapter Meeting Conference "Wetland Systems: Ecology, Functioning and Management", includes 82 papers, presented at the Conference as keynote lectures, oral or poster presentations.
The papers have been checked for technical and editorial quality, to prepare a book with a uniform layout, which should help the participants to follow the Conference presentations. This book is meant as a tool to facilitate scientific discussion among the attendees and as a guide in the choice of the session to attend.
We like to remind that we checked the editorial aspects of the submitted papers, so the views and opinions are those of the authors.
We carefully checked all the papers, but we are sure that some errors could still be found, and for those we apologize in advance. We hope that the final result is creditable and useful.

CHAPTER 1 - INTRODUCTORY NOTES

What metals can tell us about wetlands – from rhizosphere processes to ecosystem quality assessment

Marinus L. Otte, Donna L. Jacob

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Abstract More than 25 years of research has provided in-depth understanding of the processes underlying the distribution and biogeochemistry of metals in wetlands and uptake in plants. Driven by redox reactions, the biogeochemistry of iron in particular drives that of other metals and metalloids. The formation of iron oxy-hydroxides in the rhizosphere leads to the accumulation of metals near plant roots and enhances uptake into plants. This in turn may explain why many wetland plants are tolerant of high concentrations of metals in the substrate. Modern analytical techniques (e.g. Inductively Coupled Plasma spectrometry, ICP) have relatively recently led to a better insight into the behaviour of less-studied metals, such as the so-called rare earth metals, in wetlands. Analysis of multiple metals in wetland soils and plants not only helps us better understand the behaviour of metals in wetland soils, but can also be used to assess the overall health of wetland ecosystems.

Research on metals and metalloids in wetlands gained momentum during the 1980s, driven particularly by concerns about the spread of pollution via water (e.g Salomons and Förstner, 1984). Many studies focused on the distribution of metals in wetlands (Otte et al., 1991a), wetland soil processes, and uptake in plants (Otte et al., 1989; 1991b). The efficacy of wetlands in removing metals from water was quickly realised, which led to rapid growth of literature on the subject both in natural (Beining and Otte, 1996) and constructed wetlands (e.g. Kadlec and Wallace, 2009).

The biogeochemical behaviour of metals in wetlands is very different from that in drylands, because of the heterogeneity of the substrates in terms of redox conditions. The most striking characteristic is that of the deposition of iron oxy-hydroxides in the rhizosphere and on the roots, forming a so-called iron plaque. Even though some studies seem to indicate that such plaques may reduce uptake of certain metals, our work (Otte et al., 1989; Kissoon et al., 2010, 2011) shows that uptake of zinc is typically enhanced by iron plaque.

Perhaps the most striking observation regarding metals in wetlands is that wetland plants, in contrast to most dryland plants, are tolerant of high concentrations of metals in the substrate (Moran and Otte, 2004, Otte et al., 2004, Matthews et al., 2004a,b,2005a,b, and work by the group of Wong, see Deng et al., 2009 and references therein).

Wetlands in many parts of the world have been less studied than other ecosystems in terms of metals, even in the 'developed' world, and so studies on distribution are ongoing (Jacob et al., 2013). Our most recent work indicates that a clear relationship exists between metal concentrations in the soil and the ecosystem health of wetlands (Figure 1).

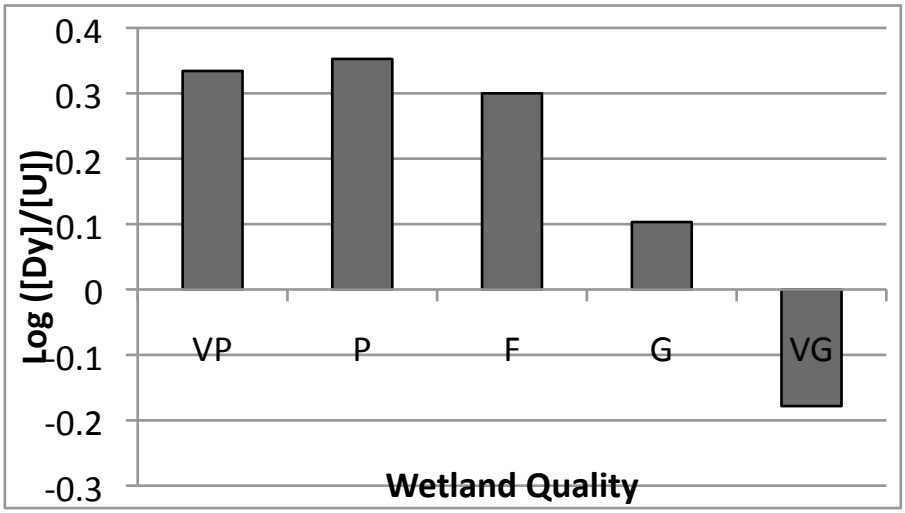

Figure 1 The ratio (log) of the concentrations of Dy and U as a function of wetland quality as measured by the Index of Plant Community Integrity of Hargiss et al. 2008. VP=Very Poor, P=Poor, F=Fair, G=Good, VG=Very Good

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Global change, management and the conservation of Mediterranean wetlands

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Abstract The Mediterranean region is a hotspot of biodiversity with high species richness and high rate of endemism. The natural diversity of this hotspot is matched by the unique cultural, linguistic and socioeconomic diversity of the region. In addition, this region is exposed to heavy anthropogenic pressures on natural resources, in particular on fresh water, and is the region at worldwide scale where the socio-economic contrast is the widest between the developed countries (Western Europe) and developing countries (South and East of the Basin). Many of the ecosystems reached equilibrium long ago with human activity dominating the landscapes. However, this delicate balance is in a precarious state as many local communities depend on remaining habitats for fresh water, food and a variety of other ecosystem services. In this region, wetlands are severely impacted by global change, defined as planetary-scale changes in the Earth system (e.g. climate change, demographic pressure, intensification of agriculture, etc.). Although comprehensive data is missing at Mediterranean scale, the Mediterranean Wetland Observatory has issued a synthesis on the status and trends of wetlands in this region. A 50% rate of loss of the surface area of wetlands is estimated in the 20th century. While the surface area of wetlands has tended to stabilize in developed countries, the losses are increasing in those located in the south and east of the Mediterranean basin as a result of the development of agriculture, and urban and industrial areas. Over the same period, artificial wetlands have been developed, in particular through reservoirs, leading to further degradation of rivers, coastal erosion and shortage of water for riverine and coastal wetlands and for the human populations depending on their resources. The rise in sea-level has exacerbated the pressure on coastal wetlands. The pressure on water resources is very high and is increasing rapidly in the southern and eastern parts of the Mediterranean basin in phase with the heavy demand from the agricultural sector.

The biodiversity of wetlands assessed using the Living Planet Index, shows contrasting trends between taxonomic groups and sub-regions. Many water-bird species show positive trends, in particular the Ardeids, ducks, gulls, etc. These species were probably favored by the protection measures established in the 70's, by the eutrophication and enhanced productivity of wetlands and the increase in the populations of exotic species which became major sources of prey (e.g. fish, Louisiana crayfish). Conversely, the native species of fish, reptiles and amphibians show a severe negative trend with multiple potential causes. The bird communities show a shift in their species composition in phase with climate warming, resulting from the decline of specialized species and increase of generalist species. Exotic species have caused increasing functional problems in Mediterranean wetlands when they proliferate in the ecosystems (e.g. *Ludwigia spp*) or threaten native species by hybridization, predation, parasitism, and so on. Similarly, emerging diseases have given rise to serious concern for wetlands in the last decades, with health crises more or less directly involving or affecting wildlife (avian flu, West Nile and USUTU viruses, Rabbit hemorrhagic disease, etc.).

What strategies should be adopted to cope with these global changes and what priorities for research for the management and conservation of Mediterranean wetlands? The main sources of stress for the Mediterranean wetlands are the increase in anthropogenic pressure on natural resources, climate change and the impacts on the rise in sea-level and on hydrological cycles and exotic species. Research on the functioning and dynamics of wetlands is needed but will not be sufficient in itself. The research results can provide information on the state of the wetlands, the impact of global change on their natural resources and their biodiversity and contribute to the design of management strategies. A critical step however is to get this information taken into consideration in decision making at different levels with the aim of achieving integrated management of natural resources and maintaining ecosystem services. At global scale, political decisions and international agreements may have a positive impact on Mediterranean wetlands and their biodiversity (Ramsar convention, E.U. directives on water, habitats, birds, etc.). While there have been some notable successes, they remain limited in the face of the pressures by agricultural and industrial lobbies in the context of the lack of any real political and the poor implementation of regulation in most Mediterranean countries.

The Camargue (Rhône delta) is a good illustration of this situation and of the challenges facing Mediterranean wetlands. The on-going research in the delta is focused in diverse directions, with the aim of analyzing ecological processes and looking for potential management strategies to be submitted to managers and decision makers. Water management in the Camargue is broadly artificial and is a central topic in negotiation between stakeholders and policy makers, with multiple interrelated issues: flood control, irrigation, salinity and biodiversity. The water resources are extensive because of the Rhône River, the second largest river in the Mediterranean in terms of discharge rate. Severe coastal erosion occurs resulting mostly from the numerous dams on the river and to a lesser extent from the rise in sea-level. Because of the rise in sea-level, the large quantities of water pumped into the delta for agriculture (rice) are increasingly difficult to remove to the sea and the level and salinity of the water in the lagoons is on the increase. The salinization of the River during severe droughts is threatening irrigated agricultural activities. The intensification of rice production and irrigation more generally (including in wetlands) has lead to major changes in the ecosystems. Invasive plant species proliferate in the wetlands which are irrigated, exotic species dominate the fish communities in the freshwaters. The use of pesticides, which is often a consequence of intensive use of irrigation in wetlands, has in turn a strong impact on biodiversity. Emerging diseases are indirectly threatening biodiversity, in particular when wildlife is suspected of being vectors. More research is needed to achieve a better understanding of the problems and potential management strategies, including the restoration of wetlands. However, the way the local decision makers take into account the research results is critical with regard to the dynamics of the territory and the protection of the wetlands.

The role of wetlands in River Basin Management

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In spite of international recognition of their importance (e.g. Ramsar, Natura2000), many wetlands are still suffering from misuse, destruction and degradation. One of the main reasons for this is that wetlands are usually perceived as standalone elements and are poorly integrated into RBM (Rebelo et al., 2013). The EU funded WETwin project (Zsuffa et al., 2012) aimed at enhancing the role of wetlands in basin-scale IWRM. Case studies from different continents were investigated in this project. This paper presents the key findings and conclusions of WETwin with regard to integrated wetland management.

Interactions between the wetland and the basin

Inadequate understanding of wetland-basin interactions is often key factor in the degradation of wetlands.

Wetlands, on the one hand, provide various *ecosystem services* with basin-wide importance. They offer resting, feeding and reproduction habitats for valuable resident/migrating species. This makes wetlands 'core areas' in basin wide ecological networks. The Danube riparian Lobau (Austria) and Gemenc (Hungary) floodplains are important core areas within the ecological network of the Danube River Basin. Thanks to their natural purification capacities, wetlands have the potential to function as 'kidneys' in the river basin (Mitsch and Gosselink, 1993), by cleaning heavily polluted surface waters. This cheap water treatment solution has already been utilized worldwide. In Uganda for example, huge papyrus wetlands are used for cleaning communal wastewaters. Besides improving water quality, wetlands are also capable of regulating water quantities. They can mitigate floods and provide stable low flow condition by temporarily storing the excess waters. The Inner Niger Delta (IND) in Mali for example, performs this regulating function for the benefit of downstream communities in Niger. Thanks to their very high biological productivity, wetlands are being utilized for food production since the ancient times. Wise adaptation to the hydrological regime enables to harvest large quantities from various food sources such as fish, crops, fruits and cattle. In this way, the IND supports the livelihood of as many as 1.5 million people, which is 10% of the total population of Mali. Last but not least, wetlands provide cultural services such as recreation, eco-tourism and preservation of traditional lifestyles. Wetlands in many countries are increasingly becoming important destinations within large scale touristic networks.

On the other hand, impacts from the basin fundamentally influence the functions and services of the wetland. Water intakes and hydropower production upstream may reduce the extent of floods, thus decreasing the size, and reducing the services of the wetland. River regulation has resulted in the partial or complete disconnection of riparian floodplains, which are being further degraded by aggradation and river bed incision. The Lobau and Gemenc floodplains are greatly exposed to these impacts. Increasing pollution of surface waters imposes serious threats on wetland. Several papyrus wetlands in Uganda are endangered by the ever increasing loads of communal wastewaters, which

will sooner or later surpass their purification capacities and start destroying the ecosystems. Climate change has considerable impacts too, especially in those regions where significant decreases in precipitation are expected. According to climate-hydrological predictions, 17% reduction in the peaks of incoming discharges is expected at the IND (Liersch et al., 2013).

Towards integrated wetland management

Wetlands thus support humans and nature on basin scale, while, at the same time, they are seriously endangered by impacts coming from the same basin. This situation really urges the efficient integration of wetlands into RBM.

The major barriers to integrated wetland management are the mismatch between local and national or basin level priorities, and lack of recognition of the ecosystem services provided by wetlands to the river basin (Rebelo et al., 2013). Wetlands still tend to fall through the cracks of water policy and legislation due to their position as partly land and partly water based systems (Ramsar, 2008). As a result, most basin-scale water management strategies (e.g. the EU Water Framework Directive) designate only marginal, supportive roles to wetlands, instead of recognizing them as key components of the basin with all their functions and services.

Usually, there are trade-offs among the ecosystem services of wetlands: enhancing one service may result in damaging another one. Integrated wetland management is thus a decision problem with conflicting multiple objectives, where the task is to find a solution, which is accepted by all stakeholders as the 'best compromise' one, across all relevant spatial and temporal scales.

To support integrated wetland management, a Conceptual Framework has been developed within the WETwin project, on the basis of the Critical Path approach put forward by the Ramsar Convention on Wetlands (Ramsar, 2008). The framework consists of the integration of the adaptive planning cycles at the wetland and the river basin levels. Integration means: (i) following a comprehensive strategy for wetland-basin management, (ii) interaction and exchange of information among agencies in charge of implementing the two management processes. An actual merge or transfer of responsibilities is not envisaged, since wetlands have their own dynamics, need to be managed at a different scale and have different challenges than river basins. The Conceptual Framework has been further elaborated and applied on the case studies of the WETwin project.

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Water under control in the Anthropocene Era. Human footprint in the land reclamation experience in Italy

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Abstract The analysis of statistical data on the Anthropocene Era has made it possible to chronologically reconstruct the gradual reduction/transformation of wetlands into cultivable lands in the Italian plains. Particularly relevant in this connection are the policies adopted by the new Italian State after its unification in 1861 with regard to the management of waters. The evolution of the concept of land reclamation, which gradually came to include draining, hygienic, agrarian and environmental factors, has been examined. Over many centuries new country areas were created, two fifths of them located below sea level. Both the State and landowners invested capital in a project that was not only meant to sustain private interest but that also met public needs. In 1882 (when the Baccarini law was passed) the subject of the 'bonifica igienica' began to be discussed in Italy. This concerned one sixteenth of the total surface of the country, affected by malaria. New livelihoods substituted those of the past.

In 2002Will Steffen, John McNeill, and Paul Crutzen coined the neologism 'Anthropocene', a new geological epoch in which human beings, for the first time, have become a "global geophysical force." The Anthropocene is first of all connected with a process of rapid climate change due to the release of increasing amounts of carbon dioxide into the air. Everything began with the Industrial Revolution. Human actions were often driven by economic interests without regard for the consequences they could have on the environment. Over the past 250 years humans have caused unprecedented changes in and on the land, oceans, and the atmosphere. For the first time in history, humans are having multiple effects on the global environment, and these effects are accelerating. However, every democratic nation, sooner or later, develops the idea that there is a public interest that needs to be preserved, that there are more and more common goods that need to be protected. Actually, humans are part of this environment, and not everything they have done has caused degradation: we must distinguish between environment adaptation, environment control, and environment destruction. According to the latest report by the Intergovernmental Panel on Climate Change, without mitigation, the average temperature on the planet may increase as much as three to five degrees Celsius in this century. Sea levels are expected to rise between one and three feet by the year 2100. At the same time this emergency brings out the thought that many of the inhabited areas lie below sea level but are kept dry thanks to age-old man-made drainage works. Human actions such as land reclamation or hydraulic works, even radical, can be interpreted as 'adaptation actions'. Humans are increasingly exerting control over earth's fresh water through reservoirs, dams, and canals. They also worked hard to fill marshes or create arable land from wetland: they built infrastructure (aqueducts, irrigation channels, residential areas), treated malaria, conducted researches to find crops suited to the new drained land. The question is to understand what consequences, positive or negative, human actions may have had in relation to privately or publicly owned and managed lands. In Italy the concept of land reclamation has gradually come to include draining, hygienic, agrarian and environmental factors, paying attention to the specific

character of both mountain basins and coastal areas. This evolution has involved changes due to humans priorities, or rather to what humans consider priorities in different historical periods. Once again, we have to examine carefully what has happened in the last 250 years with regard to the relation between man and land. We analysed data in the long run, such as, for example: the original extension of wetlands, reclaimed areas, the surface affected by malaria, channel network, the number and power of pumping stations, the level of investments, the extent of cultivated surface, products and production, population increase. Undoubtedly, the population increase is the most important factor in sparking a process of economic transformation. The main objective was to stimulate the search for new cultivable land and the creation of new jobs that could check the social unrest due to the high levels of unemployment following the agrarian crisis that had started in the 1880s. At the beginning of the nineteenth century the Italian population amounted to about 18 million people. In 1861, when Italy unified, there were 26 million inhabitants, an increase by 44%. Later on the population grew steadily by about 15% yearly with a peak of 23% in the period 1881-1911, when the involvement of the State in land reclamation works was stronger and the emigration flow from the country heavier. The analysis of statistical data collected over a long period of time has made it possible to reconstruct the gradual transformation of wetlands into arable land, suitable for human settlement and for the development of industrial activities. Over many centuries 'new lands' were created, two fifths of them located below sea level, which could be cultivated thanks to complex systems of canalization and water pumping. Both the state and landowners invested capital in a project that was not only meant to sustain private interest but that also met public needs. In 1882 the subject of 'sanitary reclamation' began to be discussed in Italy. This concerned about 7% of the total area of the country, wetlands where endemic malaria was directly or indirectly responsible for the death of thousands of people. New livelihoods replaced old ones, with the concomitant disappearance of more archaic economies, such as those based on harvesting the marshes' products or the common use of marginal lands. The recent process of industrialization, often carried out with little consideration for the environment, has eventually opened up a new chapter in the history of the Italian countryside: the need to preserve and enhance the environment has clearly emerged. Today Italy shows the highest consumption of land in Europe. 8% of the territory is occupied by infrastructures, roads, and unused spaces. The soil is not 'breathing' and does not perform its ecological functions. The territory is thus degraded and exposed to the serious risk of landslides. Finally, in the last few years, we have started to think of 'land' as a 'common good'. The environment itself is regarded as a common good, it is the product of the encounter between nature and culture. It is a common good because it is formed by the accumulation of centuries-old gestures, traditions and innovations. The main problem is to decide how to respond to the economic demands of human beings in accordance with those of the environment. Let us adopt a longer-range perspective.

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CHAPTER 2 - POLLUTION REMOVAL AND GEOCHEMISTRY IN WETLANDS

The role of in-stream and off-stream restored wetlands for water quality improvement in agricultural watersheds

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Abstract Sixteen in-stream and five off-stream wetlands were restored to improve the quality of the water outflowing irrigated agricultural fields in the Flumen river watershed 8NE Spain). Only a few in-stream and off-stream wetlands retained suspended solids and nitrate, the major water quality variables here considered, two years after restoration. The amounts of suspended solids and nitrates flowing through off-stream wetlands are much lower than through in-stream wetlands, which are highly related to their respective water flows. This may be the reason for a relatively higher percentage of retention of both of them in off-stream wetlands.

Wetlands have been extensively degraded and desiccated in agricultural watersheds to facilitate agricultural works and food production. In order to recover the multiple ecological functions of wetlands, it is necessary to plan both the spatial distribution of the wetlands in the watershed and the objectives to be accomplished by each wetland (Johnston et al., 1990). However, increasing the number of objectives decreases the efficiency of a wetland for a specific objective as design requirements for multiple objectives will lower intensity of a single ecological function. Here a comparison of the role played by two types of restored wetlands (in-stream versus off-stream) for improving the quality of the wastewater discharged from irrigated agricultural fields to rivers two years after restoration is presented.

Eleven in-stream and five off-stream wetlands were restored in the Flumen Watershed (NE Spain) in 2001-12 to demonstrate their potential for improving water quality and biodiversity in agricultural watersheds after the EU CREAMAGUA Life Project (Comín et al., 2013). Nitrogen as nitrates, suspended solids and phosphorus were of major interest as water quality variables for this study and were analysed following standard methods from samples collected at the wetlands inlets and outlets several times in 2011-13.

High data dispersion is observed during the first two years after restoration in the set of wetlands studied both for suspended solids and nitrogen. Some of the in-stream wetlands showed relatively low suspended solids at the outlet compared to the inlet . Taking into account the water discharge, the number of off-stream wetlands retaining suspended solids and nitrogen was relatively higher than in-stream wetlands (Figure 1). However, the amounts of suspended solids and nitrogen retained in some in-stream wetlands are higher than in off-stream wetlands (Figure 1).

Most off-stream wetlands work removing suspended solids and nitrogen from the water flowing through them compared to a few in-stream wetlands which play these roles. This is associated to the much higher water flow through in-stream than through off-stream wetlands (Figure 2), which reduces the hydraulic retention time in in-stream wetlands compared to off-stream wetlands and, consequently decreases the efficiency of in-stream

wetlands, at least during the first two years after restoration. Usually, a longer period of time is required for restored wetlands to perform full biogeochemical functioning (Moreno-Mateos et al., 2012)

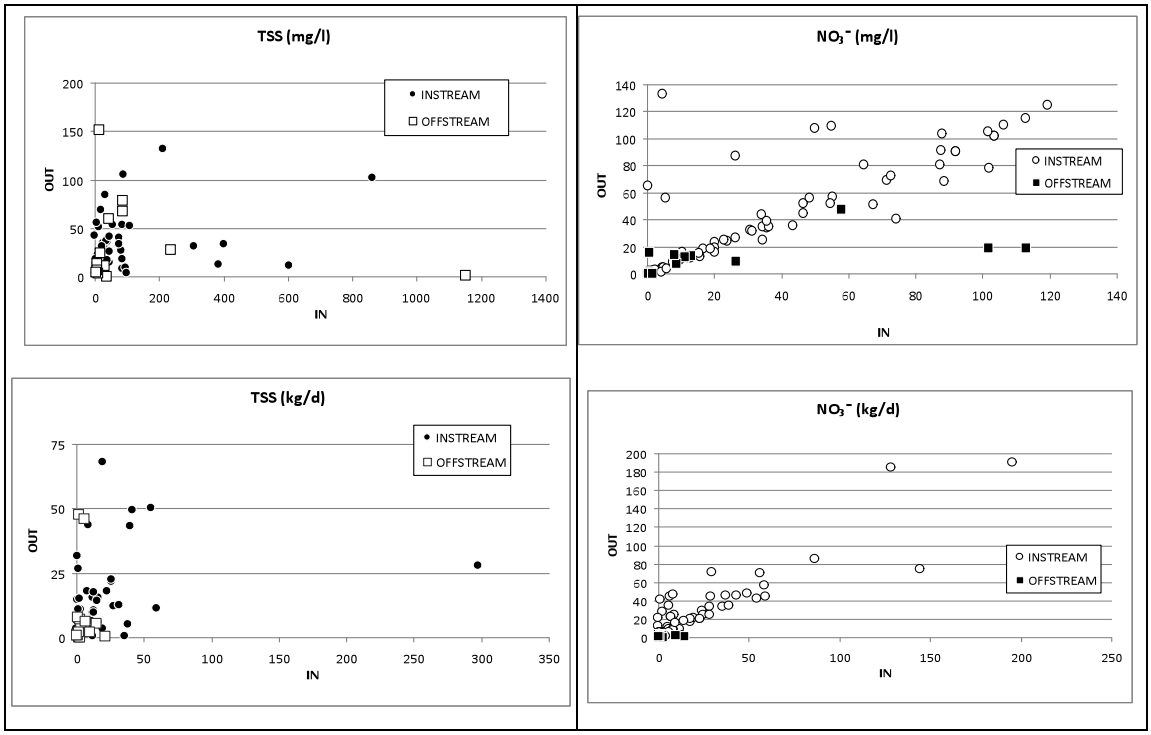

Figure 1 Suspended solids (left) and nitrogen as nitrates (right) concentrations and discharge at the inlet (horizontal axis) and outlet (vertical axis) of in-stream and off-stream wetlands restored in the Flumen River watershed

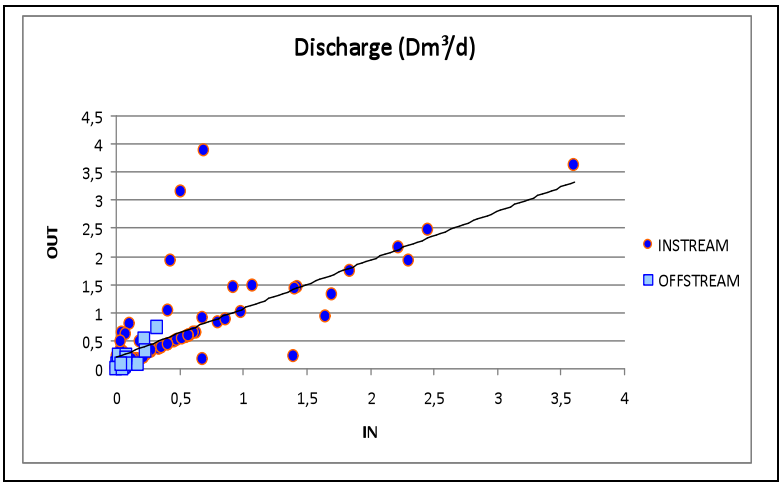

Figure 2 Water discharges at the inlet and outlet of in-stream and off-stream wetlands restored in the Flumen River watershed

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Response of duckweed to various concentrations of selenite

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Abstract The accumulation of SeIV and its effects on physiological and biochemical characteristics of duckweed (*Lemna minor* L.) were studied. Duckweed plants were cultivated in controlled conditions in different concentrations of Na selenite: 0.5, 1, 2, 5 and 10 mg Se/L for 7 weeks. In weeks 1-4 higher doses of Se (2, 5, 10 mg Se/L) increased respiratory potential in comparison to control. In weeks 5-7 respiratory potential in plants exposed to higher doses decreased since plants could not overcome stress. Higher doses of Se mostly negatively affected photochemical efficiency of photosystem II (PSII). Se addition had a minor effect on the amount of chlorophylls and carotenoids. Plants cultivated in 0.5, 1, 2 and 5 mg Se/L were exposed to Se concentrations for 50 days. Plants cultivated in 10 mg Se/L were exposed from 14-22 days. The content of Se in duckweed, growing in 0.5 mg Se/L and 1 mg Se/L was 0.90 mg Se/g DM. Duckweed exposed to 2 mg Se/L and 5 mg Se/L contained 1.6 mg Se/g and 6.4 mg Se/g DM, respectively. Duckweed exposed to 10 mg Se/L for 14 days contained 6.5 mg Se/g DM, while duckweed exposed for 20 days contained 19.5 mg Se/g DM. Our study revealed that duckweed can accumulate high amount of Se.

Selenium (Se) is a naturally occurring trace element which is toxic at high concentrations, but it is also an essential element for many organisms. Selenite and selenate are the most soluble and thus more available for plants (Carvalho and Martin, 2001) which leads to potential toxicity for aquatic organisms. Every day a large amount of pollutants are released into the environment, among them also Se. It is found in aqueous discharge from electric power plants, coal ash leakages, oil refinery effluents, industrial wastewater, as well as agricultural drainage water from irrigation (Fan et al., 2002). The aim of our study was to assess the accumulation of SeIV and its effects on physiological and biochemical characteristics of duckweed (*Lemna minor* L.).

Duckweed plants (*Lemna minor* L.) were cultured under controlled conditions (22±1°C, 160 μM $m^{-2}s^{-1}$ PAR, light:dark = 18:6 hours cycle). Plants were grown in Steinberg growth medium with various concentrations (0.5, 1, 2, 5, 10 mg/L) of SeIV for 7 weeks. Potential photochemical efficiency of PSII expressed as Fv/Fm ratio was measured weekly on 5 samples per treatment using PAM 2100 (Chlorophyll Fluorometer, Heinz Walz GmbH, Germany). Respiratory potential measured as electron transport system (ETS) activity was measured on 4 samples (0.2–0.4g) from each treatment as described by Packard (1971). The Total Se in plant samples was measured with HG-AFS (Smrkolj and Stibilj, 2004).
To present the effect of Se on potential photochemical efficiency of PSII and ETS activity in duckweed, 1mg/L (low) and 10mg/L (high) SeIV treatments were selected. PSII in 10mg/L treatment was in average 0.42, while in 1mg/L treatment was in average 0.52 (Figure 1). ETS activity in 10mg/L treatment in weeks 2, 3, 6 and 7 was lower than in low treatment, which shows on stress. In weeks 6-7 respiratory potential in plants exposed to higher doses decreased since plants could not overcome stress. Too much

stress causes a decrease in the vitality of the tissue and decreases the respiratory potential (Germ and Gaberščik, 2003).

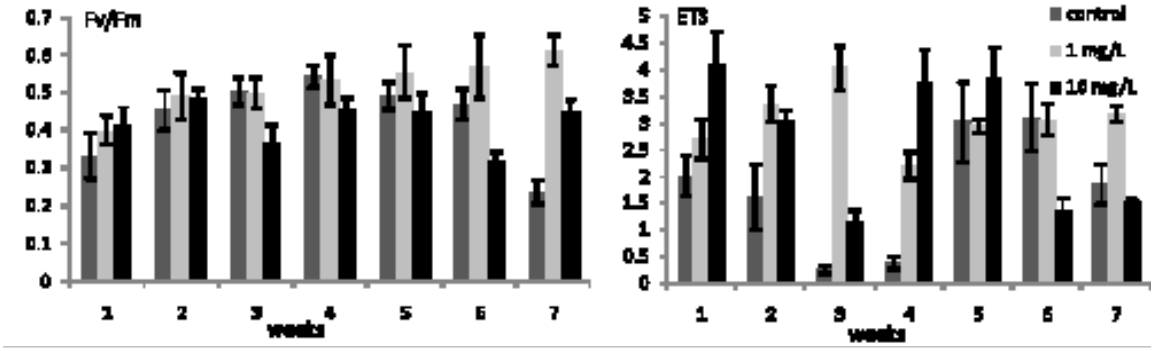

Figure 1 Potential photochemical efficiency of PSII (Fv/Fm) (left) and ETS ($\mu L(O_2)mg^{-1}(SM)\ h^{-1}$) activity for control, low (1mg/L) and high (10mg/L) SeIV treatments

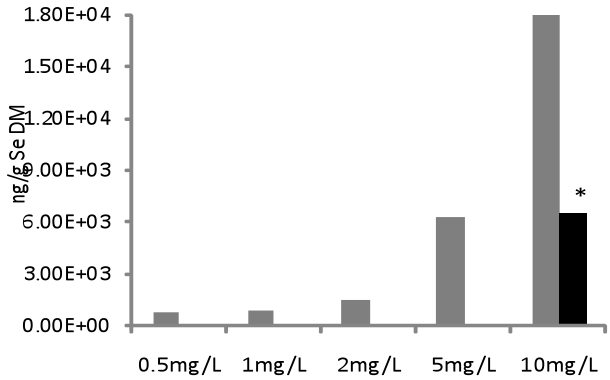

Figure 2 Content of Se in duckweed. * plants in 10 mg/L treatment were exposed for 20 days (left bar) and for 14 days (right bar)

Se addition had a minor effect on the amount of chlorophylls and carotenoids (data not shown). Duckweed plants took up a large amount of Se from media. Plants treated with 1mg/L were exposed for 50 days, while plants treated with 10mg/L were exposed only for 14-20 days. The highest content of Se contained plants exposed to 10mg/L, the value being 19.5 mg/g (Figure 2). This is 19-x times higher than in *C. demersum,* treated with 10mg/L SeIV from our previous research (Mechora et al., 2013).

High concentrations of SeIV affected PSII and ETS activity. SeIV addition had a minor impact on the amount of photosynthetic pigments. Duckweed plants exposed to high Se treatment took up a large amount of SeIV – up to 19.5 mg/g (DM).

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The use of vertical constructed wetland and ultrasound in aquaponic systems

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Abstract: The objective of this study was to reduce the water pollution in small-scale cyprinid fish farm with a diversion of recirculation water into an aquaponic system. The experiment ran in two fishponds, one as experimental (Pond A, 36 m^3) and one as control pond (Pond B, 36 m^3) with the starting fish load of 0.6 kg/m^3 per pond of common carp. From Pond A the water was pumped into the treatment train consisting of a lamellar settler (4.75 m^2) and a roughing filter (2.25 m^2) as a pre-treatment stage, a vertical constructed wetland filled with expanded clay and planted with tomatoes and of an ultrasound (LG Sonic® Tank) floatingly deployed in Pond A. The pilot system was monitored from June to September 2011 for physical and chemical parameters, chlorophyll-*a*, fish body weight and tomato biomass. The system efficiently removed TSS, BOD_5, COD, NH_4-N, and TP (57%, 49%, 35%, 42%, and 25%, respectively) but not NO_3-N and NO_2-N. The ultrasound successfully inhibited algae. The fish thrived better in Pond A as compared to Pond B due to better rearing conditions. The biomass of tomatoes was 38.4 kg/m^2 at the end of the experiment. The presented closed-loop system could be appropriate for semi-natural fish farming.

Rapid urbanization and population growth requires continuous increase of food market including fish. Because of growing demand for fish coupled to the problem of overfishing, aquaculture has increasingly gained in importance for global fish supply. Conventional fish farming methods produce large amounts of nutrient rich wastewater, partially loaded with chemicals used for fish treatment, which has a harmful effect on the receiving aquatic environment. Aquaponic is a possible solution to reduce the water pollution due to the aquaculture industry and it can open new economic possibilities for inland farmers (Graber and Junge, 2009).
The objective of this study was to evaluate the treatment performance, fish production, crop plant biomass and water consumption of a pilot aquaponic system for small-scale land-based cyprinid fish farm.

The research was carried out from June through September 2011 in two fish ponds one experimental (Pond A; 36 m^3), and one a control pond (Pond B; 36 m^3) (Figure 1). From Pond A the water flowed into TT consisting of CW (2.25 m2; height 1.1 m; filled with 8/20 mm expanded clay and planted with tomatoes) and US (LG Sonic® Tank, range 70 m, 13 W, 20-200 kHz) floatingly deployed in the corner of Pond A with the LS (4.75 m^2; height 1.0 m; lamellae from Plexiglas positioned at an angle of 60º) and RS (2.25 m^2; height 1.1 m) as a pre-treatment stage. Pond B did not receive any treatment. Groundwater was added to the ponds whenever water conditions reached threshold values that were threatening to the fish (Griessler Bulc et al., 2011) and to compensate evaporation losses. The average water flow rate through TT was 1.7 m^3/h.

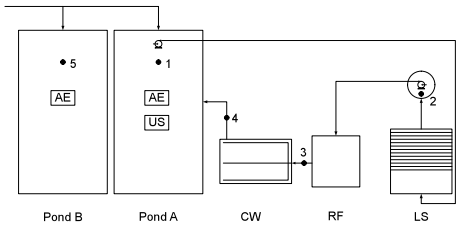

Figure 1 Experimental set up of the pilot aquaponic system. Black dots mark sampling points

The starting fish load per pond was 0.6 kg/m^3 of carps (*Cyprinus* c. *carpio* L.). Dissolved oxygen, pH, electric conductivity, temperature, and ORP were measured twice per day in each pond. TSS, BOD_5, COD, NH_4-N, NO_3-N, NO_2-N, TN, PO_4-P and TP were measured weekly in both ponds and after each device (Figure 1). Chlorophyll-*a* was determined weekly in both ponds. Fish production (specific growth rate and feed conversion rate) and tomato biomass were measured.

The TT showed elimination of TSS, BOD_5, COD, NH_4-N, TN and TP (Table 1). The mass removal for listed parameters was low, which can be explained by low mass inputs into the TT, and high variability in mass loads. There was an increase in NO_3-N, NO_2-N and PO_4-P load. The majority of pollutant removal took place in LS and RF, especially for TSS, BOD_5, COD, and NH_4-N. Chlorophyll-*a* values were markedly lower in Pond A, compared to Pond B due to the algae inhibition by US.

Table 1 Mean mass input (IN) to the treatment train (TT) and after each device

	Unit	*n*	IN	OUT LS	OUT RF	OUT CW	Mass removal of TT	Mass removal of TT (%)
TSS	kg/day	12	0.65±0.44	0.40±0.30	0.30±0.29	0.27±0.31	0.38±0.37	57%
BOD_5	kg/day	12	0.58±0.25	0.46±0.21	0.34±0.18	0.29±0.14	0.29±0.17	49%
COD	kg/day	12	1.86±0.78	1.61±0.66	1.36±0.70	1.20±0.59	0.65±0.32	35%
NH_4-N	g/day	12	2.1±1.7	2.3±2.5	1.0±0.5	0.7±0.6	1.4±1.7	42%
NO_3-N	g/day	12	24±41	24±43	27±47	31±54	-7±14	-79%
NO_2-N	g/day	12	1.9±3.2	2.4±4.1	2.2±3.3	2.1±3.8	-0.2±2.1	-315%
TN	g/day	12	98±50	92±46	82±51	73±64	26±35	31%
PO_4-P	g/day	12	10±11	11±14	13±14	12±12	-2±3	-53%
TP	g/day	12	20±12	17±12	18±13	16±11	5±4	25%

The fish thrived better in Pond A (higher total fish biomass, and average weight of fish) as compared to Pond B due to better rearing conditions. Tomato biomass was almost 100% higher than traditionally used *Phragmites australis* (Griessler Bulc and Krivograd Klemenčič, 2011). Water use efficiency was seven times higher comparing with Griessler Bulc et al. (2011) probably due to lower fish load and thus better rearing conditions in the ponds.

The aquaponic system as presented here could be useful for semi-natural fish farming. The system offers an alternative chemical-free solution for the removal and inactivation of algal cells and the linked harmful potential in fish farms.

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Ornamental plants for micropollutants removal in wetland systems

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Abstract The use of ornamental plants in wetlands systems could represent an incentive for the adoption of wetland systems for the treatment of small wastewater volumes. The objective of this paper is to evaluate the efficiency of micropollutants removal, such as heavy metals (Cu and Zn) and carbamazepine, through the use of a subsurface flow constructed wetland systems with non-conventional plants. Five plants have been selected (*Zantedeschia, Canna indica, Carex, Miscanthus and Phragmites australis*) and planted in 5 lysimeters (1.1 m height and 30 cm of external diameter), filled up with gravels (bottom layer: 20 cm 1-3 cm size and top layer: 75 cm 6-8 mm size). The lysimeters were completely saturated with a synthetic wastewater (N 280 mg/l, P 30 mg/l, Cu 3.6 mg/L, Zn 9 mg/L, Carbamazepine 5 mg/L) and the water was removed for the analysis after 15, 30 and 60 incubation days. All the plant species were able to remove nutrients and contaminants. In particular, *Miscanthus* resulted more efficient in metal removal, followed by *Phragmite and Canna indica*. The higher degradation of carbomazepine compound was in *Canna indica* and *Phragmites*

The use of constructed wetlands for the "biotreatment" of urban sewage water is increasingly gaining acceptance due to their cheap costs in construction and ease of maintenance (Cirea et al., 2005). Recently, in treated wastewater other than conventional micro-metals, also the emerging organic pollutant compounds PPCPs (Pharmaceuticals and Personal Care Products) are identified (Yanga et al., 2008). In view of this, the aim of this paper is to evaluate the efficiency of micropollutants removal, such as heavy metals (Cu and Zn) and carbamazepine, through the use of a subsurface flow constructed wetland systems with non-conventional plants. N and P and nutrient (N and P) removal, has been also evaluated in this meso-scale phyto experiment. In addition to *Phragmites australis*, commonly used in constructed wetlands plants, other four unconventional plant species were used: *Zantedeschia spp*. (calla), *Canna indica*, *Carex sp*., *Miscanthus*. These plants have been selected for their aesthetical value and because of their use in already existent phytodepuration plants in the San Giuliano Terme (Pisa, Italy) municipality. Five lysimeters (above described) planted with one of the selected plant species, were set up at CNR-ISE, Pisa. The lysimeters were completely saturated (about 30 L) with a synthetic wastewater (N 280 mg/L, P 30 mg/L, Cu 3.6 mg/L, Zn 9mg/L, Carbamazepine 5 mg/L) and the water was removed for the analysis after 15, 30 and 60 incubation days. Soluble N ($N\text{-}NH_4$ and $N\text{-}NO_3$) were measured with selective electrode (Sevenmulti Mettler Toledo). Total phosphorus was determined by the colorimetric method (Murphy and Riley, 1962). Cu and Zn were determined with atomic absorption, while carbamazepine with gas chromatography with mass detector.

In the winter-spring period, a variability in the nutrient absorption (N and P) was observed in the different incubation time (15, 30 and 60 days), while a clear increase in their removal with the increase of incubation time was found in spring-summer cycle (Figure 1). As expected, this result highlighted a greater absorption of nutrient during the

growth plant season. Among the plants, *Miscanthus* and *Zantedeschia spp*. resulted particularly efficient in P reduction.

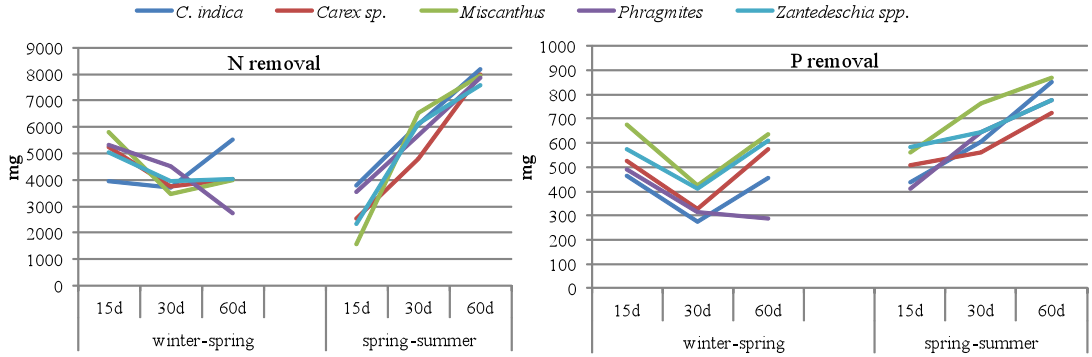

Figure 1 N and P removal in the different plant systems in two season periods. The amount of N and P in the wastewater was of 8400 mg and 900 mg, respectively

A similar trend in metal absorption was observed for each plant (Figure 2): the removal increased regularly with the incubation time in winter-spring cycle, while it remain quite constant in the second one, suggesting the reaching of a "plant absorption threshold". However, the *Miscanthus* seemed to be more effective in the metal reduction, followed by *Phragmites* and *C. indica*. Differently, *Phragmites* and *C. indica* were able to better degrade the carbomazepine with respect to the other plants, in particular in the winter-spring cycle. Moreover, a very high carbomazepine degradation was observed in 60 day incubation time in spring-summer cycle, reaching about 80-90% of reduction in presence of *Phragmites, C. indica and Carex sp*.

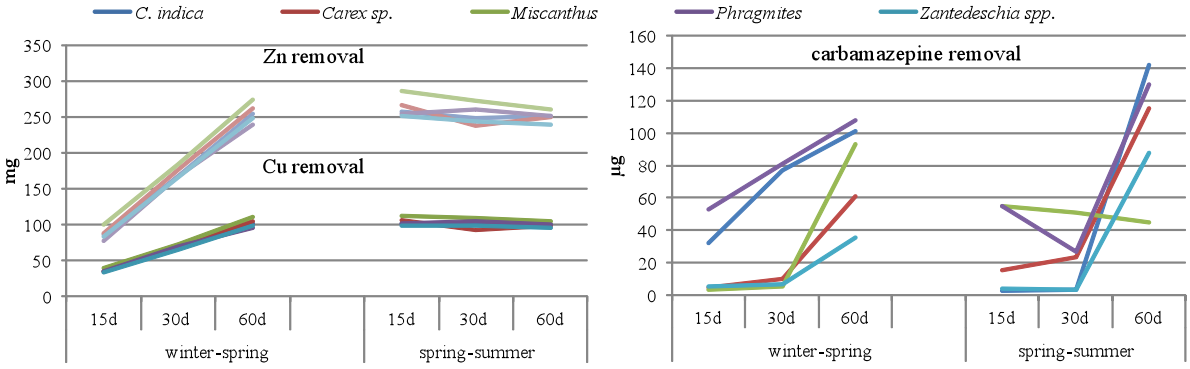

Figure 2 Pollutant removal in the different plant systems. The amount of Zn, Cu, and Carbamazepine in the wastewater was of 270 mg, 110 mg and 150 μg, respectively

In conclusion, all plant species were successful in nutrient and pollutant removal, with *Miscanthus* more efficient in nutrient and metal absorption and *Phragmites* and *C. indica* in carbomazepine degradation.

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Potential of algae turf scrubbers (ATS™) for elimination of phosphorus from swimming ponds

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Abstract Algal Turf Scrubbers (ATS) are water treatment devices that use light and nutrients in the (waste)water to grow periphyton community; undesirable chemicals are removed by physical, chemical and biological processes. So far, most ATS systems were operated in water bodies with relatively high nutrient concentrations. Little is known about the performance of ATS under low concentration of phosphorous (P), yet there are potential applications where such conditions are met. The paper presents a series of experiments that focus on the implementation of small-scale ATS systems to eliminate P from natural swimming ponds (SP). SPs are typically subject to fluctuating P concentrations and require the maintenance of very low levels of P (< 10 μg L^{-1}) in order to prevent undesirable algal growth. ATS systems proved to be capable of maintaining such low levels, both in laboratory and field conditions.

ATS systems (Adey, 1982) were used to remove nutrients from different wastewaters, among others: agricultural run-off (Adey et al., 1993), secondary treated wastewater (Craggs, 2001) and anaerobically digested dairy manure (Pizarro et al. 2002). The reported phosphorus removal rates ranged from 0.12 – 0.73 g P m^{-2} d^{-1}. Current studies thus document the successful operation of ATS systems under nutrient-rich conditions (PO_4-P levels > 1 mg L^{-1}). The question therefore arises whether such systems can be applied for nutrient elimination down to the very low levels of PO_4-P found in open water bodies (below 10 μg L^{-1}).

Swimming Ponds (SP) are small artificial freshwater bodies providing both a natural component to the garden and an opportunity for recreational swimming. Instead of disinfection with chlorine as used in conventional swimming-pools, they contain a natural water quality which is provided by active microbial biofilms on plant roots and biofilters which maintain a regenerative capacity.

Nutrient concentrations in SP vary seasonally, depending on the weather conditions and number of users (swimmers). Natural P inputs can amount up to 1 mg P per m^2 pond surface and day. For every swimmer an additional input of 100 mg P per day can be assumed (Schulz, 1981). Phosphorus promotes algal growth, which in turn reduces visibility. Safety regulations require visibility in swimming ponds to be > 2 m. Therefore it is recommended that P concentrations in SP do not exceed 10 μg P L^{-1} (FLL, 2010).

An ATS system installed next to the pond could help to reduce P concentrations in the pond water if it would be able to assimilate P at very low levels. This question was investigated, as well as P elimination under different water flow rates and the effect of prior starvation on P uptake by algae.

The ATS system in the laboratory setup consisted of 5 modules (Figure 1). Each was built of 1.5 mm stainless chromium steel (2.0 m x 0.57 m x 0.10 m), and operated at a water depth of 50 mm. Artificial light (1000 W) was provided for 8 h d^{-1}.

A modified version of BB-Medium (Bold, 1949), omitting any components containing P, was used as P-free growth medium. P was supplemented by adding Wuxal® liquid fertiliser (Maag Agro, Dielsdorf, CH). A mix of Lake Zurich and pond water was used as

inoculum. Medium was transported continuously into the tilt tray, which emptied in a short flush to the periphyton when the tilt level was reached (about 3x min^{-1}). Total algae biomass was weighed and analysed for dry weight and total phosphorus, and the water for phosphate. Oxygen, temperature, pH, and conductivity were recorded with data loggers (WTW MultiLab® P4 data logger). Total phosphorus P_{tot} was determined by spectrophotometry (Hach Lange LCK 349). Orthophosphate was measured according to Schwarzenbach (2005).

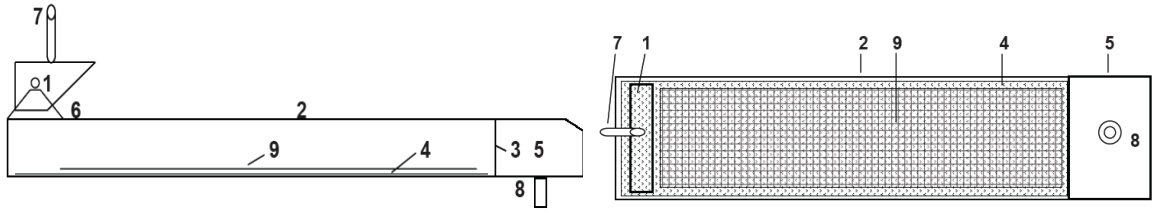

Figure 1 Algal Turf Scrubber (ATS) seen from the side (above) and from above (below). Legend: (1) tilt tray, (2) algae tank, (3) spill over rim (to 5), (4) algae turf carrier matrix (1 m^2 black PE grid, mesh size 1.8 mm, Type SEFAR Petex 07-1180/60), (5) collecting channel, (6) suspension device for tilt tray, (7) water inlet, (8) water outlet, (9) fixation grid for carrier matrices

In batch experiments, ATS were able to reduce P concentrations from 23 - 38 µg L^{-1} to 5.0 - 6.3 µg L^{-1} within 24h. P elimination was higher at higher flow rates of medium, the most efficient flow rate being 7.5 L min^{-1}.

Despite of a reduced algae dry mass, algae that were deprived of P for 7 days were capable to eliminate up to three times more P than well fed algae, both at day and during the night. Well-fed precondition of algae showed a significantly lower P elimination rate than starved (P=0.0153, F=8.53 on 1 and 10 DF).

The study demonstrated the capability of ATS systems to function well also at low P concentrations, and to be able to reduce P-concentrations down to 5 µg L^{-1}.

Acknowledgements This research was supported by the Commission for Innovation and Technology (CTI) of Swiss federation, grant 7477.1 EPRP-IWR.

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Salinization of Eutrophic Freshwater Wetlands: Risks and Opportunities

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Abstract In European lowlands, the risks of salinization of coastal wetlands are increased by the combined effects of sea level rise, land subsidence and decreased summer precipitation. To test the effects of surface water salinization on biogeochemical sediment processes under controlled conditions, we conducted two experiments at different scales. In aquaria in the laboratory, effects of constant versus fluctuating salinity levels were tested on different sediment types. In enclosures in a formerly brackish peaty wetland, the effects of increased salinity levels were tested for 2.5 years. Interestingly, salinization significantly decreased phosphate concentrations in the sediment porewater and surface water. Salinization did not seem to influence carbon dioxide emissions, but strongly decreased the emission of methane. Sediment characteristics had a strong influence on the effects of salinization. Furthermore it was shown that fluctuating and constant salinity levels can have very similar biogeochemical effects, and may result in a decreased mineralization and nutrient availability. The results show that salinization may not only be a risk for freshwater peatlands, but might also be a good restoration measure for formerly brackish, eutrophied peatlands, that are now freshwater agricultural lands. The restoration of the natural freshwater - brackish water gradient is expected to greatly increase biodiversity.

In European lowlands the risk of salinization of coastal wetlands is increasing by the combined effects of sea level rise, land subsidence and decreased summer precipitation. In the Netherlands drainage of peaty soils resulted in enhanced land subsidence leading to increased salt water influence through inundations and seepage, since the Middle Ages. This resulted in unique brackish peatlands with characterised vegetation and fauna communities. During the twentieth century the brackish influence in these peaty lowlands was actively decreased by infrastructural works and a changed water management. The decreased influence of brackish surface water in combination with eutrophication due to an intensified agricultural use led to an almost complete collapse of brackish communities. In this study biogeochemical effects of re-salinization of these areas were investigated to be able to predict the effects of re-salinization, which is considered to restore brackish water communities in peaty lowlands.
Salinization effects on aquatic sediments were tested both in a lab experiment with aquaria and a field experiment with enclosures. In a half year duration laboratory experiment effects of constant (both fresh and brackish) versus fluctuating salinity levels were tested on two sediment types. In a former brackish peaty wetland, the effects of increased surface water salinity levels (19, 35, 70, 140 mmol Cl/l) were tested for 2.5 years. In both experiments biogeochemical parameters were analysed in surface water and sediment porewater.
Surface water salinization showed to have fast and major influences on biogeochemical processes in aquatic sediments. Salinization resulted in a rapid mobilization of cations

(i.e. calcium & ammonium) from the cation adsorption complex (depended on sediment characteristics). The mobilization of cations influenced porewater phosphorus concentrations in the sediment. In other studies either phosphorus absorption (i.e. Baldwin et al., 2006) or phosphorus desorption (i.e. Spiteri et al., 2008) were shown as a result of salinization. In our study, salinization significantly decreased both porewater and surface water phosphate concentrations (Figure 1). Although our results do not provide sound evidence that phosphorus desorption did not occur the brackish water treatments, clearly indicate that phosphorus immobilization overrules phosphorus mobilization. The decrease in phosphorus is very probably caused by co-precipitation with calcium(-carbonate) and to a lesser extent co-precipitation with iron or aluminium. Due to this salinity induced immobilization the increase of sulphate concentrations in the brackish water treatments did not cause a net mobilization of phosphorus, as is often seen in freshwater wetlands (i.e. Lamers et al., 2002). Salinization did not seem to influence carbon dioxide production in the aquatic sediments. Methane production however was strongly decreased in the peat sediments in both experiments (Figure 1). This might be explained by competition for organic substrates by sulphate reducing bacteria and methanogenic bacteria (i.e. Baldwin et al., 2006). The laboratory experiment showed that fluctuating and constant salinity levels can have very similar biogeochemical effects, and may result in decreased nutrient availability and methane emission.
This study shows that salinization may be a viable restoration measure for formerly brackish eutrophied peatlands. Furthermore the restoration of the natural freshwater - brackish water gradient is expected to greatly increase biodiversity.

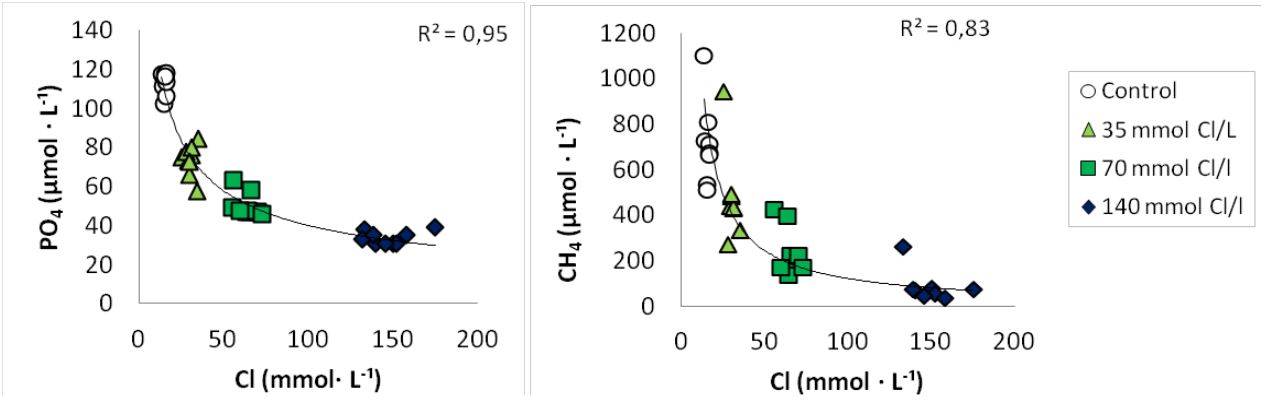

Figure 1 Porewater phosphate and methane concentrations in different salinity treatments in enclosure experiment in the field

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Integrating nature values for lakes in Cost-Benefit Analyses for spatial planning in the Netherlands

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Abstract Cost-benefit analysis for complex spatial planning with different local impacts needs to include impact on nature and water values. As different sets of values are used in the EU Nature 2000, EU Water Framework Directive and Wetlands Convention, a method was developed to integrate the values to meet requirements of the standards for water and nature quality. These integrated water and nature values were required for cost-benefit analysis for two wetland areas in the Netherlands. One potential development is Markermeer, the second largest lake of the Netherlands, with the creation of an artificial island for a new residential area, including water quality improvement and nature restoration. The other is for water level management in Ijsselmeer, the largest lake in the country. Both development plans have potential impacts on the spatial distribution and quality of the ecosystems. A method to aggregate the nature and water values for each lake was developed based on area, quality and relative importance of different ecosystems in the specific lake, which is crucial in distinguishing terrestrial and aquatic ecosystems. Quality was based on criteria used in EU Water Framework Directive and Nature 2000. The results were used in an early moment in strategic decision-making.

Cost benefit analysis are needed in spatial planning at an early moment in the planning process. Different options have to be evaluated to their costs and their effect to several aspects, e.g. employment, economy, recreation, landscape and biodiversity and nature values. Effects to nature and biodiversity are presented in these plans, but they are often shown as the effect to a list of specific species. In a cost benefit analysis all effects to nature have to be integrated to one quantitative value, the Ecological Quality Area (EQA) to make an easy comparison possible with the costs and benefits of different options (Sijtsma et al., 2013).
Different systems of nature quality are defined; e.g. Nature 2000 (based on birds and specific habitats), the biological evaluation of the WFD (fish, macrofauna, algae and water plants) or terrestrial ecosystems (breeding birds, butterflies and plants); these methods differ in scale and targets and not easy to integrate to a nature value.
A method was developed and used to calculate an overall biodiversity value. This nature value was based on the quality of the ecosystem, the differences in area between ecosystems and their relative importance for the ecosystem: EQA = ∑(area * quality * weigh factor) for all ecotopes. The weigh factor is based on the number of food consuming birds (top consumers), as a weigh factor for the relative importance of different ecosystems. These birds are feeding on the most import biological groups of the lake (fish, fresh water mussels, water plants, reed).
This method was applied for major decisions on water management in the Netherlands. The Markermeer is the second largest lake (700 km^2) and has a declining nature quality in the last decade. The spatial plan for the lake included an artificial residential island, improvement of the water quality and a new artificial marsh wetland. The overall effect of these measures had to be positive to meet the Nature 2000 targets and to compensate

the loss of biodiversity of the whole lake. The other case was the lake Ijsselmeer and connected lakes Ketelmeer, Vossemeer and Zwartemeer (1200 km^2). The water level is now 20 cm below sea level with a restricted variation of 10 cm. Different water level management scenarios were made to adapt climate change and sea level rice. Increase of the water level results in a decrease in area of important ecotopes for water birds and water plants. Model results were available to calculate the effect to spatial distribution of the ecotopes in both lakes (Haasnoot and Van der Wolfshaar, 2009). These results were aggregated with the quality data of the WFD.

Figure 1 presents the nature points for different options. The residential area in Markermeer had only a small negative effect on the nature values, but the artificial wetland had a major effect and compensates the loss of nature values in the last decades. In Ijsselmeer all options with an increase of the water level had a negative effect on the nature values. One option with an incidental decrease of the water level in case of a dry summer, had a positive effect on the nature values.

With this method the nature values were presented on an early moment in the decision on spatial development and water management. The result is the combination of the areas of the ecotopes with mussels, water plants and reed, in combination with change of the water quality. With the aggregation to one index, the nature values are included in the decision. But with this approach, local differences are neglected. Some groups are not included, e.g. birds that use the lake to sleep, are not included. Also the effect to fish migration is not accounted in this approach. Further research is needed to weigh different ecosystems to their relative importance and to integrate aquatic and terrestrial nature values.

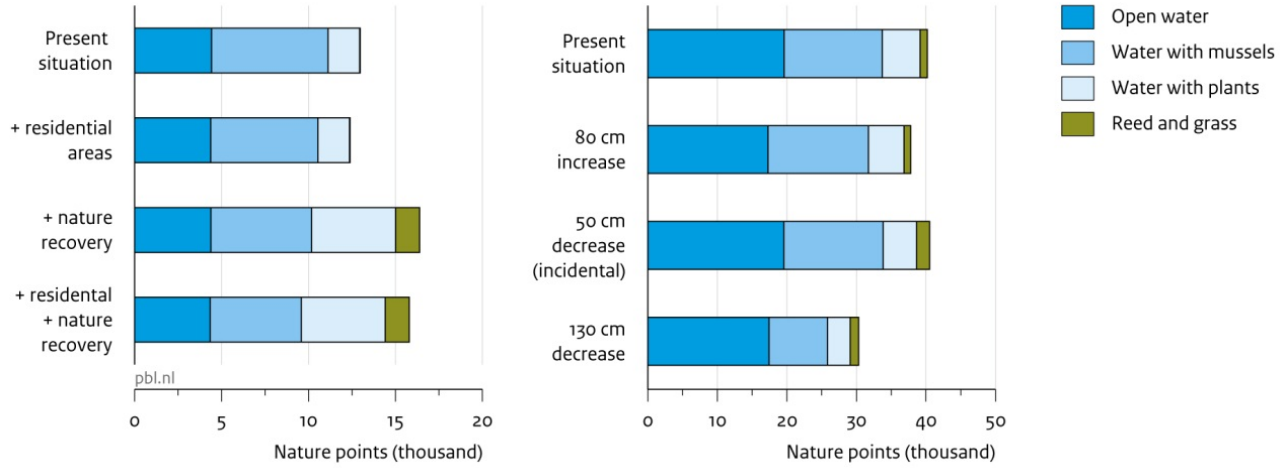

Figure 1 The nature values of Markermeer (left) and Ijsselmeer with the different spatial and water management options

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Effect of air pollution on bryophyte vegetation of bogs in NE Estonia and NW Russia

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Abstract Bogs in northern latitudes are characterized by hummock-hollow complexes shaped mostly by *Sphagnum* mosses. Human disturbances, such as air pollution, cause changes in bog vegetation and geo-chemistry. For instance, in the second half of 20th century, from bogs in the industrial region of NE Estonia, affected by alkaline calcium-rich fly ash, *Sphagnum* mosses almost disappeared. In a community scale, we have shown that such pollution causes ombrotrophic bog ecosystems degradetion toward less-structured transitional mire-like communities. In the present study, we hypothesized that bogs with high atmospheric input, will lose not only characteristic bryophyte species of natural bogs, but also bog specific features such as microtopographical structure, high bog water acidity level and low ash content of *Sphagnum* mosses. We sampled bryophyte vegetation in 36 bogs at different distances from polluters in Estonia and in Kingissepp Region of NW Russia. Our results show that species composition of bryophytes on hummocks and in lawns became rather similar toward highly polluted bogs. The pollution effect is more evident in lawns, where two factor act in parallel at a community level - changes of pH level and of hummock's height. We related observed compositional patterns with species dependent niche ranges.

Bogs in northern latitudes are characterized by the stable patterned hummock-hollow complexes shaped mostly by *Sphagnum* mosses. Human influence on bogs, including air pollution, causes essential changes in their vegetation and geo-chemistry driving to the degradation of ombrotrophic bog ecosystem into more uniform transitional mire-like system. In the second half of 20th century, bogs in the industrial region of North-Eastern Estonia and neighboring region of Russia have been influenced by alkaline calcium-rich fly ash, originated from the power plants burning oil-shale. We hypothesized that in bogs influenced by high atmospheric input main features of natural bogs as clear hummock-lawn-hollow microtopography, high bog water acidity level *etc*. will vanish and change in species composition toward the unification at a microsite level is followed.
The bryophyte vegetation was analyzed in 34 bogs at different distances from polluters in NE Estonia and in Kingissepp Region, NW Russia cross the border downwind from main polluters. DCA was applied on presence-absence data of species. Hummocks, lawns and pooled list of species included to the analysis as a sub-groups. Species reaction to the environmental gradient (indicted by bog water pH and conductivity) was estimated separately for hummocks and lawns, using Spearman correlation coefficient. Significant correlation was plotted as cross-scatter to illustrate, which species grow mostly on hummocks, lawns or both. Altogether 71.7% of total variation in species composition is described with the first two DCA axes. Analyzed sites form a clear gradient along the first axis of DCA, where bogs in natural conditions are located on the left side and polluted bogs on the right side of the ordination diagram (Figure 1). Hummocks are

ranked in the upper part of the graph, lawns in the lower part. The ordering of sites follows the pH gradient of bog water. Also differences in bog water chemistry and peat ash content between hummocks and hollows follow air pollution gradient. Significant correlations with axes are illustrated as correlation vectors (Figure 1).

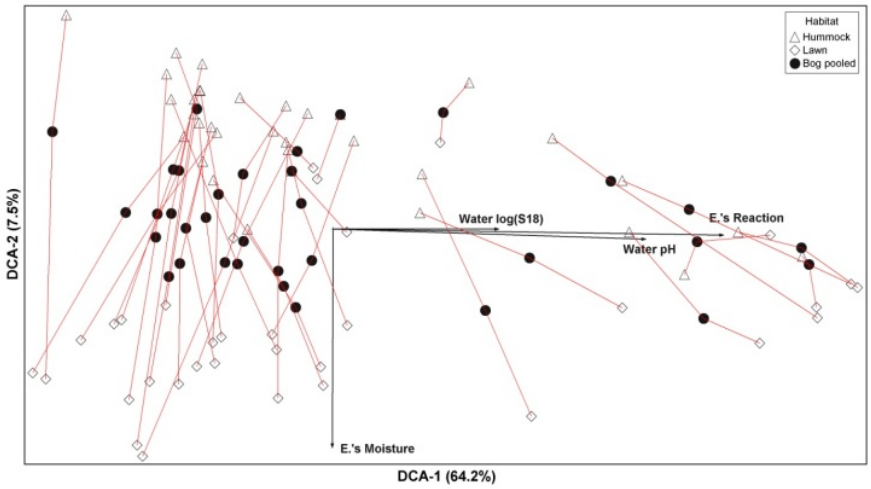

Figure 1 DCA ordination diagram of bogs by bryophyte species on lawns, hummocks and pooled data and environmental parameters

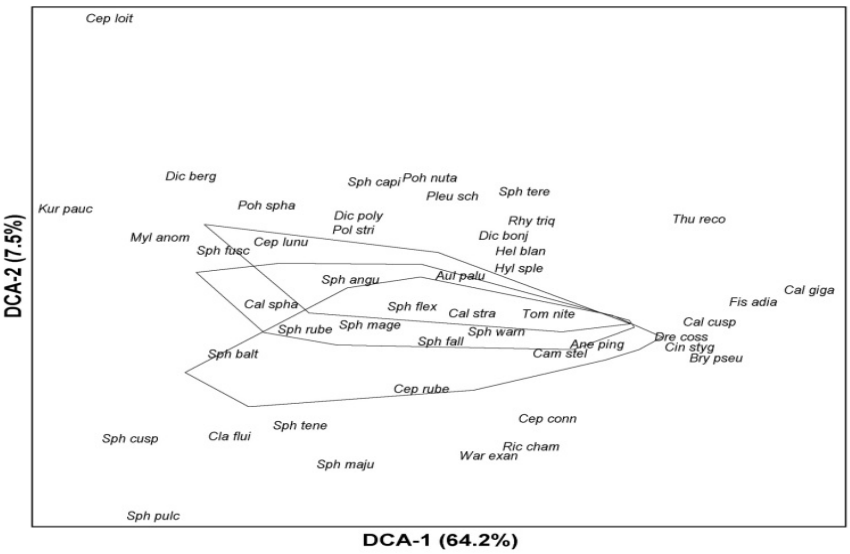

Figure 2 DCA ordination diagram illustrating the arrangement of bryophyte species of analyzed bogs. Demarked areas present species characteristic to the hummocks (upper area), lawns (lower area). The pollution load is growing along the DCA-1 axis

In intensively polluted bogs the bryopflora of different microforms has turn more similar and no remarkable differences appeared between species diversity on hummocks and lawns (Figure 2). In unpolluted or less polluted communities (on the left of the figure) more species characteristic for bogs grow on hummocks, e.g. *Dicranum bergeri* and *Pohlia sphagnicola*. In hollows beside the bog species also species more typical for transitional mires and fens can be find. In more polluted bogs fen species *Drepanocladus cossonii, Calliergonella cuspidata* etc. prevail both in hummock and lawns.

Acknowldegements: We are thankful to Olga Kalanina and Maria Noskova for assisting in fieldworks in NW Russia.

How efficient are constructed wetlands in removing pharmaceuticals from wastewater? - A review

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Abstract This study deals with the ability of constructed wetlands (CWs) in removing 138 pharmaceutical compounds (PhCs) belonging to 20 therapeutic classes from wastewater. It reviews 50 peer-reviewed journal articles, referring to experimental investigations carried out in about 100 plants including surface flow systems (SF), horizontal and vertical subsurface flow beds (H-SSF, V-SSF) (pilot or full scale) acting as primary, secondary or tertiary treatment. Occurrence of the selected PhCs in the CW influent and effluent, as well as in sediments and gravel is presented and discussed; removal mechanisms and efficiencies for the different compounds are presented, discussed and correlated to the main chemical properties of the compounds themselves (pK_a, $LogK_d$, $LogK_{ow}$…), the design parameters and the operational and environmental conditions of the corresponding treatment system; average pharmaceutical mass load for the effluents of a CW is evaluated. Finally an environmental risk assessment, based on the risk quotient RQ, is carried out for treated effluents providing to a ranking of the most critical compounds that can be present in the final effluent. This is compared with that found for activated sludge effluents (Verlicchi et al., 2012). The study completes with a discussion of the perspectives in the adoption of CWs in removing such persistent organic compounds.

The ability in removing common PhCs by means of different kinds of CWs and their combination is an issue of emerging concern worldwide. The possibility to reduce concentrations of recalcitrant compounds, like PhCs, in the effluent prior of its discharge in surface water represents a goal of recent studies which investigated their fate in CWs. The wide spectrum of chemical, physical and biological processes occurring within these treatment systems would seem to favour their removal. The current study wants to focus on the results obtained by the different research groups which dealt with this topic.
The study drew data from 50 peer reviewed papers, published between 2002 and 2013, referring to the occurrence of 138 PhCs belonging to 20 different therapeutic classes in the influent and effluent of different CWs. About 100 treatment plants were examined, acting as primary (7 %), secondary (51 %) or polishing treatment (43 %). About 30 % of them were full scale plants and 80 % were fed with real wastewater, the remaining with a synthetic mixture. Plants under review were mainly H-SSF beds (51 %) and SF systems (46 %); only 3 % V-SSF beds. 10 % of the selected plants were hybrid systems. Investigated plants were mainly placed in Europe (64 %, Spain, Portugal, Italy, Denmark, England, Sweden), followed by USA (14 %), Canada (11 %), Korea (5 %), South America (5 % Mexico and Brazil) and Australia (2 %).
Some of the main findings resulting from the study are here reported for a selection of compounds and for the three kinds of CWs. Figure 1 shows the variability ranges of concentrations in the secondary effluent and Figure 2 the corresponding removal efficiencies observed in the same plants; Figure 3 reports PhCs concentrations in polished effluent and Figure 4 the removal efficiencies achieved in those plants. The results of the

environmental risk assessment are shown in Figure 5 (secondary effluent) and Figure 6 (tertiary effluent), by means of the risk quotient.

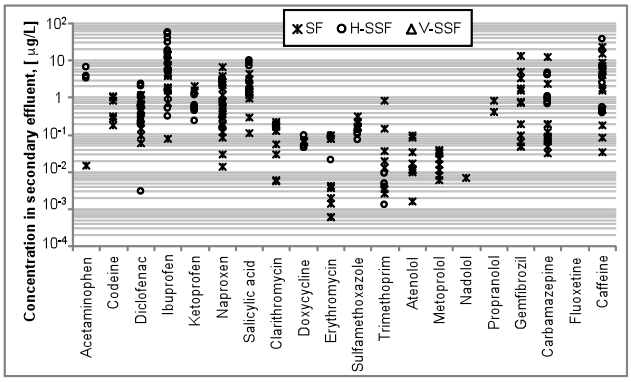

Figure 1 Concentrations of selected compounds in secondary effluent from different CWs

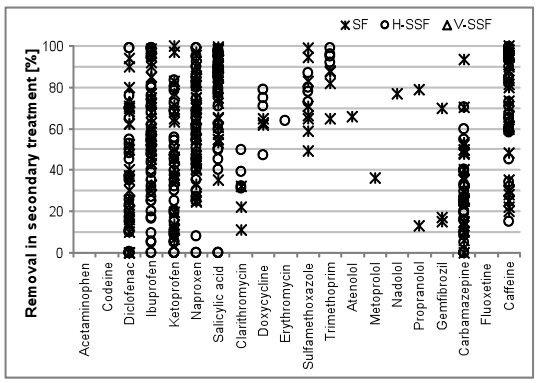

Figure 2 Removal of selected compounds in different CWs acting as a secondary step

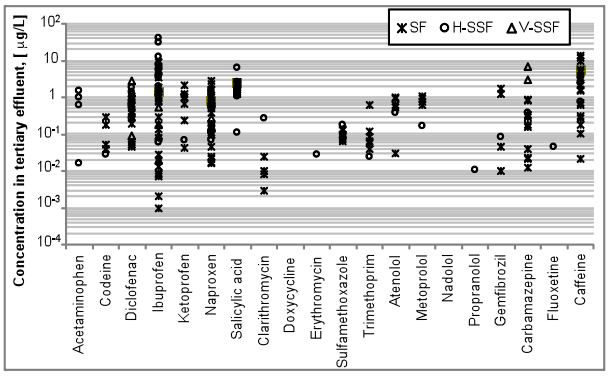

Figure 3 Concentrations of selected compounds in polished effluent from different CWs

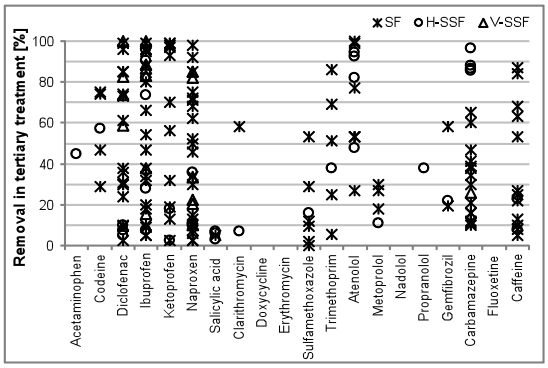

Figure 4 Removal of selected compounds in different CWs acting as a polishing step

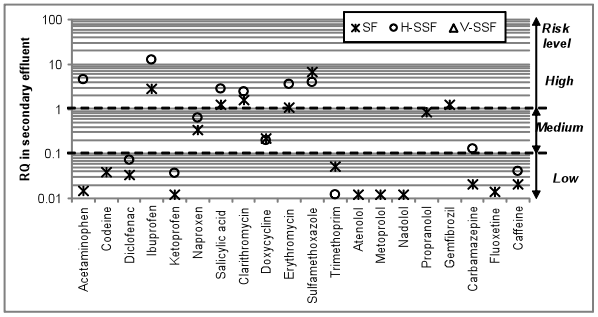

Figure 5 RQ of selected compounds in polished effluent from different CWs

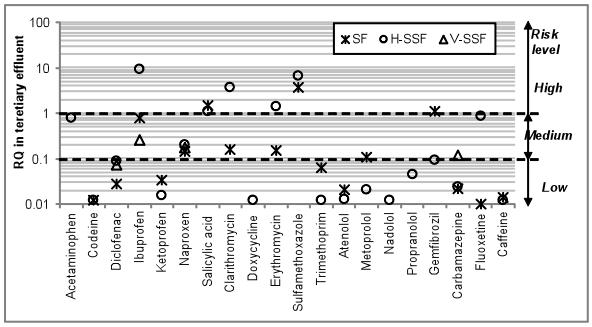

Figure 6 RQ of selected compounds in different CWs acting as a polishing step

A great variability was observed in the occurrence of PhCs in secondary as well as tertiary effluent, being the highest values detected for ibuprofen, salicylic acid, carbamazepine and caffeine. Data on removal exhibit a great variability, depending on many design and operational factors. CWs may reduce the environmental risks, but for some common analgesics/anti-inflammatories (ibuprofen, salicylic acid) and the antibiotics clarithromycin and sulfamethoxazole the risk still keeps high, even after a polishing treatment.

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Recent Active Tropical Peatland Fires in Indonesia (South East Asia)

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Abstract Since the historically worst air pollution of 1997-1998, peatland fire events in Indonesia are one of recent big issue for the world environmental. Kalimantan and Sumatra Island had selected as the study interest, to clarify recent peatland fire distribution, annual fire occurrence trends, and seasonality of fires. Hotspot (fire) NASA MODIS from 2002 to 2012 was analyzed using 0.5º grid cell sizes of latitude and longitude. To determine the seasonal trends of fire occurrence in active fires years were carried out using recent hotspot and precipitation data at 10-day intervals. The study area was divided into two climatic zones, which has affect the fire trends for these both largest peat islands. The severest fires for the Mega Rice Project (MRP) area in Kalimantan occurred in late September in 2009 under the driest conditions for Palangkaraya. The severest fire incidents for Dumai area in Sumatra occurred in March in 2005 under the driest conditions for Medan and Pekan Baru. Fire activities in the last 11-year in south Kalimantan and Sumatra were severe than other areas due to the peat become dryer under the relatively longer dry season (> 3-month).

Approximately 60% of total global tropical peatland is located in Southeast Asia, and mostly of that peatland (~80%) is distributed only in Indonesia (Page et al., 2011). The worst fires mainly on peatland in Southeast Asia history occurred during the strongest the El Niño event of 1997-98, which was the strongest El Niño event on record prior to 2000. Since then, recurring fires and haze problem in Indonesia have become an annual phenomenon (Putra et al. 2008). Thus, the emissions of carbon solely from peat fires in Southeast Asia (mostly from the Sumatran and Kalimantan peatlands) are very similar to emissions from the whole of Sub-Saharan Africa (Harris et al., 2012). Indonesia has now been requested to reduce not only carbon emissions from peatland fires under the programme on Reducing Emissions from Deforestation and Forest Degradation plus (REDD+). Hotspot data captured by MODIS (Moderate Resolution Imaging Spectroradiometer) from 2002 to 2012 was analyzed to better comprehend the problems associated with fires in Indonesia, Kalimantan, and Sumatra. Due to Indonesia's size and number of islands, 0.5° × 0.5° grid sizes utilizing latitude and longitude angles were used in this study. Precipitation data was mainly analyzed to explain fire activities in several regions in Kalimantan and Sumatra, simply because precipitation was a common weather data for all the major weather stations in Indonesia. Most data were tallied every 10 days, enabling a detailed understanding of the seasonal and spatial fire occurrence and precipitation trends. Results of detailed analyses clearly show the two severe fire regions (7 adjacent cells) were identified in the MRP region in Kalimantan, and in the Dumai region in Sumatra. Most fire-prone regions in Kalimantan and Sumatra are located on the peatland and its vicinity (see Figure 1). The severest fires for the MRP area and its vicinity area (south latitude) occurred in late September 2009 under moderate El Niño-driven drought. Contrary, the severest fires for the Dumai area (north latitude) occurred

in early March 2005 under drought enhanced by psedou-El Niño (Modoki), as shown in Figure 2. Fire occurrence tendencies in fire-prone regions are mostly explained using the two different precipitation patterns of the region: the summer dry season pattern (S_D) and the winter and summer dry season pattern (WS_D). The southern part of Kalimantan and Sumatra, which are located in the southern hemisphere and belong to the S pattern, show severe fire activities over a relatively longer dry season over a few summer months. The northern part of Sumatra, which is located in the northern hemisphere and accords with to the WS pattern, shows separate periods of fire activities, due to two dry seasons in both winter and summer months. From a comparison of fire activities in several areas on both islands, it is evident that the most severe peat fires occur in the southern part of Indonesia, due to the relatively longer dry season (of more than 3 months under El Niño) compared with other areas.

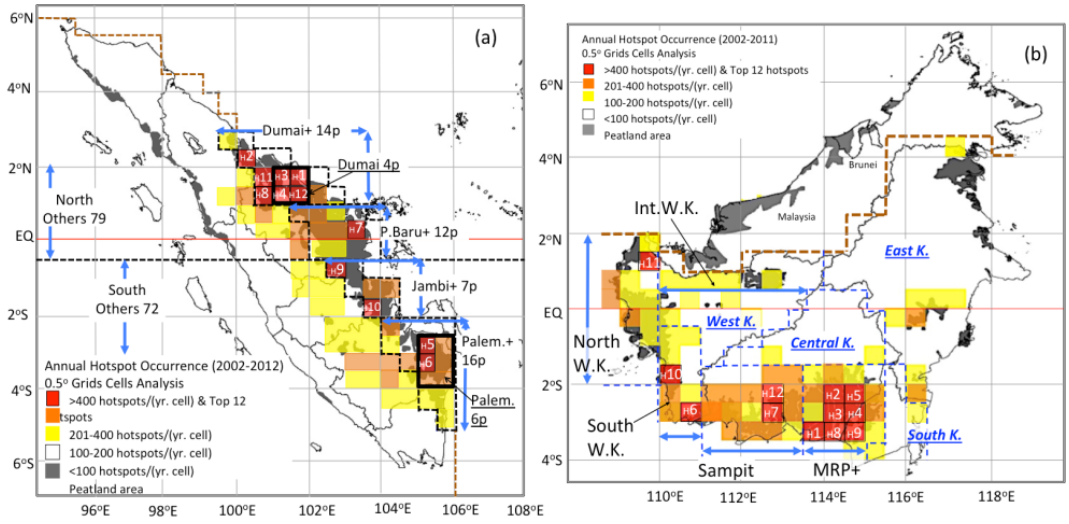

Figure 1 Map of the highest hotspot cells in Sumatra (a) and Kalimantan (b), Indonesia, Southeast Asia

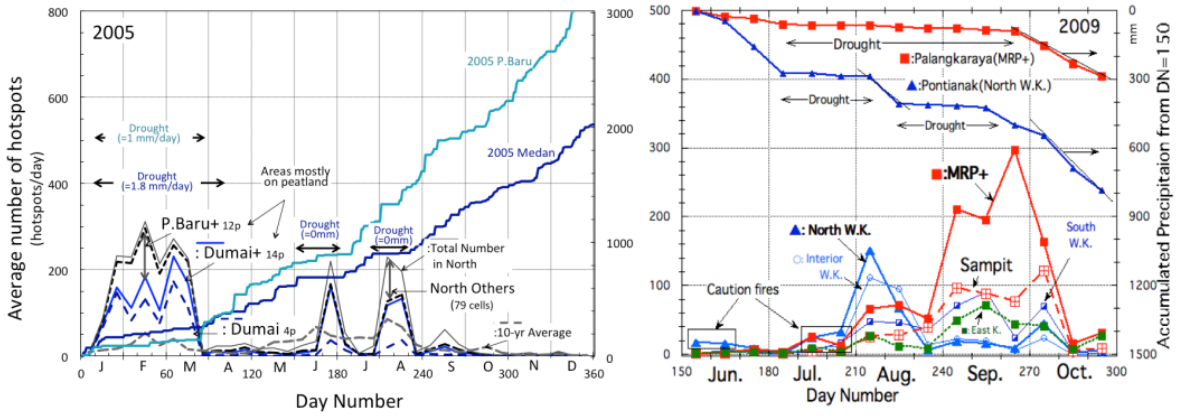

Figure 2 Severe fire occurrence and drought in north Sumatra (2005) and south Kalimantan (2009)

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Mitigating Zn and Pb content from artificial runoff events using vegetated biofilters

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Abstract The quality of stormwater runoff from the highway and urban environment is of increasing concern to urban communities and, consequently, greater emphasis is now being placed on the management of stormwater quality. In this context we examined the efficiency of vegetated biofilters applying simulated road runoff containing Zn and Pb (3 and 1.5 mg L^{-1} respectively). The experiment was carried out from September 2011 to June 2012 and consisted in 18 biofilters (0.8 m^3 volume each) designed as follows: two types of soil (silt loam, and silt loam with 10% zeolite), three different vegetations (*Salix eleagnos* Scop., *Carex pseudocyperus* L., *Iris pseudacorus* L.) and three replications per treatment.. Zn and Pb content was analyzed monthly in outlet samples. In November 2013, in correspondence of sediment sampling for metals analysis, vegetation was sampled and aerial part and roots tissues analyzed for biomass, fresh/dry weight, and metals content. The obtained results evidenced a considerable abatement of both metal species, particularly for lead with a median higher than 90%. No statistical differences were observed among the modules. Zinc was more accumulated in plant biomass than lead, with higher concentration of both metals in roots than in shoots.

Stormwater runoff generated from roadway and other land usages has been increasingly found to be one of the major sources of non-point source pollution to receiving waters and soil (Ellis et al., 1994; Kayhanian, 2012). In particular, highway runoff includes several constituents such as metal elements and suspended solids, which result from traffic activities, atmospheric deposition, roadway degradation and highway maintenance. In order to manage and control this source of pollution, emphasis is paid to develop new cost-effective techniques (Trowsdale and Simcock, 2011). In this context 18 vegetated biofilters have been studied from September 2011 to June 2012, to identify the simulated highway traffic sources pollutant removal effectiveness of three different vegetations species (*S. eleagnos*, *C. pseudocyperus, I. pseudacorus*) combined with two media (silt loam, S and silt loam with 10% zeolite, SZ) and three replications. The experimental facility was installed under a cool greenhouse with a transparent impermeable roof, which allowed full natural sunlight, but prevented rainfall into the modules. Each module was composed of two structures to reproduce real grass swale condition: the upper part (1.6x1.3x0.4m), filled with the medium, where the plants were planted and a lower container used to store the percolation water (approximately 210 L).
A total of 20 rainfall events were simulated in correspondence of precipitation higher then 5mm of daily rainfall. The volume added to each module was obtained by the rainfall height and the hypothetical road surface runoff connected to the biofilter. The ratio between surface of biofilter and surface of road was 1:2. The simulated road runoff was added of Zn and Pb (3 and 1.5 mg L^{-1} respectively). Metals content in the water

storage module were determined twice a week until November and then monthly using ICP/AES (USEPA, 1997). In November 2013 the concentration in soil and plant tissues was also analyzed. Inflow ranged between 0.52 to 2.00 mg L^{-1} Zn and 0.26 and 1.00 mg L^{-1} Pb. These values were 5-10 times higher than the standard runoff concentration (Stagge et al., 1994; Trowsdale and Simcock, 2011). All biofilters significantly reduced the metals concentration, with median abatements of 80% and 92% of Zn and Pb, respectively (Table 1). The percolation water samples exceeding the National Water Quality Requirements (D. Lgs. N.152/2006) were within the range 17-25% for Pb and 25-33% for Zn. No significant differences were observed among the treatments. As previously observed in other studies, higher performance of biofilters is primary due to sedimentation and filtration processes (Ellis et al., 1994; Stagge et al., 2012).

Table 1 Median abatement (%) and outlet water samples (%) exceeding the National Limits

	Water Quality Goal	***Salix eleagnos***				***Carex pseudocyperus***				***Iris pseudacorus***			
		S		**SZ**		**S**		**SZ**		**S**		**SZ**	
	(mg L^{-1})	Remov. (%)	Exceed. (%)	Remov. (%)	Exceed. (%)	Remov. (%)	Exceed. (%)	Remov. (%)	Exceed. (%)	Remov. (%)	Exceed. (%)	Remov. (%)	Exceed. (%)
Zn	0.5	79	25	77	50	79	25	81	33	82	33	81	25
Pb	0.3	92	17	95	17	92	25	94	17	95	25	93	8

Above ground part of *S. eleagnos* demonstrated a statistical higher Zn accumulation ability compared to the other plants, whereas Pb in the aerial part exhibited concentration below the analytical detection limits in all the species (Table 2). When considering roots, statistical higher concentration of both metals was observed in *C. pseudocyperus* in respect to *S. eleagnos*. Soil factor did not significantly influenced accumulation in the treatments.

Table 2 Median concentration of Zn and Pb (ppm DW) in plant tissues in the different treatments

		Salix eleagnos		***Carex pseudocyperus***		***Iris pseudacorus***	
		S	**SZ**	**S**	**SZ**	**S**	**SZ**
Zn	aerial	92.89	80.81	22.76	24.47	20.52	18.85
	roots	53.35	54.95	69.85	128.10	71.46	55.28
Pb	roots	0.40	1.25	3.55	12.76	1.19	3.39

The performance of field-scale biofilters was evaluated as a simple and effective runoff control system for reducing metals content. Plants selected in this study showed resistance to Zn and Pb and some capacity to absorb Zn, whereas the addition of zeolite to soil did not affect metal abatement. Vegetated biofilters generally improved runoff water quality and could be used as a cost-effective alternative to non-point sources of pollution.

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Towards a standard method for the assessment of filter materials for biologically treated bathing water

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Abstract In biological swimming ponds different filter systems are used to reduce nutrient levels in the water and thus control the algal growth in the utilisation zone. The optimal construction (material, structure) and operating conditions (hydraulic loading rate) for these filters, which treat the already oligotrophic swimming ponds, are not known. The systems are mostly build based on empirical know how of different constructors. To advance the swimming pond technology, a system-independent way to compare the performances of filter systems is needed. Here I present a modular test stand that can be used for the investigation of filter materials and operating modes.

Swimming ponds are classified in five categories, according to their construction and the level of technical equipment (SVBP 2012). In swimming ponds of the categories 4 and 5, filter systems are used to avoid the eutrophication of the water and thus control the unwanted algal growth in the utilisation zone. Filter systems contain biofilms, community of microorganisms that eliminate nutrients by various physical, and chemical and biological mechanisms from the water (Kuljian et al., 1995, Neufelt et al., 1994). This ability of the biofilm to extract nutrients from the medium, to accumulate them locally, and to fix by cell growth, is used in swimming pond systems for nutrient removal. Excess microorganisms are removed from the system by a back-flush of the filter system after short anaerobic period with fermentation.
Favourable conditions within the filters should promote the development of the biofilm. However, the ideal construction (materials, structure) and conditions (loading rates) for treating the already oligotrophic water of swimming pools is not known yet.
Baumhauer and Schmidt (2008) showed that filters had higher elimination rates if they were operated at lower loading rates. However, they obtained their results within a single filter run and not from the overall balance in continuously operated closed system. The recommendations for the design, construction and maintenance of private swimming ponds of "Forschungsanstalt Landschaftentwicklung und Landschaftsbau e. V." (FLL, 2006) advise hydraulic loading rates of 0.05-5 m/d. The new version (FLL, 2011) recommends levels of 3-10 m/d. In most conventional systems, which are built in Europe, flow rates of 12-240 m/d are usually used. Frei (2012) showed that the biofilm growth increases proportionally with higher flow rates at same concentration. As a consequence, several new systems are operating at flow rates up to 3200 m/d.
So far, the study of the conditions for the biofilm growth was hampered by the absence of a suitable system, which would allow for testing various filter materials, flow rates and operating modes. Here I present a new modular testing unit which will fill this gap.

Two identical prototype units were constructed (Figure 1). The filter systems were made from glass, with a height of 1 m and diameter of 100 mm, and were filled with 2 L of chemically inert glass beads with a defined surface (SiLibeads). A glass container served as a reservoir, and was filled with 100 L of test water according to DIN EN ISO 38 412 with additional carbon component (5 mg/l) and phosphorus levels of either 10 μg/l or 100

μg/l. Both reactors were operated in a separate circuit with hydraulic load of 33 m/h. Prior to the test, the reactors were run for 10 weeks, to allow for development and adaptation of the biofilm. The test period was two weeks, with daily measurements of the carbon, phosphorus and nitrogen in the reservoir, followed by fertilization on the target value. Conductivity, redox potential and pH were recorded continuously with data loggers (GHL).

The phosphorus levels were recorded for two weeks (Figure 1). The filter units were highly efficient, reducing phosphorus concentrations very fast to the level, when P became limiting, and as a consequence the filter functions temporarily stagnated. Even at high loading rates very efficient nutrient reduction took place.

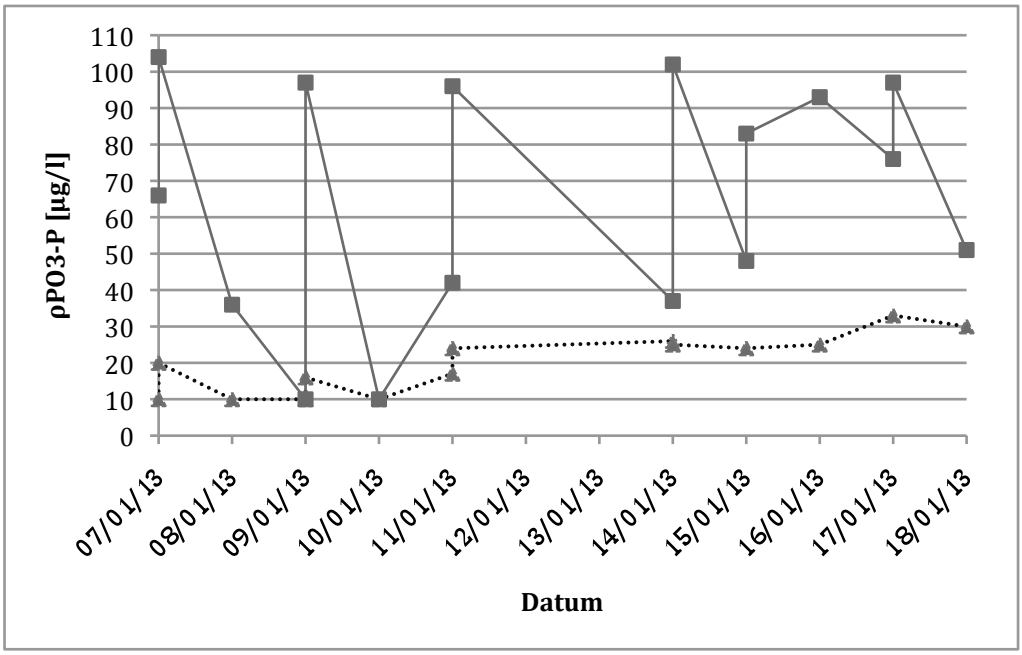

Figure 1 Phosphate-Phosphorus levels during the two week test. Squares and full line: Unit 1, operated with 100 µg P/l, triangles and dotted line: Unit 2, operated with 10 µg P / l

The test unit and the methods proved to be suitable for the evaluation of filter performance, but need to be further optimized.

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Dissolved Organic Nitrogen (DON) fractionation using XAD-4 and DAX-8 resins.

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Abstract Studies by Evans et al., (2012) have shown that the trend of dissolved organic carbon (DOC) concentrations increasing in wetland derived freshwater could be due to decreasing sulphur deposition, returning the waters to their pre-industrial, high DOC concentration state. Wetlands, such as those in north Wales, are a common source of water for human consumption. However, wetlands have high concentrations of DOC, which is transported in water draining the land. Because of the increasing DOC concentrations, water companies face increasing treatment costs, and once the water is disinfected, there is a higher probability of potentially harmful disinfection by-products (DBPs) forming, caused when the disinfectant reacts with DOC. These DBPs are known to be of a health concern to the consumer, with links to various health complications. DOC, the major constituent of dissolved organic matter (DOM), has been closely examined to understand its contribution to the formation of DBPs, however, the nitrogen-based component of DOM, dissolved organic nitrogen (DON), has only recently been recognised as being a precursor for potentially more harmful DBPs – nitrogenous disinfection by-products (n-DBPs). As further research is required to better understand the role of DON in n-DBP formation, this work uses an unpublished method to study the structural character of DON.
Adapting a method commonly used to characterise DOM in the research of DOC characterisation, a resin based fractionation method has been used to characterise DON into five different classes, with promising results.

This experiment focussed on 12 streams that fed 3 different reservoirs in North Wales, UK (Alwen Reservoir, Llyn Conwy and Llyn Cefni). These reservoirs store water for human consumption, and were selected for research because they were thought to represent a range of nitrogen concentrations from oligotrophy conditions (Conwy) to eutrophy conditions (Cefni).
The samples were collected every 4 weeks to monitor changes in the properties and character of the streams and the reservoirs. Each one litre sample of water was initially filtered through a 0.2μm pore size Whatman nylon membrane and acidified with HCl to pH 3. The DOM of the samples was then fractioned by passing through a series of XAD-4 and DAX-8 resins in tandem. The hydrophobic and hydrophilic fractions of the DOM were adsorbed onto the resins and the effluent passing through both resins was collected and classified as the hydrophilic neutrals. The adsorbed hydrophobic DOM was then desorbed off each resin using 0.1M NaOH and collected as individual samples. A further desorption of each resin using 0.1 M HCl was carried out and the samples collected were classified as the hydrophilic fractions. The resulting 5 fractions contained various concentrations of DOM depending on its character. Once the sample cycle was complete, the hydrophobic fraction samples were acidified to pH 3 with dilute HCl, before all samples were stored in the dark at 4°C. Each recovered fraction was then analysed for total nitrogen (TN) content using a Thermalox TC/TN analyser. The same samples were

analysed on a Metrohm 850 IC for anion and cation concentrations and the total inorganic nitrogen (nitrite, nitrate and ammonium) concentrations was subtracted from the TN value to derive DON.

Previous studies of these fractions have focused on DOC, however, DON, which is also present in these fractions, is often neglected. This method involved little extra work from DOC analysis of the fractions, and could be utilised as a method for DON character analysis. With research into the potentially harmful effects of n-DBPs increasing, it is fundamental that a complete understanding of DON and its character is achieved. It was suggested by Templeton (2011), that more DON data from a range of UK source waters will help in the understanding of n-DBP occurrence at the treatment works and beyond.

Although the experiment is still in process, initial results show that the majority of DON can be found in the hydrophilic neutral fraction, with very little found in either of the base fractions. This differs from the fractionation of DOC, where the hydrophobic acid fraction contains the majority of the DOC, with the next highest concentration found in the hydrophilic acid fraction. The various concentrations collected will reflect the DOM characteristics in the stream catchment, data of which can help to create localised DON stabilisation or reduction techniques, reducing the risk of n-DBP formation at the treatment works. Such stabilisation and reduction techniques could include alternative land management regimes.

Acknowledgements The authors would like to thank Dŵy Cymru (Welsh Water) and KESS for the funding to make this project possible.

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Are metal nanoparticles more available to wetland plants than to dryland plants?

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Abstract Rapidly growing use of engineered nanoparticles, particularly for agricultural applications, means these materials are entering natural wetland and aquatic systems via waste streams and watersheds. There are few studies on the uptake of nanoparticles on plants in these ecosystems, particularly higher plants and rooted macrophytes. Our research has shown that the wetland plant species, *Rumex crispus*, translocates Ti into the shoots when the roots were exposed to TiO_2 nanoparticles, which contrasted with dryland plants (wheat and bean) that showed little translocation. The crop plant spinach, grown under hydroponic conditions, did show translocation of Zn when the roots were exposed to ZnO nanoparticles. The submerged aquatic plant *Elodea canadensis* also took up Ti, but showed a different uptake response when the water matrix contained P. Our research highlights (1) the potential for plants to take up metals associated with nanoparticles in aquatic systems, (2) the difference in uptake behaviour between wetland and dryland plants, and (3) the importance of interactions between nanoparticle metals and other elements in the plants and in the water matrix.

Engineered metal nanoparticles (defined as particles < 100 nm) are of concern due to their rapidly increasing use in various commercial products and agricultural applications and also due to the gaps in our knowledge regarding their activity in ecosystems. Research on higher plants, primarily food crops, has shown nanoparticles have varying effects (depending on type of nanoparticle, plant species) on germination rates, root elongation, biomass production, and genetic effects (see Miralles et al., 2012). Because engineered nanoparticles can easily enter waste streams and watersheds, they will enter natural wetland and aquatic systems. Several groups are investigating the nanoparticle behaviour and impacts on organisms in aquatic systems, but only a few articles have been published on impacts of nanoparticles on wetland or aquatic plants, including root elongation in seedlings of several species (Yin et al., 2012), movement of nanoparticles into rice grains (Lin et al., 2009), and potential movement in wetland food chains (Yeo and Nam, 2013).

Our research has shown wetland plants to take up titanium associated with TiO_2 engineered nanoparticles when grown under hydroponic conditions (Jacob et al., 2013). The rooted wetland plant R*umex crispus* L. (curly dock) translocated Ti into the shoots (Figure 1a). This was in contrast with two dryland plants, wheat (*Triticum aestivum*) and bean (*Phaseolus vulgaris*), which took up Ti into the roots, but showed no transfer into the shoots. *E. canadensis* Mich. X (Canadian waterweed), a floating aquatic plant, can take up Ti via the roots, but more importantly also via the shoots, and revealed interactions between Ti from nanoparticles and other elements (Figure 1b). Increased

uptake of Ti resulted in decreased uptake of Mg and Mn. However, Ti uptake decreased with higher concentrations of P in the nutrient solution.

Our current research involves plant uptake of Zn upon exposure to ZnO nanoparticles. We are investigating the plants *Oryza sativa* (Asian rice), *Lemna* spp., *Spinacia oleracea* (spinach), and wheat grown under hydroponic conditions. Results for spinach show the plants take up and translocate Zn from the roots to the leaves (Figure 1c). Our study includes potential genetic effects of nanoparticle exposure. Future studies will also include effects of carbon nanotubes on plant growth and gene expression.

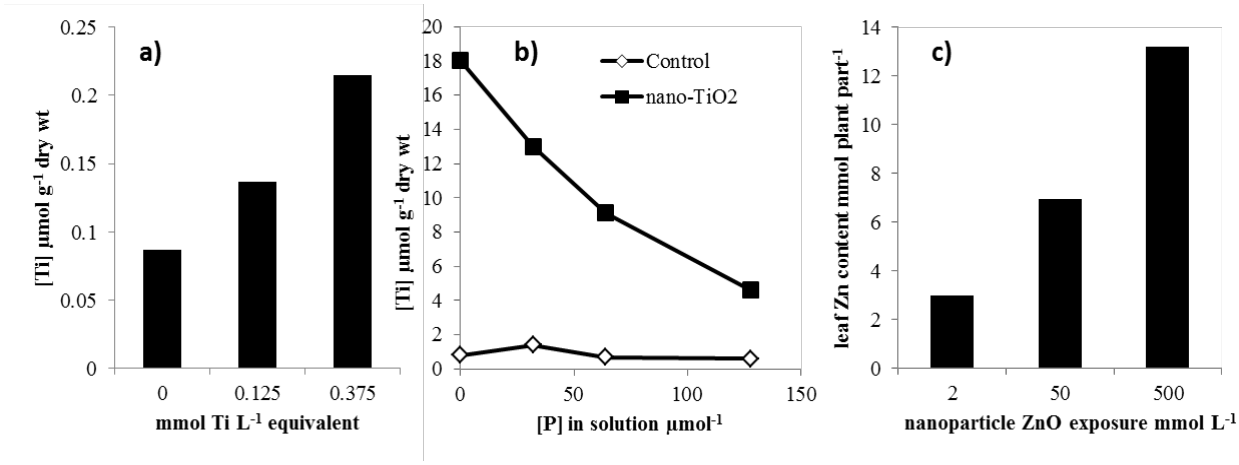

Figure 1 a) uptake of Ti into leaves of *Rumex crispus* (μmol g^{-1} dry wt) when roots were exposed to different concentrations TiO_2 nanoparticles in nutrient solution; b) uptake of Ti into *Elodea canadensis* when exposed to different concentrations of TiO_2 nanoparticles (0.125 mmol Ti L^{-1}) (compared to control of no Ti addition) in different concentrations of P in the nutrient solution; c) uptake of Zn into leaves of *Spinacia oleracea* (mmol plant $part^{-1}$) when roots exposed to different concentrations of ZnO nanoparticles

Our research highlights the differences in availability of nanoparticles to wetland and aquatic plants compared to dryland plants. This raises questions about the potential for trophic transfer and effects on the ecosystem.

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Landfill leachate treatment by oleaginous plants

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Abstract Plant utilization for landfill leachate treatment is considered a possible alternative to less sustainable systems. In order to evaluate phytotreatment efficiency, three oleaginous plant species, Helianthus annus, Glycine max and Brassica napus, were grown in pots filled with sand. Half pots were treated for three months with diluted leachate at increasing nitrogen concentration. The remaining pots were treated with nutrient solution. Promising results were obtained by the leachate phytotreatment process. The plants growth was positively affected by leachate irrigation, although a lower shoot biomass of soybean and rapeseed plants compared to controls was observed. High nitrogen removal efficiencies were obtained for the three plant species during the first 8 weeks of treatment. In the last 4 weeks, plants underwent to the senescence phase and the capacity of nitrogen absorption was consequently reduced.

One of the major environmental issues in landfill management is the formation of leachate. Due to the high variation in the composition of leachate (Kulikowska and Klimiuk, 2008), different treatment systems can be applied, but most of them pose critical questions about their sustainability. Phytoremediation appears as a valuable alternative to other energy intensive processes for landfill leachate treatment (Jones et al., 2005), as it can combine an efficient pollutants removal to the production of a potential energy source, such as wood from short rotation coppice, or biodiesel from oily crops plantations.
Leachate was collected from a municipal solid waste landfill located in the North East of Italy. Among several parameters, nitrogen content of the leachate was measured. Seeds of three common oleaginous species, *Helianthus annus*, *Glycine max* and *Brassica napus* were germinated in moisted paper and the obtained seedlings were then transplanted in 20 L pots filled with sand. Plants were irrigated for a week with nutrient solution and then were divided in two groups: one watered with the same nutrient solution (control plants) and the second fed with tap water added with leachate. The percentage of leachate increased from 2% in the first week of treatment to 30% in the last week. After 3 months, plants were harvested, and shoot and root fresh and dry weight measured. A draining system allowed to collect liquid samples at the bottom of the pots. Samples were analysed for nitrogen concentration. Nitrogen removal percentage was calculated from the difference between the amount of N input and the N output.
At the end of the experiment, shoot and root dry biomass of the plants was determined in order to evaluate plant growth. Even if occasional signs of stress (older leaves desiccation) were detected during the irrigation period, leachate treated plants developed larger root biomass than controls (Table 1). Only sunflower shoot took advantage of the water-leachate irrigation, while shoots of soybean and rapeseed grew less than control plants. Most likely, the reduction in biomass production in the above ground parts of these two plant species was related to the lower tolerance to leachate toxicity.

Table 1 Shoot and root biomass (g D.W) of the three crops irrigated with nutrient solution (control) or with diluted leachate

	Shoot (g D.W.)		**Root (g D.W.)**	
Plant species	Control	Leachate	Control	Leachate
Sunflower	26.4±2.1	20.3±1.9	3.34±0.85	1.14±0.42
Soybean	16.7±1.4	18.8±1.6	2.36±0.77	1.93±0.66
Rapeseed	16.8±1.6	20.7±2.7	10.30±1.31	7.92±0.91

At the beginning of the experiment, nitrogen concentration of the diluted leachate was 15 mg N L^{-1} and at the last week of treatment it achieved 370 mg N L^{-1}. During the first 8 weeks of treatment, nitrogen removal efficiency ranged between 70% and 95%, with the highest values observed in soybean pots (Figure 1). Afterwards, the efficiency in N removal drastically dropped to very low percentage values. Rapeseed plants maintained the highest removal efficiency during the last weeks.

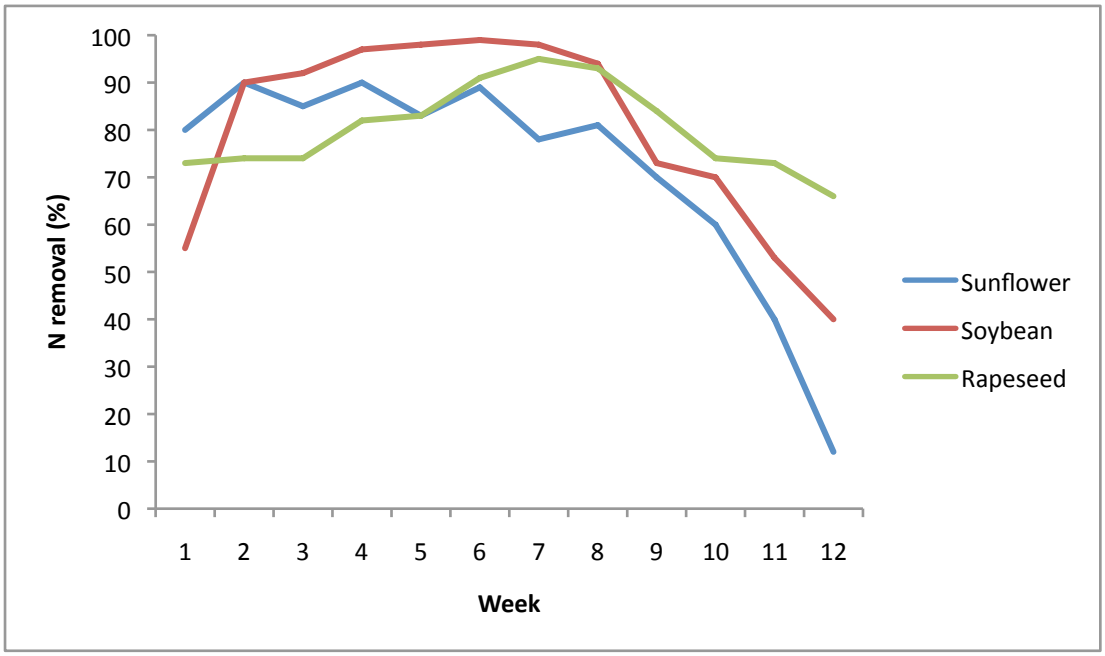

Figure 1 Time course of the nitrogen removal (%) of the three plant species irrigated with water-diluted leachate

The reduction in N removal efficiency displayed in the last 4 weeks, particularly by sunflower and soybean plants, could be ascribed to the phase of senescence of the plants, which limited the absorption of nitrogen.

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Metal partitioning in plant-soil-water compartments under EDDS-assisted phytoextraction with *Brassica carinata* A. Braun

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Abstract New easily degradable chelating agents have recently been proposed as alternatives to the more recalcitrant EDTA for metal phytoextraction with biomass species, but there is still little information on their possible environmental side-effects. In a pot study, the fate of mobile Cu, Pb and Zn was evaluated in a mixture of contaminated pyrite waste and sand after one [S,S]-EDDS-assisted (ethylene diamine disuccinic acid) phytoextraction cycle with *Brassica carinata* A. Braun. In comparison with untreated controls, doses of 1 mmol kg^{-1} of EDDS were repeated five times at 5- and 10-day intervals during cultivation, and 2.5 and 5 mmol kg^{-1} were applied once to the substrate one week before harvest.
All EDDS treatments increased shoot Cu and Zn concentrations, but their removal by the harvestable biomass improved only in close-to-harvest applications; a worsening was observed in the repeated treatments, due to impaired plant growth. In contrast, Pb was only taken up by treated plants. During cultivation, considerable Cu leaching occurred under EDDS, especially with repeated applications (20 mg Cu L^{-1} in leachate), but concern may also arise after single close to harvest applications, due to the high residual Cu bioavailability in the substrate (e.g., +68% with 5 mmol EDDS kg^{-1} vs. controls). Instead, bioavailable Zn and Pb seldom decreased, perhaps due to their colloidal re-adsorption by virtue of the greater Cu- and Fe-EDDS affinity. Of the total mobile metal pool (bioavailable + taken up + leached), the bioavailable fraction in the substrate was still the largest, regardless of chelator application, whereas plants removed a negligible amount (<1%).

EDDS (ethylene diamine disuccinic acid) has been introduced in order to replace more recalcitrant chelators, such as EDTA (ethylenediaminetetraacetic acid) in assisted-metal phytoextraction with biomass species (Quartacci et al., 2007), but many studies suggest that even fast-biodegradable chelating agents can dangerously increase metal leaching (Kos et al., 2004; Meers et al., 2005). Currently, there is still little information available on the real risk of metal movements in soil and water after amendment with such chelators.
In this study, the fate of mobile Cu, Pb and Zn was evaluated at pot level in a mixture of contaminated pyrite waste and sand (1:1 w/w) (total Cu: 870 mg kg^{-1}; Pb: 250 mg kg^{-1}; Zn: 1.200 mg kg^{-1}) after one [S,S]-EDDS-assisted phytoextraction cycle with *Brassica carinata* A. Braun. Treatments were: 1 mmol kg^{-1} of EDDS applied five times at 5- and 10-day intervals during cultivation starting from 48 and 28 days after sowing respectively, and 2.5 and 5 mmol kg^{-1} applied once to the substrate one week before harvest, in comparison with untreated controls.

Controls removed 0.045 and 0.12 mg per plant of Cu and Zn respectively; Cu accumulation generally increased with EDDS supply, although it was reduced when the chelator was added at 10-day intervals; Zn removal also worsened with both repeated EDDS treatments (-54% on average). In contrast, Pb was accumulated in plant tissues only when EDDS was supplied, although at very low concentrations (maximum 0.84 mg kg^{-1} with 5 mmol EDDS kg^{-1} applied close to harvest). Residual Cu, Pb and Zn bioavailability in the substrate of controls was 66, 39 and 11 mg kg^{-1}, respectively. Copper bioavailability increased only with the maximum single EDDS application close to harvest (+67%), whereas those of Pb and Zn were reduced in all treatments (on average: -14% and -21% for Pb and Zn, respectively), with the exception of the earliest EDDS application (at 10-day intervals). The increased Cu availability was due to its greater affinity with EDDS compared with other metals (log K: 18.4 vs. 12.7 and 13.4 of Pb and Zn, respectively; Tandy et al., 2006), whereas diminished Pb and Zn mobility was probably due to lower competition with Cu and Fe in binding EDDS and subsequent re-adsorption or precipitation (Meers et al., 2005). The overall leaching of these metals (Cu+Pb+Zn) over the cultivation cycle was increased in the single-dose treatments (~1 mg vs. 0.01 mg per pot of controls), but reached a peak (~22 mg) in the treatment with the earliest chelator application. Copper accounted for almost the whole leachate. EDDS had not significant effects on metal partitioning in plant-soil-water compartments, and ~99% of the total mobilised metals (bioavailable + plant uptake + leached) was still bioavailable in amended soil as well as in controls at the end of the experiment. Bioavailable Cu, Pb and Zn at harvest were not correlated with concentration of residual EDDS in the substrate, suggesting that the effectiveness of the chelator may be short-lived and a new soil equilibrium is quickly reached. In general, we observed that repeated chelator treatments and early applications tend to increase metal leaching, whereas a single close-to-harvest supply facilitates plant uptake, although harvestable biomass removes a negligible amount of mobile metals (<1%).

It is concluded that, after one cycle of assisted-phytoextraction at standard EDDS doses, metal partitioning did not greatly differ from unamended controls, regardless of application time. Although the fraction of leached metals was relatively low, concern derives from repeated EDDS applications as Cu concentration exceeded the Italian Guideline Values (IGV) for groundwater (~20 mg L^{-1} for EDDS supplied with a 10 day-interval vs. 10 mg L^{-1} of IGV), and potential risk may also arise from single-close-to harvest amendment as a relatively high amount of Cu in soil is still bioavailable after plant harvest.

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Remediation of As-contaminated site by growing *Brassica juncea* plants

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Abstract The capacity of *Brassica juncea* plants to remediate arsenic-contaminated soil was studied. Thiosulphate and potassium hydrogen phosphate were added to the soil to promote the release of As from soil surfaces, improve the phytoavailability and thus the plant absorption. The addition of thiosulphate and phosphate favoured the growth of the plants and increased the accumulation of arsenic in root and shoots.
Assisted phytoextraction is a promising technology for the remediation of As-conaminated sites.

Arsenic (As) is naturally present in soil, ranging between 1 and 40 mg As Kg^{-1} soil. Arsenic is recognised as a toxic metalloid and a strong pollutant in soils of many countries. The inorganic forms generally identified in soils are As(6) and As(3) (Manning and Goldberg, 1997). Thus, the reclamation of contaminated areas is fundamental in order to protect both human health and agricultural production.
This study is focused on the assisted phytoextraction, a technology for reclaiming polluted soils that takes advantage of the capability of some plants to extract inorganic elements from soils with the aid of additive agents (Meers et al., 2008). The nutrients phosphorus, as phosphate, and sulphur, as thiosulphate, can compete with the most oxidised form of arsenic, both in soil and plant.
Soil was sampled from an industrial area strongly contaminated by As (790 mg As kg-1 soil) and then mixed and sieved. *B. juncea* plants were grown in pots filled with soil. Ammonium thiosulphate $(NH_4)_2S_2O_3$ (0.27 M) or potassium hydrogen phosphate KH_2PO_4 (0.05 M) were then added to the soil.
The biomass of B. juncea plants was determined and the accumulation of As in root and in the above-ground tissues was analyzed.
Our results showed that thiosulphate (Th) and phosphate (Ph) acted either as nutrients and detoxifying agents, as influenced both the biomass production and the As accumulation in plant tissues.
When Th was added to the soil, the shoot growth was about three times higher than the shoot biomass of the control plants (Table 1). The addition of phosphate also induced a greater shoot biomass production, although lower than Th.
As accumulated at higher levels in the roots than in the above-ground part (Table 2). Plants grown in soil added with Th and Ph accumulated more As in the above-ground tissues than control plants. Although no significant differences were observed in As concentration of the shoots, the accumulation of the metalloid in the roots was substantially greater in roots of plants treated with thiosulphate.
It is known that sulphur may increase metal detoxification in plants, due to the formation of chelating compound, such as cysteine, glutathione and phytochelatins. The addition of thiosulphate to the soil may have increased the capacity of *B. juncea* plants to tolerate the

accumulation of arsenic, at the same time promoting the plant growth. The data obtained suggest the presence of interactions between the pollutant and the two nutrients, both in soil and plant. *Brassica juncea* showed a potential as suitable species in programs of assisted phytoextraction of As.
Further clarifications of the existing relations between nutrients and plants are needed in order to develop an efficient system to remediate As-contaminated sites.

Table 1 Dry weight of shoot and root of *Brassica juncea* grown in control soil (Contr) or in soil added with Thiosulfate (Th) or potassium hydrogen phosphate (Ph)

	Dry weight (mg)	
	Shoot	Root
Contr	51.2±7.1	2.6±0.4
+ Th	171.4±22.2	4.6±0.9
+ Ph	119.5±12.6	3.8±0.6

Table 2 Arsenic content in shoot and root of *Brassica juncea* grown in control soil (Contr) or in soil added with Thiosulfate (Th) or potassium hydrogen phosphate (Ph)

	As (mg kg^{-1})	
	Shoot	Root
Contr	-	161.9±13.4
+ Th	66.2±9.8	772.5±19.3
+ Ph	51.4±5.3	382.7±11.5

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Nutrient and organic matter transformation performance of municipal wastewater through a pilot-scale constructed wetland in a subtropical climate.

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Abstract Constructed wetlands (CWs) are an alternative technology recently implemented in Latin America. To protect the Chapala Lake a pilot-scale horizontal subsuperficial flow constructed wetland (HSSCW) was built. The HSSCW was sown with two ornamental plant species, *Canna hybrids* and *Strelitzia reginae*. A good acclimatization and development was found for both plants. The complete system was integrated with an upflow anaerobic filter (UAF) as a pre-treatment. Both processes used tezontle as biofilm support. The HSSCW operated at three hydraulic residence time (HRT) of 2, 3 and 4 days with municipal wastewater. Each one was monitored during four months and sequentially. The best mean removals rates achieved for COD, BOD_5, Org-N and TN were 60, 62, 68 and 32% respectively corresponding to a HRT of 4 days; while TP removed was of 22% in a HRT of 3 days. The range of first-order area-based removal rate constant ($m \cdot day^{-1}$) estimated was of 0.08-0.11 for BOD_5, 0.03-0.045 for TN and 0.01-0.03 for TP.

The wastewater treatment plants (WWTPs) in Mexico are not enough to treat the wastewater produced by an approximate total population of 112,337 inhabitants, distributed in 2,440 municipalities and delegations, which in their most part (98.1%) are small communities (INEGI, 2010). The CWs represent a good treatment for small communities since they are natural depuration systems designed and constructed to imitate hydrodynamic mechanisms and biogeochemical degradation processes that occur in natural wetlands, but with a higher degree of control over the hydraulic regime of the system (Vymazal, 2007). The HSSCW is a widely studied and tested CW. In this treatment system the permeability of bed is elevated and the water flows horizontally beneath its surface (Reed et al., 1995, Kadlec and Knight, 1996). Also, it offers a sustainable wastewater treatment fitting perfectly with the local situation. The pilot-scale CW was built in the installations of the WWTP of Chapala, Jalisco, Mexico and it is located in the vicinity of Chapala Lake. It is also used as a demonstrative module thereby the representatives of small communities surrounding will be able to implement this technology and to protect the Lake´s integrity. The complete pilot plant made up of an UAF followed by a HSSCW. This sequence allows reducing the required area of CW and decreasing clogging problems (Álvarez et al., 2008). The UAF and HSSCW use tezontle as granular media due to its high porosity, specific surface, low cost, since it is abundant in this part of México and its ferrous composition (Zurita et al., 2009). The HSSCW was divided into two parts; the first was sown with *Canna hybrids* and the second with *Strelitzia reginae* with a density of 3 plants $\cdot m^{-2}$. Three monitoring points were placed along the HSSCW: in the outlet of UAF-inlet of HSSCW (M2), in HSSCW middle part (M3) and in the effluent (M4). Three HRT were evaluated of 2, 3 and 4 days (Kadlec and Knight, 1996) sequentially and during four months each one. The main parameters

measured weekly were: chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), organic nitrogen (Org-N), ammonia nitrogen (AN), total nitrogen (TN) and total phosphorus (TP).The measurements taken of plant appearance were: tallness (T), thickness, leaves number (L), flowers number and shoots number (S).

The parameter's data were evaluated by means of a statistical model known as Nested Design with a crossover factor in order to determine the differences between sampling points and HRT. The COD and BOD_5 removals show a similar performance (Figure 1), the organic matter concentration decrease regarding to the distance. However it exists a major removal in the HSSCW first half where the *Canna hybrids* is located, this difference was also found in the HRTs tested. In the Figure 2 is possible to observe the ammonification process in the depletion of Org-N in every sampling point and HRT. Nevertheless the removal of AN is low, probably due to a lack of oxygen; therefore the anaerobic conditions are predominant and the nitrification process is not completed. This assumption was confirmed doing a nitrites and nitrates test and it was possible to prove the decrease of both forms in every sampling point. The data phosphorus obtained were wide variations and a significant difference was not found. During the study period the average characteristics of the zone were a temperature of 20.85 ^{0}C, a relative humidity of 59.59% and a precipitation of 0.013 mm (CNA, 2013). Fifteen plants of each species were selected by random in order to measure their growth. After to applying the Friedman statistic test the T and L, in the case of *Strelitzia reginae*, showed significance difference. While for *Canna hybrids* the growth differences in T and S were significant. In this way it was possible to prove good plant acclimatization in these environmental conditions. The average removal efficiency reached in every HRT and the first-order area-based removal rate constants (RC) for BOD_5, TN and TP are shown in table 1. The best removals for COD, BOD_5 and TN were established with a HRT of 4d, while the TP removal was better in a HRT of 3d.

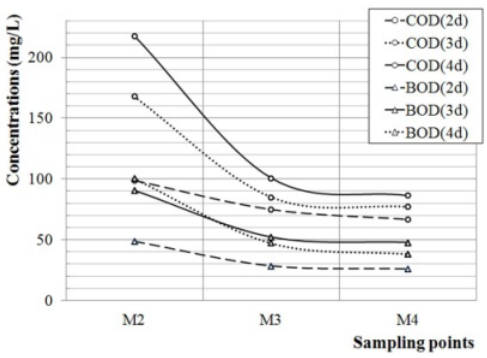

Figure 1 Organic matter performance

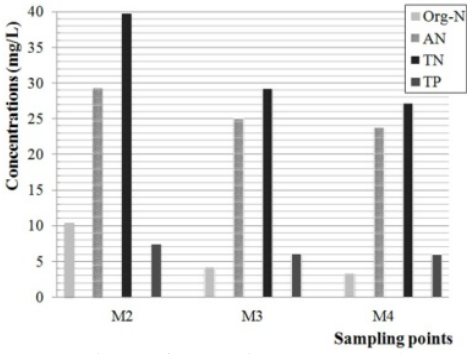

Figure 2. Nutrients removal performance in a HRT of 4d

Table 1 Average Efficiencies percentages (Eff) and RC ($m \cdot day^{-1}$) obtained in HSSCW. NA=Not Applicable

Meas.	HRT2d		HRT3d		HRT4d	
	Eff	RC	Eff	RC	Eff	RC
BOD_5	46.98	0.105	47.29	0.081	61.76	0.093
COD	32.29	NA	54.18	NA	60.36	NA
Org-N	35.89	NA	32.92	NA	67.72	NA
AN	13.20	NA	28.14	NA	18.57	NA
TN	17.10	0.033	29.78	0.041	31.55	0.033
TP	13.53	0.02	21.65	0.027	19.55	0.018

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Anaerobic Denitrifying Bioreactor

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Abstract The use of organic and inorganic fertilizers in agriculture results in leaching of nitrogen and its compounds into the drainage water, hence the surface waters. This leads to deterioration of water quality and aquatic ecosystems in the farmed landscape. It is therefore highly relevant to ensure cleaning of drainage water. Denitrification of nitrate in drainage water can be effectively implemented on the biofilter (bioreactors), as shown in many laboratory experiments abroad as well. Conditions of use are the high efficiency, easy operation, good availability and low operating costs of equipment that could be used in practice. These requirements are met by the use of biological anaerobic denitrifying filter that uses its biological function of various filtration materials(straw, sawdust, leaves, pine needles, etc.).

Recently, the research has focused on anaerobic denitrification under natural conditions in the area of the drainage systems outfall to surface waters. This method has been pioneered in the USA (Iowa, Illinois, Minnesota), Canada (Ontario), Australia and New Zealand. The study carried out by Van Driel et al. (2006) in Canada has provided one of the first information on anaerobic denitrifying bioreactor, which consisted of alternating layers of fine and coarse woody material, for cleaning drainage water in the field. Cooke et al. (2001) were the first to explore enhanced denitrification reactors for systematic drainage in Illinois. Boubaker et al. (2001) investigated and modelled managed denitrification in a biofilter.

An essential part of the biofilter is a reducing agent (electron source) which is placed in a suitable container and through which the water passes through. In such a system, adequate retention time is required. Reducing substance are preferably organics. Chemoorganotrophic bacteria, such as genera *Pseudomonas*, *Alcaligenes*, *Paracoccus* and *Bacillus* mediate the process of denitrification. As an alternative filtration materialswood chips and wheat straw wee used (Saliling et al., 2007; Lowengart et al., 1993; Soares and Abeliovich, 1998; Aslan and Turkman, 2003).

Research facility for drainage water treatment by means of anaerobic denitrification bioreactor is located in an experimental watershed at Černičí (Central Bohemia Region). The land use in the experimental area (1.34 km^2) is 16% forests, 75% arable land and 9% grassland. Twenty eight percent of the total catchment area is drained by systematic tile drainage. The altitude of the catchment varies between 462-562 meters, the long-term average air temperature is 7.3 °C and long-term annual average precipitation is 724.4 mm.

The anaerobic denitrifying filter filed with wheat straw is buried underground in the file drainage stream. The volume of the filter is 3.2 m^3 and catchment area is 4 ha. During the period 2005 - 2010 the performance of the filter was monitored intermittently, since 2011 the sampling has been carried on a regular basis (monthly). Monitored chemical parameters include pH, NO_3-N, NO_2-N, NH_4^+, $N_{org.}$, TN, PO_4^{3-}, TP. Hydrological characteristics (runoff, groundwater level) were recorded regularly as well. The results

revealed that the average inflow NO_3-N concentration during the period 2005-2012 was 58 mg L^{-1}, while the effluent concentration of NO_3-N was only 2.8 mg L^{-1}.

Besides the treatment efficiency one of the major goals of the research was to estimate the lifetime of anaerobic denitrification straw biofilter under the given conditions of the Czech Republic. After 7 years of operation, the effectiveness of the bioreactor remained unchanged with the reduction of nitrate exceeding 95%. However, after 5 years of operation, straw decomposition caused by bacterial activity caused the clogging and swelling of the filter reducing the flow rate more than 10 times. Therefore it seems that clogging is the most important factor affecting the longevity if the filter. Rezaee et al. (2008) measured the 90% efficiency of nitrogen removal in straw biofilter in laboratory conditions. Blowes et al. (1994) reported that nitrate removal through denitrification amounted nearly 100% in Ontario, Canada. Also, Saliling et al. (2007) reported 99% efficiency of denitrification in an experiment with various media reactors (woodchip or wheat straw). The bioreactor of wheat straw degraded in the amount of 0.269% per day, the loss of 2.69 grams per kilogram of initial weight per day. These estimates assume that the weight reduction rate is linear. They also found signs of physical decomposition of straw, which included discoloration and structural transformation. Changes in porosity were expected to change biodegradation media and accumulation of bacterial biomass. Changes in the porosity had an impact on the hydraulic retention time, as well as the hydraulic velocity.

Anaerobic denitrifying biofilters have their place among the technologies for various types of wastewater. For agricultural diffuse pollution, the biological denitrification in passive reactors represents the efficient technology in terms of both capital and O&M costs (Jaynes et al., 2008).

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Evaluation of a cascade constructed wetland for the treatment of piggery wastewater

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Abstract In 2012 an integrated pilot system of filters and a cascade constructed wetland (CCW) for the treatment of piggery wastewater has been installed and monitored in North-Eastern Italy. This paper presents the chemical removal results of three plant species (*Typhoides arundinacea* L. var. picta, *Mentha aquatica* L. and *Carex divisa* Hude) derived from four monitoring cycles.
The CCW was composed of six lines with three tanks each, positioned at different heights to allow the flux of wastewater by gravity.
Inlet consisted in filtered piggery wastewater diluted with tap water to achieve an electrical conductivity suitable for plants (on average 2.11 mS cm^{-1}). The mean inlet concentrations were: 97.3 mg L^{-1} total nitrogen (TN), 52 mg L^{-1} nitrate nitrogen (NO_3-N), 15.9 mg L^{-1} ammonium nitrogen (NH_4-N), 6.9 mg L^{-1} total phosphorous (TP), 5.9 mg L^{-1} soluble phosphorous (PO_4-P), 509.5 mg L^{-1} chemical oxygen demand (COD) and 125 mg L^{-1} 5-day biochemical oxygen demand (BOD_5), respectively.
All the parameters were reduced passing through the CCW, in particular NH_4-N (98% on average), without significant differences in reduction efficiency among the three species, except for NO_3-N (*T. arundinacea* 75%, *M. aquatica* 52% and *C. divisa* 41%) and TN (*T. arundinacea* 79%, *M. aquatica* 65% and *C. divisa* 59%).

High contents of organic load and nitrogen and presence of heavy metals in swine waste require a pre-treatment system that can reduce these components before its depuration by wetland plants. Also wastewater salinity is an important parameter to be considered according to plants, as it can cause different negative effects in no tolerant or resistant plants, such as productivity loss, reduced growth, damage to aerial part and root system, and also plant death (Parida and Das, 1995; Shannon and Grieve, 1998).
In this experiment the phytodepuration system was composed of a constructed wetland with six lines. Every line consisted of three plastic tanks arranged in a "cascade", where the first tank received waste and discharged by gravity to the second tank that was connected with a third one. For every line the treated effluent was finally collected in a plastic vessel to measure the volume and then discharged. The tanks were filled with light expanded clay aggregate and vegetated with three plant species (*Typhoides arundinacea* L. var, picta (Ta), *Mentha aquatica* L.(Ma) and *Carex divisa* Hude (Cd)), with two repetition for species.
Cascade constructed wetland (CCW) was feed with filtered swine wastewater (60 L d^{-1}) derived from six pre-treatment filters, filled with different materials (bamboo stems, giant reed (*Arundo donax* L.) stems, two types of gravel with pumice stone, sand and gravel, only gravel, and plastic tops). Before to entry to CCW, waste was diluted with tap water to low salinity (6.5 mS cm^{-1} on average) and to achieve an electrical conductivity suitable for plants (2.11 mS cm^{-1} on average).
In 2012 four monitoring cycles of 4 days were performed: the first and the second in September, the third in October and the last in November. In each monitoring cycle

sampling was done at the inlet and outlet of every cascade wetland line. The retention time of CCW was in average 3 days.

The following physical parameters were measured: electrical conductivity (EC, mS cm^{-1}), dissolved oxygen (DO, mg L^{-1}), temperature (T, °C), and turbidity (NTU). Also chemical parameters (mg L^{-1}) were analyzed: ammonia-nitrogen (NH_4-N), total nitrogen (TN), nitrate-nitrogen (NO_3-N), soluble phosphorous (PO_4-P), total phosphorous (TP) chemical oxygen demand (COD), 5-day biochemical oxygen demand (BOD_5). Chemical analyses were conducted using a Hach-Lange spectrophotometer, DR 2800, BOD_5 was measured with the Oxitop® system (WTW) and turbidity with a Hanna Instruments turbidimeter, HI 83414.

The mean air temperature of the entire monitoring period was 16.1°C, decreasing from September (19.9°C on average) to November (10.8°C). Rainfall was negligible with 2 mm in the second monitoring cycle and 0.4 mm in the third.

Considering all monitoring cycles, EC was lower than the average (1.73 mS cm^{-1} on average), DO higher (82.82 mg L^{-1}), while pH remained about the same (8.23) for all plant species. Turbidity was lowered of 91 % (5.59 NTU).

In table 1 the mean concentration of every chemical parameter at inlet and outlet of CCW is reported. All chemical parameters were reduced, mainly NH_4-N (98% on average), PO_4-P (89%), BOD_5 (89%), and TP (86%). There are abatement differences between plants for TN (Ta 78%, Ma 65%, Cd 58%) and NO_3-N (Ta 75%, Ma 52%, Cd 41%). COD had lower reduction (49% on average).

Table 1 Chemical concentrations (mg L^{-1}) at inlet and outlet of CCW

	TN	**NO_3-N**	**NH_4-N**	**TP**	**PO_4-P**	**COD**	**BOD_5**
	Concentration (mg L^{-1})						
Inlet	97.3	52.0	15.9	6.9	5.9	509	125
Outlet Ta	20.9	12.9	0.35	0.62	0.36	271	14.4
Outlet Ma	34.2	25.1	0.26	0.55	0.23	268	13.1
Outlet Cd	40.4	30.9	0.27	1.8	1.3	247	13.1

All plant species proved an improvement of the wastewater characteristics in output and a good chemical abatement performance especially for the ammonia-nitrogen. In general the plant species more efficient were *T. arundinacea* e *M. aquatica*.

The constructed cascade wetland worked efficiently for the amelioration of swine pre-treated wastewater, giving excellent future prospects.

Acknowledgements Research supported by Progetto AGER "Solutions for Environmental and Economic sustainability of PIG manure – SEESPIG", grant n° 2010-2220.

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Quality and natural possibilities of dump water treatment

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Abstract: In the areas of brown coal mining, the vegetation cover is usually damaged and due to lowering of water table the water cycle is disrupted. The spoil heaps are drained by many springs of dump water and the quality of a particular dump water depends on the chemical composition of the site where it origins. The research objective of this study is to find solutions that would allow for improving the quality of water flowing by means of economically affordable methods. As a very promising tool for dump water quality improvement appears to be the treatment of these waters in constructed wetland systems, namely for removal of iron and manganese.

Dump waters poses a very serious problem, because due to their chemical composition they can greatly affect the quality of surface waters (Flanagan et al., 1994; Nyquist and Greger, 2009). In the eastern part of Germany, greater number of residual lakes after mining activities exhibited pH values less than 2.0 (Katzur and Ziegler, 1997). High concentration of sulfates, iron, arsenic, zinc, cadmium and lead were measured in dump waters in Spain (Romero et al., 2011). In Germany, water pollution resulting from the dumps after brown coal mining, was reported by Van Berk and Wisotzky (1995) or Lenk and Wisotzky (2011). A similar situation was found in Poland at Trzebinia Rudki Wiesciszowice, where elevated concentrations of sulphate and iron were recorded (Uzarowicz and Skiba, 2011).

In the research area of Velká podkrušnohorská výsypka (Velká Podkrušnohorská Dump) in northwest Czech Republic, water quality along the dump water stream through the series of natural wetlands was evaluated (Table 1). The results indicated that concentrations of iron and manganese gradually decreased along flow pathway. Also, concentrations of ammonia, nitrate and total phosphorus decreased as well.

Table 1 Changes in the water quality along the dump water stream through the series of natural wetlands. Sampling point 1 refers to the spring of dump water, sampling point 9 refers to the point before the recipient

		Sampling points								
Location	**Unit**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
pH		6.5	6.6	6.9	7.6	7.7	7.9	8.0	8.0	8.0
Alkalinity	mmol/L	19	20	21	18	18	16	16	15	15
NH_4-N	mg/L	2.4	2.5	0.8	0.1	0.1	0.01	0.01	0.05	0.01
NO_3-N	mg/L	0.1	0.1	0.1	0.5	0.4	0.7	0.6	0.6	0.6
TP	mg/L	0.1	0.08	0.08	0.05	0.02	0.03	0.03	0.03	0.04
Fe	mg/L	7.7	5.6	0.2	0.4	0.3	0.08	0.1	0.1	0.4
Mn	mg/L	3.4	3.2	2.9	1.2	1.0	0.3	0.3	0.4	0.3
Conductivity	mS/cm	4.80	4.75	5.08	4.00	4.55	4.69	4.75	4.58	4.67

The results obtained in a natural wetland were promising and therefore, it was decided to build a constructed wetland for the treatment of dump water stream. The wetland consists

of three shallow free water ponds (Figure 1) planted with a mixture of various wetland macrophytes such as *Phragmites australis* (Common reed), *Phalaris arundinacea* (Reed canarygrass), *Glyceria maxima* (Sweet mannagras), *Schoenoplectus lacustris* (Bulrush), *Typha latifolia* (Broadleaf cattail), *T. augustifolia* (Narrowleaf cattail), *Sparganium erectum* (Bur reed) and *Juncus effusus* (Soft rush).

Figure 1 Photo: Tichackova Jirina

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CHAPTER 3 - WETLANDS AND GLOBAL CHANGE

Wetlands, climate change and hydrological management

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Abstract Different types of wetlands have different mechanisms for receiving and releasing water and some of these can be influenced by human management whilst others cannot. For example direct rainfall recharge is the dominant hydrological driver in freshwater dune slack wetlands, whilst ditch and river water levels (in combination with rainfall recharge) drive the conditions in many floodplain wetlands. With site managers feeling pressure to restore and/or maintain good habitat condition, an understanding of the role of hydrological management in different types of wetland system is vital.
Monitored and modelled data from 3 types of wetland (coastal dune slack, lowland fen, floodplain meadow) are used to investigate the impacts of different types of hydrological management on water level regimes. The magnitude and sustainability of these impacts is presented in relation to future climate scenarios. The results of this work identify which management techniques are most effective for each wetland type, and therefore help to optimise the allocation and use of resources in conserving wetland habitats.

Wetlands, hydrologically dependent ecosystems, are influenced by many factors, some of which are natural processes and some are human-induced. The most significant of these are habitat encroachment, as our growing population develops space to live and work, reduced water availability as more water is required for drinking, food productions and industry, and changing climate which in the UK is predicted to see a shift in rainfall and evaporation patterns towards wetter winters and drier summers (Jenkins et al., 2009). Our understanding of the importance of wetlands in supporting human life is greater now than in the past, and this is evident through the development of concepts such as 'Ecosystem Services'. There is a desire to see ecosystems in good health and therefore better able to support and deliver ecosystem services, and for wetlands this requires an appropriate hydrological regime. So we now live in a time when both the pressures on hydrological resources and the need for water to sustain wetland habitats have never been greater.
Whilst a great deal of attention is currently paid to wetlands influenced by groundwater (Groundwater Dependent Terrestrial Ecosystems are a popular topic for discussion), many wetland systems have a much weaker relationship with groundwater. More of the influence on the water table regime in these wetlands is due to surface water processes. It is these surface-water influenced wetlands that are the focus of this study.
Different types of wetlands have different mechanisms for receiving and releasing water and some of these can be influenced by human management whilst others cannot. For example, in a rain-fed wetland (e.g. coastal dune slack) one of the main factors in determining the hydrological conditions will be rainfall recharge. In ditch dominated wetlands (e.g. restored drained lowland fen), as well as rainfall recharge there will be lateral movement of water between the ditch system and the soil. In a river dominated wetland (e.g. floodplain) there will be rainfall recharge, possibly some movement of water to and from the ditch system (if present) and also a movement of water (both surface and subsurface) between the river, surrounding land, and the wetland.

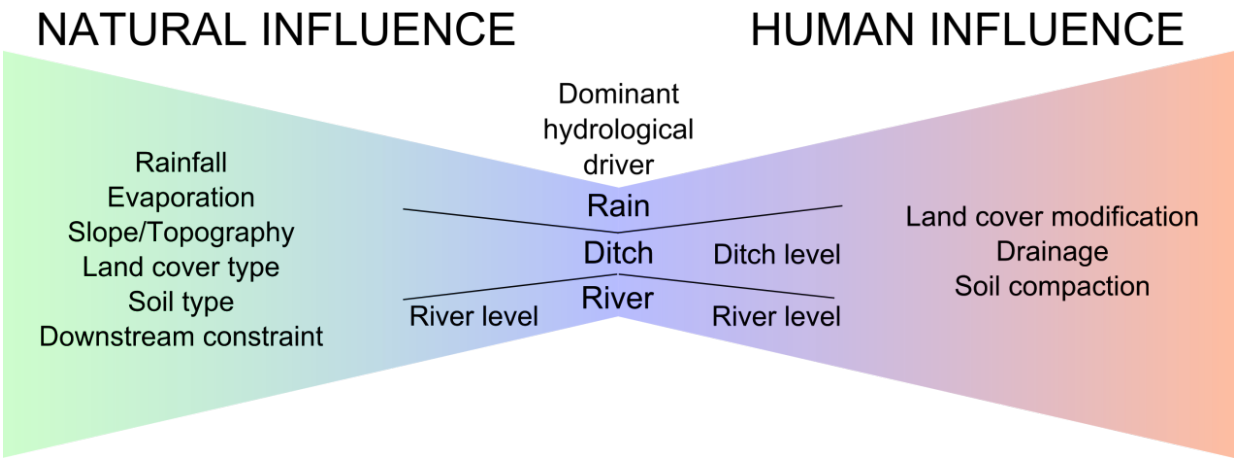

Figure 1 The main natural and human influences on the hydrological conditions in surface-water fed wetlands

Understanding the hydrological impact of natural and human influences (Figure 1) is important to guide effective and sustainable site management which in turn facilitates optimum delivery of ecosystem services. In order to do this for these different types of surface water wetland, simple conceptual hydrological models have been developed and the natural and human influences have been quantified. Scenarios based upon the present and future possible situations have been run through the hydrological models in order to compare the relative impact of influences upon the broad hydrological regime.

In the predominantly rain-fed coastal wetland, the water balance is primarily driven by natural influences - rainfall, land cover and geomorphological change on the coast. In the ditch dominated wetland, human ditch water level management has a noticeable but localised effect, but this is limited both by the hydraulic properties of the soil substrate and availability of water to maintain ditch levels. The river dominated wetland is influenced by human water level management of both the river and ditch system, but the extent of influence is ultimately limited by river level. The management of wetland systems is effective within a range of conditions, but outside those conditions is ineffective at overriding the more powerful effects of climate and geomorphology. This work demonstrates the importance of quantifying the range of conditions.

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Climate impacts on groundwater in a UK coastal wetland

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Abstract Groundwater levels fundamentally control wetland environments and in dune systems groundwater levels are driven by the dynamics of seasonal, inter annual and longer term climatic conditions. Inter annual variations in these systems can be large and are often incorrectly attributed to climatic change. In this paper we present a 40 year record of groundwater levels and compare observed inter annual variations with estimates of the effects of anticipated climate change.

There are1200 ha of humid dune slacks in the UK and these account for 4.3% of the area reported in Natura 2000 for Europe. Important species occurring in dune slacks include Liparis loeselii, Petalophyllum ralfsii (petalwort) and stonewort. Seasonally flooded pools within the slacks provide a vital breeding site for the Natterjack toad (Bufo calamita). Dune slacks are also important for a range of rare mosses and liverworts, including Petalophyllum ralfsii and several species of Bryum (thread-mosses). Liparis loeselii is confined to short swards of rich fens and damp calcareous dune slacks (Houston, 2008). Ranwell, (1959) started to make the links between hydrological regime and vegetation communities. Ranwell (1959) divided slacks into "wet", "transitional" and "dry", and assigned maximum and minimum summer and winter water table levels to each category. This framework has been used as a baseline for subsequent studies and only now are attempts being made to refine this using longer time-series data (Davy et al., 2006).

The longest continuous record of water levels in costal dunes in the UK is at Ainsdale, near Liverpool. Regular monitoring of water levels began in 1972 and are a sequence of groundwater levels affected only by natural processes - drainage, land use changes or other interventions were absent. Figure 1 shows water level measurements at a typical "humid" slack site. The annual amplitude of water level change is +/-0.5m. Wet winters, where water levels are above ground (+9.45m above sea level) occur in approximately 50% of the years. There are notable medium term cycles in the data but no overall trend is apparent.

This data set provides a useful insight into how climatic variation has a significant impact on water table levels and that 5 -10 year sequences of wet and dry years can give a false impression of the term "climatic change impacts". We have developed a 1-Dimensional recharge model linked to groundwater flow and soil moisture deficit model to simulate the changes in water levels (Clarke and Sanitwong, 2010). The key drivers affecting groundwater levels were found to be rainfall (30%), vegetation cover (30%), coastal erosion (0-20% depending on distance from the sea over a range of 0-3km) and sand permeability (12%). Factors associated with climatic change had a lower effect on the model: evapotranspiration (7%) and sea level rise (0-5% again depending on distance from the sea).

The 1-D recharge model was extended to include groundwater flow and regional inland drainage. The model was used to investigate the impacts of future climate under a Medium High $C0_2$ emissions scenario using 1000 sets of stochastically generated weather

data obtained from the UK Climate Impacts Programme (UKCIP02). In each run the total amount of rainfall remained the same.

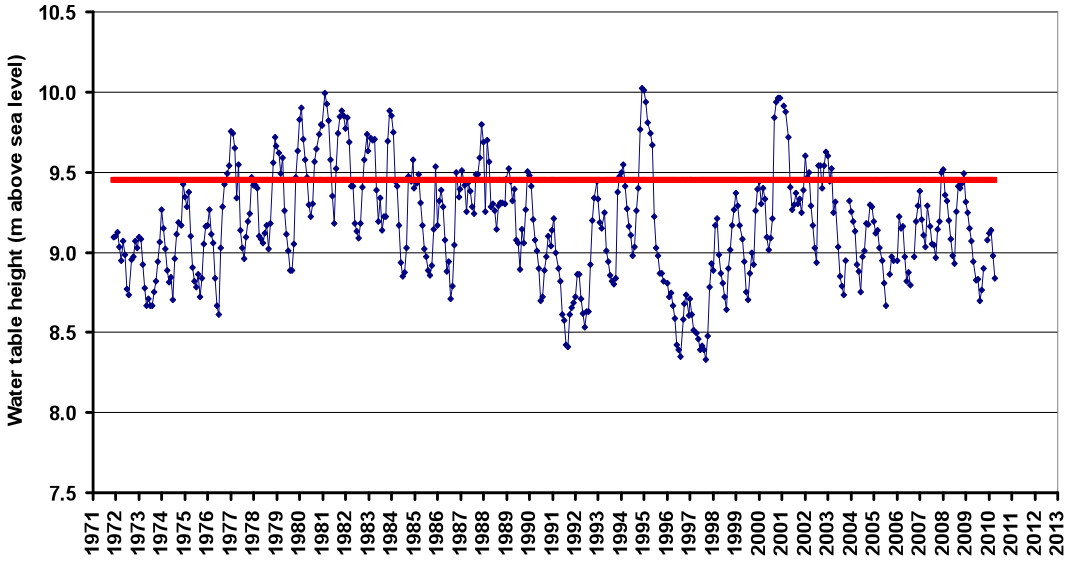

Figure 1 Observed groundwater levels in a humid dune slack 1972-2010

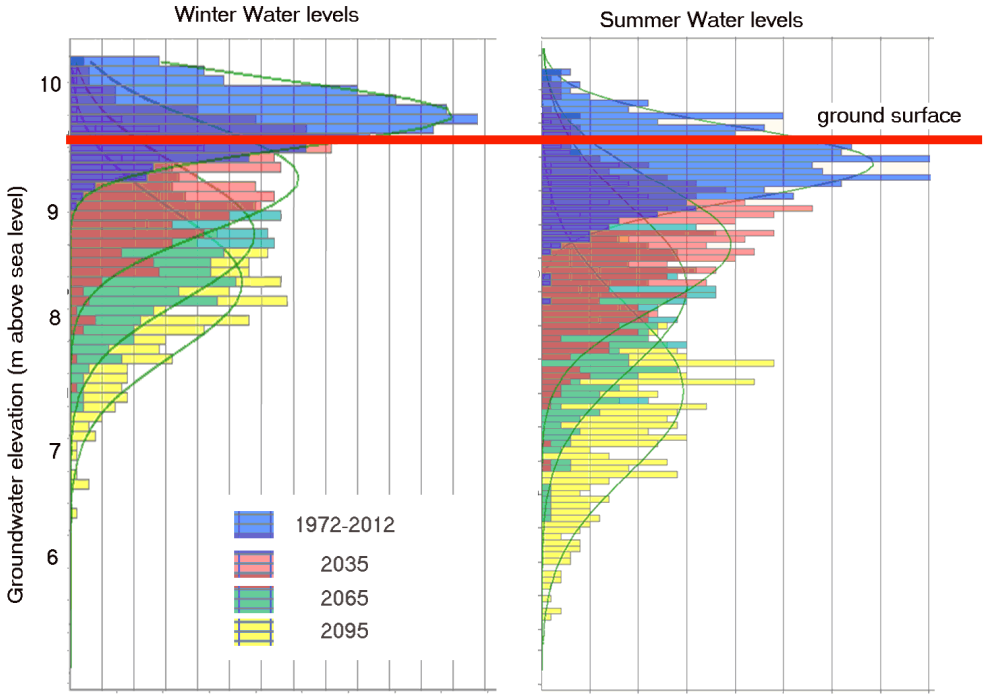

Figure 2 Frequency distribution of observed and modelled winter and summer water table levels. Observed data (1972-2012) and with climate change scenarios (2035, 2065, 2095) assuming Medium High CO_2 emissions.

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Climate change and the Inner Niger Delta – An assessment of GCM-related uncertainty

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Abstract A semi-distributed hydrological model is developed for the Niger River above the Inner Niger Delta. It is forced with meteorological data derived from global datasets and calibrated / validated against observed discharge from 12 gauging stations. Modelled discharge upstream of the Delta is employed within a water balance model that simulates flood extent. This is calibrated against estimates of annual maximum inundation. GCM-related uncertainty in the impacts of climate change are investigated using seven GCMs for a 2 °C increase in global mean temperature, the hypothesised threshold of 'dangerous' climate change. With the exception of one GCM (HadGEM1), which projects a very small increase (1.7%), discharge to the Delta is projected to decline. There is, however, considerable uncertainty in the magnitude of these reductions that range from 3.2% (HadCM3) to 51.7% (IPSL). With the exception of HadGEM1, flood extent within the Delta decreases in every month with mean declines in peak inundation varying between 460 km^2 (4%) and nearly 7700 km^2 (58%). For HadGEM1, mean peak inundation increases by 910 km^2 (6.7%). Uncertainty in climate change impacts represent a challenge to managing the wetland whilst the predominant declines in flood extent are likely to be compounded by upstream dam construction.

Climate change represents a considerable threat to wetland ecosystems. Changes in precipitation and higher temperatures will impact catchment hydrological processes that sustain wetland water supplies. In regions where human communities rely on ecosystem services provided by wetlands, hydrological modifications may induce enormous ecological, social and economic impacts. African floodplains are classic examples of wetlands that sustain human populations as well as providing internationally important habitat. Many have already been impacted by water resource developments. Assessment of the impacts of climate change, and their associated uncertainty, on such wetlands is a priority area for research.

A semi-distributed hydrological model is developed for the Niger River upstream of the Inner Niger Delta using the Stella system modelling system. The basin is divided into 11 sub-basins in which soil, groundwater and surface water stores and interactions between them are simulated. Models of each sub-basin are forced with meteorological data from global datasets and simulate runoff that is routed downstream to subsequent sub-basins and ultimately to the Delta (at Douna and Ke Macina). These inflows are used within a water balance model of the Delta that simulates the extent of inundation and includes a routine for simulating discharge at the downstream end of the wetland (e.g. Thompson and Hollis, 1995). Calibration and validation, undertaken for two 25-year periods, is based on observations of mean monthly discharge at 12 gauging stations and peak annual flood extent within the Delta. The impacts of climate change on river flow and flood extent are investigated using seven GCMs for a 2 °C increase in global mean

temperature, the hypothesised threshold of 'dangerous' climate change (e.g. Thompson et al., 2013).

Excellent model performance, as indicated by values of the deviation from the observed mean discharge (DV), Nash-Sutcliffe efficiency (NSE) and Pearson product moment correlation coefficient (r), in the simulation of river discharge is achieved (as illustrated in Figure 1 a&b for discharge into the Delta). Similarly, peak annual flood extents are reproduced well albeit with a slight underestimation (Figure 1c).

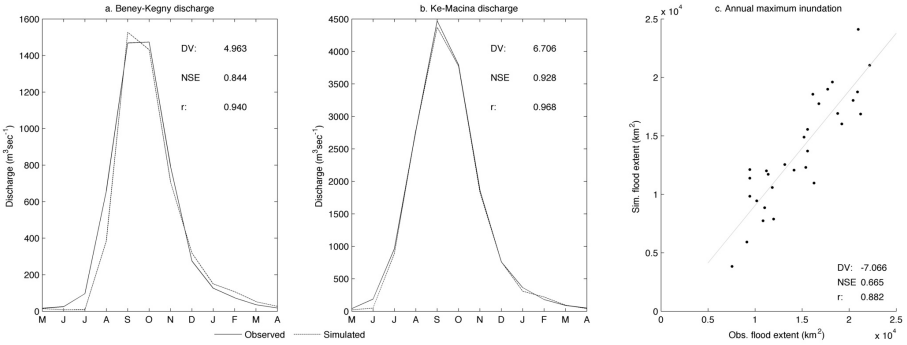

Figure 1 Model results for a 1960-1989 baseline period: observed and simulated mean monthly discharge at (a) Beney-Kegny and (b) Ke-Macina, (c) observed and simulated mean annual flood extent within the Inner Niger Delta

HadGEM1 projects a very small increase (1.7%) in annual inflow to the Delta (although wet season discharges, especially at Beney-Kegny, increase by a larger amount). The other GCMs project declines in inflow although there is considerable uncertainty in the magnitude of these reductions (Fig. 2a&b). Mean discharge declines by only 3.2% for HadCM3 whilst for IPSL it more than halves (-51.7%).

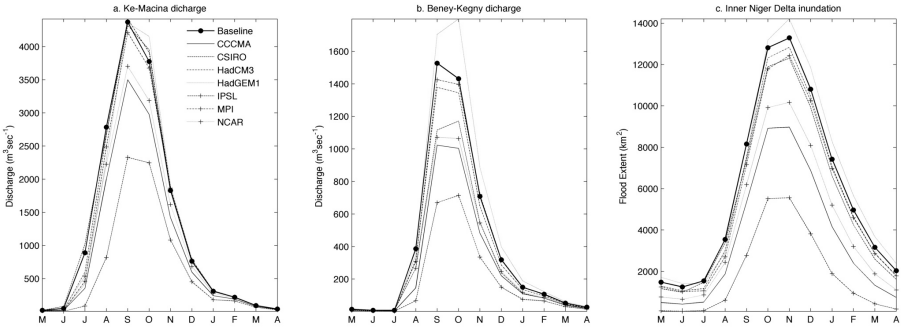

Figure 2 Baseline and climate change scenario results: mean monthly discharge at (a) Beney-Kegny and (b) Ke-Macina Model, (c) Inner Niger Delta flood regime

With the exception of HadGEM1, flood extent within the Delta decreases in every month with mean declines in peak inundation varying between 460 km^2 (4%) and nearly 7700 km^2 (58%). Mean peak inundation increases by 910 km^2 (6.7%) for HadGEM1. Uncertainty in climate change impacts represents a challenge to managing the Inner Niger Delta. The predominant declines in river flow and flood extent are likely to be compounded by upstream dam construction.

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Projecting uncertain impacts of climate change on wetlands: a risk-based web tool for England and Wales

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Abstract The UK climate is projected to continue changing over coming decades. Estimates produced in 2002 predicted wetter winters and drier summers, with the greatest changes in the south and east where, in late summer, soils are likely to become drier for longer (UK Climate Impacts Programme, UKCIP02). In addition, impacts on rain-fed wetlands will be greater than on those dominated by river inflows (Acreman et al., 2009). These projections have been updated (UKCP09) and although the general pattern of change is broadly similar, the projections are now probabilistic in nature, allowing climate change impact uncertainty to be evaluated. Such changes will have significant implications for wetlands, which require periodic saturation or inundation. Changes to the hydrological regime of wetlands are likely to impact on the ecosystems services they provide including flood management, water quality improvement, provision of wildlife habitats and carbon sequestration. Future management, restoration and adaptation of wetlands, particularly delivery of the Wetland Vision in England, will thus require tools to help understand the potential impacts of climate change so that appropriate adaptation plans can be developed.

We have developed an open-access, web-based tool that quantifies the potential impacts of climate change on wetland hydro-ecology at the regional scale. The conceptual framework for the tool includes regional differences in climate change and different water supply mechanisms to wetlands (i.e. rain-fed, river-fed and groundwater-fed). New improved reduced-complexity models for these three end-member mechanisms have been developed that balance sufficient process representation with simplicity to make them fit for purpose. The models are computationally efficiency, enabling assessment of the 10,000 possible climate realisations available for each of the twelve Water Framework Directive river basin regions of England and Wales for the selected climate change time period and emissions scenario. The models are driven by projected hydrological data produced by the Future Flows project for 2050. Results are presented in a risk-based framework and provide wetland managers, consultants and researchers with an initial assessment of the probable impacts of climate change on a variety of interest features including wetland water levels, plant communities, birds and the historic environment.

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Extreme climate events and wet grassland plant communities: mesocosm and field experiments

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Abstract Some of the effects of climate trends on wetlands have been documented but awareness of the impacts of extreme climate events (ECE) caused by climate change is lacking. ECE are of greater magnitude over shorter duration than typical climate effects and are expected to increase in frequency, duration and intensity in response to climate change. There is evidence to suggest ECE, such as intense flooding, can provoke profound changes in ecosystems because they exceed stability and resilience thresholds. Wet grasslands are wetlands providing multiple ecosystem services, which rely upon diverse functional plant traits that may be lost due to extreme weather events. However, as wet grasslands are already adapted to regular disturbance regimes in the form of cutting and grazing, they could resist extreme events through flexibility in community composition and trait diversity. Thus, wet grasslands may prove to be either resilient to, or provide early indicators of, climate change. This paper introduces research that aims to investigate responses of wet grassland plant communities to extreme flooding and disturbance using measures of functional diversity and plant traits in mesocosm and field experiments.

Easterling et al. (2000) suggest that the natural environment is 'strongly' affected by extremes in climate and weather. Extreme events are predicted to have greater impacts because of the speed in which environmental change may occur following an event (Jentsch et al., 2007). Nevertheless, research focused on the ecological impacts of extreme climate events is limited (Thompson et al., 2013).

Floodplains and other wet grasslands are areas next to a water source, generally a river, which periodically become inundated with water as the river floods. It is not yet clear how wet grassland plant communities respond to extreme climate effects, and the role of plant functional traits in maintaining stability. However, changes in water quantity are projected to be the biggest climate impact on wetlands (Ramsar, 2002), as well as heat stress, increased flooding, mudslides, soil erosion, fire, and vectors for invasive species.

Plant traits are the characteristics of a particular species. These include morphology, phenology, physiology and behaviour (Díaz and Cabido, 2001). Many ecosystem functions including ecosystem services, resilience to disturbance and long-term stability in a community have all been closely allied to functional trait diversity (Hooper et al., 2005). This indicates that plant traits and functional groups are a powerful tool in assessing a community's ecological responses to, and effects of, perturbation, including extreme climate events.

Floodplain grasslands can be productive and diverse ecosystems with the flora and fauna adapted to regular disturbance, including episodic inundation and saturated ground. Floodplain plants have developed a number of strategies through specific traits to survive

flood events which would otherwise compromise survival of many terrestrial species; and different water levels correlate directly to the type of community found on floodplains (Toogood and Joyce, 2009). A community already adapted to dynamic environmental factors, such as a floodplain could therefore potentially resist and/or recover from extreme climate events. Alternatively, as a transitional habitat, floodplain grasslands may be more likely to respond negatively to climate events and therefore act as early indicators of change (Beier et al., 2012).

This new research will investigate the role of extreme events in shaping plant communities, and will incorporate plant functional traits.

Methods for determining whether floodplains could remain stable under extreme climate events include a mesocosm experiment to test the effects of chaotic flooding on plant communities. Plants have been selected based on traits which either confer flood tolerance or not. A field site consisting of two contrasting floodplain grassland communities has also been established to complement the mesocosm experiment. Here the effects of the loss of species with particular traits on community composition will be examined through removal treatments in order to identify whether species loss leads to rapid turnover of trait similar species and community stability.

The results of this research will aid the development of wet grassland management practices for nature conservation and other ecosystem services.

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Rate of Carbon Accumulation in Oligotrophic Bogs in Southern Taiga of Western Siberia

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Abstract The results of research carbon content in peat deposits oligotrophic bogs in southern taiga of West Siberia are presented. As a result of radiocarbon dating (46 samples) was determined by the age of the studied peatlands. On the basis of a detailed analysis of the stratigraphy of peat deposits assesses regularities of development peatland during the Holocene. The rate of accumulation of peat (carbon) during the Holocene varied to climate change and vegetation covers the peatlands. This is reflected as a change in the rate of accumulation of carbon, and change in rate of vertical growth of peat. The modern rate of carbon accumulation in peatlands was estimated from data on net primary production, transformation of plant remains and CO_2 emissions from the surface of the bogs. The average long-term rate of carbon accumulation during the Holocene almost 2 times higher than previously obtained estimates for the bogs of Western Siberia. Changes the vertical growth rate of peat and carbon accumulation is determined by changes in climatic conditions and changing vegetation. Current rate of carbon accumulation in peat of 1,5-2 times higher than the long-term rate. Modern carbon accumulation is about 50% of the net primary production of peatlands.

Peatlands occupy only about 3-5% of the terrestrial surface, but the global peat resources are estimated at 120 - 455 PgC (Vomperskii, 1994; Gorham, 1991). The peat carbon pool of Russia is estimated at 215 PgC. The area of peatlands in Western Siberia is about 42% of the area of Russian peatlands. Western Siberia peatlands contain about 36% of all soil carbon of Russia. Detailed analysis of the stratigraphy of the peat deposits allows not only assesses the amount of carbon in the studied peatland ecosystems, but also to trace the patterns of development of bog massifs when changing of climate conditions during the Holocene. The study of production, the transformation of plant remains and emissions of CO_2 from the surface of the marsh gives opportunity to evaluate the current sequestration of carbon in bog ecosystems.

The objects of the study were peat soils at oligotrophic bog located at the northeast part of the Great Vasyugan Mire at the field station "Vasyuganie" (IMCES SB RAS). Four ecosystems typical for oligotrophic bogs were chosen: pine-shrubs-sphagnum biogeocenosis (tall and low ryam), ridge-hollow complexes (RHC) and open sedge-sphagnum fen. The peat deposit in the study region is 1–3 m thick.

The formation of bog in the study area is characterized by a predominance of eutrophic and mesotrophic stages which changed oligotrophic stage of development. Age of peatlands in the study area is 2600-7100 years. At each observation point samples of peat were taken at the depth of peat deposits (every 10 cm) for the analysis of botanical composition, density, carbon content of peat, etc. 46 radiocarbon dating of peat were obtained (Laboratory of Geology and paleoclimatology of Cainozoe at the Institute of Geology and Mineralogy, RAS and the Laboratory of bioinformatics technologies

IMCES SB RAS for QUANTULUS 1220). To estimate the rate of carbon sequestration were also been measured NPP and CO_2 emissions, and the estimated rate of decay of peat-forming plants. The rate of accumulation of peat was determined on the basis of the radiocarbon dating of peat on carbon stocks in peat deposits.

The average rate of accumulation of carbon in the studied oligotrophic bog peat deposits is 19 gC/m^2/year and ranges from 11.4 to 26.0 gC/m^2/year, at a maximum rate of accumulation on the ridge of RHC and low ryam, minimum - on a tall ryam. The obtained values significantly lower than estimates presented in papers E.D. Lapshina (2004) for bogs in Western Siberia, M.S. Boch et al. (Boch et al., 1995) for bogs in the former Soviet Union. The most similar values were obtained for Finnish researchers bogs of northern Europe and Canada (Tolonen and Turunen, 1996, Turunen, 1999; Ovenden, 1990; Gorham, 1991). The rate of peat accumulation during the Holocene varied with climate change and, accordingly, bogs vegetation. The maximum rate of accumulation in the main characteristic of the early stages of peat formation. Among oligotrophic phytocenoses maximum rate of growth of peat is characterized by RHC (0.77 mm/year) and low ryam (0.63 mm/year), minimum - tall ryam (0.25 mm/year). However, during the development of bogs vertical speed of bogs growth peat may vary by 2-7 times.

The modern deposition rate of peat and carbon can be estimated indirectly, using data from NPP and the rate of decomposition of plant remains. The current rate of carbon accumulation in the average for the studied oligotrophic phytocenoses is 155 gC/m^2/year. The resulting rate of annual carbon sequestration of 1.5 - 2 times higher than the average long-term carbon sequestration estimates obtained for the oligotrophic bog.

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The impact of a pulsing groundwater table on greenhouse gas emissions in riparian grey alder stands

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Abstract. We studied the effect of changing groundwater depth on the emission of CO_2, CH_4, and N_2O in two riparian grey alder (*Alnus incana*) stands in Kambja, southern Estonia, using the closed static chamber method. The older alder (OA) stand (ca 40 yrs) is situated on the alluvial soil of a small stream. The younger alder (YA) stand (5-6 yrs) is growing in patches in combination with common reed, at the dry bottom of a former peat extraction site in which 0-10 cm of raw humus covers till, and a small stream passes through the sites. The groundwater table manipulation significantly increases CH_4 emission and decreases both CO_2 and N_2O emission. There was no significant difference in CO_2 and CH_4 emission between the OA and YA sites, whereas in OA sites with higher N concentration in the soil, the N_2O emission was significantly higher than in the YA site. Methane emission shows a negative correlation with groundwater depth, whereas in terms of CO_2 and N_2O, the deeper groundwater table significantly increases emission.

Organic carbon and total nitrogen content in the topsoil in OA is 4.5 and 0.5 %, and <1.0 and <0.1 % in YA respectively. In both stands, one site was chosen for water table manipulation (Manip) and another remained unchanged with a stable and deeper groundwater table (15 to 17 cm below ground in YA, and 45 to 50 cm in OA, later called as Dry sites). In July and August 2011 we twice changed the water table at the Manip sites, closing the streams with temporary dams for two days and measuring gas emission two days after the flooding. At all sites, 5 replicate gas samplers (closed conical-frustum-shaped PVC chambers, height 50 cm, ∅ 50 cm, volume 65 L, sealed with water-filled rings on the soil surface and painted white to avoid heating during application) and two replicate groundwater observation wells (∅ 50mm, 1.5m deep PVC pipes perforated and sealed in a lower 0.5m part) were used. At dry sites the chambers were located outside the flooded area. Gas samples were taken in 10 sampling sessions 0, 10, 30 and 60 minutes after installing the chambers on rings and analysed for GHG in the lab using the Shimadzu 2014 GC.

Our study shows that the groundwater table manipulation significantly increases CH_4 emission and decreases both CO_2 and N_2O emission (Figure 1). There was no significant difference in CO_2 and CH_4 emission between the OA and YA sites, whereas in OA sites with higher N concentration in the soil, the N_2O emission was significantly higher than in the YA site. We found a significant correlation between groundwater depth and the emission of all GHGs.

Methane emission shows a negative correlation with groundwater depth, i.e. a deeper groundwater table causes a clear decrease in CH_4 emission, whereas the 20 cm depth seems to be a significant limit below which most of the produced methane is oxidized (Figure

2B). In terms of carbon dioxide (Figure 2A) and nitrous oxide (Figure 2C), the deeper groundwater table significantly increases emission.

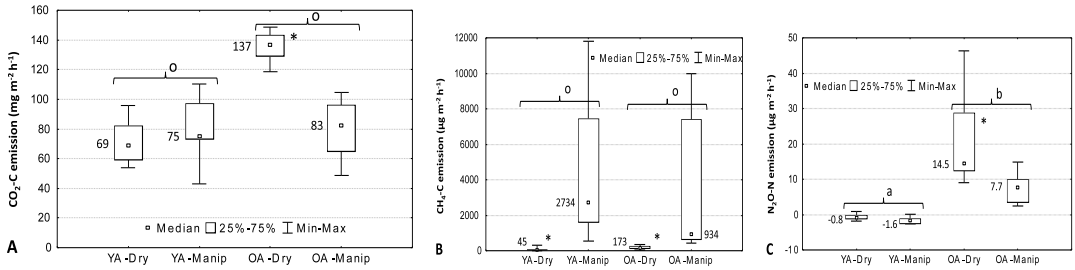

Figure 1 Median, 25 and 75% quartile and min-max values of CO_2 (A), CH_4 (B) and N_2O (C) emission in grey alder stands at the Kambja study area in Estonia. YA – young alder stand, OA – old alder stand, Dry – stable deep water table, Manip – changing groundwater table. Different lower-case letters (a, b) indicate significant ($p < 0.05$) differences between study sites, o-o - no significant differences. * - significant difference between the dry and manipulated sites. Numbers show median values

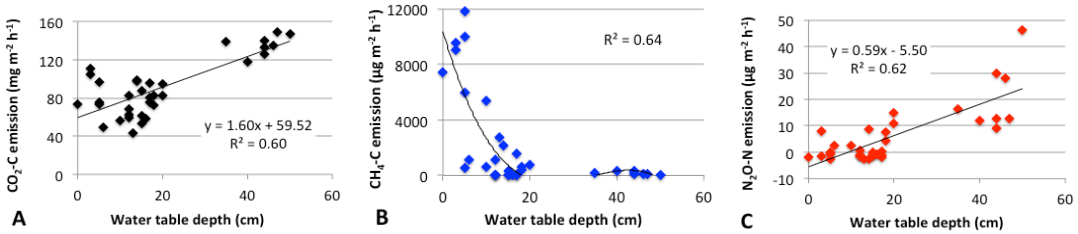

Figure 2 The correlation between groundwater depth (cm from the surface) and emission of CO_2 (A), CH_4 (B), and N_2O (C) in all sites in the Kambja study area

Our preliminary results from a relatively short-term experiment differ somewhat from studies by Altor and Mitsch (2006) and Mander et al. (2011), which demonstrate that in created riverine wetlands and constructed wetlands for wastewater treatment, pulsing hydrological regime/intermittent loading decreases CH_4 emission. Regarding N_2O emission, the literature offers contradictory results: Jia et al (2011) and Mander et al. (2011) show that pulsing can enhance N_2O emission due to the increasing importance of the nitrification process in N_2O release, whereas Hernandez and Mitsch (2006) show an opposite effect. Long-term studies in analogous *A. incana* stands show that CH_4 emission is not remarkably high in these riparian ecosystems (Soosaar et al., 2011).

Further studies are needed on the impact of hydrological regime on GHG emissions in riparian ecosystems. The eddy covariance method is preferred.

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CO_2 and CH_4 emission from constructed wetland pilot plant vegetated with five different species in Mediterranean basin

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Abstract Constructed wetlands (CWs) are systems widely used for wastewater treatment where organic pollution are also removed through volatilization of various greenhouse gases (GHGs) such as CO_2 and CH_4. Many studies have been carried out on plants effect on GHGs emission in CW, but only few in Mediterranean basin. In this study the effects of 5 different plant species (*Mischantus giganteus*, *Cyperus papyrus*, *Vetiveria zizanioides*, *Arundo donax* and *Phragmites australis*) on CO_2 and CH_4 emission were evaluated in an horizontal subsurface flow beds pilot plant treating urban wastewater in Sicily. CO_2 and CH_4 emissions showed both species-specific and seasonality effects. Mischantus and Arundo beds showed a significatively higher CO_2 emissions in the fall, 25.0±5.1 and 24.0±1.8 g m^{-2} d^{-1} respectively whereas the other species showed higher emissions in the summer (6.4±0.9, 22.3±3.9 and 7.0±2.6 g m^{-2} d^{-1} respectively for Papyrus, Phragmites and Vetiver). The higher CH_4 emissions for all species were recorded in the summer season, almost null were measured in the winter one. Significative differences between the plant species were monitored in the summer with the highest CH_4 emission for the bed vegetated with Vetiver (1100.0±763.5 mg m^{-2} d^{-1}).

Constructed wetlands (CWs) are widely natural-like systems used for wastewater treatment where organic pollutant are also removed through volatilization of various greenhouse gases (GHGs) in the atmosphere as carbon dioxide (CO_2) and methane (CH_4). The aim of this study has been to evaluate the species-specific effects on CO_2 and CH_4 emission of 5 different plant species (*Mischantus x giganteus*, *Cyperus papyrus* L., *Vetiveria zizanioides* L. Nash, *Arundo donax* L. and *Phragmites australis* (Cav.) Trin. ex Steud.) in an horizontal subsurface flow beds pilot plant used for urban wastewater tertiary treatment in Sicily. CO_2 emissions were estimated in situ using the static-stationary chamber technique sequestering the CO_2 emitted from the bed in a sodium hydroxide (NaOH) solution trap (Barbera et al., 2013). CH_4 flux was measured using the static non-stationary chamber technique (Di Bella et al., 2011) measuring the temporal change in CH_4 concentration inside the chamber using a portable FID (Crowcon Gas-Tec®). Both CO_2 and CH_4 emissions showed species-specific and seasonality effects. In particular plant species with different physiology and so different oxygen (Wigand et al., 1997) and exudate release (Ström et al., 2003) determine a different GHGs bed emission. Mischantus and Arundo beds showed a significatively higher CO_2 emissions in the fall, 25.0±5.1 and 24.0±1.8 g m^{-2} d^{-1} respectively whereas the other species showed higher emissions in the summer (6.4±0.9, 22.3±3.9 and 7.0±2.6 g m^{-2} d^{-1} respectively for Papyrus, Phragmites and Vetiver) (Figure 1). The higher CH_4 emissions for all species were recorded in the summer season, almost null were measured in the winter one in

agreement with Søvik et al. (2006). Significative differences between the plants species were monitored in the summer which the highest CH_4 emission for the bed vegetated with Vetiver (1100.0±763.5 mg m^{-2} d^{-1}) (Figure 2). Although further insights are needed, first results showed a seasonality related species-specific effects both on CO_2 and CH_4. The greater CH_4 emission was registered during the summer months for each species with high variability, whereas CO_2 emission has been showed species-specific effect during all the study periods.

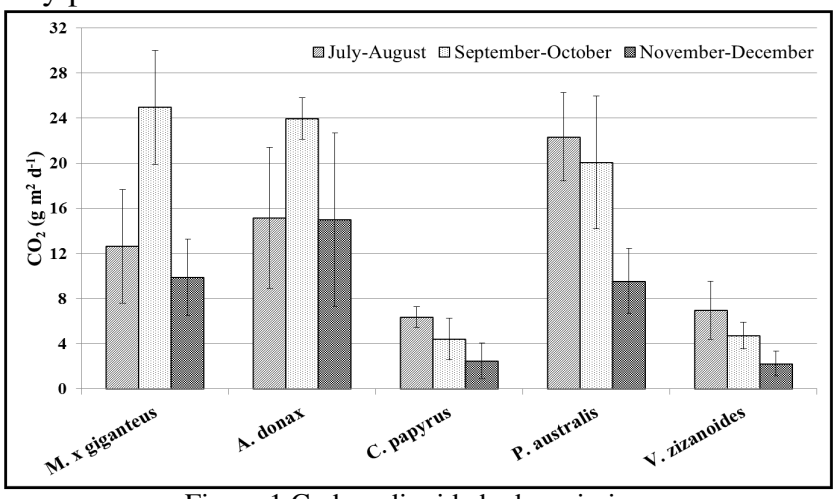

Figure 1 Carbon dioxide beds emission

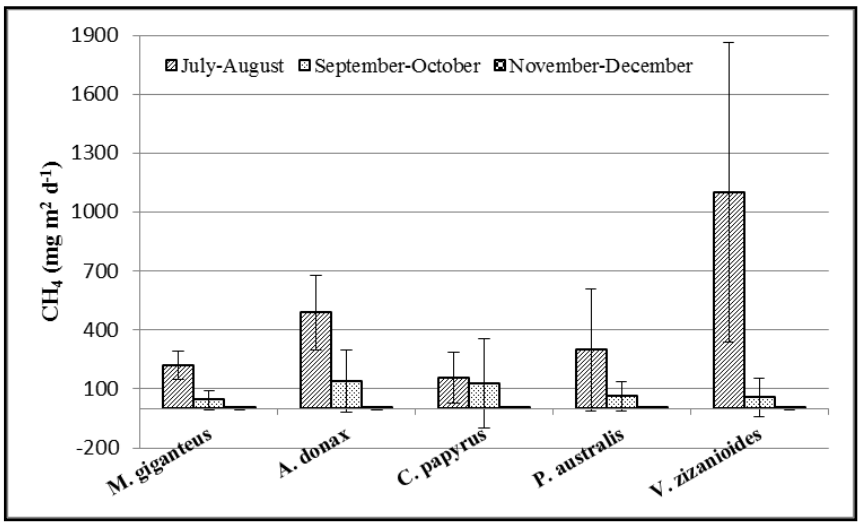

Fig.ure 2 Methane beds emission

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Nitrogen limitation of plant growth and organic matter decomposition in wetlands: implications for carbon sequestration

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Nutrients limit the growth of plants and microbes in the majority of wetlands. Although either nitrogen or phosphorus or both elements may be in short supply, nitrogen-limited systems are especially interesting because atmospheric nitrogen deposition continues to be high and is on the rise in many parts of the world. If nitrogen enrichment would stimulate plant growth more than decomposition, this would enhance the carbon sequestration function of wetlands, whereas if decomposition would be stimulated more, sequestration would be diminished.

In several types of peat-forming wetlands, from northern tundra to tropical mangroves, primary production has been shown to increase after N enrichment. The reports on decomposition show more complicated patterns. Most information is available on the effects on decomposition of easily degradable plant litter compounds, such as cytoplasm structures and cell wall (hemi)cellulose. There is increasing evidence that nitrogen enrichment is actually inhibiting the decay rate of more recalcitrant compounds.

To unravel the consequences of N enrichment on carbon sequestration in N-limited wetlands, studies focusing particularly on the breakdown of recalcitrant carbon compounds are urgently needed. Examples of such studies in fen wetlands and mangroves will be presented.

Top soil removal as a strategy for managing risks associated with the mobilisation of phosphorus, dissolved organic matter and methane from rewetting peatlands

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Abstract A valid strategy to mitigate the eutrophication of freshwater systems due to diffuse phosphorus pollution is to restore minerotrophic riparian peatlands. However, long-term drainage and intensive agricultural use of such peatlands has made it unlikely that the original P sink function and low nutrient conditions can be re-established within a human time perspective. In the past, the rewetting of degraded fens has often resulted in the formation of new, highly productive shallow lakes. In contrast to the original percolating mire systems with water levels at or near the ground surface and covered by a low-productive peat-forming community of brown mosses and sedges, these shallow lakes are dominated by high productive helophyte species. The removal of the highly degraded peat layer, prior to rewetting, can be a suitable method to minimize the high nutrient mobilisation as well as high biomass production causing in high methane emissions in the first decades of rewetting.

In several German states, peatland restoration programs involving rewetting, through flooding or raising water levels, has been used as a strategy to mitigate the potential impacts of peat mineralization, downstream eutrophication and the loss of long-term stored C (Zerbe et al., 2013). The objective of peatland restoration should be to re-establish hydro-ecological processes and to develop a self-sustaining, naturally functioning ecosystem (Wheeler and Shaw, 1995). In North East Germany, as a result of soil subsidence and shrinkage, often shallow lakes are formed post-rewetting, producing systems which can delay the re-establishment of targeted peatland species for decades (Zak et al., 2010). Studies have also shown that rewetting has had very limited effects on species enrichment (Klimkowska et al., 2007) and in some cases generated high rates of P mobilization increasing the risk of eutrophication to downstream systems (Zak et al., 2010). In addition, elevated methane emissions have been recorded as a consequence a high biomass production after peatland rewetting (Hahn-Schoefl et al., 2011). Topsoil removal (TSR) has been recommended, and partly already applied, as a very cost-intensive option in order to re-establish the naturally functioning, nutrient-poor conditions following fen rewetting, without the risk of eutrophication and elevated releases of methane. Although TSR can support the rehabilitation of degraded peatlands (Klimkowska et al., 2010), there is a lack of knowledge regarding how this measure

influences the mobilization of P, dissolved organic matter (DOM) and CH_4 exchange after rewetting of fens.

To evaluate the effect of TSR we performed several lab and field experiments in six rewetted and inundated peatlands without TSR compared to six peat holes as reference systems for TSR. In addition we sampled a rewetted peatlands where the degraded peat was removed from about half of the area, however here ground water levels were just beneath the soil surface.

The results emphasized that newly mud layers formed from plant litter above peat are the dominating source for P and methane in particulate in inundated sites without TSR but also in sites with TSR, however with significant lower rates (Figure 1). Although highly decomposed peat effectively released no methane, DOM mobilisation was highest in these substrates while less decomposed peat was characterized in general by lowest rates of matter mobilisation.

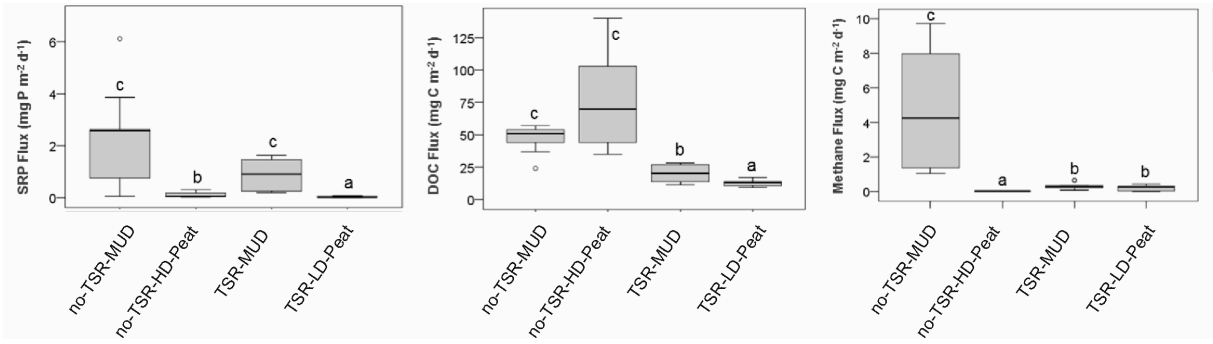

Figure 1 Distribution of flux rates (SRP, DOC, methane) from soil to surface water and SRP production from soil to porewater among different types of soil (no-TSR-Mud = mud from sites without tops soil removal [TSR], no-TSR-HD-peat = highly decomposed peat from sites without TSR, TSR-mud = mud from sites with TSR, TSR-LD-peat = less decomposed peat from sites with TSR)

In conclusion, the removal of the degraded peat layer before of rewetting is a suitable method to minimise P and CH_4 releases after rewetting. Despite of the unquestionable benefits, TSR should not be declared as universal method, i.e. it needs detailed consideration before it becomes applied. But, it is suggested that without any further management, high rates of mobilisation of P, DOM and methane has to be accepted for decades or even for centuries in rewetted peatlands.

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Depurative performance and methane emission of a pilot hybrid constructed wetland plant treating biogas digestate liquid fraction

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Abstract Constructed wetlands (CWs) are an efficient system to treat wastewater, but only few information are available on CWs performance when biogas digestate liquid fraction (DLF) is treated. The aim of this research was to gain information of an hybrid CW pilot plant treating DLF in North-East Italy both on depurative performance and CH_4 emission (before and after plant cutting). The system consists of two vertical subsurface flow (VSSF) beds vegetated with *Phragmites australis* and *Arundo donax* and an horizontal one (HSSF) vegetated with *P. australis*. The DLF main value pollutants input concentrations were: Total Nitrogen (TN) 427.3±58.7 mg L^{-1}, COD 4955.5±1017.9 mg L^{-1} and turbidity 2639.1±731.9 NTU. The hybrid system abated TN by 49%, COD by 41.1% and turbidity by 53.9%. Regarding plant management, mean higher CH_4 emissions were registered after plant cutting (378.9±337.9 mg m^{-2} d^{-1}) whereas with plants the average emissions was 68.5±115.2 mg m^{-2} d^{-1}. HSSF bed showed lower CH_4 emission, both before and after cutting (28.5±49.3 and 110.3±51.8 mg m^{-2} d^{-1} respectively), than VSSF ones (88.6±137.2 before and 513.25±341.58 mg m^{-2} d^{-1} after cutting). VSSF beds vegetated with *A. donax* emitted higher CH_4 than *P. australis,* both before (177.1±153.4 vs 0 mg m^{-2} d^{-1} respectively) and after cutting (716.8±350.6 vs 309.8±211.1 mg m^{-2} d^{-1} respectively).

Constructed wetlands (CWs) are an efficient system to treat wastewater but only few information are available on CWs performance when biogas digestate liquid fraction (DLF) is treated (Florio et al., 2012). Although the few information available CWs could be a good perspective to reduce this residual pollutant load, due to their removal efficiency and the low management costs. In these systems organic pollution are removed through various mechanisms including greenhouse gas evolution (e.g. CH_4). The aim of this research was to gain information on depurative performance of a hybrid CW pilot plant treating DLF in North-East Italy during summer-fall period and its CH_4 emission (before and after plant cutting).

The experimental activity was carried out in Terrassa Padovana, Padua (Eastern Veneto Region, latitude 45°14'42"00 North, longitude 11°54'13"32 East, altitude 4 m a.s.l.) from August to November 2012. The pilot plant, designed to treat up to 0.7 m^3 d^{-1} of DLF and with a total hydraulic retention time of 3 days, consisting of two parallel vertical subsurface flow beds (VSSF) vegetated respectively with *Phragmites australis* (Cav.) Trin. ex Steud. and *Arundo donax* L. functioning every two days; and one horizontal subsurface flow bed (HSSF) vegetated with *P. australis* that received the outflow of VSSF beds. During monitoring period samples were taken by inflow and outflow wastewater to quantify total nitrogen (TN), ammonium nitrogen (NH_4-N), nitric nitrogen

(NO_3-N), total phosphorus (TP), orthophosphate (PO_4-P), chemical oxygen demand (COD) and turbidity. Furthermore in situ, were measured DLF pH, Redox potential (Eh), and Electrical conductivity (EC). CH_4 flux was measured using the static non-stationary chamber technique (Di Bella et al., 2011) using a portable FID (Crowcon Gas-Tec®). Chemical and physical pilot plant inflow and outflow wastewater results are reported in Table 1.

Table 1 DLF chemical and physical characteristics and plant abatement

Parameter	IN	OUT	% abatement
TN (mg l^{-1})	427.3 (±58.7)	276.0 (±46.5)	49.0 (±24.3)
NH_4-N (mg l^{-1})	237.4 (±14.2)	160.7 (±19.4)	46.1 (±22.6)
NO_3-N (mg l^{-1})	28.6 (±3.7)	41.5 (±15.2)	-29.8 (±118.3)
COD (mg l^{-1})	4955.5 (±1017.9)	3485.0 (±514.3)	41.1 (±32.6)
Turbidity (NTU)	2639.1 (±731.9)	1434.7 (±282.8)	53.9 (±21.9)
TP (mg l^{-1})	32.6 (±1.4)	29.2 (±1.8)	27.1 (±33.5)
PO_4-P (mg l^{-1})	29.7 (±1.6)	26.5 (±1.6)	30.1 (±32.7)
pH	9.2 ± 0.2	8.5 ± 0.2	
EC (mS cm^{-1})	5.1 ± 0.3	5.0 ± 1.1	
Eh (mV)	-389.4 ± 57.0	-111.8 ± 150.8	

The CH_4 higher emission was measured after plant cutting (378.9±337.9 mg m^{-2} d^{-1}) than before (68.5±115.2 mg m^{-2} d^{-1}) in agreement with Zhu et al. (2007) who reported higher CH_4 emissions immediately after plants harvest. Considering beds water flux, HSSF bed showed lower CH_4 emission, both before and after cutting (28.5±49.3 and 110.3±51.8 mg m^{-2} d^{-1} respectively), than VSSF ones (88.6±137.2 before and 513.3±341.6 mg m^{-2} d^{-1} after cutting). About vegetation in VSSF beds, *A. donax* emitted higher CH_4 than *P. australis* (Fig.1) both before (177.1±153.4 vs 0 mg m^{-2} d^{-1} respectively) and after cutting (716.8±350.6 vs 309.78±211.1 mg m^{-2} d^{-1} respectively).

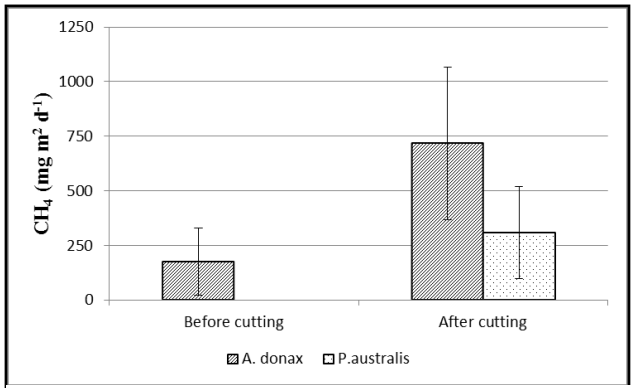

Figure 1 VSSF beds methane emission before and after cutting

The preliminary results of the hybrid CW pilot plant performance indicate interesting perspectives for TN, N-NH_4, COD and turbidity removal. *P. australis* has showed the more interesting results regarding low CH_4 emission. The plant cutting increased CH_4 beds emissions suggesting a single plant harvest for CW management to reduce this greenhouse evolution in the atmosphere.

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CHAPTER 4 - WETLANDS VEGETATION

Competition of *Phalaris arundinacea* and *Phragmites australis* in constructed wetlands treating municipal sewage

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Abstract *Phalaris arundinacea* (reed canarygrass) and *Phragmites australis* (comon reed) are frequently planted together in constructed wetlands (CWs) for wastewater treatment in the Czech Republic. The monitoring of growth parameters of both plants revealed that *Phalaris* grows much faster than *Phragmites* creating full cover and maximum biomass even during the first growing season. For *Phragmites*, it usually takes 3-5 years to establish the full biomass. In a long-term run, *Phragmites* usually outcompetes *Phalaris*. However, the length of this process varies among constructed wetlands. In CW Břehov, common reed started to encroach into reed canarygrass stand after four years of operation and four years later *Phalaris* was eliminated from the beds. On the other hand, in CW Příbraz the process of overtaking started only after seven years and small areas of reed canarygrass were found even after 13 years of operation. It is believed that the major reason for *Phalaris* elimination is the fact that *Phalaris* does not grow well in organic soils. In both constructed wetlands the change in vegetation cover did not affect the treatment performance of the system.

In general, there are many plants that can be planted in constructed wetlands with horizontal subsurface flow (Vymazal, 2011). However, only a few species are actually used. Common reed and reed canarygrass are two most commonly used plant species in constructed wetlands in the Czech Republic (Vymazal and Kröpfelová, 2005). They are usually planted in lines perpendicular to the flow of wastewater. Because both plants grow very aggressively, there is an interspecific competition, which often ends in complete replacement of one species. In most cases reed canarygrass is displaced (Vymazal and Kröpfelová, 2005; Fu et al., 2011). The aim of this study was to evaluate the time period of displacing reed canarygrass by common reed from constructed wetlands in Czech Republic.

The study was carried out at two constructed wetlands. The first one is situated in Břehov near České Budějovice. CW consists of two parallel beds with a total area of 504 m^2 and it is designed for 100 PE. For our study, one bead with vegetated area 21(L) x 9(W) m was selected. In this field, competition between *Phalaris* and *Phragmites* was monitored during the period 2004-2012. The competition between both plants was also evaluated at CW Příbraz near Jindřichův Hradec during the period 1999-2012. CW Příbraz treats municipal wastewater from 150 PE. The study was carried out in bed with vegetated area 24x27 m.

At Břehov, common reed started to encroach into *Phalaris* stand after four years of operation and four years later *Phalaris* was completely eliminated from the beds (Figure 1). In Příbraz (Figure 2), *Phragmites* gradually grew into the *Phalaris* stand but a substantial difference was evident only after 7 years of operation. The total displacement

has not completed and even after 13 years of operation, small patches of *Phalaris* are still present.

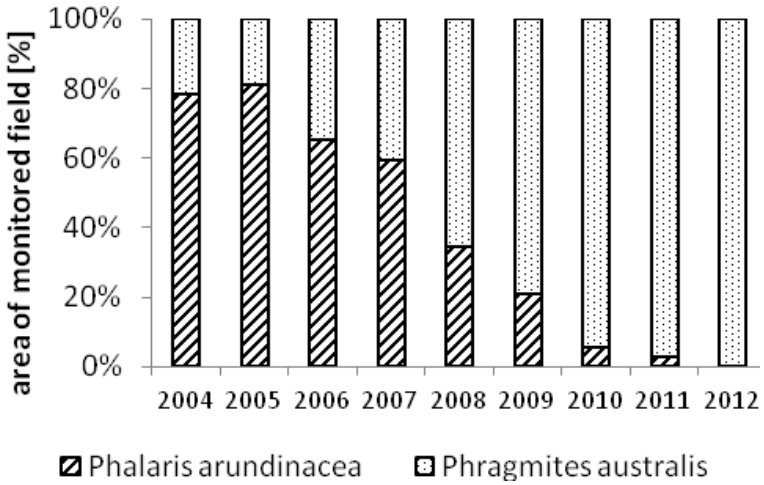

Figure 1 Percentage of the surface area covered by reed canarygrass and common reed in CW Břehov during the period 2004-2012

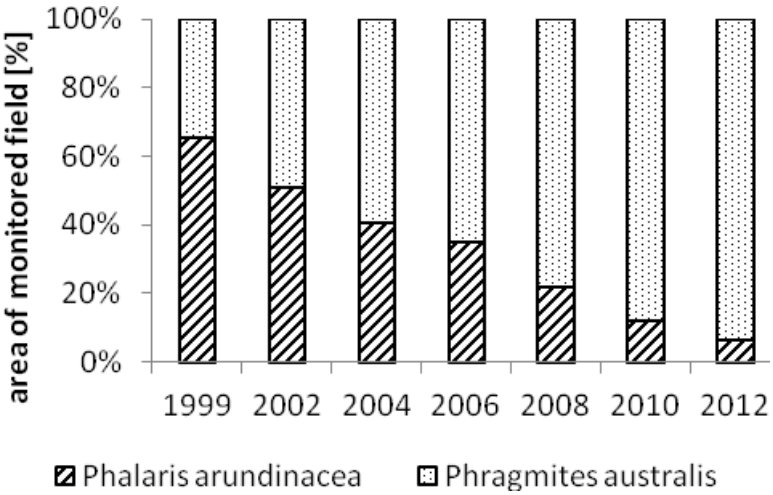

Figure 2 Percentage of the surface area covered by reed canarygrass and common reed in CW Příbraz during the period 1999-2012

The evaluation of the treatment performance of both systems has not revealed any changes in treatment efficiency and the outflow concentrations of measured parameters (BOD_5, COD, TSS, NH_4-N, TP) remained steady after *Phragmites* took over *Phalaris*.

Acknowledgements
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Vulnerability of riparian zone to alien plant invasions depends on its integrity

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Abstract Riparian zones are crucial part of aquatic ecosystem, playing significant role in its structure and function. The type of vegetation and width of the riparian zone are closely related to the ecological status of the river ecosystem and indicates its vulnerability. Besides, riparian zones also support a great part of biodiversity of the landscape. The degradation of the riparian zone is often associated with the degradation of vegetation. Invasive alien plants are considered as a disturbance that negatively impacts the biodiversity of native plants and ecosystems. They mainly colonise habitats where original vegetation was removed and/or failed to establish. We aimed to study the distribution and abundance of invasive alien plant species along the river Sotla in relation to morphological properties of riparian zone. In the survey 13 alien invasive species were identified. The most of their variability was explained by the height of riparian vegetation, changes in channel structure and land-use pattern beyond the riparian zone. Comparison of selected sections between the years 2008 and 2012 showed, that the abundance of alien species slightly increased in 2012 and two additional alien species, namely *Spiraea japonica* and *Ailanthus altissima*, were identified.

Riparian zones are a crucial part of the aquatic ecosystem, playing significant role in its structure and function. They support high diversity of local organisms and present important corridor for migrating species (Malanson, 1993). The amount of organic matter entering aquatic ecosystem depends on the type and complexity of riparian vegetation - therefore it also affects aquatic organisms (Naiman et al., 2005). In spite of their importance the riparian zones belong to vulnerable and endangered parts of the landscape, due to human impacts and natural stress events, because they occupy only a small proportion of the landscape limited to land/water interface. Invasive alien plant species are considered as a disturbance that negatively impacts native ecosystems. They affect ecosystem *via* through-flow of energy and cycling of matter, by changing habitat characteristics, by excessive use of resources, production of litter and changes in erosion dynamics. They mainly colonise the habitats where original vegetation was removed or failed to establish. When invasive alien plants become dominant in a community they alter ecosystem conditions to become less suitable for the native plants (Pyšek and Richardson, 2007). The aim of this study was to determine the presence, distribution and abundance of alien invasive plants as well as their preferences to habitat characteristics in the riparian zone along the right bank of river Sotla.

In 2008 the mentioned river was divided into 86 stretches of 100 m length. The conditions of riparian zone and land beyond the riparian zone were estimated (Petersen, 1992), the invasive species along the river Sotla were surveyed, their phenological phases were identified and phytosociological cover-abundance values were determined. In 2012

the inventory on 17 random selected sites was performed again to detect the possible changes of alien invasive plants occurrence and abundance.

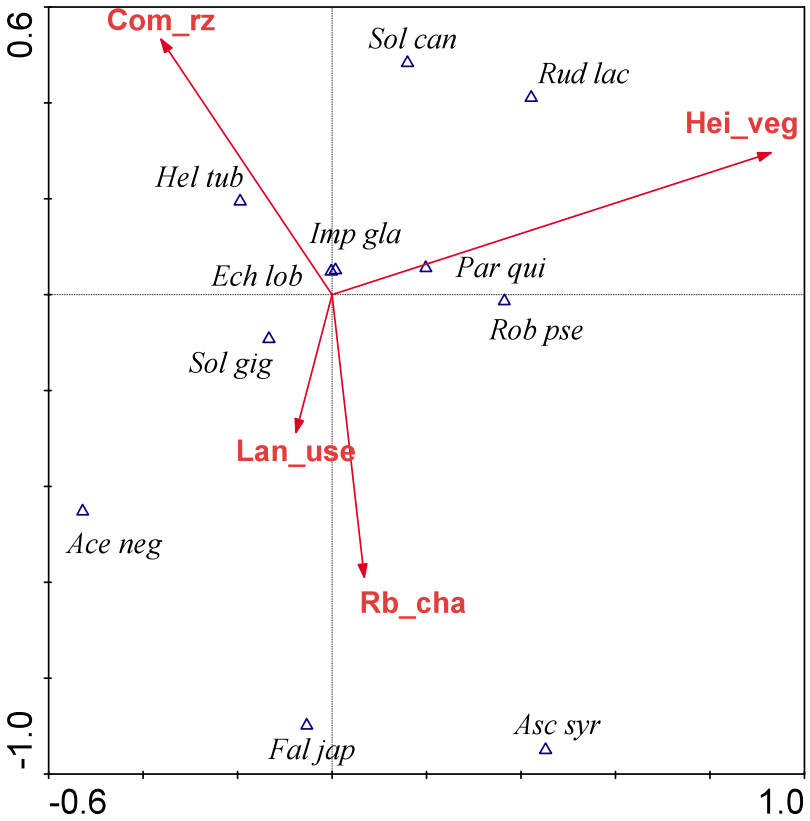

Figure 1 Ordination plot showing the distribution of invasive alien species in the riparian zone of the Sotla river in relation to environmental parameters that significantly affect their presence and abundance

In most of the sections the riparian zone was in good condition. Poor condition was detected in the middle and lower river course, which is a consequence of land-use patterns beyond the riparian zone. 13 alien invasive plant species were identified. The most frequent species were: *Echinocystis lobata*, *Solidago gigantea*, *Robinia pseudacacia*, *Helianthus tuberosus* and *Impatiens glandulifera*. The most of the variability of invasive species distribution was explained by the height of riparian vegetation, completeness of riparian zone, changes of the river channel and land-use pattern beyond the riparian zone. The comparison of selected sections between the years 2008 and 2012 showed that the occurrence of alien invasive plants was higher in 2012. Two additional alien invasive species – *Spiraea japonica* and *Ailanthus altissima* were identified.

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Recent Distribution and Genetic Variation of the endangered Water-soldier *Stratiotes aloides* (L.) in Austria

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Abstract The Eurasian/continental distribution range of *Stratiotes aloides* (Water-soldier; Hydrocharitaceae) is scattered over a broad area from Europe to Western Siberia. Typical habitats are riparian meadow lands, but it can also be found in ditches, shallow lakes and ponds. Freshwater ecosystems with a stable and sometimes even dominant occurrence of the Water-solider often reveal high biodiversity which indicates its importance for conservation. For example, the Green Hawker (*Aeshna viridis*) as well as the Black Tern (*Chlidonias niger*) are two known species which depend to a certain degree on the occurrence of Water-Soldier for successful reproduction. Unfortunately, a considerable decline of *Stratiotes aloides* has been reported within the last decades. These reports come from many European countries such as the Netherlands (Smolders et al., 2003) Germany (Korneck et al., 1996) and Austria (Schratt, 1993). In these countries the species has been classified as "Endangered", emphasizing its high risk of extinction in natural stands. Ditches in pasture lands are important retreat areas in north-western Germany. However, population decline has been reported in these habitats as well (HANEG, 2010). Factors which are involved in this rapid decline are on-going water engineering resulting in flow regulation and altered water level dynamics or eutrophication. *Stratiotes aloides* is also discussed as a keystone species in the hydrosere because some populations are characterized by a massive number of individuals due to a high potential of clonal propagation. Sexual reproduction is apparently limited because of low habitat connectivity, but also because many European populations are reported to harbour male or female plants only (Cook & Urmi-König, 1983).

In Austria, the distribution of *Stratiotes aloides* is restricted to riparian meadow lands along the rivers Danube and March. We started our monitoring in 2012 to evaluate the existence and condition of populations mentioned in the literature. At least two populations can be treated to be autochthonous, one in Lower Austria and the other in Vienna. Both locations are shallow ponds without any connection to the natural water dynamic of the Danube. Anyway, both populations harbour thousands of individuals and hydrosere is advanced in both cases. In the Lower Austrian population the situation is particularly worse because of constant eutrophication and shadowing (Bernhardt, 2012, pers. communication) and very low water level. Our primary goal of the on-going study is to establish a conservation strategy for Austrian populations of *Stratiotes aloides* populations with special regard to the genetic composition of stands in Lower Austria and Vienna. The genetic study is focused on the differentiation within and among both populations and compare the two natural stands with one *ex-situ* collection. So far we

could not detect any within population differentiation which is certainly due to a high degree of clonal propagation. Indeed, both populations are unisexual.

In this first analysis, we identified almost no genetic differentiation among populations on this narrow geographical scale. Additional AFLP analyses including geographically more distant populations have been initiated and preliminary results support our view that genetic differentiation is hardly detectable within a low geographic range but only detectable for isolated populations on a broad range (e.g. Austria *vs* Wesermarsch). A similar pattern has already been described for populations in Northern Germany (Haneg, 2010). In additional studies, samples will be added from populations in Northern and Western Germany as well as the UK, to further improve the understanding of the biogeography of *Stratiotes aloides*.

The high genetic similarity of populations from Vienna and Lower Austria suggests that these are of same biogeographical origin and may thus be useful for inoculation of suitable water bodies like old river beds along the Danube. The existence of at least one male and female autochthonous population gives hope that *Stratiotes aloides* can be successfully protected in Austria. Our monitoring and the results from the genetic study may provide substantial indications to set up a comprehensive management and conservation strategy for this species.

Acknowledgements We thank the team of the National Park "Donau-Auen" and the city government of Vienna for the successful cooperation and valuable information on recent populations of *Stratiotes aloides* in Austria.

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Nutrient retention before and after restoration of the riparian areas and remeandering of the Odderbaek stream, Jutland, Denmark

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Abstract The Odderbaek River in the western part of Jutland, Denmark, was remeandered in December 2010 and concomitantly the riparian areas were restored by disconnection of drains and ditches. From autumn 2009 to November 2012 the whole project area was investigated with a field set-up comprising transects across the river valley with piezometer nests and stream monitoring stations along the river.
There was a 50-90% decrease in nitrate concentrations following rewetting of the riparian areas while phosphorus concentrations varied considerably from transect to transect but with a clear tendency towards higher concentrations after the restoration. Mass balances for the riparian areas showed that there was a loss of 2 kg nitrate-N ha^{-1} yr^{-1} before and a removal of 81 kg nitrate-N ha^{-1} yr^{-1} after the restoration, while there was a loss of phosphate both before, 0.3 kg P ha^{-1} yr^{-1}, and after, 1.2 kg P ha^{-1} yr^{-1}, the restoration.

The study was conducted along a second order stream, Odderbæk, a tributary to one of the main rivers in Denmark, River Skjern, located in the mid-western part of Jutland (UTM N 55.926°, E9.296°) The catchment area is 29.8 km^2 and land use is agriculture 58.9 %, forest 31.8 %, grassland heathland and wetlands 5.3 %, and urban areas 3.9 %. The upland soils comprise 90 % coarse sand and 10 % clayey sandy soil. A series of transects were established across the river valley in the section to be restored and piezometers mounted with screens of 0.5 m length were installed at different depths along the groundwater flow line. The piezometers were used for measuring the groundwater table (GWT) and for sampling of groundwater. Water samples were analysed for NH_4^+, NO_3^- and PO_4^{3-} according to European Standard Methods. Water and mass balance calculation were performed by use of a model based on the Darcy equation and which has been thoroughly described in Hoffmann et al. (2006). Input data to the model were measured data on horizontal and vertical distances, hydraulic heads, hydraulic conductivity and concentration of phosphate, nitrate and ammonia. The statistical analysis was performed by use of the SAS STAT software package (SAS Institute, 9.03). To improve normality data were log transformed.
The nitrate mass balance showed some variation before and after restoration especially on the right side of the floodplain where the area covered by transect 1 and 2 (R1 and R2) changed from loss of nitrate, 169 and 167 kg NO_3^--N ha^{-1} $year^{-1}$, respectively, to removal of 375 and 110 kg NO_3^--N ha^{-1} $year^{-1}$. On the left side of the floodplain the area covered by transect 7 (L7) changed from loss of 271 kg NO_3^--N ha^{-1} $year^{-1}$ to having almost no load (2.0 kg NO_3^--N ha^{-1} $year^{-1}$, nor removal (1.5 NO_3^--N ha^{-1} $year^{-1}$). The differences in amounts and removals of nitrate were caused by changed land use, raised GWT and changed flow patterns and volumes due to disconnection of drains after the restoration. Overall nitrate retention changed from -2 before to 81 kg N ha $year^{-1}$ after the restoration.

Table 1 Mean groundwater table in cm, GW, with 95 % confidence limits for each transect before and after the restoration. Also shown is minimum and maximum GW before and after restoration. Sign - indicates GW below soil surface. N_before = 95-99 and N_after = 130-134

Transect	Before restoration		After restoration	
	GW table	GW Min – Max	GW table	GW Min – Max
1	-125.6 ± 9.1	-261.7 – -24.6	-68.4 ± 6.8	-186.2 – 2.7
2	-86.2 ± 6.8	-152.8 – -14.6	-39.5 ± 5.1	-90.8 – 24.3
3	-73.6 ± 6.6	-153.4 – 14.1	-44.6 ± 4.2	-102.9 – 6.5
4	-68.3 ± 6.7	-111.4 – 12.0	-26.9 ± 5.7	-85.0 – 70.0
5	-107.0 ± 15.8	-306.0 – -23.2	-103.5 ± 13.4	-294.9 – -18.0
6	-118.5 ± 12.0	-184.7 – -66.0	-61.6 ± 5.3	-135.7 – -10.2
7	-105.7 ± 24.2	-170.3 – -48.7	-60.7 ± 9.4	-125.9 – 6.0

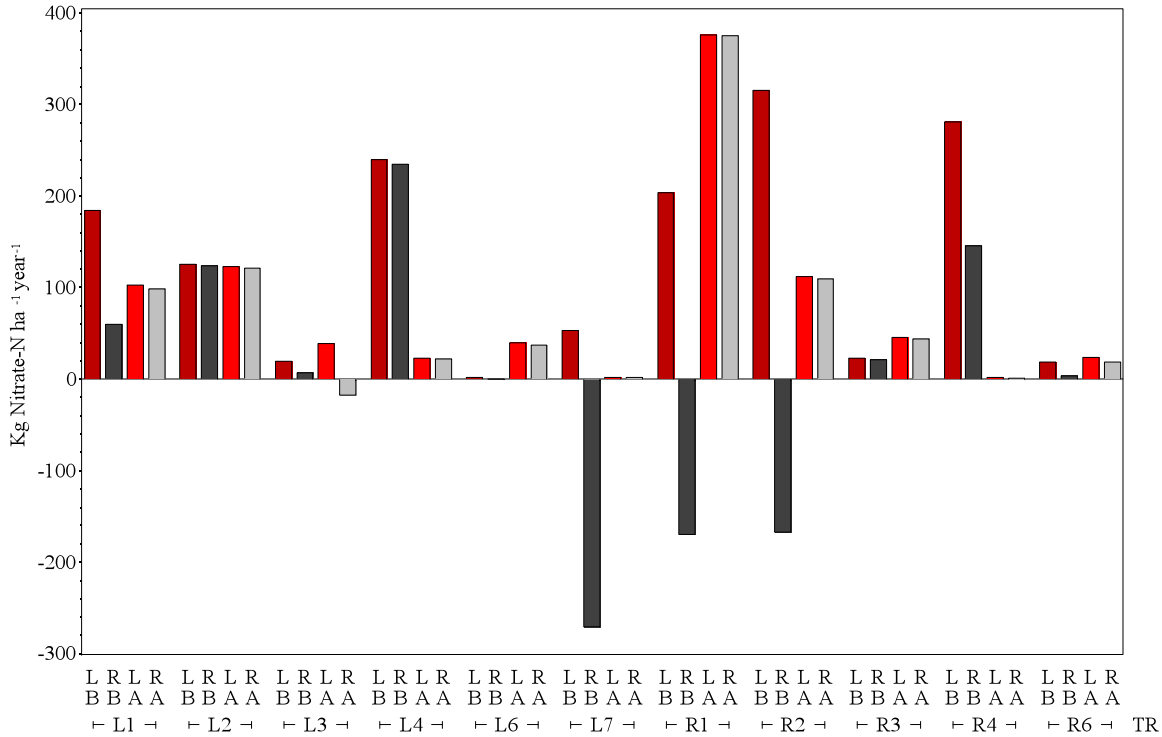

Figure 1 Nitrate mass balance showing: LB = load before; RB = retention before; LA = load after; RA = retention after restoration. L1 – L7 transects on left side of the floodplain and R1 – R6 transects on right side of the floodplain. Units kg Nitrate-N ha^{-1} $year^{-1}$

Also NH_4^+ balance changed significantly as the loss increased from 0.4 kg before to 7.0 kg ha^{-1} $year^{-1}$ after the restoration. PO_4^{3-} loss increased from 0.3 to 1.2 kg P ha^{-1} $year^{-1}$ especially due to loss of 6.6 and 3.1 kg P from transect 1, left and right side, respectively.

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Reflectance spectra of different stands in intermittent wetland

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Abstract The presentation summarises preliminary results on reflectance spectra in different stands in intermittent wetland. The stands were selected in the area with high homogeneity. Both monospecific (e.g. *Polygonum amphibium*, *Euphorbia lucida*, *Phalaris arundinacea*) and mixed stands were monitored. We examined reflectance spectra in the range from 290 to 887 nm. Twenty scans of each stand were performed. Stands were monitored from 2 to 4 times during the season. At each sampling selected properties of plants and plant stands were estimated. We hypothesised that reflectance spectra will differ due to different stand properties. However the reflection spectra in visible and UV-A range were shaped according expectations, while in UV-B range the results were very variable. In some stands the measured values were scattered around zero, while in many of them relatively strong reflectance in UV-B range was observed. The pattern was changing during the vegetative season. The comparison of stands' response with single plant response showed little accordance; therefore we presumed that the reflection is likely to be a consequence of the stand structure.

Cerkniško jezero is an intermittent lake appearing at the bottom of the depression Cerkniško polje. A variety of habitats, delineated by local water regime and as soil properties, could be found on water/land gradient. The result is a specific vegetation pattern comprising fully aquatic, amphibious, to mire and wet meadows communities (Martinčič and Leskovar, 2003). Leaves are complex structures that regulate the uptake of light at multiple levels, from the biophysical structure to the orientation of leaves (Ustin et al., 2001). Leaves of plants from different habitats have different leaf forms with specific structural characteristics that affect optical properties (Klančnik et al., 2012). In the present study we aimed to analyse differences in optical properties of different plant stands that grow at water/land gradient, measuring reflectance spectra. We wanted to point out the structural properties of communities that explain the most of variability of reflectance spectra.

Both monospecific and mixed stands were monitored. Plant stands were selected in the area with high homogeneity. Measurements of reflectance were conducted on the day of sampling using a portable spectrometer Jaz Modular Optical Sensing Suite (Ocean Optics, Inc., Dunedin, FL, USA). Total adaxial reflectance spectra of leaves were recorded between 280 and 887 nm, during illumination of leaf with a UV–VIS–NIR light source (DH-2000, Ocean Optics, Inc., FL, USA). A Spectrolon white reference panel was used to calibrate the instrument to 100% reflectance prior the measurements. Twenty scans of each stand 2 to 4 times during the season. At each sampling properties of plant stands were estimated. Measurements were performed 90 cm above the stand. Constant angle of measurements was applied. The following stand properties were monitored: the number of species, species abundance, plant cover and the height of the stand. We also measured selected properties of prevailing species namely plant height, phenological phase, vitality and leaf angle. In addition environmental parameters: PAR, T and RH were monitored.

The analysis of stand reflectance spectra showed that the reflection in UV-A and UV-B spectra is very pronounced in many plant stands but not at the species level and that stands' reflection differed during vegetation period. The RDA analysis revealed that leaf angle, species height and the level of stand homogeneity significantly affected reflection spectra. However to draw a final conclusion additional studies at leaf level are needed.

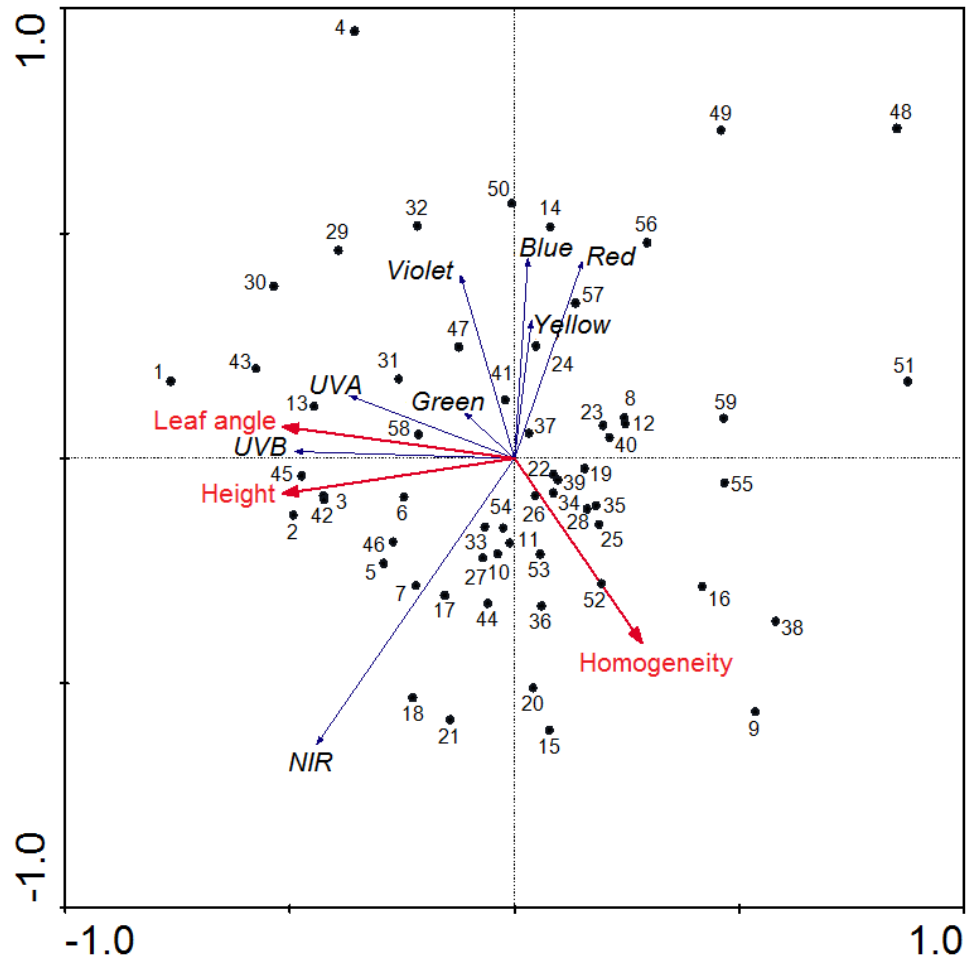

Figure 1 RDA ordination diagram showing the strength of associations between community properties and different ranges of reflectance spectra. Variables are represented by arrows, numbers represents different community types

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Role of Wooded Buffer Zones in retention of effluent nutrients, after sewage treatment plant

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Abstract

Surface water is still increasingly polluted by nutrients (N, P), responsible for eutrophication. This increase can be due to effluents from sewage treatment plants (STP). Constructed wetlands such as Wooded Buffer Zones (WBZs) have been created in order to improve the quality of the water which is discharged in the stream or infiltrates through the soil leading to soil retention and/or nutrient uptake. The objective of this presentation is to compare the efficiency of this "tertiary treatment" in two WBZs with different physical characteristics (size, soil permeability) and planted with willow species. P and N were measured in water (inlet and outlet of the WBZ), in soil and the leaves and boughs of willow-trees. We showed that the functioning of WBZs differed according to substrate permeability. Leaf and bough nutrient content was relatively high. There is no difference between willow species, or between plants collected at the inlet and outlet. The N/P ratio in plants confirmed the limiting effect of nitrogen in tree growth. These preliminary results led to a research project over 3 years on the hydraulic functioning of the WBZs and the role of plants and substrate in nutrient retention or in the reduction in nutrient transfer to the receiving environment.

Nitrogen and phosphorus are essential compounds in biological processes. Effluents from STP are largely loaded with soluble phosphate and thus contribute to water eutrophication. In France, regulation measures were taken to reduce this pollution. In order to respect standard fluxes, numerous STP set up a tertiary treatment. One of them is the Wooded Buffer Zone (WBZ) largely inspired by natural wetlands. Some studies have suggested that plants are the main actor in nutrient retention in WBZs, (especially due to increase in biomass rather than leaf nutrient content (Silvan et al., 2004). Other studies showed that leaf N and P content increased with nutrient supply (Martin and Stephens, 2006). WBZs were commonly planted with willow species leading to high biomass production. This production can be increased by 30 to 100 % with effluent irrigation because roots are able to pick up 75 to 95% of nitrogen (Borjesson and Berndes, 2006). The aim of this work was to study the reduction in nitrogen and phosphorus in two WBZs planted with willows which complement vegetated STP.

One STP, located at Viviers-sur-Artaut, was designed for a PE (person equivalent) of 200 with a 680 m^2-WBZ (soil: silty in surface and clayey in depth, permeability: 158 mm/h^{-1}). The second site, located at Bray, was designed for a PE of 500 with a 325,5m^2-WBZ (soil: silty-clay, permeability: 49 mm/h^{-1}. Both STP exhibited a river as receiving environment. Water was sampled at the inlet and outlet of the WBZ and in the river. Kjeldahl Nitrogen (TKN), ammonia nitrogen (NH_4), nitrite (NO_2), nitrate (NO_3), orthophosphate (PO_4) and total phosphorus (TP) were analysed and the global nitrogen (GN) calculated. Total N and P content were measured in leaves and boughs of willow

species. Soil samples in gutter leads (0-5 cm, 5-25 cm and 25-45 cm) were collected and mineralized in order to analyze total P content.

Difference in nutrients reduction in water was observed in both WBZ (Table 1).
At Bray, the little nutrient reduction and retention within can be explained by the low soil permeability and the design of the WBZ. Its surface was too small compared to inlet water load, leading to the formation of a surface water layer. In spite of its potential for denitrification (water-saturated soil), there is no reduction in the nitrate concentration. At Viviers, water infiltrated through the first meters of the gutter lead. This is probably due to a combined remediation effect of soil and plant.

Table 1 Evaluation of nutrient reduction in water of Bray and Viviers WBZ

	GN	**TKN**	**N-NH4**	**N-NO3**	**TP**	**P-PO4**	**N and P mineralization**
Viviers	High	High	High	High	High	High	Complete
Bray	Medium	High	Low	Unchanged	Unchanged	Unchanged	Complete

Total N and P in willows leaves and boughs were comparable or even higher than already observed in other studies (Labrecque et al., 1998). Total N and P content were higher in leaves than in boughs, confirming leaf as a nutrient storage organ.
At both sites, no significant difference in N and P content in leaves and boughs was found between the willows located upstream and those located downstream of the WBZ. This can be explained at Bray by a superficial water layer, supplying equally upstream and downstream zones of the WBZ, and at Viviers by the fast infiltration of effluents. The role of nutrients already present in soil (without any effluent input) in the nutrition of willows should be further considered.
The N and P content in the leaves and boughs were compared in different willow species. No significant difference was found. Thus, every species of willow can be planted in such systems.
We observed a decline in willow nitrogen nutritional status at Viviers in summer, confirmed by the lower N/P ratio (<8) indicating that nitrogen could be the limiting factor in the growth of willows.
As a conclusion, we showed that the effect of plant on effluent remediation was low and the nutrient content of the soil seems to be sufficient for plant nutrition. The species of willow and its location in WBZ played no significant role in nutrient retention. Efficiency of WBZs depends on soil structure (permeability) and ratio between WBZ area and the incoming hydraulic load. Further studies will focus on hydraulic functioning of the WBZs and the role of plants and substrate either in nutrient retention or in the reduction in transfer to the receiving environment.

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Screening of eighteen species for digestate phytodepuration

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Abstract The experiment aims to assess the capacity of adaptation of 18 species in treating the Digestate Liquid Fraction (DLF) with a floating wetland treatment. The pilot system was realised in 2010 in NE Italy and consists in 180 floating elements (Tech-IA) vegetated with ten halophytes and other eight species. The species have been transplanted in July 2011 in basins with a proportion of DLF/water (DLF/w) 1:15; after transplanting periodical increasing of DLF/w ratio has been imposed, reaching the worst conditions for plants in summer 2012 (EC around 7 mS cm^{-1} and NH_4-N content 208 mg L^{-1}). BBCH scale show that *C. dactylon*, *T. latifolia*, *E. atherica*, *H. portulacoides*, *S. fruticosa*, *A. caerulescens*, *S. maritima* and *P. palustris* were able to survive. Halophytes showed higher dry matter production than other plants. The best roots development was registered for *C. epigejos*, *P. australis*, *T. latifolia* and *J. maritimus*. The highest nitrogen (10-15 gm^{-2}) and phosphorus (1-3 gm^{-2}) uptake were obtained with *P. palustris*, *I. pseudacorus* and *A. tripolium*. In conclusion, two halophytes, *Puccinellia palustris*, *Elytrigia atherica* are the species that present higher potential to be used in floating wetlands to treat DLF.

The treatment of agricultural effluents, by means of land spreading, is regulated by the Nitrates Directive (91/676/ECC). However, the problem of the liquid fraction, rich in nutrients, cannot be solved only by land spreading. Constructed wetlands (CWs), by advanced system layout, could offer an efficient and environmentally valuable approach to the treatment both of wastewater and liquid fraction of digestate (Comino et. al, 2013) because they are effective in removing biodegradable organic matter, as well as residual suspended solids (García, 2004; Kadlec et al., 2000; Soto et al., 1999). The aim of the study is to perform a screening of 18 species, including 10 halophytes, planted in floating elements in a surface-flow wetland system treating the DLF. In particular, their survival potential in DLF, their adaptability to floating systems and their aptitude to depuration have been evaluated. 10 halophytes (*Artemisia caerulescens, Aster tripolium, Halimione portulacoides, Inula crithmoides, Juncus maritimus, Limonium narbonense, Puccinellia palustris, Sarcocornia fruticosa, Spartina maritima, Elytrigia atherica*) and other 8 species (*Cynodon dactylon, Alnus glutinosa, Arundo donax, Iris pseudacorus, Phragmites australis, Typha latifolia, Calamagrostis epigejos, Cladium mariscus*) were planted in July 2011. After a short adaptation period the DLF/w ratio showed periodically increasing values reaching the highest concentration (DLF/w 1:7) in summer 2012. Temperature, redox potential (Eh), Electrical Conductibility (EC), Oxygen Demand (OD) and pH have been weekly determined inside the pools with a digital electrochemical measuring system (Hach Lange HQ 40d). Every two weeks water samples have been analysed for Total Nitrogen (TN), ammonia nitrogen (NH_4-N), nitrate nitrogen (NO_3-N), Total Phosphorus (TP), ortophosphate (PO_4-P), Chemical Oxygen Demand (COD), turbidity (NTU). In November 2011 and October 2012 the biomass has been harvested and Total Kjeldahl Nitrogen (TKN) and Total Phosphorus (TP) have been measured. Morevorer, in 2012 the development of roots and phenological scale (Biologische Bundesanstalt Bundessortenamt and Chemical industry, BBCH) were determined. The

worst conditions for plants have been registered in July 2012 (Table 1) inducing death of nine species and anticipating senescence of five. Results of BBCH scale (Table 2) indicate that only C. dactylon, T. latifolia, A. caerulescens, E. atherica, H. portulacoides, P. palustris and S. maritima were able to survive in the floating systems and in wastewater concentration reported in Table 1 with highest values as 7 mS cm^{-1} EC and as 208 mg L^{-1} NH_4-N. Among these species P. palustris (14.93 g m^{-2} N in 2012), E. atherica (11.03 g m^{-2} N in 2012), S. maritima (10.40 g m^{-2} N in 2011) and T. latifolia (7.94 g m^{-2} N in 2011) showed the highest nitrogen uptake values.

Table 1 Monthly median values of waste water parameters measured in the basins in 2011 and 2012

	VI-11	VII-11	VIII-11	IX-11	X-11	XI-11	III-12	IV-12	V-12	VI-12	VII-12	VIII-12	IX-12	X-12
NO_3-N (mg L^{-1})	0.57	3.54	5.44	12.30	13.90	10.90	8.79	13.05	10.90	17.70	17.90	23.00	11.25	12.60
NH_4-N (mg L^{-1})	0.08	34.05	43.55	91.05	85.51	102.00	85.05	99.50	70.95	162.00	193.00	157.00	71.45	85.80
TN (mg L^{-1})	13.40	55.90	71.40	156.00	152.50	152.00	71.30	131.00	117.50	223.00	236.00	177.00	80.10	105.00
COD (mg L^{-1})	116.0	692.0	887.0	2085.0	2066.5	1594.0	1163.0	1962.5	1784.0	2695.0	3505.0	2916.0	1385.0	1495.0
TP (mg L^{-1})	-	9.31	10.60	23.55	25.35	21.50	11.65	24.55	19.50	27.50	17.30	28.70	17.10	22.30
EC (mS cm^{-1})	-	1.62	2.37	3.76	4.18	3.57	3.74	3.63	3.72	4.25	6.10	5.38	3.92	4.14
Eh (mV)	-	-57.8	-99.85	-140.05	94.47	177	-	-218	-158.2	-210.55	-266.8	-280.25	-266.9	-362.1

Table 2 List of species with related parameters. Senescence (S) or death (D) date (BBCH)

Specie	(BBCH)	DW (g m^{-2})		TKN – DW (%)		TP – DW (%)		Root depth (cm)
	2012	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**	**2012**
A. caerulescens	S: 21/08	177.2	147.3	3.46	2.12	0.81	0.11	7.7
A. donax	D: 22/06	242.0	-	3.22	-	0.80	-	-
A. glutinosa	D: 22/06	46.5	-	1.41	-	0.06	-	15.0
A. tripolium	D: 09/08	324.8	765.3	3.91	1.71	0.52	0.49	7.0
C. dactylon	S: 31/07	69.4	202.3	4.04	3.66	0.22	0.36	11.5
C. epigejos	D: 02/07	20.9	105.7	3.75	2.14	0.20	0.27	36.5
C. mariscus	D: 24/07	201.2	60.7	2.08	2.40	0.30	0.46	13.7
E. atherica		251.2	518.2	3.29	2.13	0.94	0.16	8.0
H. portulacoides		308.8	105.7	4.13	3.09	0.40	0.20	5.8
I. crithmoides	D:21/08	224.2	7.9	3.29	2.83	0.59	0.20	9.2
I. pseudacourus	D:16/07	158.0	477.2	2.41	2.77	0.32	0.33	17.8
J. maritimus		175.1	32.8	2.29	2.22	0.34	0.14	34.3
L. narbonense		46.5	77.8	4.08	2.49	0.24	0.20	6.5
P. australis	D:09/07	338.6	312.9	2.69	2.53	0.51	0.23	32.0
P. palustris	S:22/06	348.3	691.9	3.55	2.16	1.00	0.30	9.0
S. fruticosa	D:10/05	402.8	-	3.16	-	1.19	-	-
S. maritima	S:09/07	44.5	309.8	2.34	2.33	1.06	0.22	9.2
T. latifolia	S:31/07	422.3	200.2	1.88	2.04	0.08	0.25	34.0

In conclusion, according to the obtained results, *P. palustris* and *E. atherica,* both halophytes, showed a good adaptability to the system performing an uptake higher than *T. latifolia* and *P. australis*.

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Organic matter and pollutants monitoring in reed bed systems for sludge stabilization: a case study

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Abstract In this study, results about sludge stabilization and pollutant monitoring in a reed bed systems (RBSs) situated in Central Italy (Colle di Compito, 4000 pe) were presented. To evaluate the process of sludge stabilization, parameters that highlighted the biochemical and chemical properties of organic sludge matter have been followed during the entire period of operation (seven years). Moreover, the trend of heavy metals (bioavailable fractions and total content) was monitored during all the period. The trend of all parameters related to overall microbial activity, Water Soluble Carbon and dehydrogenase activity) clearly demonstrated that stabilization of the sludge successfully proceeded in RBS. At the same time, the level of toxic organic compounds decreased significantly; a similar trend was also noticed for the bioavailable heavy metal fractions, thus meaning that as the stabilization process occurs in the RBS, the level of pollutants decreases in the stabilised sludges. Moreover, through statistical analysis modelling, it is possible to determine how the stabilization process influenced the content of pollutant compounds present in the stabilised sludges.

Reed bed systems (RBS) represent a valid technology for sludge treatment. Several studies demonstrated that this technology is able to dewater and stabilize sludge, improving the organic matter quality (Peruzzi et al., 2011). The objective of this research is to quantitatively evaluate the stabilization process occurring in the RBS, fitting a logistic model to parameters related to sludge organic matter stabilization processes. In this paper, results about the quality of the stabilized sludges within a reed bed systems during the operational phases of loading and resting periods (seven years) are reported (Table 1).

Table 1 Wastewater treatment plants and loading program

	RBS – Colle di Compito
Population equivalent (p.e.)	4000
Basin area (m^2)	225 (5 beds)
Loading rate (kg dw m^{-2} y^{-1})	67
Sludge type	Activated sludge (1.5% dw)
Loading/Resting Autumn-Winter-Spring (days)	1/14-20
Loading/Resting Summer (days)	1/7-10
Operating period	2006-2013 (0 – 78 months)

The time course of the studied parameters has been fitted with a logistic curve, even though the process was operative under dynamic and not under static conditions. The logistic equation has been proposed both for biological growth and for organic compounds degradation (Gimsing et al., 2006). The logistic curve is given by the following function, $y = K/(1+c\ e^{-rt})$, where y is any parameter concentration, t is the considered time, and K, c and r, are parameters found by fitting. The parameters r and K can represent the rate constant and the expected value at the end of the process, respectively. The procedure for logistic (Geogebra) and for non-linear model, (Statistica)

were used for fitting data. Water-soluble carbon (WSC) and Dehydrogenase (DHase) enzyme were determined according to Yeomans and Bremner (1988) and Masciandaro et al., (2000) methods, respectively. The bioavailable heavy metal fractions (Fraction 1+2) and the Fraction bound to organic matter (Fraction 3) were determined using the Mocko and Waclawek method (2004).

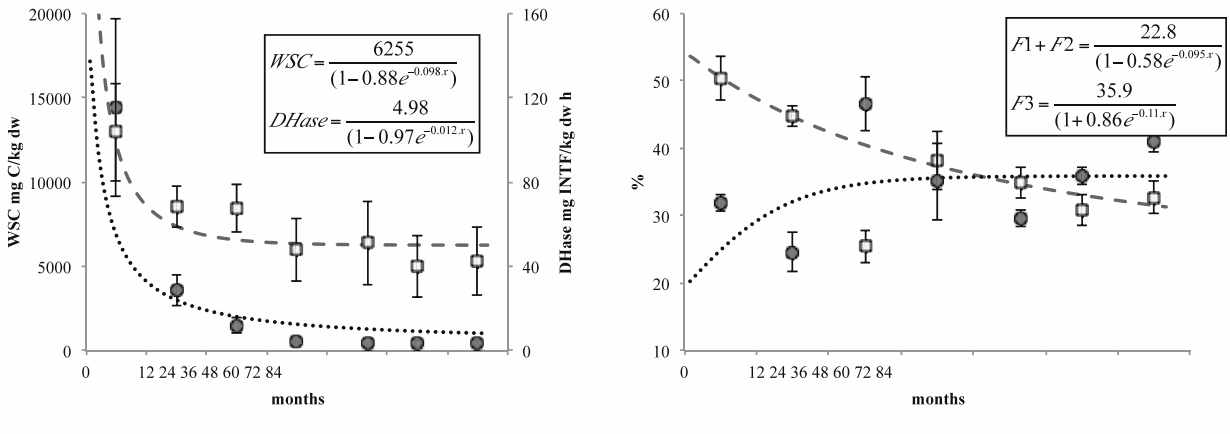

Figure 1 a) Water soluble carbon (mg C/kg dw - white squares) and logistic fitting (dashed line);Dehydrogenase activity (mg INTF/kg dw h – gray dots) and logistic fitting (dotted line). b) Fraction 1+2 (%, white squares) and logistic fitting (dashed line); Fraction 3 (gray dots) and logistic fitting (dotted line)

In general, the parameters related to organic matter mineralization showed a drastic reduction over time (Figure 1a): in fact, both the soluble form of carbon (WSC) and the DHase activity, which measures indirectly the overall microbial metabolism, reached particularly small values after 30 months of operation and reached significant lower values after 42 months of operation. Also the logistic fitting, in fact, set as expected final values 6255 mg C/Kg dw and 4.98 mg INTF/kg dw h for WSC and DHase, respectively; these values, in fact, mean a low metabolic activity for sludge matrices at the final time, thus indicating that organic matter was going towards a biostabilization process. The stabilization process also affected the bioavailabilty of inorganic contaminants: the Fractions 1 and 2 (the most available), in fact decreased significantly over time, while, the level of metals bound by organic matter (Fraction 3, less available) increased. The two concomitant processes occurred in a similar way: in fact, the logistic fitting individuated similar values for the rate constant for Fractions 1 and 2 (0.095) and Fraction 3 (0.110), respectively.

In conclusions, the logistic fitting well describe the trend of the organic matter sludge stabilization, even though the process occurred in reed bed systems was under dynamic conditions. Moreover, the final values found by fitting model represent suitable and indicative values for the management of RBS.

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Radial oxygen loss from roots of *Vallisneria spiralis* L.: biogeochemical implications in eutrophic aquatic ecosystems

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Abstract Organic matter accumulation in freshwater ecosystems has been addressed among the major factors determining the decline of vulnerable submerged vegetation and the consequent loss of key ecosystem functions. *Vallisneria spiralis* L. (Hydrocharitaceae family), a perennial rooted plant, grows in nutrient-rich waters and on a wide range of sediment organic content. Several experiments were performed to investigate how *V. spiralis* affects the biogeochemical dynamics in eutrophic sites, both directly (uptake) and indirectly (root oxygen release). *V. spiralis* acts as an *engineer species* controlling interstitial features and benthic fluxes (e.g. NH_4^+, NO_x^-, PO_4^{3-}, Fe^{2+} and CH_4) even in organic-rich sediments. A seasonal variable amount of the photosynthetically produced oxygen is transported towards the rhizosphere to counteract the changing interstitial chemical environment, affecting significantly the redox-dependent processes. Under eutrophic conditions, the high nitrogen availability weakens the competition between macrophytes and nitrifying and denitrifying bacteria, thus promoting nitrogen removal through a combination of plant uptake and dissimilative microbial processes. Ultimately, *V. spiralis* can partially buffer the negative implications connected to organic enrichment and modify sedimentary features with positive feedbacks for the restoration of impacted water bodies (i.e. regeneration of ferric iron buffer and phosphorus retention in sediment, stimulation of coupled nitrification-denitrification).

Freshwater ecosystems in human-impacted watersheds are subjected to increasing rates of nutrient and organic matter supply. The decline of submerged macrophytes in eutrophic water bodies and the switch to phytoplankton or floating plant dominated states have been addressed to a combination of increased turbidity and interstitial chemical conditions unfavorable to roots. Some tolerant plants have developed adaptations that allow not only their survival along pronounced gradients of sedimentary organic content, but also their fast response to short-term variations of pore water chemistry, as those occurring seasonally in freshwater temperate ecosystems. In this context, it is relevant to assess: a) how less vulnerable macrophytes can control biogeochemical dynamics in environments subjected to progressive modifications of water column and sediment chemistry, as those occurring in aquatic systems undergoing eutrophication, b) how the sediment conditions affect rooted plant performances, and c) if, within certain perturbation thresholds, benthic vegetation can act as a buffer to organic enrichment, promoting the maintenance of the ecosystem services connected to its presence (e.g. nutrient retention). *Vallisneria spiralis* L. (Hydrocharitaceae), a perennial stoloniferous species, is tolerant to eutrophication and colonizes both lentic and lotic environments. It performs photosynthesis in low light conditions, grows in nutrient-rich waters and on a wide range of substrates, from gravel bottoms to organic-rich muddy sediments.
We performed several experiments in order to evaluate the rhizosphere-microbial communities interactions in freshwater ecosystems under excess nitrogen and organic matter availability. Different methodological approaches have been adopted (i.e.

hydroponic incubations of plants, characterization of pore water, sediment microbial activity assays, incubations of intact cores or microcosms) to investigate the following aspects: I) direct (uptake) and indirect (oxygen release) effects of *V. spiralis* presence on pore water features and benthic fluxes of gases and nutrients; II) *V. spiralis* plasticity to colonize substrates with increasing organic content and changes of its influence on redox-dependent processes along the gradient; III) relation between assimilative (mediated by vegetation) and dissimilative nitrogen processes (mediated by bacteria) under excess nitrogen. Here a comprehensive synthesis of the main outcomes is presented and discussed in the context of the ecosystem services provided by submerged vegetation. Multiple evidences support the hypothesis that *V. spiralis* varies seasonally the oxygen quota transported to the below-ground tissues to counteract the changing interstitial chemical conditions (Soana and Bartoli, 2013). Radial oxygen loss increases in the transition winter-summer and peaks in early autumn, when the lowest sediment redox occurs, due to a combination of exhaustion of energy yielding electron acceptor pools and input of labile organic matter from senescent meadows. The oxygen injected in the pore water by *V. spiralis* meadows constitutes a relevant amount of the daily benthic oxygen consumption, with relevant implications for the quality of both sediment and water column compartments in term of oxidation status. *V. spiralis* acts as an *engineer species* controlling actively interstitial features (NH_4^+, NO_x^-, PO_4^{3-}, Fe^{2+} and CH_4) over a wide range of trophic conditions and along its whole vegetative cycle. This plant promotes less reducing conditions in the rhizosphere and the consequent maintenance of an active nitrifying community (Racchetti et al., 2010; Soana et al., 2012). In sediments with a moderate organic enrichment, radial oxygen loss promotes denitrification coupled to nitrification, thus enhancing the ecosystem capacity to control nitrogen contamination (Racchetti et al., unpublished). Furthermore, the high nitrogen availability in both pore water and water column weakens the competition between macrophytes and nitrifying and denitrifying bacteria, favoring nitrogen removal through a combination of plant uptake and dissimilative microbial processes. However, at extremely elevated organic enrichment, vegetated sediment lose their role as nitrogen traps due to inhibition of nitrification and plant stress induced by very reduced conditions.

In conclusion, *V. spiralis* has the potential to withstand large perturbations of sedimentary features, being able to colonize organic matter impacted substrates. Even pore water conditions potentially hostile to roots do not affect its function as a benthic metabolism regulator. This macrophyte plays a crucial role in driving water-sediment exchanges of gases and nutrients, partially buffering the negative effects of organic enrichment. Moreover, it modifies benthic dynamics with positive feedbacks for water bodies restoration (i.e. regeneration of ferric iron buffer and phosphorus retention in sediment, stimulation of coupled nitrification-denitrification, attenuation of internal organic load), which makes this plant an interesting option in programs for improving sediment conditions and favoring ecosystem recovery.

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Pollution and environmental restoration: characterization of the riparian species *Salix alba* L. in contaminated site.

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Abstract The management of contamined sites is now of major concern for most industrialized countries. Remediation methods may be very helpful to restore polluted soils and water. In particular, phytoextraction is defined as the use of plants to remove heavy metals from soils and accumulate them in their biomass. Many species or clones of the genus *Salix* have the capacity to accumulate elevated levels of metal in their biomass, but each species, pollution and site leads to differences in absorption, translocation and allocation of extracted metal. Therefore there is the need to find the most suitable species/clones for specific sites and types of contamination. The objective of this study was to evaluate the exposure of riparian vegetation to heavy metals in the Site of National Interest "Valle del Sacco" (Lazio Region, Italy), known for its high degree of environmental pollution due to the spread of organic and inorganic contaminants. *Salix alba* L., was chosen for the analysis. Two experimental sites were selected along the river Sacco: station S1, located upstream near the river spring, far from the main sources of contamination as industrial areas and urban centers, in which the tree layer is co-dominated by *Populus tremula* L. and *Alnus glutinosa* L; station S4, located in the river valley next to major anthropogenic impact, where the tree layer is co-dominated by *Populus nigra* L., *Acer negundo* L. and *Robinia pseudacacia* L. During the years 2010-2013 gas exchanges measurements (CIRAS-2 PP System) and chlorophyll *a* fluorescence were conducted (Handy Pea, Hansatec Intruments). The content of heavy metals and nutrients in the soil and leaf level were determined respectively with ED-XRF (X-Lab 2000 - Spectro) and ICP-OES spectrometry (Vista-MPC, Varian). In the soil samples it was observed an higher content of trace elements (Pb, As, Zn, Cu) in S4 as compared to S1, while in both stations the values of these elements were below the threshold of phytotoxicity for plant species at leaf level. It is interesting that Zn content was significantly higher in S4 than in S1 in both soil and leaves (Table 1). An high accumulation of zinc in aerial tissues, in particular in adult trees leaves, was observed by other authors on Salicaceae family members investigated in metal-contaminated sites in Central Europe (Unterbrunner et al., 2007; Migeon et al., 2009). The ability to accumulate and translocate contaminants in plant organs makes *S. alba* suitable in the management of the phytoextraction processes. Gas exchange analysis showed a different response in terms of transpiration rate (E) and stomatal conductance (gs), between the two stations in the three years. Both parameters decreased more in S4 than in S1. The reduction of Performance Indices total (PItot), derived from chlorophyll *a* fluorescence (JIP-test, Strasser et al., 2010), showed an alteration of photochemical processes in 2012. The presence of organic and inorganic pollutants can have negative effects on metabolic processes, as observed by other authors in studies on tree species in field (Borisev et al., 2012) and in laboratory experiments (Bernardini et al., 2012). The relationships between the concentration of contaminants in the soil and in the plants growing in the same site

are complex. The negative correlation (Pearson's, $p<0.005$) between heavy metals (Zn, Pb, Cu) and gas exchange parameters, induced to hypothesize effects on stomatal apparatus (Table 2). Heavy metals can affect carbon dioxide assimilation through damage to the photosynthetic and stomatal apparatus or to the water conducting system (Bernardini et al., 2011). Further studies are in progress in order to understand the ability of different clones of the genus *Salix* to tolerate elevated heavy metals concentrations in experiment in controlled environmental conditions. These assessments allow us to use willows in phytoextraction and re-naturalization projects of riparian areas, as in degraded areas as the Sacco River Valley.

Table 1 Concentrations of heavy metals (mg kg^{-1} DW) in dry tissues of *S. alba* leaves and soil samples collected from S1 and S4. Values are mean ± SE (n=3). Asterisks indicate significant differences (n.s, no significant; ***, $p<0.001$; **, $p<0.01$; *, $p<0.05$) from one-way Analysis-of-Variance statistical tests between stations. Abbreviation "n.d." indicates values no detectable

	Station	Zn	Cd	Cu	Pb	As	V
Leaf level	S1	43.35 ± 3.77	0.42 ± 0.02	10.42 ± 1.25	n.d.	n.d.	n.d.
	S4	113.46 ± 19.93	0.65 ± 0.10	2.97 ± 0.49	n.d.	n.d.	n.d.
	p<0.05	**	n.s	**			
Soil	S1	54.80 ± 1.56	0.78 ± 0.02	21.76 ± 0.89	29.05 ± 3.79	5.50 ± 0.28	80.69 ± 7.01
	S4	149.65 ± 14.56	0.85 ± 0.03	63.05 ± 5.47	67.40 ± 2.31	13.68 ± 0.98	104.50 ± 7.10
	p<0.05	***	*	***	***	***	n.s.

Table 2 Correlation matrix between transpiration rate (E), stomatal conductance (gs), net photosynthesis (A), measured in September 2012 in *S. alba* and heavy metals concentrations in leaves (F) and in soil (S). Marked correlations are significant at $p < 0.05$ (n=4)

	E	gs	A	Cd F	Cu F	Zn F	Zn S	Pb S	Cu S
E	1.000000	0.913606	0.881474	-0.849529	0.978266	-0.806898	-0.910816	-0.831295	-0.941242
gs		1.000000	0.921909	-0.948842	0.904095	-0.943177	-0.997562	-0.985251	-0.996707
A			1.000000	-0.753246	0.792399	-0.970492	-0.945708	-0.882642	-0.937371
Cd F				1.000000	-0.906254	0.805647	0.924758	0.949857	0.933139
Cu F					1.000000	-0.739746	-0.887014	-0.832480	-0.923185
Zn F						1.000000	0.962257	0.944517	0.939005
Zn S							1.000000	0.981345	0.996260
Pb S								1.000000	0.968501
Cu S									1.000000

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Vegetation Composition and Soil Seed Bank Analyses in ephemeric semiaquatic Environments – Examples from *Coleanthus subtilis* and other endangered shoreline Plants

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Abstract Limnic habitats with alternating situations between terrestrial and aquatic conditions are populated by shoreline plants such as the tiny therophytic grass *Coleanthus subtilis* (Poaceae). This species might be one of the rarest plants in Central Europe (listed in annexes II / IV of the EU-Habitats-Directive). The ephemeral species *Coleanthus subtilis* is listed in the national Red Lists of all the countries where it occurs (Schnittler and Günther, 1999) as well as in annexes II and IV of the European Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora of the European Community (EC Habitats Directives). Habitats of *Coleanthus subtilis* belong to code number 31.30: oligo-mesotrophic waters with vegetation type of *Littoreletea uniflorae* and/or Isoëto-Nanojuncetea, species that are habitat specialists, weak competitors, rare or at the edge of their range are considered to be especially at risk of extinction (Walker and Peston, 2006). The Austrian Red List classified it as "extinct" since *C. subtilis* has not been reported for decades in Austrian floristic surveys.

During investigations of the soil seed bank of fish ponds in the "Waldviertel" region in Austria, a few populations have been re-discovered recently (Bernhardt et al., 2004). The population biology of *C. subtilis* has been investigated and the composition of the belowground floristics in the soil seed bank and in the aboveground vegetation has been compared. The results achieved in *C. subtilis* so far, showed that seed banks may play important roles in the conservation of genetic diversity and natural restoration to wetland vegetation as well as to recover endangered plant species. Successful re-examination of *C. subtilis* locations documented by older herbarium entries generally encouraged the idea to compare herbarium material of today highly endangered or extinct plant species with seeds of soil samples collected in corresponding localities. Most of those species, like the ones growing along the shoreline, need unique conditions to survive. Shoreline plants are able to colonize ephemeric semiaquatic environments, i.e. conditions alternating between terrestric and hydric. One characteristic of these plants is their capacity to survive in the soil seed bank during unsuitable conditions. Due to the longevity of seeds, those species remain present for decades. Therefore the soil seed bank contains an important portion of the species diversity as well as the genetic diversity of populations (Koch et al., 2003)

With 426,000 seeds/m^2, the average density of diaspores in the soil reaches a very high level. Regarding the seed potential of the examined soil samples, a few species take a dominant part with very high diaspore densities, i.e. *Callitriche* sp., *Elatine* spp.,

Gnaphalium uliginosum, *Juncus articulatus*, *Juncus effusus, Juncus bufonius, Peplis portula* and *Veronica peregrina*. Despite low densities in vegetation, high diaspore density levels occur in species such as *Coleanthus subtilis, Limosella aquatica* and *Rorippa palustris*. This implies high quantities of seeds produced by individuals or a relative longevity of diaspores.

Detectable in the diaspore bank of all soil samples was a considerable number of species that were not traceable in the current vegetation. In individual locations, the number reached 7 to 14 individuals. Among the species that were found in the soil samples, between 28 and 61 percentage exist only in the seed potential and do not appear in the current vegetation. In case of an altered management of fish ponds, like observable in Lower Austria, the seed potential might have crucial influence on vegetation development and may be considered in conservation plans.

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Investigation of the seed bank of semi aquatic dwarf rushes communities

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Abstract Persistent soil diaspora banks are characteristic of annual, fugitive species and play a fundamental role in their life history. Especially the species of semi aquatic dwarf rushes communities (class Isoëto-Nanojuncetea) are known for building up enormous seed banks. In Europe these communities are declining and represent a priority habitat of the European NATURA 2000 directive (Code: 3130).
Historically important retreat areas of dwarf rushes are secondary, man-made fishponds and storage ponds, with a European centre of distribution in the Bohemian Massif, Czech Republic.
For the poster we are investigating the seed bank composition of 36 plots, including extensive managed fishponds, fish storage ponds and natural riverbanks in Czech Republic, Austria and Slovakia. Aim is to compare it to the aboveground vegetation with the composition of the emerging seedlings to reveal the role of the seed bank as a integral part of the life history of semi-aquatic plant species.
A particular attention is paid to the small brow sedge *Cyperus fuscus*, which is a typical representative of this vegetation and will be examined in a bigger context, which will also include genetic analyses.

The seed bank has been defined as 'a reserve of viable seeds, fruits, propagules and other reproductive plant structures in soils' (Poiani and Johnson, 1989).
Genetic and/or phenotypic variation is required for populations to adapt to environmental change (Frankham et al., 2010). In many annual plant species with a persistent soil seed bank is an additional, temporal component of genetic variation in the soil. Seeds of ephemeral, fugitive species may be long-lived (50-100 yr) resulting in a complex age structure of the soil seed bank (Levin, 1990).
This project aims at illuminating the role of the persistent soil diaspore bank as an integral part of the life history of ephemeral, semi-aquatic plant species.

For the experiment we analysed the seed bank of 32 Plots over Czech Republic, Austria, Slovakia and Poland. These Plots belonging to the three groups of man-made fishponds or fishstorage ponds and natural habitats like riparian stripes of rivers.
We collected ten soil samples per plot in two depths (0-5cm and 5-15cm) and mixed the samples of these two. Also vegetation relevees ($1m^2$) of the exact these plots were taken. Of these 625ml mixed soil sample of each horizon we spread out 600g (320-500ml) on 2.5 cm of silica sand (Skoglund and Hytteborn, 1990). So we analysed 64 soil samples at all. Because of the small seed size of *Cyperus fuscus*, which is in the main interest of the whole project, and the time-consuming aspects of the rinsing method we decided

according to Thompson et al. (1997) to use the seedling-emergence method (Roberts, 1981, Ter Heerdt et al., 1996 and Ter Heerdt et al., 1999).
Essential for the success of seedling emergence is that greenhouse conditions are suitable for the germination of as many species and individuals as possible (Thompson and Grime, 1979, Roberts, 1981, Ter Heerdt et al., 1999 and Boedeltje et al. 2002). We had a 12/12 hour day/night cycle with 30°C days (germination phase) and 12°C for the nights. After three weeks we went down with the day temperature to 20°C for the growing phase. The trays were watered daily and fertilized twice.

From the samples emerged in average seedlings of 8.5 different species, while the relevees of these Plots contained in average 19.1 different species. From these 64 soil samples emerged in average 871606 Individuals per m^3, ranging from 3909 to 29 germinated seeds per l soil. These semiaquatic habitats are known for a huge amount of seeds in the seedbank (e.g. Skoglund and Hytteborn 1990, Baskin and Baskin 2001, Goodson et al. 2001).

The evaluation of the comparison of the aboveground Vegetation with the seed bank will follow. This experiment is just part of a bigger project in which we are investigating the genetic variability of the brown sedge *Cyperus fuscus* and the role of the seedbank as a genetic memory. For that we will analyse the *Cyperus* plants of the vegetation and the two soil fractions with microsatellite markers.

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Functional Plant Diversity – Resisting Climate Extremes?

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Abstract Biodiversity incorporates the diversity of species and functional traits. Plant traits are physical, physiological and phenological characteristics. Biogeochemical processes, ecosystem services and resilience to disturbance are all linked to functional diversity. This indicates that plant traits, groups and functional strategies are a powerful tool in assessing community responses to environmental changes such as climate events. Extreme climate events are of greater magnitude and shorter duration than 'typical' climate change trends and are expected to increase in frequency, duration and intensity in response to climate change. There is evidence to suggest extreme events could provoke profound changes in ecosystems by exceeding stability thresholds. Recovery from disturbance in plant communities to a prior state signifies resilience. As environmental conditions change the best adapted species replace others in stable communities via complex adaptive strategies. Wet grasslands are wetlands providing multiple ecosystem services. They are adapted to regular flooding and other disturbance regimes, but could endure extreme flood events through flexibility in community composition. This poster aims to examine why plant functional diversity may be essential for community resilience against extreme flooding on wet grasslands, and how this can be determined using mesocosms and field-based removal experiments.

Extreme climate events include floods, heat waves and other extremes of temperature or weather. Some extreme events are expected to increase in frequency and duration in response to the changing climate (IPCC, 2012). Extreme events are defined by great magnitude over short temporal scales that may cause an 'extreme' response within an ecosystem (Smith, 2011). Therefore, extreme events are predicted to have greater impacts because of the speed in which environmental change may occur following an event (Jentsch et al., 2007). There is also evidence to suggest extreme climate induced changes to environments may be irreversible (Holmgren et al., 2001).

There is projected to be an increase in extreme precipitation events, particularly in the temperate and boreal regions of both hemispheres (O'Gorman and Schneider, 2009).

Wetlands including floodplain grasslands may have a role in mediating some consequences of increased intense precipitation by providing water storage and flood attenuation. However, extreme climate events could disrupt the functioning of floodplains as it is not yet clear how the plant communities will respond. Temporal seasonal shifts in intense precipitation may exceed hydrology thresholds for vegetation within the growing season (Poiani et al., 1995).

Floodplain plant communities are known to exhibit stability under dynamic environmental conditions, which may provide the foundations for resilience under extreme events. Many floodplain plants carry physiological and mechanistic traits to cope specifically with disturbance regimes, especially inundation and waterlogging (Voesenek et al., 2006). Vegetation abundance on floodplains does not necessarily decrease after extreme flooding, although diversity and species turnover are affected directly (Ilg et al.,

2008). This suggests a high level of stability is determined by long term processes, and resilience through complex adaptive strategies (Norberg, 2004), allowing the community to remain functional through species turnover. Resilience may also be enhanced by the higher number of viable seeds from species tolerant to both wet and dry conditions compared to those from submergent or terrestrial only species (Nielsen et al., 2013). Stability could also be maintained through plant-plant facilitation in which a species indirectly modifies the environment to the benefit of another. Facilitation has been observed in severe environments including wetland ecosystems, and as a result of multiple environmental stressors (Brooker et al., 2008).

This new research aims to determine whether floodplain plant community stability is vulnerable to changes under extreme climate events, or, whether resistance is evident through either resilience or facilitation.

Methods for determining whether floodplains could remain stable under extreme climate events include a mesocosm experiment to test the effects of chaotic summer flooding on plant communities. Two communities have been assembled based on selected traits which either confer flood tolerance or not. Through monitoring plant growth and phenology the study will establish whether flood tolerant species facilitate growth and fitness in other species under chaotic flood conditions. A field site consisting of two contrasting floodplain grassland communities has also been established to compliment the mesocosm experiment. The effects of the loss of species with particular traits on community composition will be examined through removal experiments in order to identify whether species loss leads to rapid turnover in trait similar species and therefore confers resilience in the plant community.

The results will be used to re-evaluate current floodplain grassland management practices in light of the growing appreciation of future extreme climate impacts.

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Decomposition of dominant plant species in two wet grasslands with differing soils

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Abstract The effect of fertilization on litter decomposition of dominant plant species (C*arex acuta*, *Glyceria maxima*) was measured in 2009-2010 in wet grasslands occurring on mineral (Hamr: HA) or peat (Zablatske Louky: ZL) soils. Litter bags (2 g air-dried material) were placed in No and High (300 $kg*ha^{-1}*yr^{-1}$) plots of the two sites. Selected bags were collected in March and June 2010, their dry weight and C, N and P contents of the remaining litter determined and compared to initial values. The amount of litter mass remaining significantly decreased over time in both sites and for both species. Fertilization weakly affected ($p=0.053$) loss of material only for the *C. acuta* litter in HA (High > No). However, the rate of mass loss of *C. acuta* in ZL was significantly slower than that for the same species in HA ($p<0.001$). HA is a nutrient-richer site, which was reflected in the litter C:N ratio (ZL = 23-30; HA = 15-17). Also, within HA, *G. maxima* litter decomposed faster than *C. acuta* litter ($P<0.001$) even though the two species had similar C:N values. These differences reflected more the differences in plant chemical composition.

The area of wet grasslands in Europe has greatly declined over the last 60 years, partly due to increased fertilizer application and intensified management practices (Joyce and Wade, 1998). Increased nutrient application can lead to decreased species diversity as well as changes in species composition (Brinson and Malvarez, 2002). Such changes can also affect nutrient flows and fluxes through changes in decomposition rates. The aim of this study was to determine the effect of fertilization on decomposition of common plant species in wet grasslands with either organic or mineral soil. The litter bag method was used to measure the decomposition rates of aboveground plant structures of the dominant species in two wet grasslands in south Bohemia, Czech Republic. Záblatské Louky (ZL) is a marginal wet grassland associated with a fishpond. It lies on organic soil and is dominated floristically by *Carex acuta*. Hamr (HA) is a floodplain wet grassland and lies on mineral soil. It has two dominant plant species, *C. acuta* and *Glyceria maxima*. Leaves of the dominant species were collected in August 2009 from fertilized (300 $kg * ha^{-1} * yr^{-1}$; Lovofert 15:15:15 NPK,) or unfertilized control plots and air dried. Then 2 g of air dried material were put into mesh bags and placed back into the plots from which the leaves were collected in November 2009. There were three sets of bags per plot in ZL while there were six (3 each for *C. acuta* and *G. maxima*) in HA, with each set containing five litter bags. One litter bag per set was to be collected at selected time intervals (0, 3, 6, 8, 10, 12 months). However, the experiment had to be prematurely concluded following site perturbation after six months of exposure. The material that was collected (0, 3 and 6 months) was analyzed for dry weight and nutrient (C, N) content. Data were analyzed by ANOVA following natural log transformation to achieve normality and homogeneity of variance. There was a weak fertilizer effect on the decomposition of *C. acuta* from HA ($p = 0.053$; fertilizer > control), but not for either *G. maxima* in HA or *C. acuta* in ZL. *C. acuta* from HA decomposed significantly faster ($p < 0.001$) than that from ZL. This difference was most likely due to the greater litter quality (measured as

C:N ratio) for the HA *C. acuta*. The C:N ratio for *C. acuta* from ZL ranged from 23-30, while that from HA was only 15-17. The C:N ratios of *C. acuta* and *G. maxima* from HA were similar, but *G. maxima* decomposed significantly faster ($p < 0.001$) than *C. acuta*. This is likely due to *C. acuta* having a greater content of recalcitrant compounds, such as lignin.

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Turnover of aboveground biomass OF *Carex acuta*, a dominant of a sedge-grass marsh

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Abstract As part of research focused on the role of plants in carbon budget of a temperate wetland, this study aims at estimating the turnover of aboveground biomass of the dominant sedge species (*Carex acuta* L.) in a sedge-grass marsh, the Wet Meadows near Třeboň, Czech Republic. The biomass turnover was estimated using both destructive and non-destructive types of measurement and was assessed separately for generative and vegetative tillers, which markedly differ in their life cycles: while vegetative tillers last throughout the vegetation season, generative tillers have a fast development at the beginning of the vegetation season but die out soon after seed development.
Vegetative shoots reached their seasonal maximum dry weight at the end of August. The average dry weight of all leaves produced so far was 1.96 g per tiller and the average total dry weight was 2.31 g. The turnover coefficient was 1.19 $year^{-1}$ and 1.30 $year^{-1}$ for leaves and whole tillers, respectively. Generative shoots reached their seasonal maximum dry weight at the end of June. The average dry weight of aboveground biomass produced so far was 1.95 g per tiller. The turnover coefficient was 1.38 $year^{-1}$and 1.10 $year^{-1}$ for leaves and whole tillers, respectively.

Study of the carbon cycle in wetlands is interesting due to important feedback to the global climate system. Wetlands, depending on climatic and hydrological factors, can influence regulation of the amount of carbon (CO_2, CH_4) in the atmosphere (Bohn et al., 2007). One of the limits of current methodological approaches remains the difficulty of accurate determination of net primary production. The problem is normally solved by establishing a turnover coefficient, which presents the ratio between net primary production and biomass. This coefficient sets the rate of renewing the biomass. Such studies are nevertheless rare. As part of research focused on the role of plants in carbon budget of a temperate wetland, this study aims at estimating the turnover of aboveground biomass of a sedge species, *Carex acuta* L., a common dominant plant of temperate wet grasslands. *Carex acuta* is a rhizomatous perennial plant. It has the long and short life-cycles. The short life-cycle takes 2 years. In the first year vegetative tillers are formed. In the second year of their life they develop fast at the beginning of the vegetation season, produce flowers and seeds, and die out soon after seed development. The long life-cycle represents the ontogenetic development of one plant (genet). This genet is developed from seed and subsequently creates a tussock by tillering (Soukupová, 1988). The wetland Mokré Louky (The ‘‘Wet Meadows’’) situated near the town of Třeboň, South Bohemia, Czech Republic (centre of the Třeboň Basin Biosphere Reserve, 4980103000 N, 1484602000 E, 426.5 m. a.s.l.) is a flat depression with an area of 450 ha (Jeník et al., 2002). The study site, which represents the wettest part of this wetland, used to be mown once a year until the 1950s. The resulting vegetation consists mainly of tall sedges (*Carex acuta, C. vesicaria*) and wetland grasses (mostly *Calamagrostis canescens*) (Prach and Soukupová, 2002).

The biomass turnover was estimated by combining destructive and non-destructive measurements on 9 sampling dates during the vegetation period from April to November 2011. Non-destructive measurement took place in three hummocks where 54 tillers (33 vegetative and 21 generative tillers) were marked. The measures included. There were determined length of tiller from base to top of the tallest leaf and numbers of live, dead and missing leaves, respectively. If a dead leaf occurred, it was cut off and its dry weight was determined. The destructive measurement consisted of cutting off tillers (min. 15 vegetative and min. 10 generative tillers in every measurement) in close vicinity of the three hummocks. All leaves were numbered from the oldest to the youngest. The leaves were then cut off and sorted into categories by number (separately for live and dead leaves). After that the real numbers were assigned to them according to the average values recorded on the non-destructively measured tillers. The dry weight of these leaves was finally determined.

Vegetative tillers were formed by leaves and a base. They persisted throughout the vegetation season and bore most of assimilation apparatus. They produced on average 14 leaves during the vegetation period. The number of live leaves was quite stable from May to July (7-8 live leaves per tiller), and decreased afterwards. Production of new leaves ended by the end of June. Between two successive measurements on average two leaves died and two leaves fell off. Dry weight of the base was stable during the vegetation period (0.2-0.24 g) but increased at the end of vegetation period (September, October) (0.35 g). Average dry weight of live leaves increased from 0.02 g to 0.27 g. Dry weight of all live leaves was 1 g from July to September. Vegetative tillers reached their seasonal maximum dry weight at the end of September. The average dry weight of all leaves produced by that time was 1.96 g per tiller and the average total dry weight (including base) was 2.31 g. The turnover coefficient was 1.19 $year^{-1}$ (at the end of August) and 1.30 $year^{-1}$ (at the end of September) for leaves and whole tillers, respectively. Generative tillers developed fast at the beginning of the vegetation season but died out soon after seed development in July. They produced on average 10 leaves, but the leaf production stopped by the beginning of May. In June they formed on average 3 live leaves, 2 dead leaves and 4 missing leaves. The dry weight of generative tillers was formed mainly by stem and inflorescence. Leaves of all categories represented only 1/3 of total aboveground biomass. Generative tillers reached their seasonal maximum dry weight at the end of June. The average dry weight of all leaves produced was 0.65 g at that time and the average total dry weight was 1.95 g per tiller. The turnover coefficient was 1.38 $year^{-1}$and 1.10 $year^{-1}$ for leaves and the whole tiller, respectively.

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Monitoring of population and habitat preferencies of *Littorella uniflora* (L.) Asch. in the Czech Republic

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Abstract *Littorella uniflora* (L.) Asch., a member of *Plantaginaceae* family belongs to a group of isoetids, small, slow-growing, evergreen, aquatic plants. They are characterized by a strong and stiff leaves with a basal form and a large amount of roots biomass. Oligotrophic and mesotrophic freshwaters are typical habitats for this plant. In the Czech Republic, as well as in other areas of occurrence, number of suitable habitats is rapidly decreasing.
In the year 2012, monitoring of all known areas of *Littorella uniflora* occurrence was carried out in the Czech Republic. Population was evaluated using the phytosociological frames and estimates of abundance. Physicochemical characteristics of water and sediment were monitored and comparison of different fishpond management on these localities was evaluated as well.

Littorella uniflora is a criticaly endangered water plant in the Czech Republic. According to the latest research, it can be found only at 8 localities (Chytrý, 2011). This oligotrophic plant is affected mostly by eutrophication of water bodies caused by agriculture and fishpond management. No program for its rescue has been developed so far.
Research has ben carried out at 8 localities in Czech Republic from April to September 2012. *L. uniflora* occurs at two drinking water reservoirs and six extensively used fishponds (Table 1). Populations were measured using the phytosociological frames and estimates of abundance. Abundance was determined as a sum of individuals at experimental areas (100 cm^2) and its conversion at the whole population area at each locality. For assessment of each counting classes, modified scale of Szmeja (1994) was used. Physicochemical characteristics of water and sediment were evaluated by means of measurement of pH, transparency, TN, TP, chlorophyll-*a*, and alkalinity for water (Table 2); TN, TP, TOC, Ca and Mg ions for sediments (Table 3).

Table 1 Area and estimated abundance of *Littorella* population

	Staňkovský	Hejtman	Mrzatec	Nový	Osika	Králek	Karhov	Láz
area of reservoir (ha)	272	79	6	0,5	67	3,5	17	17
area of Littorella population (m^2)	0.13	0	7.6	86	4.1	703.4	1.65	8005
estimated abundance (ex)	122	0	18716	12900	6585	1355100	165	1197100

Table 2 Mean water characteristic of surveyed *Littorella* reservoirs

	Staňkovský	Hejtman	Mrzatec	Nový	Osika	Králek	Karhov	Láz
pH	7.6	7.6	7.2	6.2	8	7.9	6.9	7.4
transparency (cm)	120	83	110	152	80	120	170	310
TN (mg/l)	1.27	0.98	0.89	0.76	1.29	2.54	0.76	0.73
TP (mg/l)	0.09	0.12	0.08	0.08	0.09	0.07	0.03	0.01
chrophyl a (mg/l)	11.7	11.7	17.27	10.5	22.16	39,28	6.6	2.72
alkalinity (mmol/l)	1.55	0.45	0.53	0.15	0.29	1.26	0.17	0.18

Table 3 Sediment characteristics of surveyed *Littorella* reservoirs.

	Staňkovský	Hejtman	Mrzatec	Nový	Osika	Králek	Karhov	Láz
TN (g/kg DM)	0.87	-	0.79	9.39	0.69	1.12	1.42	2.86
TP (g/kg DM)	0.121	-	0.121	1.19	0.104	0.128	0.174	0.467
TOC (g/kg DM)	10.2	-	10.785	151	5.8	10.1	16.5	39.685
Ca (g/kg DM)	0.321	-	1.43	2.89	0.274	0.746	0.611	3.461
Mg (g/kg DM)	0.321	-	0.314	2.55	0.18	0.467	1.01	1.95

Physicochemical characteristics of water and sediment at all studied water bodies are quite similar except Láz a Nový reservoirs. These two reservoirs exhibit the same characteristics which, according to Roelofs et al. (1994), allow *L. uniflora* to thrive. It is a natural oligotrophy with high carbon a nitrogen ratio. Those factors slow down decomposition of organic matter, so *L. uniflora* can grow on the high layer of organic sediment.

For future research it is important to take into consideration the level of fishpond management and fish stock. Apparently, those factors have important influence on *Littorella* population.

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The structure and production of belowground organs in a herbaceous wetland

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Abstract The main aim of this work was to gather and further develop knowledge of the structure of belowground organs (growth dynamics and life span of roots) of a model wetland plant, Carex acuta, in relation to biomass production and carbon allocation. The study was carried out in the wetland Mokré Louky (the "Wet Meadows") near Třeboň (South Bohemia, Czech Republic). On each of three sampling dates, six tussocks of Carex acuta were excavated, and separated into the "hummock" part situated above the soil surface and "soil" part, situated below. The hummock part was then separated into shoots and roots. The soil part contained only coarse roots. About 50% of all live roots occurred in the volume of the hummock elevated over the soil surface. The median of the root:shoot ratio was 2.5 in August. In spite of their greater numbers, the fine roots formed about 10 to 30% of the total root biomass. The data also indicate a strong seasonal variation.

The recent interest in understanding the carbon budget of wetland ecosystems has revived also the interest in the seasonal dynamics of plant biomass. Compared to aboveground plant parts, dynamics of belowground organs has received less attention as it is difficult to assess the seasonal dynamics of root biomass in stands of perennial plants. Yet, belowground organs represent about 50-80% of the total plant mass at the time of the seasonal maximum aboveground biomass. The aim of this study was to describe the structure of the belowground parts for a model wetland graminoid species, *Carex acuta*.
The wetland Mokré Louky (The "Wet Meadows"), situated near the town of Třeboň, South Bohemia, Czech Republic (centre of the Třeboň Basin Biosphere Reserve), is a flat depression with an area of 450 ha. The area is covered by up to several meters thick layer of peat, which is superimposed on quarternary alluvial sands and clays (Jeník et al., 2002). The site is situated in the inundation area of a large human-made lake (Rožmberk fishpond, 5 km^2). The water level is controlled by a system of ditches, which interconnect the man-made lakes (fishponds) in the whole region, and is thus fairly stable throughout the year (Dušek et al., 2009).
On three sampling dates of 2012, six tussocks of *Carex acuta* were excavated, and divided into the "hummock" part situated above the soil surface and "soil" part situated below. The hummock part was then divided into shoots, fine roots and coarse roots (Končalová, 1990). The soil part contained only coarse roots. Each fraction was washed with tap water. Finally, live and dead roots were separated visually.
On average five roots and two coarse roots were found on one tiller in August (Figure 1). In spite of their greater numbers, the fine roots formed about only 10 to 30% of the total root biomass (Figure 2). The median of the root:shoot ratio was 2.5.

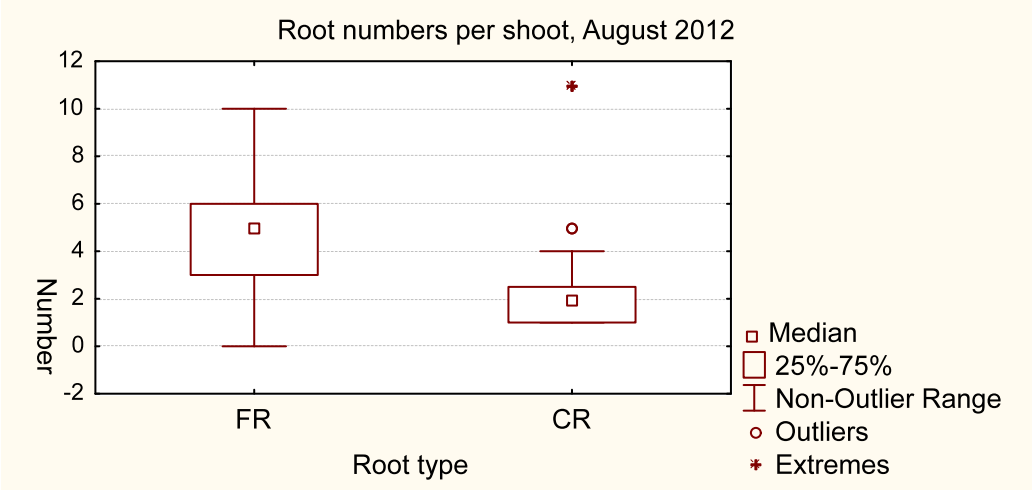

Figure 1 Example of root numbers of individual tillers. FR – fine roots, CR– coarse roots

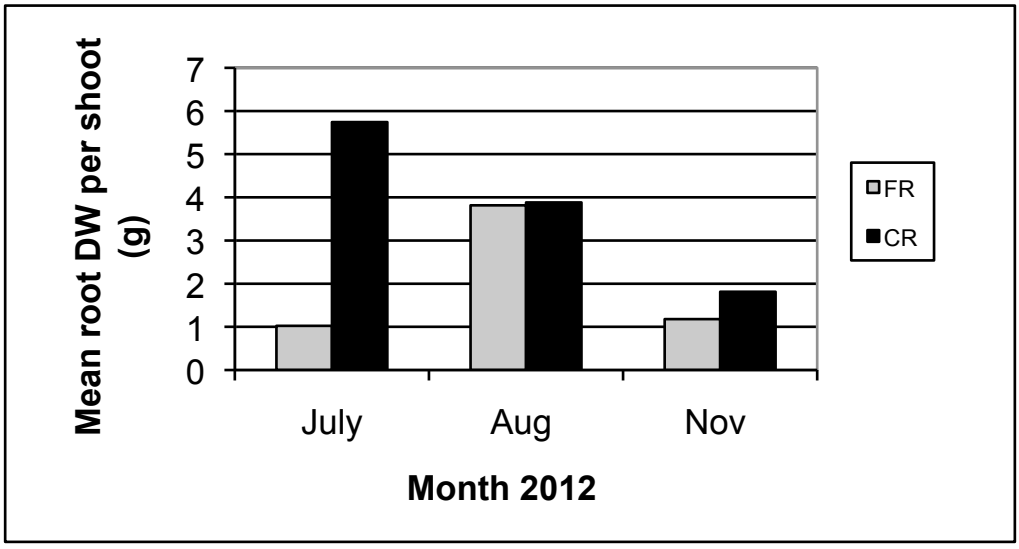

Figure 2 Changes in mean dry weight of root types in the second half of the growing season. FR – fine roots, CR– coarse roots

This contribution shows preliminary results of a study continuing throughout 2013. The data indicate a strong seasonal variation. Further research will be, therefore, focused on a more detailed assessment of the dynamics of root growth of *Carex acuta* throughout the vegetation season.

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Potential For Methane Production From Wetland Biomass

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Abstract The objective of this research was to evaluate the potential for biogas production from macrophyte biomasses used as wetland plants. Their exploitation for biogas production may permit to reuse wastewaters and, at the same time, to create a chain with alternative renewable energies. Seven crop species were tested in laboratory reactors. Two treatments were compared: biomasses obtained from a unique harvesting event and biomasses obtained by mixing plant tissues deriving from frequent cuttings. Significant differences were observed in methane (CH_4) production depending on the crop species. In general, anaerobic digestion (AD) of biomasses from frequent cuttings was characterized by a higher time of microbial adaptation than AD using biomasses from a unique harvest.

Nowadays manure management is one of the main topics in agriculture research. Several treatments have been studied to handle it and constructed wetlands are one of them. Constructed wetlands often produce a huge quantity of biomass, that could be used for biogas production, with new perspectives for the development of marginal areas and the reuse of poor quality waters (Venendaal et al., 1997). The objective of this study was to compare the potential for CH_4 production of macrophyte biomasses obtained from a unique harvesting event (TU) or by mixing plant tissues deriving from frequent cuttings (TF). The hypothesis was that biomass from TF could give rise to a higher CH_4 production than biomass from TU, due to its higher digestibility.
Aboveground biomass samples belonging to 7 species of macrophytes (ArD, *Arundo donax* L.; CA, *Carex acutiformis* Ehrh; CR, *Carex riparia* L.; IP, *Iris pseudacorus* L.; MG, *Miscanthus x giganteus* Greef et Deu.; SS, *Scirpus sylvaticus* L.; SOA, *Symphytus officinale asperrimum* L.), harvested according to TF or TU treatments, dried at 65 °C and 1-mm sieved, were used as substrates for AD in laboratory reactors. Biogas production (volume and composition) was measured according to Owen et al. (1979) during the incubation of the reaction mixture (substrate + inoculum) in 100-mL reactors in strict anaerobiosis conditions at 35 °C and pH 7 (3 replicates per species and treatment, 42 reactors in total). The reaction mixture contained 1.25-g dried sample (2.5% total solids, TS, in the overall mixture volume), 23.75 mL of phosphate buffer and 25 mL inoculum. The substrate concentration was chosen on the basis of preliminary tests (data not reported), performed to identify the most adequate substrate amount. The inoculum included 80% digestate from pig slurry and 20% selected microbial consortia. The comparison of the cumulative CH_4 production curves during a 2-month incubation period was based on the parameters: maximum cumulative CH_4 production, *Hmax* (mL CH_4); daily rate of CH_4 accumulation, *R* (mL CH_4 d^{-1}) and lag time duration, that is the time of adaptation before the starting of CH_4 production (λ, d). These parameters were estimated by fitting a modified Gompertz equation (Lay et al., 1999) to each curve of measured data. ANOVA was applied to the Gompertz parameter estimates for evaluating the significance of differences due to treatments and species.

Overall, the kind of harvest management had no effect on Hmax (Table 1). This was expected because the maximum CH_4 production, for a given type of substrate, depends on its volatile solid (VS) content, and the VS content of TF and TU did not differ significantly (VS_{TF} =83% TS; VS_{TU} =85% TS). The mean estimated Hmax value, equal to 211 mL CH_4, corresponds to a biomethanation potential (BMP) of 187 mL CH_4 g^{-1} VS, for standard conditions of temperature and pressure. This BMP is analogous to that measured by Raposo et al. (2006) for maize. The Hmax value was influenced by the plant species: the AD of ArD, CA, CR and MG gave rise to more CH_4 in TF than in TU, whereas the AD of SS produced much lower amounts of CH_4 in TF than in TU. The R value was influenced solely by the plant species. The kind of harvest management significantly influenced the duration of the lag phase: λ was significantly higher in TF than in TU; it was higher for ArD, IP e SS, and very low for CA. In practice, a longer lag time duration in AD is negative because it implies a longer hydraulic retention time, and consequently larger reactor volumes are needed.

In conclusion, the AD of biomasses from wetland macrophytes permits to obtain good CH_4 yields. Plant species evaluation may help in the identification of the most suitable biomass substrate for AD. The initial hypothesis of higher CH_4 yields in TF was only partially confirmed. The biological factors that may influence the lag phase duration depending on the type of harvest management deserve to be identified.

Table 1 Anaerobic digestion of macrophyte biomasses. Gompertz parameter estimates and statistical significance of the variation sources (Treatment, Species, and Treatment x Species interaction)

Species	**Hmax, mL CH_4**		**R, mL CH_4 d^{-1}**		**λ, d**	
	TU	**TF**	**TU**	**TF**	**TU**	**TF**
AD	176	264	4.37	5.02	9.2	10.1
CA	182	221	4.67	4.48	1.8	0.6
CR	270	336	6.25	6.51	2.4	6.6
IP	209	209	6.32	8.25	11.4	14.1
MG	166	205	5.04	4.69	1.9	5.9
SOA	211	193	6.74	7.79	0.2	4.2
SS	260	47	3.92	1.83	4.2	11.4
Means	*211*	*211*	*5.33*	*5.51*	*4.4*	*7.6*
F values and significance of the model						
Treatment	0.0 NS		0.18 NS		25.08***	
Species	23.85***		8.43***		26.26***	
Interaction	28.90***		1.28 NS		2.69*	
LSD (α<0.05):						
Treatment	14.5		0.87		1.27	
Species	27.6		1.62		2.38	
Interaction	38.4		2.29		3.37	

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CHAPTER 5 - WETLAND MANAGEMENT

Potential Paludiculture Plants

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Abstract Paludiculture, the wet cultivation of peatlands, is a sustainable way of using peatlands as it conserves the peat soil and has much less negative impact on the environment than conventional drainage-based peatland agriculture and forestry. A good example of paludiculture is the wet cultivation of *Phragmites australis* as a bioenergy crop or building material. Next to the few well-established paludicultures a wealth of wetland species is promising for paludiculture, including traditionally used species and species that provide biomass for innovative applications. The Database of Potential Paludiculture Plants (DPPP) presents standardized data on these species with respect to (1) plant characteristics and morphology; (2) distribution and natural habitats; (3) cultivation and propagation, and (4) utilisation options.
Currently the database comprises 660 plant portraits, including 200 species with good actual market potential. Utilisation options vary from medicinal and energy use to food and fodder crops for humans and animals. The DPPP presents an important source of information to inspire innovative ideas to promote paludiculture worldwide.

Paludiculture (Latin '*palus*' = swamp), the cultivation of biomass on wet and rewetted peatlands, is an alternative to conventional agriculture and forestry on drained peat soils. The precondition for paludiculture is that the peatland is so wet that the peat soil is conserved and that new peat may even accumulate. Paludiculture plants must thrive under such wet conditions and produce utilizable biomass in sufficient quantity and quality. On rewetted peatlands, paludiculture has the potential to:

- reduce greenhouse gas emissions,
- restore carbon and nitrogen retention,
- restore productivity of degraded peatland sites,
- restore habitats for rare and threatened wetland species,
- revitalise traditional types of land use and combine these with new ones and
- produce biomass for various utilisation options (Tanneberger and Wichtmann, 2011).

In recent decades, various paludicultures have been tested in pilot projects on rewetted peatlands. The cultivation of Common Reed *Phragmites australis* as a bioenergy crop or as an industrial raw material illustrates the practical and economic feasibility of paludiculture. Technical solutions for harvesting natural or artificially established stands are available, its use for thatching roofs and making paper is well established, whereas application for bioenergy has been implemented in form of bales, pellets and biogas (Wichmann and Wichtmann, 2009). Furthermore Common Reed has been and is being tested as a raw material for insulation mats, fibre-based damming material and various applications of cellulose. Next to Common Reed, cultivation, harvest and use of *Typha* spp., *Alnus glutinosa* and *Sphagnum* show promising results (Tanneberger and Wichtmann, 2011). These successes have fostered the search for a wider range of paludiculture. The results of an extensive literature survey have been compiled in the 'Database of Potential Paludiculture Plants', the DPPP. Until now the DPPP includes 660, mainly Holarctic plant taxa, of which 300 forb/herb, 125 tree, 115 graminoid, 85 shrub

and 30 fern species and one moss genus (*Sphagnum*). For every plant species the DPPP contains a 'plant portrait' (Figure 1).

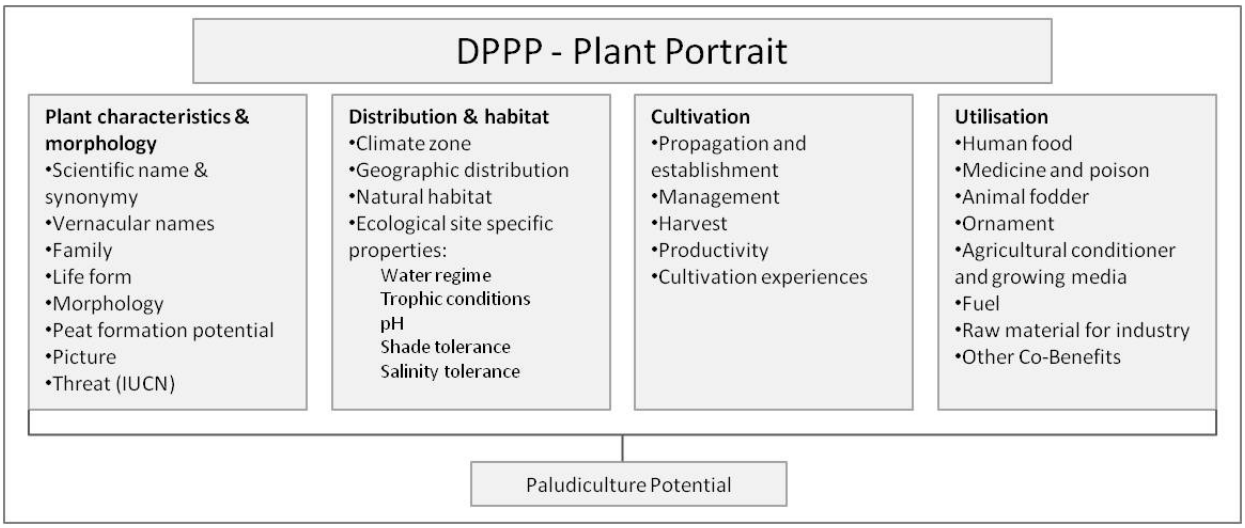

Figure 1 Structure of the DPPP 'Plant portrait' entries

Established or comprehensively studied paludiculture energy crops include *Phragmites australis*, *Phalaris arundinacea*, *Typha* spp. and *Carex* spp.. Furthermore wetland biomass offers perspectives for utilisation as construction materials. Of particular interest are *Typha* species whose aerenchymatic tissue has excellent insulation properties. Cultivation of medicinal paludiculture crops is illustrated by *Drosera rotundifolia* which is used in the treatment of asthma and bronchitis. Other traditional forms of paludiculture are the utilisation of wet fens and coastal transgression peatlands for harvesting animal fodder or berry collection of *Oxycoccus palustris* and *Rubus chamaemorus* in bogs.

The DPPP demonstrates the highly diverse utilisation options for plants from wet peatlands. Traditional use and recent implementation have illustrated the feasibility of wet peatland cultivation. Further research is required into optimization of cultivation techniques, selection and propagation of suitable eco-types, development of site adapted machinery, and long-term environmental effects (peat hydraulics, peat formation, emissions, biodiversity). The growing demand for sustainable land use options can be expected to boost innovations in these fields.

The DPPP is an important source of information to inspire innovative ideas on the basis of existing knowledge. The output of the DPPP will soon be made available as a book publication 'Paludiculture Plants of the Holarctic' that will function as a decision making support tool for establishing paludicultures in different habitats and climates.

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The use of intensifications for upgrading nutrients removal in vertical flow constructed wetlands

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Abstract: Vertical flow constructed wetlands (VFCWs) represent a popular system to treat wastewater in small villages in France (more than 2500 in operation in 2012). Considering the recent legislations evolution, many of these systems will need to be upgraded for P and N removal in the future. As it is generally assumed that French VFCWs can achieve a good aerobic treatment (COD<125 mg/L and TKN < 15 mg/L), the system has a poor denitrification (TN < 70-80 mg/L), and almost no phosphorus is treated (TP < 15 mg/L).

The aim of this work was to review the main intensifications that have been developed to achieve an increased treatment to reach discards limits of TN<20-30 mg/L and TP<2 mg/L. Intensifications including the use of recirculation of treated effluent, the use of saturated/unsaturated conditions (combination of vertical and horizontal systems) and the use of reactive materials inside or downstream of the CW have been considered. The main results of demonstration scale systems implemented under process conditions will be summarized. Some results observed in several full scale references will be presented as well. The most effective solutions observed so far will be presented and the main treatment mechanisms will be explained. Finally, the technical and economical feasibility of each intensification will be discussed.

Sediment resuspension and the effect on light climate in shallow wetlands and ditches

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Abstract Flow-induced resuspension of sediment can have a large effect on the transparency in shallow wetlands and ditches, and thus on the ecological stability. We studied the effect of water movement on resuspension of sediment and light attenuation in an experimental setting. Sediment cores (ø 15 cm) were collected, with minimal disturbance, and placed in the laboratory. A rotor was applied to set flow velocity accurately, increasing from 0.01 to 0.30 m s^{-1} in the overlying water column. With a light source and light meter transparency in the water column was measured continuously. We determined critical flow velocity for resuspension, which varied from 0.04 to 0.13 m s^{-1}. This correlated well with the organic matter content of the top 5 cm of the sediment. Furthermore we studied the recovery of the transparency after full disturbance, both in standing water and with decreasing flow velocities. Time of recovery was mainly determined by particle sizes and lasted up to several days. For some sediments we found a clear 'hysteresis' pattern for transparency with increasing and decreasing flow velocity. We developed a dynamic sedimentation-resuspension model that was parameterised with the results of the experiments. The model was used to simulate transparency in a managed network of ditches.

We studied suspended solids dynamics in shallow wetlands and ditches, due to water flow. An important characteristic of the sediment is the critical flow velocity for resuspension. Below this velocity resuspension generally does not occur because the shear stress low compared to the sediment consolidation. Above this velocity resuspension is started and increases with increasing flow.

To determine critical flow velocity experimentally we constructed a laboratory setup for small undisturbed water/sediment columns, that was adapted from previous research by Zambrano et al. (2005). The so-called mini-hydrocopter consists of a set of rotor blades that can create a waterflow above the sediment varying in small steps from 0 to 0.3 m s^{-1}. With a horizontal light source and light receiver the transparency of the water column is measured (figure 1). In total 14 sediment/water columns were sampled and measured, taken from ditches with either peat soils (6), clay soils (6) or sandy soils (2). Experiments were done ten times with each column at 2 different temperatures (10 and 20 °C).

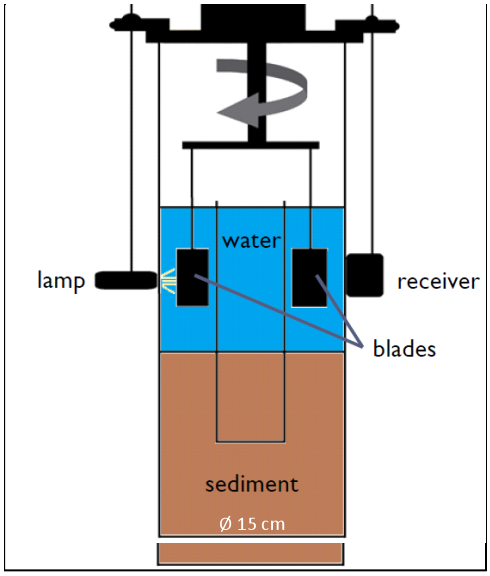


Figure 1 Experimental setup for determining critical flow velocity for resuspension (mini-hydrocopter)

A typical result of an experiment with stepwise increasing flow velocity is presented in figure 2. At low flow velocities light transmission is maximal followed by a range of velocities where a sharp decrease of transparency is measured. At high flow velocities transparency is minimal. The critical flow velocity for resuspension is defined as the velocity where the change in light transmission is largest.

Figure 2 Typical result of mini-hydrocopter experiment. Light transmission (% of starting value) and flow velocity during the time of the experiment

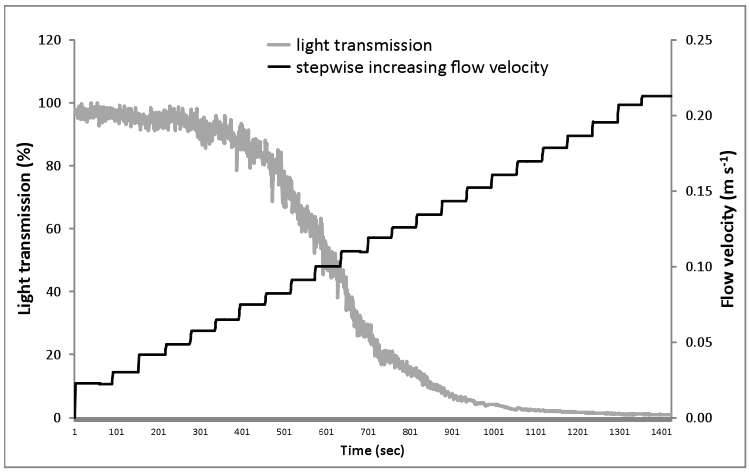
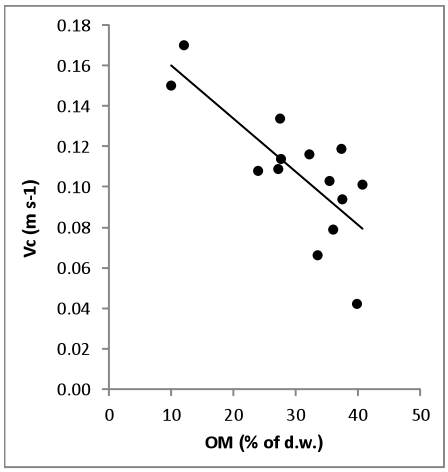


Figure 3 Relation between the critical velocity (Vc) and organic matter fraction (OM) of the sediment top layer



The experiments reveal that the critical flow velocity (Vc) ranges from 0.04 to 0.17 m s^{-1}. Vc is clearly correlated with the organic matter fraction of the sediment top layer (Figure 3, p=0.001). Higher organic matter content reduces the critical velocity for resuspension. Surprisingly, Vc does not change when multiple hydrocopter experiments are performed at the same column. Furthermore, no difference in Vc was found between 10 and 20 °C incubation.

We also studied the recovery of light transmission after a period of increasing flow velocity, by either stopping the rotor completely or reducing the flow velocity in small steps comparable to the resuspension part. We found rather long recovery periods, in both cases, especially in columns with relatively high OM fraction. But also with the sandy columns a 'hysteresis' pattern was observed. Obviously, settling of the resuspended particles take far more time than resuspension. We set up a sedimentation/resuspension model to simulate the results of the hydrocopter experiments. For the model three fractions of particles were defined with different characteristics. Model parameters were derived from the experiments, estimated from theory or calibrated. Figure 4 shows an example of an experiment and model simulation.

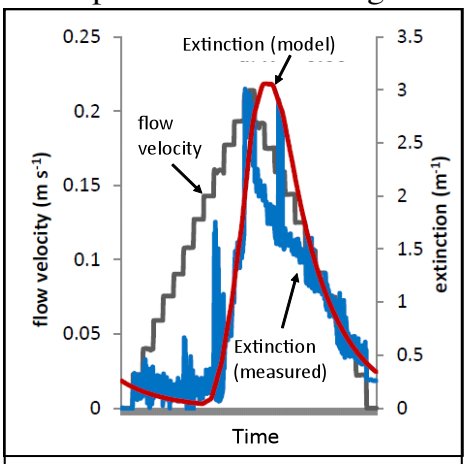


Figure 4 Experiment and model simulation

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The potential role of wetlands in European crop farming and grassland management. Problem statement

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Abstract European crop farming is mainly based on plant species originating from relatively dry areas. Wet (waterlogged and/or inundated) fields have therefore been often drained to make them suitable for these crops. The situation is similar for managed European grassland (meadows and pastures). Irrigation systems are designed so that the water supply merely reduces or removes the losses of soil moisture resulting from evapotranspiration under the given climatic conditions. Hardly any serious attempts have been made to keep European agriculturally used land wet or waterlogged while supporting productive agriculture. This would require introduction of crops adapted to wetland conditions (waterlogging or even temporary inundation) and improvement of the fodder quality of wetland graminoids. Neither has been fully appreciated the positive climate-modifying effect of wetlands, interspersed with crop fields and/or managed grassland. The resulting energy and water budget with predominant dissipation of the energy of incoming net radiation by evapotranspiration and substantial water retention in the soil facilitates the establishment of a sustainable production potential of such areas. The production potential and use of both spontaneously occurring and cultivated reed canary grass (*Phalaris arundinacea*) as a wetland crop illustrate the importance of wetlands for crop farming and grassland management.

The principal problem is how to make the present European (and other) agriculture more interested in and friendlier to wetlands. During the development of agriculture, crops and managed grassland vegetation gradually replaced natural vegetation. The most widely cultivated crops are cereals derived from steppe grasses, which do not tolerate excessive soil moisture. In Europe, large-scale drainage of agricultural landscapes occurred in the 19th to 20th centuries. Even floodplains of mostly straightened rivers and streams were largely drained and turned into dry land; water discharge was thus speeded up and the (ground)water table sank substantially over large areas. More than 50% of European wetlands ceased to exist within the last 150 years. Among natural wetlands, the unfavourably most affected were springheads, mires - especially fens - and floodplains.

Direct or indirect unfavourable impacts of present industrialised agriculture on wetlands, and their consequences, can be divided into two categories:

(a) Destruction of wetlands, especially by the following intentional impacts:

- Drainage of fens and spingheads, and transformation of the drained sites into arable land.
- Straightening and deepening of riverbeds, drainage of floodplains plus landfilling of alluvial pools and backwaters followed by transformation of all such sites into agricultural land.

(b) Degradation of wetlands, especially by the following unintentional impacts:

Note: This category of impacts is mostly associated with enrichment of water bodies and wetlands with mineral nutrients and pollutants washed out or eroded from intensely managed agricultural land.

- Eutrophication and/or pollution of both standing and running waters and wetlands, resulting in decline or extinction of plant and animal species adapted to meso- to oligotrophic habitats.
- Increased biomass production of littoral or riparian vegetation making it more susceptible to noxious factors such as damage by pests or anoxia in the root zone overloaded with decomposing plant litter.

Highly intensified crop farming based mainly on monocultures and industry-like animal husbandry, widespread use of pesticides, often combined with land drainage, have damaged the balance of natural biogeochemical cycles and the water balance in many agricultural areas of the world. Together with deforestation aimed at obtaining more agricultural land, urban sprawl and other kinds of so-called development, these impacts also enhance water runoff from the landscape. Consequently, the climate reacts by wider air-temperature amplitudes and increased air turbulence. Only co-ordinated sustainable management of whole catchments can protect sufficiently water resources and wetlands.

In inland areas of Europe, especially two types of wetlands and shallow water bodies represent well-developed productive agricultural systems: (a) wet grassland managed as hay meadows and/or pastures, (b) fishponds for rearing commercial fish. In order to be managed sustainably, neither type should be overloaded with mineral nutrients and organic matter inputs. The maintenance of their balanced hydrological regime and water budget is also essential for them both ecologically and economically. A prospective grass of wet grassland that can secure sustainable high yields of good-quality fodder (frequent cuts) or energy from biogas or fuel (1 to 3 cuts per year} is the reed canary grass (*Phalaris arndinacea*).

At present, relatively numerous drainage systems installed in former wetlands in the past have become less effective or ineffective due to clogging or disintegration of the drainage tubes. After many years, such sites are gradually regaining their wetland character in the process of spontaneous succession. Sometimes rather rare plant and animal species populations occur on such sites, especially during early successional stages. Return to intense agricultural management of such sites is undesirable ecologically and would bring no economic yield. It is, however, desirable to predict the final ecological potential of these wetlands on the basis of their pre-drainage maps, aerial photographs, etc., combined with monitoring of their successional development. The later successional stages will most frequently be dominated by helophytes on these sites. But the aim may also be to maintain earlier successional stages with a high plant and animal species diversity. A low-impact agricultural management can achieve this efficiently and relatively cheaply. In any case, drainage, pesticides application and usually also fertilising or manuring must be avoided not only at the wetland site itself, but also in its close surroundings.

It is also desirable to develop, hopefully relatively soon by a combination of breeding and gene manipulation, new wetland crops for the Temperate Zone, particularly cereals, with a nutritional use similar to that of rice. Such a development would help keep more water in the soil in agriculturally managed areas of Europe and other temperate territories. In Europe, it may be worthwhile to explore the breeding potential of grasses of the genus *Echinochloa* for this purpose.

Survival improvement of riparian reforestation based on bank hydromorphology

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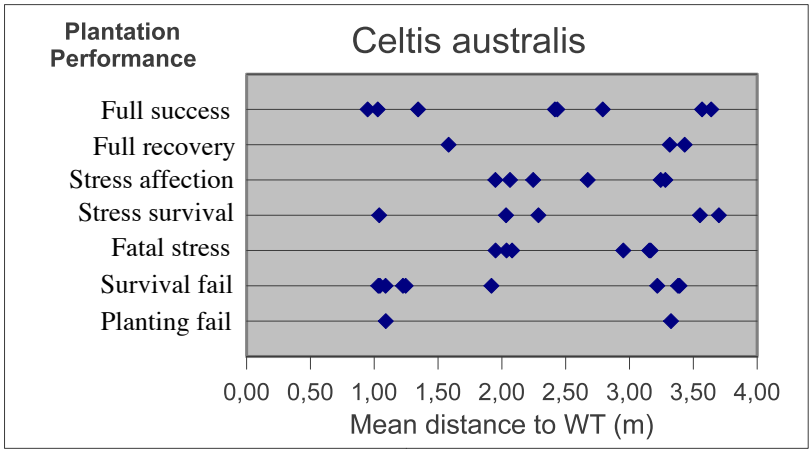
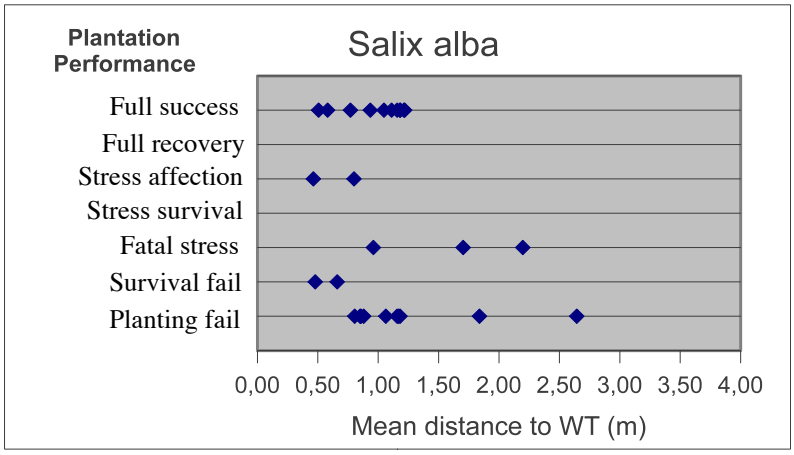
Abstract Riparian restoration can be approached at different conceptual scales. We propose that planting species with a hydromorphological related spatial distribution improves the plantation's survival on the first summer water stress, one of the main factors driving mortality in the semi-arid regions. Two reforestations, carried out in successive years (2012 and 2013) on the same area, have been surveyed to analyze the survival of a total of 13 different riparian species from 10 genus (*Populus, Salix, Fraxinus, Scirpus, Sambucus, Rosa, Lonicera, Ulmus, Celtis*) based on the distance to the water table (WT). In the first year 443 2-year old cuttings of 8 different species were planted in a floodplain of River Flumen (Huesca, NE Spain). Their vital state, based on the proportion of green, senescent and dead leaves, was monitored before and after water stress (July and September 2012). The 2013 reforestation has been improved with a more systematic methodology for species distribution and plantation naturalization, as well as the inclusion of 5 more species for its evaluation. Obligate-Phreatophytic species (e.g. *Salix* genus) planted far from the WT (>1,5m) show almost no survival, supporting the idea that vertical distance of the tree roots to the water is the key factor regulating their survival and performance. Other species like *Populus alba* or *Fraxinus angustifolia* show less dependence across the environmental degree studied.

A great effort has been made to enlarge the knowledge about factors driving the establishment of reforestations (Bunting et al., 2011). In semiarid riparian zones like the Flumen river in the NE Spain, the effect of the water summer stress is one of the key causes of plantation mortality, since the colonization period between the plantation time and the summer stress must be enough for the plants to overcome the distance between the surface and the humidity needed for the survival of each specie. The main goal of our study is to find the relationship between riparian plantation survival and the water table (WT) level, so a better planning of the distribution of riparian species within reforestation actuations could let to survival improvement and the generation of natural-like plantations based on topography and hydrology (Mosner et al., 2011)
To analyze the performance of the plantations we surveyed the trees before (July) and after (September) the summer stress, and used GPS location to place each tree in the study zone. We also used three categories to know the vital state of each individual: Green-Healthy, Yellowing or Dead-Dry. After the two samplings we were able to classify the evolution of each tree based on these categories and the two sampling periods. The monitoring of the groundwater level and the elevation raster of the study area allow us to infeer the relationship of this evolution with the mean distance to the WT level.

Based on the results obtained we can see how the obligate-phreatophytic species like *Salix alba* had a really strong dependence on the ground water, since are unable to

survive with a distance greater than 1,5 m. In contrast, Species like *Celtis australis*, a facultative-phreatophytic specie, linked to riparian areas in arid and semiarid regions, show no dependence on the water table distance in the range studied, although the effect of the summer stress is important and these specie is affected by the evapotranspiration deficit, regardless of the planting point.
Preeliminary results of 2013 plantations, based on a method improvement for the placing of the different species, is showing a much better vital state in the July survey than in the same period of 2012.





Figures 1 and 2 Colonization performance within the range of distance from surface to the mean groundwater level, for an Obligate-phreatophytic specie (Salix alba, Top), and a Facultative-Phreatophytic specie (Celtis australis, Bottom)

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Microtopographic enhancement of wet grasslands used as soil/land-based wastewater treatment systems

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Abstract As regulations tighten there is an increasing requirement for smaller domestic wastewater treatment works to include a tertiary treatment stage. One tertiary treatment option is the application of wastewater onto the land to achieve treatment through natural processes – so called "soil/land-based systems" (Crites et al., 2005). Secondary treated effluent can be characteristically: high in nutrient content, which can have a detrimental and diversity-reducing impact upon the habitat into which it is released; and low in organic carbon, limiting removal of nitrate through denitrification. Conventional thinking would suggest that a soil/land-based system would perform optimally with a flat surface to maximise the available surface area for treatment. A proposed novel approach to raising the value of such systems is to enhance microtopography, i.e. 'soil surface variation within an elevation range from 1cm to 1m' (Bledsoe and Shear, 2000). It is hypothesised that enhancing the microtopography of a created wet grassland used as a treatment system, will result in an engineered difference in nutrient removal and grassland vegetation species diversity.

Potential benefits of successfully engineering a difference are: an increase in the water treatment potential; increased robustness; and an increase in the inherent conservation value of these systems. The proposed mechanism for an engineered difference in nutrient removal is the creation of physiochemical gradients within the soil-root-water matrix, resulting from enhanced microtopography. For example, it is expected that created soil moisture and organic matter gradients within a microtopographically enhanced system, will result in conditions that may promote removal of nitrate through denitrification. These conditions may be found in the depressions and are: a reduction in redox potential due to extended saturated periods and an availability of organic carbon resulting from an accumulation of organic matter. It is also proposed that coupled nitrification-denitrification may be enhanced as a result of the close proximity of saturated and unsaturated soil. These proposed mechanisms are based upon the findings of recent mitigation wetland research (Moser et al., 2009) & (Wolf et al., 2011). Creation of soil moisture gradients within a microtopographically enhanced system is also the proposed mechanism for a hypothesised increase in grassland species diversity. The premise for this is that soil moisture gradients will provide a wider range of conditions and promote hydrological niche segregation, (a mechanism identified as the basis for plant community species richness in semi-natural wet grasslands (Silvertown et al., 1999)).

To evaluate the effect of enhancing the microtopography of a created wet grassland used as soil/land-based treatment system, a field trial has been established at a treatment works in Hampshire, UK. The trial consists of three grass plots with soil of a clay loam texture, each sown with an MG8 wet grassland mix. The plots are irrigated with secondary (trickling-filter) treated effluent, at a loading depth of 4m year^{-1}. An intervention analysis approach has been adopted for the trial. During the first phase, each of the plots has non-

enhanced microtopography ('flat' surface). In phase 2, microtopographic enhancement by means of ridge-and-furrow is applied to one of the plots. Microtopography is characterised using limiting slope (LS) and limiting elevation difference (LD) indices (as proposed in (Linden and Van Doren Jr, 1986)). Subsurface soil-water samples taken from 60 cm below the surface are analysed for a range of water quality parameters including: nitrate and phosphate, and compared with the secondary treated effluent used to irrigate. Vegetation diversity is characterised using various indices including the Shannon-Weiner Index.

Figures 1 and 2 present the subsurface soil water nitrate content and vegetation diversity results respectively, from phase 1 of the trial. The mean microtopography of the 'flat' plots of phase 1 was recorded at 0.065(LS) and 0.009 m(LD)

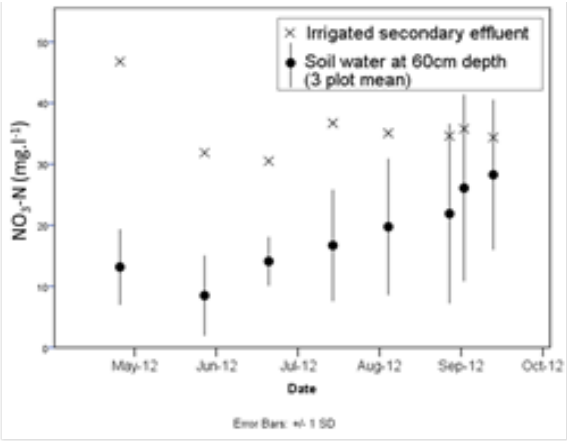

Figure 1 Irrigation and subsurface soil water nitrate concentrations for trial plots - phase 1

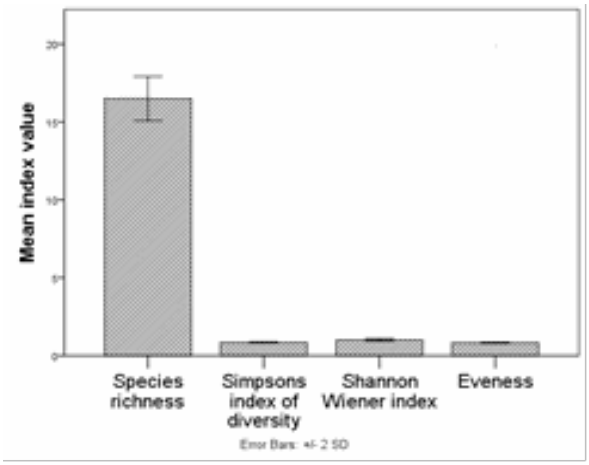

Figure 2 Vegetation diversity results. Mean indices values for trial plots - phase 1, July 2012

The converging nitrate concentrations of the sub-surface soil water and the irrigated secondary effluent, towards the end of phase 1 (Figure 1) may support the idea that denitrification is limited in a 'flat' system. The higher nitrate removal earlier in the year could be attributed to assimilation into vegetation during the growing season. The results of the vegetation survey in phase 1 (Figure 2) support the hypothesis that a 'flat' soil/land-based treatment system will have low species diversity. Phase 2 of the trial will allow the impact enhanced microtopography has upon these systems to be observed.

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Choosing between Evils: Management Dilemmas in P dynamics of Sulphur-Rich Peatlands

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Abstract In Dutch peat meadow areas we have investigated the interactions between terrestrial and aquatic biogeochemical processes. Due to former inundation by the sea, these peatlands are enriched in reduced sulphur. To prevent land subsidence, strict anthropogenic water management is a common strategy. This is realised by the inlet of water from surrounding areas, often leading to direct eutrophication. Moreover, these peat soils have high phosphorus levels in the top layers, immobilised by oxidized iron. During high water levels, iron is reduced and phosphate becomes mobilised, leading to eutrophication in surface waters.

To alleviate eutrophication, a change in water management by allowing water level fluctuations might favor hydrological conditions. However, oxidation of the top layer during lower water levels results in sulphate mobilisation because of the oxidation of reduced sulphur compounds. At the same time iron will become oxidized, immobilising phosphorus in the soils. Sulphate, however, can be transported to surrounding surface waters where it becomes reduced in the sediment, provoking phosphate mobilisation. This will increase the phosphate release from the sediments indirectly, leading to eutrophication of the water layer.

Our results highlight the conservation problems for sulphur-rich peatlands. Therefore, implications of these issues will be discussed.

During the last decades, eutrophication has become an important problem in many wetland systems worldwide. Interactions between terrestrial soils, submerged sediments and surface water greatly determine the actual water quality in peatlands. In densely populated coastal peatlands such as the western part of the Netherlands, vast areas of terrestrial peat soils have been drained for agricultural purposes. Intrusion of oxygen, and the consequential oxidation of these peat soils, leads to peat degradation and to irreversible land subsidence (Kasimir-Klemedtsson et al., 1997). As these coastal peat soils are often rich in reduced sulphur, oxidation of the soils also leads to the mobilisation of large amounts of sulphate (SO_4) (figure 1; top). This generates additional problems in surface waters, as eutrophication is a well-known problem in freshwater systems as a consequence of high SO_4 reduction rates in sediments (Smolders et al., 2006). To counteract unfavourable effects of aerobic conditions in peat soils, such as increased decomposition and SO_4 mobilisation rates, and concomitant SO_4 discharge to the surface water, groundwater levels should be raised.

This was therefore tested by allowing more natural surface water level fluctuations in ditches surrounding peat meadows in areas where these levels had before been strictly

regulated by the inlet and outlet of surface water. The experiments were carried out in different peat meadow areas throughout the Netherlands, and the results were compared to sites with regulated water levels. Surface water and groundwater levels were monitored frequently, and analysed for their nutrient and ionic composition on a monthly base. In addition, terrestrial peat soils were collected to measure total nutrient- en ion concentrations available in the soil.

A more fluctuating surface water level resulted in an increase of the mean surface water level. This was mainly due to rain water retainment, accompanied by a decrease of chloride, bicarbonate and sulphate concentrations in both surface water and groundwater. As mean water levels were increased, the terrestrial peat soils also became wetter. This, however, resulted in increased phosphorus (P) and iron (Fe) concentrations in the groundwater (Figure 1; bottom), enhancing the discharge of P to the surface water. The oxidised upper part of the terrestrial peat soil is loaded with P bound to Fe, due to peat degradation and agricultural use. At high groundwater levels, the dissolution of P as a result of Fe reduction, was enhanced in the terrestrial peat soil. Therefore, wetter conditions directly lead to eutrophication of surface water.

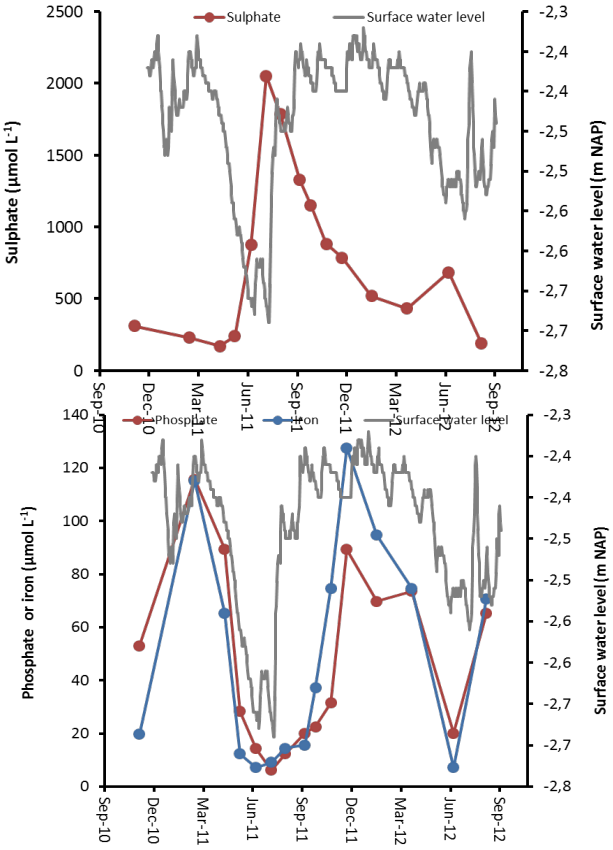

Figure 1 Sulphate- (top) and phosphate- or iron concentrations (bottom) in the groundwater on shore

This creates an important dilemma. To preserve peatlands, anaerobic conditions are essential. By only changing water management to promote higher groundwater levels, peat degradation and sulphate mobilisation are diminished, but at the same time eutrophication remains a significant problem in sulphur rich peatlands. Consequently, additional measures are needed to decrease phosphorus concentrations in peat soils. One option is to remove the enriched topsoil before rewetting. However, this seems to be contradictive to the aim to prevent soil subsidence. Another option is to change land use by growing alternative crops that will deplete phosphorus in the top soil and favour peat development (Wichtmann and Tanneberger, 2011).

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Changes of the plant communities along a hydrological gradient in intermittent lake Cerknica (Slovenia)

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Abstract Vegetation of the littoral zone of the lake Cerknica with some ecological factors along the altitudinal gradient was studied. Plots of 4x4 m were selected in different types of wetland vegetation that are distributed within a 2.7 m of height gradient on a very gentle sloping shore and considerably long distance of 650 m.
Vegetation was investigated with standard Zürrich-Montpellier approach. Aboveground biomass of the vegetation was measured within each plot. Soil samples were collected as well and pH, conductivity and the content of organic matter were measured. Great differences in plant community composition were found, ranging from mesic hay-meadows (alliance *Arrhenatherion*) in the highest sites that are rarely flooded (adlittoral) transferring downwards to wet grasslands communities (alliances *Molinion* and *Deschampsion*) and fen meadows (*Caricion davallianae*). Different types of marsh vegetation (alliance *Caricion elatae*) were found in lower frequently flooded sites. In the lowest sites (eulittoral) truly aquatic vegetation (alliance *Phragmition*) was found, consisting mostly of emergent hydrophytes that are flooded for the most of the year. Plant species number was decreasing with decreasing relative height and increasing moisture of the sites.

Gradients and diversity of wetland plant communities have been the object of many studies for years (Wassen et al., 2002, Hájková et al., 2006; Zelnik and Čarni, 2008), since the threat to biodiversity of these ecosystems is very high. The correlation between water regime, composition and distribution of herbaceous wetland plant communities has been proved many times. Several authors (Grime 1973, Wassen et al., 2002; Dwire et al., 2004) found higher species richness in vegetation types of elevated, drier parts. In the wettest sites, stress tolerating species dominate, but in wet meadows, competition plays a greater role in determining species composition (Keddy, 1992). We hypothesized that in studied complex wetland the hydrological gradient is correlated with plant community composition and species richness.

Studied gradient lies on a very gentle sloping shore of the intermittent lake Cerknica, which is a Ramsar locality. Plant stands of the 4x4-m plots were investigated with standard Zürrich-Montpellier approach. Aboveground plant biomass was measured. A square of 0.5x0.5 m was placed in the stand within each plot and plants were cut, weighted and dried at 105 °C to constant weight. Compound soil samples were collected and dried as well. Soil pH, conductivity and organic matter content were measured.

Vegetation of hay-meadows of alliance *Arrhenatherion* was found in the highest sites that are rarely flooded changing downwards to wet grassland communities of alliance *Molinion*. There is also a plot on slightly raised ground, where fen species dominate (alliance *Caricion davallianae*). On more frequently flooded sites wet meadows of alliance *Deschampsion* were found. Two types of marsh vegetation (alliance *Caricion*

elatae) were found on soils that are often waterlogged till July. Aquatic vegetation of alliance *Phragmition* was found at the bottom of the gradient, consisting mostly of emergent hydrophytes that are dried up only during the summer. Over hundred species of vascular plants were recorded along the gradient. Species number was decreasing with decreasing elevation and increasing moisture of the sites. Species richness was the highest in communities of the elevated parts (>60 taxa) and lowest on frequently flooded sites (9-15 taxa per plot) (Figure 1).

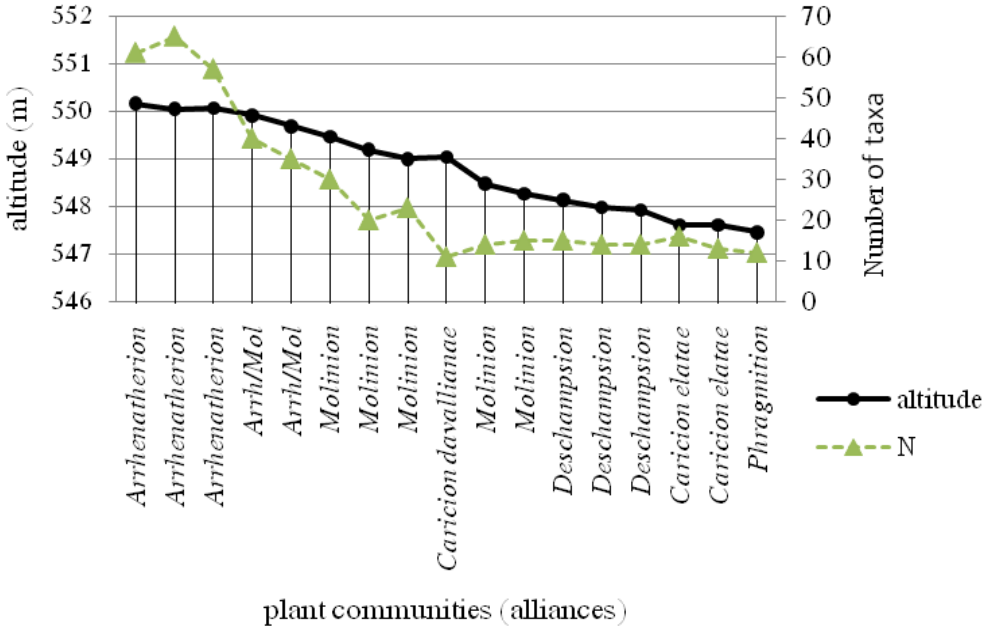

Figure 1 Plant communities and species richness along decreasing elevation and increasing moisture of the sites

We have demonstrated that hydrological gradient has the crucial role in shaping the distribution and species composition of wetland plant communities and also governs species richness. Species richness was the lowest on sites where unfavourable conditions exclude all but a few specialized species and is a function of flood duration (Wassen et al., 2002; Dwire et al., 2004). Floods stem from base-rich water, while elevated parts are fed mostly by rainwater that facilitates nutrient leaching (lower pH, conductivity). This makes the soil more nutrient-poor, which often enables higher species diversity.
We found that hydrological gradient has created a specific distribution of plant communities, as well as the correlation with species richness was confirmed.

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Creation and restoration of wetlands for the improvement of water quality and biodiversity in agricultural watersheds

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Abstract Riparian forests and wetlands were restored (increasing the hydrologic connectivity, constructing simple dikes and planting native species) in the River Flumen watershed (NE Spain) (Life09ENV/ES/431 CREAMAgua) to show their potential for improving the quality of the water discharged from irrigated fields and the biodiversity of agricultural watersheds. Restoration sites were selected following a protocol which integrates scientific-technical, social and economic aspects. Nitrogen and suspended solids in the wetlands showed a high dispersion after two years. Fast development of low diversity plant cover is observed in permanently flooded (in-stream) wetlands compared to off-stream wetlands. Repeated planting was required in riparian zones after the first year flood disturbance. Bird communities show an initial increase of diversity in permanently flooded wetlands; developing a landscape structure is required in other types of wetlands. Integrated planning and development is required for successful wetland restoration at watershed scale.

An ecosystem restoration project must be based on the integration of scientific-technical, social and economic aspects to be successful (Comín et al., 2005). The objective of the Life CREAMAGUA project is to show the potential of restoring wetlands at watershed scale for improving the quality of the water exceeding agricultural fields and improving biodiversity. Project planning and preliminary results of the first two years of wetlands functioning are presented here to show the potential of this approach for planning wetland restoration at watershed scale.

In 2011-12, sixteen wetlands were restored (extending the flooding area through diking) following a protocol based on SWAT (Soil and Water Assessment Tool) and first order areal removal model for, respectively, selecting sites and dimensioning wetlands for nitrate removal (Comín et al., 2013). Fourteen degraded riparian zones were restored (facilitating flooding in riparian zones through lowering river banks and channels) to improve the biodiversity and landscape of the region. Planting with native species was performed in all the sites.

The greedy algorithm used (Figure 1) is a method to select sites for restoring wetlands and accomplishing the social and economic requirements of CREAMAGUA project. It is, according to the UE Life Programme, to demonstrate actions which can be performed later at larger scale. It does not give a solution for the improvement of the water quality of the whole river watershed. However, it shows a way to integrate the social and economic aspects for restoring wetlands at watershed scale. In a few wetlands 25% of the

incoming nitrates are removed after two years functioning. A rich plant community developed fast after the works (plant cover represented 80 % of the wetland area) but diversity is still low two years after restoration. Riparian zones showed contrasted features: geomorphology is changing rapidly showing natural forms (e.g., side meandering channels) as result of flood impacts but plant community is still present in low density and diversity. The bird community show indicators of fast richness and diversity improvement (nesting ducks, different functional groups).

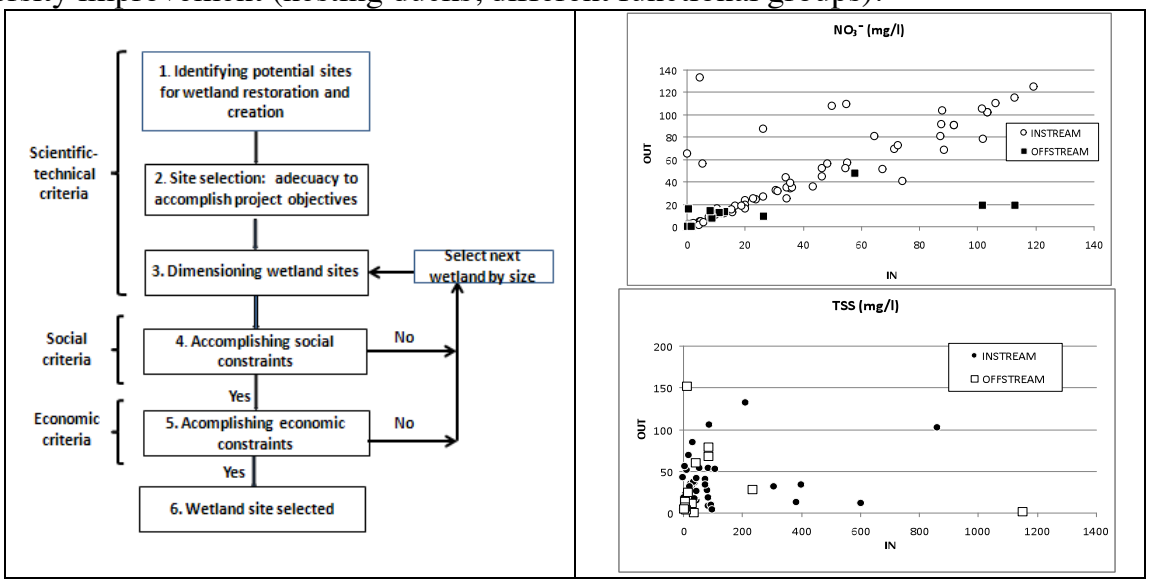

Figure 1 Left: protocol used for selecting sites for restoration. Right: Nitrate and suspended solids concentrations in the water inflowing and outflowing the restored wetlands

Acceptance of restoration works was common in all the municipalities were wetlands were restored, after the high number of persons and groups performing visits to the restored sites. The economic restrictions of the restoration project budgeting limited some constructive aspects. The average cost of restoration ranged between 4,972 €/ha for restoring wetlands and 2,163 €/ha for restoring riparian zones, which is in agreement with similar simple wetland restoration works (Russi et al., 2013).

A marked contrast between different types of wetlands is observed two years after restoration, which is common for this type of approaches (Tanner and Kadlec, 2013). Riparian zones show a high dynamic community (including plants and birds); off-stream wetlands are showing a slow recovery of functional aspects (improvement of water quality); a few in-stream wetlands show a marked nitrate and suspended solids removal just two years after restoration works. A longer time after restoration is required for wetlands to show all their functional performances.

Acknowledgments This work is part of the European Union Life09 ENV/ES/431 CREAMAgua project.

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On the question of wetland evolution in two key landscapes in South-Eastern Baltic Region

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Abstract Main patterns on natural history and geochronology of wetland ecosystems in two landscapes in the Russian sector of South-Eastern Baltic (Kaliningrad Region) are provided on a basis of investigations on two large raised bogs Zehlau and Bol'shoye Mokhovoye. These mires are typical ecosystems within two key landscape districts in the region – the coastal deltal lowland of Neman river and the glaciolacustrine plain in the central part of the region. Palynological investigations and analysis of plant macroremnants of sampled peat cores were carried out in order to identify vegetational successions and environmental change during the Holocene time. Stratigraphic profiles for these mires are given indicating mire kettle bottom relief as well as structure of peat deposits. The detailed analysis outcomes on botanical composition of peat on mentioned raised bogs are presented for the first time.

Mires cover appr. 84 000 hectares or 6% of the total territory of the Kaliningrad Region; among them 32.5% are raised bogs, 67.5% are fens and swamps (Napreenko, 2000). Wetland are very differentially spread in the region. The most paludified part of the region is the lowland of Neman delta in the north-west with 20% of wetland area (typical peatland pattern is Bol'shoye Mokhovoye or Grosses Moosbruch) while the mire rate on major part of the Kaliningrad Region is 2-3% (typical peatland pattern is Zehlau). Peatlands here are mainly situated on heavy soils (clays) of glaciolacustrine plain.

Investigations were carried out on profiles which stretched along different mire sites and crossed solid mire area completely. There have been done the following field explorings: levelling survey of the bog surface, exploratory peat body drilling (every 50 meters, in particular cases – every 20 m.), selective coring and peat sediment sampling (every 10 cm, for the bottom layers – every 5 cm). There have been sampled and analysed 265 peat samples from 5 cores on Bol'shoye Mokhovoye raised bog and 134 peat samples from 4 cores on Zehlau raised bog. Peat types were defined and described on a basis of Tyuremnov's (1957) approach applied for the peat classification in European Russia.

Raised bog peat deposits obviously dominate on Zehlau mire, they are represented by thick solid layers of *fuscum*-peat, *magellanicum*-peat и complex *Sphagnum*-peat. Layers of fen peat and swamp peat are very thin (15-80 cm), in spite of this, they are stretching along all the peat body length of the mire. Fen peat is mainly presented by *Phragmites*-peat, that is sharply changed upwards to *Sphagnum*-peat with different rate of decomposition. Transitional mire peat is recorded on Zehlau mire only in separate places in the form of small thin stripes. Entire peat body thickness is 5-6 meters. Thus, Zehlau mire could be identified as a peatland with raised bog peat body type. Such peat body structure as well as lack of gittja and other lake sediments goes to prove that Zehlau is a

typical pattern of mire originated via paludification process which started, apparently, in small depressions in different parts on mire kettle bottom on the glaciolacustrine plain. These small depressions became the genetic centres of future mire. Afterwards, these shallow genetic centres emerged having formed solid fen covered with vast reed communities, which, although, existed rather short time and rapidly changed to *Sphagnum* communities of the large raised bog. Such rapid and distinct transition from the fen communities to the raised bog nearly without transitional mire stage was, likely, caused by poor minerotrophic nutrient supply from the ground waters of glaciolacustrine clay (these kind of soils is one of the poorest in the region). This fact should had favoured a quick expansion of *Sphagna* on that area. Taking into account that some peat samples from various depths (4.5-0.15 m) included numerous burnt plant remnants, fires occurred regularly on Zehlau bog and, apparently, became the reason of high decomposition rate in some *Sphagnum*-peat streaks.

Peat body structure on Bol'shoye Mokhovoye mire is characterized by massive fen peat deposits those consist of highly decomposed wood, reed and sedge peats. The thickness of fen peat layers is 3-4 meters here (up to 5 m in the deepest kettles). Fen peat layers end up at a depth of 6 meters from the bog plateau surface there they are changed in major boring cores by obvious streak of transitional peats (0.25-1 meter thickness). Raised bog peat goes from the depth of 5.5 meter having mean thickness 5-6 meters and covering all the mire with entire canopy. Peat body structure here points out to a rather long-term fen and swamp stage on that area. Fens and swamps existed here primarily for a long period as separate reed or wood-and-reed mires in different kettles. This long existing duration of the fen stage is, likely, connected with the high level of ground waters and frequent floodings on that area during high water time. As soon as different kettles became filled up with the peat they emerged into solid mire where sedge communities spread throughout. Sedge communities dominated on the mire also for a long time having formed thick peat deposits. Since *Sphagna* settled Bol'shoye Mokhovoye, raised bog peat deposits accumulated here already in a very quick tempo on the solid mire.

Basing onto peat composition analysis on two key mire ecosystems in main landscape districts of Kaliningrad Region it could be concluded that mires on the glaciolacustrine plain in the central part of the territory in the Kaliningrad Region evolved generally due to paludification processes on a flat surface from one genetic centre. They came quickly into raised bog stage within the Atlantic. Vice versa, the mires in the Neman delta started their formation in numerous inter-mound depressions of ancient moraine. Stages of fen and transitional mire were rather long-term. As far as deposition of raised bog peat commenced many genetic centres merged into large entire mire bodies.

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A GIS-based assessment of energy potential from wetland plants growing in the secondary hydrographic network in a reclamation area: the case of Consorzio di Bonifica Adige Euganeo

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Abstract Renewable Energy Sources are presently playing a pivotal role in re-addressing energy policies to mitigate climate. EU, through the directive 2009/28/EC, strives for the "20-20-20" triples goals for 2020, orienting energy efficiency on biomasses. Biomasses derived from cultivated bio-energy crops show critical socio-ecological issues mainly linked to direct and indirect land use changes, both on natural ecosystems and agricultural lands; on the other hand biomasses from natural and semi-natural vegetation associated to water bodies could represent an important challenge towards a sustainable and delocalized energy production. In this case biomasses from perennial riparian vegetation can be turned from a waste disposal matter to an opportunity window to perform a sustainable renewable energy production. Using high resolution geospatial information on the secondary hydrographic network of the Consorzio di Bonifica Adige Euganeo and fieldwork data on energy performance of riparian vegetation such as Common Reed is achievable to develop different GIS-based energy scenarios at different scale. The aim of the paper is to perform at local scale an ecological-economical assessment of energy potential of riparian vegetation biomasses in three technology scenarios: combustion, biogas and bio-ethanol. Remote sensing technologies such as Light Detection and Ranging (LiDAR) and GIS modelling allow to identify, categorize and estimate biomasses of riparian vegetation and to simulate a potential energy scenario from sustainable biomasses resources at different scales.

European Union established to reach 20% of Renewable Energy Sources (RES) in the energy supply and 10% in energy in transport sector replacing roughly 50 billion litres of fossil transportation fuels. A cornerstone issue towards the EU "20-20-20" triples goals is represented by energy from biomass which is expected to account 56% of RES supply by 2020 (Bentsen and Felby, 2012). However, sustainability aspects of energy from biomass have to deal both with land management system and the bioenergy chain: the former refers to ecosystem dynamics (biodiversity, soil and water bodies), the latter to the entire Greenhouse Gases (GHG) balance of the production chain (from biomass collection to the conversion process). Notably, CO_2 mitigation costs from cultivated bio-energy crops such as corn-based ethanol and wheat for biofuels purposes showed an overall increase of GHG through emissions from land-use change (Searchinger et al., 2008). On the other hand use of biomass from non-agricultural areas such as marginal lands and semi-natural habitats populated by wetland vegetation showed significant performances in different energetic scenarios (Hampicke, 2010 in Wichtmann and Wichmann, 2011). For instance, advantages to use Common Reed as bio-energy in GHG and carbon balance are attested: on a re-wetted peatland reduction of 15 t CO_2-eq per hectare per year underlying that, whereas there is a conservative yield of 13 t Dried Matter (DM) per hectare per year and a heating

value of 17.5 MJ per kg DM, one hectare could potentially replace fossil fuels in a Combined Heat and Power (CHP) plant that would otherwise emit 30 t CO_2-eq (Wichtmann and Wichmann). The aim of this paper is to assess energy potential from biomass of common reed surfaces associated to the secondary hydrographic network, performing engineering parameters on different technologies and simulating three different power scenarios such as combustion, biogas and second generation ethanol. The study site is localized within the reclamation area of the "Consorzio di Bonifica Adige Euganeo" which covers 119.207 ha in the North East of Italy. It encompasses about 1.800 km of secondary hydrographic network mainly characterized by continuous common reed surfaces. The research method is based on a cross-methodology which combines survey analyses on the field with GIS-based spatial simulations: the first one consists of direct measurements, metering distance and sampling biomass production; the second one on spatial analyses and scaling up simulations at the secondary river network level (Thomas et al., 2013). To perform scenario simulations at the study site scale previous experimental data about the energy potential of common reed biomass to produce electric energy (Eel) and thermal energy (Et) through CHP, biogas (BG) and second generation biofuel have been acquired and will be validated by the field survey. Remote sensing technologies such as Light Detection and Ranging (LiDAR) are extremely useful tools to dentify, categorize and estimate biomasses of riparian vegetation. Nowadays, LiDAR Digital Terrain Models (DTMs) are available and by Automatic or semiautomatic extraction of features are suitable and reliable in engineered landscapes as well, such as the agricultural floodplains (Sofia et al., 2013). Based on the availability of high resolution topographic data, a semiautomatic approach has been developed by Cazorzi et al., 2013 to identify the minor drainage network system and estimate parameters such as drainage length and drainage density. Such methodology relies on a morphological parameter named Relative Elevation Attribute (REA) derived from high resolution DTM. A threshold approach based on the standard deviation of REA has been used in order to automatically extract the small-scale topography features, thus the ones that constitute the minor drainage network system. Previous experimental data and results from fieldwork survey will be modelled in GIS environment in order to project different management scenarios to optimize efficiency of common reed biomass exploitation, considering for the sustainability of the system factors such as collection costs, distance, transportation and the most appropriate plant size. Different scenarios will be performed to identify the most appropriate sites for efficient and sustainable energy biomass exploitation.

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Restoration Of A Mediterranean Drained Peatland: A Case Study In The Massaciuccoli Lake Basin (Tuscany, Italy)

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Abstract Lake Massaciuccoli with the nearby palustrine areas is one of the most important marshy areas in Tuscany (Italy). Large part of its basin, characterized by a Mediterranean climate, is a typical artificially drained coastal floodplain impacted by excess nutrient loading from agricultural activities and other sources (wastewater treatment plants, soil organic matter mineralisation), causing eutrophication to the lake system. Due to the complex hydrological setting (artificial drainage) of the area and to the high soil organic matter content problems such as phosphorus leaching and subsidence are exasperated.
A project started in 2012 has identified a solution in rewetting part of the cultivated land, with the aim of decreasing the nutrients transfer from soil to surface waters. In our pilot experimental field (15 ha), three different management systems with an increasing anthropogenic intervention will be tested: natural (restored) wetland, constructed wetland and vegetation filters. The hydrological cycle, surface- and ground-water quality, peat oxidation rate, methane-cycling microbial communities activity, CH_4 and CO_2 soil emissions, plant nutrient removal, biomass production and energy efficiency will be monitored in order to assess the most effective and sustainable management system.

Lake Massaciuccoli with the nearby palustrine areas is one of the most important residual coastal marshy areas in Tuscany (Italy). Since the 1970s, the lake, initially oligotrophic, progressively converted to an eutrophic/hypereutrophic status. Since 1930, large part of its basin has been drained by a complex network of artificial canals and ditches and pumping stations, forcing water from the reclaimed areas into the lake. This network drains the superficial aquifer and some excess rainfall, maintaining a water table depth suitable for cultivation. In the drained areas, cultivated peat soils (eutri-sapric and endo-salic histosols) are largely present with values of organic matter reaching 55% in some cases.
After land reclamation started, the peatland subsided (2–3 m in 70 yr), leaving the lake perched above the lower drained area, now 0 to 4 m below mean sea level (Autorit. di Bacino del Fiume Serchio, unpublished data).
Land use is characterized by intensive agriculture (80% of the surface) and periurban Infrastructures (a wastewater treatment plant is also present). Cropping systems are based on spring crops, continuous maize (Zea mays L.), and sunflower (Helianthus annuus L.)–wheat (Triticum spp. L.) or maize–wheat rotations in the peatland and mainly winter cereals in the remaining part of the basin
(Silvestri et al., 2012).
The excess nutrient loading from agricultural activities and other sources (wastewater treatment plants, soil organic matter mineralisation). Due to the complex hydrological

setting of the area and to the high soil organic matter content problems such as phosphorus leaching are exasperated (Pistocchi et al., 2012).
A project started in 2012 has identified a solution to restore the lost ecological functions in rewetting part of the cultivated land, with the aim of decreasing peat oxidation and therefore the nutrients transfer from soil to surface waters. In our pilot experimental field (15 ha, Figure 1), three different management systems with an increasing anthropogenic intervention will be tested: natural (restored) wetland, constructed wetland and vegetation filters (short rotation coppice and managed grassland). The hydrological cycle, surface- and ground-water quality, peat oxidation rate, methane-cycling microbial communities activity, CH_4 and CO_2 soil emissions, plant nutrient removal, biomass production and energy efficiency will be monitored in order to assess the most effective and sustainable management system.

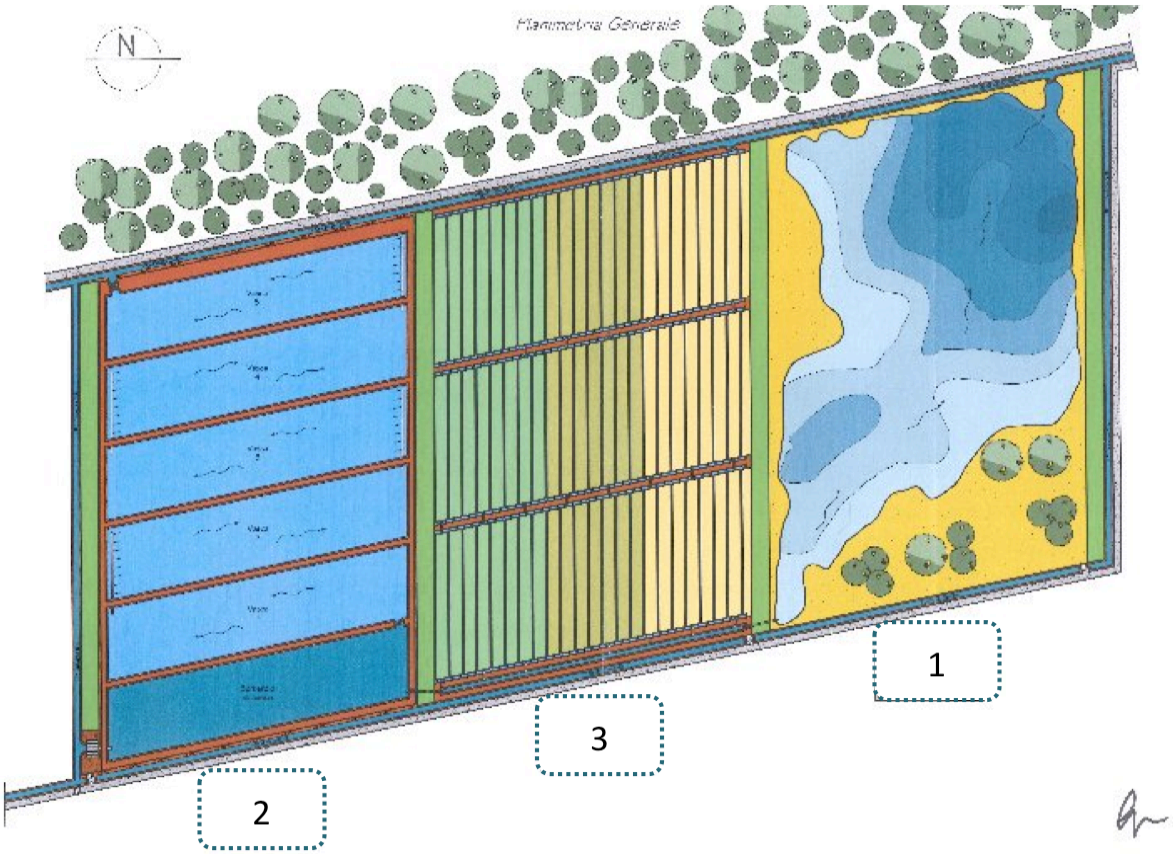

Figure 1 Scheme of the experimental setting of S. Niccolò, 1: constructed wetland, 2: vegetation filters (SRC + wet meadow), 3: restored wetland

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Assessment of reed beds yield for biomass energy production in the "Valli del Mincio" Natural Reserve

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Abstract Despite many protection measures, the "Valli del Mincio" Natural Reserve is threatened by natural evolution. The accumulation of decomposable organic matter, increased by un-harvested reed biomass, is progressively reducing open water spaces. Therefore a long-term management plan is required. Energy utilization of common reed biomass would generate several benefits, but many factors impact the profitability of harvesting chains. The purposes of this study were to evaluate reed yield in the Natural Reserve and to imagine some management scenarios. Hence, we studied dry weight (DW) production in May and November 2012, sampling biomass in 15 representative sample areas (4 m^2) and evaluating several management factors. We found 1.01 kg DW m^{-2} as maximum productivity. Secondly, considering 647 t DW of available biomass for year over the whole Reserve, we evaluated the energetic potential of local reeds, for biogas production (anaerobic digestion and combustion). Electricity production (MWh_{el}) and thermal recovery (MWh_t) were estimated. According to results, 461 MWh_{el} or 2,265 MWh_t (647 MWh_{el}) could be recovered respectively with anaerobic digestion or harvested biomass combustion. Hypothetical wetland restoration options were also taken into account. Finally, we evaluated the profitability of local bioenergy chains in the light of current Italian subsidies, founding advantages for biomass combustion.

Several factors have been responsible for the degradation of wetlands, most of which promoted by human (Van Diggelen et al., 2005; Bragg and Linsday, 2003). The cultivation of biomass on wet and rewetted peatlands, could represent a sustainable way both to avoid further degradation and provide renewable energy (Wichtmann et al., 2010). However energy utilization of mass harvested in high productivity reeds sites requires a long-term management plan, so both SCI (Site of Community Importance) regulation and local logistical aspects have to be considered to define the harvestable biomass.

The study area is located within the "Valli del Mincio" Natural Reserve (Northern Italy), a SCI/SPA (Special Protection Area). The site is characterized by extended non homogeneous reed surfaces, globally about 450 ha mainly populated by Phragmites australis (Cav.) Trin. ex Steud. We identified the study area which extends across 387 ha. Within the study area we collected samples of biomass and soil (50 cm depth) from 15 representative sample areas (each one 4 m2). We analyzed the biomass to determine nitrogen (N) content (Kjeldahl method) and DW. The soil was analyzed by determining CNS. We found high variability between sample areas in aboveground biomass. The maximum yield was around 10 t DW ha-1, while average productivity in current manageable reed beds and sinking areas were respectively 9.4 t DW ha-1 and 6.4 t DW ha-1.

Since a management plan of reeds (four year rotation) has to be respected for the Natural Reserve conservation purposes, we estimated an annual biomass availability of 913 t DW y-1 or 647 t DW y-1 respectively with maximum or current productivity. These data are

dramatically bigger supposing to restore part of the whole wetland extension (originally about 2,000 ha) and according to the site regulation it was estimated about 2,800 t DW y^{-1} as maximum biomass production.

Table 1 Estimation of reed beds biomass production in the "Valli del Mincio" Natural Reserve. R: management regulation; NR: no management regulation

Productivity hypotesis	**Biomass production (t DW y^{-1})**			
	Study area		Wetland restoring	
	R	NR	R	NR
Maximum	913	3,652	2,794	11,177
Current	647	2,589	-	-

We assumed several engineering parameters to evaluate the reed beds energetic potential through calculations. We considered anaerobic digestion (AD) and incineration as options of biomass utilization aimed to produce electric energy (E_{el}) and thermal energy (E_t) through Combined Heat and Power systems (CHP). However the harvesting time strongly affects the energetic value of reed biomass and the SCI regulation has to be considered. Therefore results are only a starting point for further research. Based on current estimation reed biomass locally harvestable could be used to produce about 2.3 MWh_t (647 MWh_{el}) or 494 MWh_t (461 MWh_{el}) respectively by combustion or AD.

Table 2 Energy potential of reed beds in the "Valli del Mincio" Natural Reserve. R: management regulation; NR: no management regulation

Productivity hypotesis	**Combustion**				**AD**			
	Study area		**Wetland restoring**		**Study area**		**Wetland restoring**	
	R	**NR**	**R**	**NR**	**R**	**NR**	**R**	**NR**
	$MWh_t\ y^{-1}$ ($MWh_{el}\ y^{-1}$)							
Maximum	3,196 (913)	12,783 (3,652)	9,780 (2,794)	39,121 (11,177)	696 (650)	2,788 (2,602)	2,132 (1,990)	8,531 (7,962)
Current	2,265 (647)	9,062 (2,589)	-	-	494 (461)	1,976 (1,844)	-	-

Concerning the energy chain profitability, we estimated approximately 125 € t^{-1} FW (fresh weight) and 70 € t^{-1} FW as global biomass harvesting costs respectively with farm machinery and an amphibious prototype.

Finally AD was compared with combustion in both energetic and economical terms, drumming up interest in reed incineration within a pre-existing plant. According to the last Italian regulation concerning renewable electrical energy, we estimated 185 € MWh_{el}^{-1} and 15 € MWh_{el}^{-1} as the maximum combustion profit calculated respectively for the amphibious and farm machinery harvesting chain. On the contrary the profit range was negative in all the AD cases. However the legal definition of this kind of biomass is currently uncertain in Italy, making dubious the subsidies payments and as consequence limiting the energy chain feasibility.

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Marshes of Southern Iraq: New Eden in Iraq treatment wetlands project

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Abstract The "**Eden in Iraq**" project is building demonstration Wastewater Gardens for the Marsh Arab communities in southern Iraq area who are in the process of rebuilding their war devastated homeland and legendary historical marshes. The Wastewater Garden art/ecology project was enthusiastically received and approved by local, provincial and state environmental authorities.

The wetlands in southern Iraq are one of the world's largest aquatic habitats, in a desert region where freshwater is scarce. As a consequence, all forms of life in the region, including humans, depend upon the wetlands. The Marsh Arab culture, whose way of life centers on water buffalo, marsh reeds, and fish is at least 8000 years old (Heyvaert and Baeteman, 2008). **Eden in Iraq** is a land art project in the wetlands of southern Iraq using environmental design, imagery, and wastewater to create gardens to transform centuries of conflict into art. It will bring an effective, ecological treatment system for sewage and water recycling into a region which lacks such basic hygiene. In 1991 Saddam Hussein drained the immense wetlands by diverting the Tigris and Euphrates Rivers turning what was likely the site of the Garden of Eden in the "Fertile Crescent", into a desert. Once Saddam was deposed, the Marsh Arabs who were forced to leave have been returning to re-green and restore the marshes with the help of **Nature Iraq,** an Iraqi NGO located in El-Chibaish, the largest Marsh Arab city in the region. These reflooded marsh lands are now characterized by higher concentrations of chloride and bicarbonates in surface water as a result of decades of aridity and subsequent chemical pollution. (Hamdan et al., 2009).
We are working under the umbrella of the Iraqi NGO **Nature Iraq** with research support from Nanyang Technological University.
In this area lies the cradle of Western Civilization. When the Shi-ites rose in revolt after the Iran-Iraq War and the U.S. led "Desert Storm" war, Saddam Hussein retaliated against Shi-ite Moslems and diverted the Tigris and Euphrates Rivers, thus cutting off the source of the water for the marshes. He secretly built a giant canal slowly sending the water from the marshes directly into the Persian Gulf. Once there was enough visibility to hunt down the Shi-ite rebels, he moved in to burn and destroy the ancient Marsh Arab homeland. The Marsh Arabs had been living an unchanged traditional life, raising water buffalo, living on floating islands and weaving reeds into everything from their architecture to boats. The diversion canal changed the lush marshes into desert. **Eden in Iraq** has been offered three sites to build on. An international team composed of the authors in collaboration with the NGO Nature Iraq consider these to be both demonstration, environmental art , and educational projects.
The sites offer 3 different kinds of locations for initial demonstrations of the approach. The intention is that through these examples other simple Wastewater Gardens, subsurface flow constructed wetlands with high plant biodiversity and use of the treated

water for subsurface final irrigation (Nelson et al., 2006) will be replicated to improve basic sanitation and safeguard water resources from pollution. Projects such as these can alleviate the current situation which have included open sewage running in the homes and or raw sewage pumped into the Euphrates which is used for recreation and drinking water, causing disease and pollution of the environment. Each project would also provide green open space and shaded community gathering locations. Each project offers a reflective possibility to connect the poetry of water, the losses and individual personal histories of war, the grace of art and a deeply necessary practical treatment system. The three sites are:

1) The Mohammed Shrine, west of Al-Chibaish, is a privately owned family shrine honouring a descendent, Mohammed, who fought in the war circa 700 A.D. This site is visited weekly by 200 pilgrims en route to significant Islamic sites to stop, pray and rest.

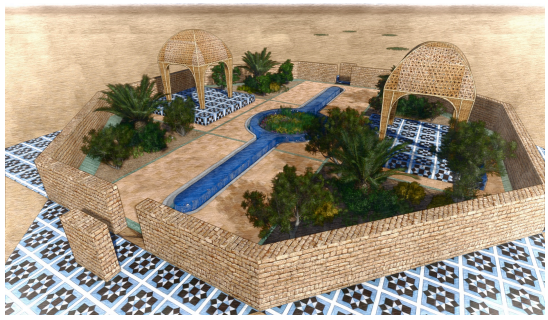

Figure 1 Site n.1. Proposed design

2) Nature Iraq Visitors and Conference center, Al-Chibaish. featuring innovative architecture which uses traditional reeds and adobe (sun-dried clay bricks). This beautiful complex of buildings, including areas for workshops and conferences with a traditional Mudhief reed structure meeting hall, will house visitors to one of the entry points for the proposed Mesopotamian National Park, Iraq's first National Park.

3) The Al Sajeah Switch Station. There is a pump-switch station which receives sewage and rainwater from a large section of the city of Al-Chibaish. Currently, the switch station simply pumps the sewage, completely untreated, through pipes into the Euphrates River nearby. There is great interest in installing treatment wetland system in a Civic Park layout to treat the sewage and using the treated wastewater to subsoil irrigate useful and beautiful plants.

The southern Iraq Wastewater Gardens concept outlined in this proposal will be a synergy of art and ecology, both enhancing the entrance to the National Park and serving nearby villagers. A prime objective of Nature Iraq NGO is to demonstrate how ecological and traditional cultural values/forms can continue to make a much richer future rather than using high-tech and unsustainable technologies and building styles which are inappropriate for the region.

Acknowledgements Nature Iraq is an Iraqi NGO working on preservation of important ecological regions and distinctive cultures in Iraq. They have proposed the southern marsh area as the country's first, the Mesopotamian National Park.

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CHAPTER 6 – PEATLANDS AND POLLUTION

The PEATBOG project: an overview

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Abstract PEATBOG (Pollution, Precipitation and Temperature impacts on Peatland Biodiversity and Biogeochemistry) is an international research consortium within the European Research Association. PEATBOG aims to understand how nitrogen pollution and climate change will affect the biodiversity and ecosystem properties of peatlands across Europe. We investigate these questions with cross-European surveys, field manipulations, and laboratory experiments. By combining these different approaches, we have increased our understanding of both the sensitivity, and the resilience, of peatlands to environmental change. We are building this understanding into models to better predict the response of these extraordinary ecosystems to environmental change in the future.
This talk provides a brief overview of the PEATBOG project.

Peatland plant species richness and biogeochemistry are rather robust to environmental change: result from a cross-European survey

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Nitrogen is tightly cycled in peatlands. Although peatlands are to some extent self-regulating and relatively resistant to environmental perturbations, including N deposition, prolonged environmental disturbance might change the peatland species composition, impact microbial communities and alter biogeochemical processes. The effects of changing environmental conditions on peatland plant communities have been studied using a gradient in climate and environmental properties. Shortly, we performed a survey on species diversity, and biogeochemistry in 59 ombrotrophic bogs (Figure 1) located across the European gradient of N deposition, aiming to (1) elucidate the extent to which plant species composition and diversity are governed by regional- and local-scale environmental factors, and to (2) tease out effects related to climate gradients from effects related to gradients in N deposition. To prevent potential co-correlations between atmospheric N deposition and climate chose sites across different combinations of mean annual precipitation, climate, and pollutant deposition.

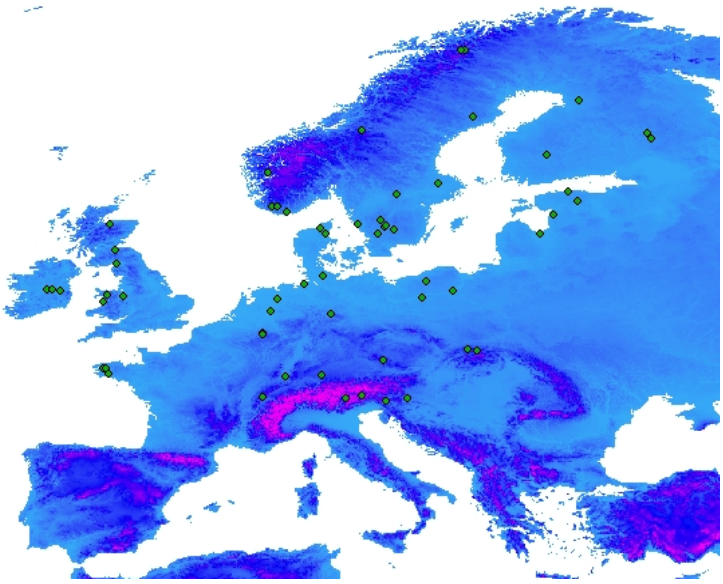

Figure 1 Distribution of the surveyed peatlands across Europe

Peatland plant community composition was highly influenced by climatological parameters, but can largely be explained by geographical distribution. Opposite to earlier reported negative relationships between N deposition and species richness in grassland ecosystems, in peatland no clear relationships were found between N deposition and species richness and diversity. Nevertheless, low N deposition sites harbor more species than high N deposition sites, and important peatland species seemed to decline at levels exceeding 5 kg N ha^{-1} yr^{-1}. Increased nitrogen loads decreased the C:N ratio of the peat mosses (Figure 2) and it increased the N:P ratio in vascular plant tissue. These results are envisaged to have strong effects on future C cycling. Our study suggest that changing environmental conditions, will induce shifts in the plant community composition and plant traits which may change the functioning of peatland ecosystems.

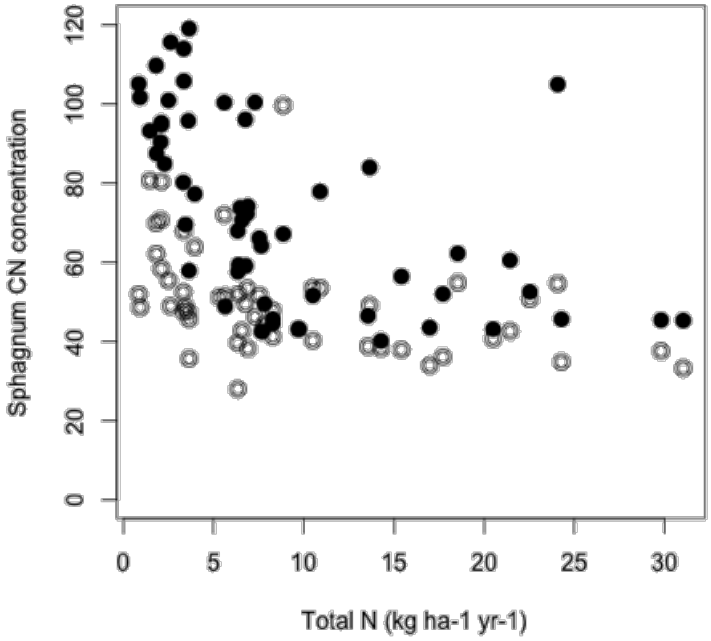

Figure 2 The relationships between nitrogen deposition and peat moss C:N ratio. White dots represent lawn species, while black dots represent hummock species

Acknowledgements We thank all agencies and land-owners for permissions to execute this work. his study is part of the BiodivERsA-PEATBOG project, which is funded as an ERA-net project within the European Union's 6th Framework Programme for Research through NWO-ALW (grant 832.09.003), and was supported by the Swiss National Science Foundation (grant 205321-129981 to LB). We are also indebted to the Dutch Foundation for the Conservation of Irish Bogs for financial support to BJMR.).

Microbial community variation in European ombrotrophic raised bogs

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Abstract Peatlands play an important role in the global carbon balance and greenhouse gas exchange with the atmosphere and are regarded as one of the most vulnerable aquatic systems to the projected climate change. A systematic study of the impact of nitrogen, warming and precipitation on the biodiversity changes of the flora and microbial communities of peatlands along gradients of N-deposition and latitude in Europe was undertaken. As a part of this effort a quantification of the *mcrA* functional gene was used to elucidate activity and distribution of methanogenic archaeal communities in micro-topographic gradients (microscale) in three Scandinavian ombrotrophic raised peatlands differing in latitude, climate and atmospheric N-deposition. Our results suggest that increasing average temperatures in the northern hemisphere together with higher atmospheric nitrogen loading might contribute to an increase of methane emissions from Scandinavia ombrotrophic raised bogs. The 454-pyrosequencing technique on the 16S rRNA gene was used to study the microbial diversity in three European peatlands (macroscale) along N-deposition and latitudinal gradients. The three sites showed the same bacterial community (phylum level) distribution, but differed at the archaeal community (genus level). Our results suggest that the peat microbial community is robust and homogenously distributed in the peatlands, while the distribution of specific functional groups differed in relation to environmental factors.

Ombrotrophic raised bogs are nutrient poor and acidic peatlands and important sources of atmospheric methane (Gorham, 1991). Methanogenic archaea communities, responsible for the methane production, differ among peatland types (Galand et al., 2005). The main factors affecting the methanogenic community composition and function are season and inter-seasonal water table fluctuations, nutrient input and availability, plant functional types, pH and seasonal dynamics (Artz, 2009). Most of these factors are projected to be affected during the climates change scenarios predicted by IPCC (Limpens et al, 2008; Luo and Weng, 2011). However, despite the overall importance of peatlands, the ecology of the microbial community inhabiting in these peatlands is poorly understood. Thus, a comprehensive understanding of the peatland microbial community response to climate change is called for in order to understand and predict effects of climate change for these ecosystems.

Three European ombrotrophic raised peatlands (ORP) along an atmospheric N-deposition, climate and latitudinal gradient were selected for a microbial diversity study (macroscale). Furthermore, three Scandinavian ORP also differing in latitude, climate

and N-deposition levels were selected for a detailed study of the diversity, distribution and activity of the methanogenic archaeal community in micro-topographic gradients (microscale). The microbial diversity on the macroscale was addressed by the application of the 454-pyrosequencing technique on the amplified 16S rRNA (Sundberg, 2013). The distribution and activity of methanogenic archaea on the microscale included quantification of the *mcrA* functional gene and its transcripts, respectively, while its diversity was studied by applying the terminal restriction fragment length polymorphism (T-RFLP) technique (Martí Generó et al., in process).

The microscale study revealed that temperature and NO_3-deposition had a significant effect ($p \leq 0.001$) on the methanogenic archaeal distribution and that the methanogenic activity was highest in peat from the site receiving the highest N-load. The family *Methanoregulaceae* performing hydrogenotrophic methanogenesis showed the highest relative proportion and activity in all three sites.
In the macroscale study, bacterial composition was similar for the three sites, while a difference was observed in the archaeal composition. The most abundant bacterial phylum was Proteobacteria, which includes methane oxidizers, followed by Acidobacteria, a recently discovered phylum believed to be ecologically important due to its high abundance in soils (Quaiser et al., 2003). The hydrogenotrophic genus *Methanobacterium* dominanted in peat from the site receiving the lowest N deposition. This was contrasted by the other two sites, where the mainly acetoclastic genus *Methanosarcina* was most abundant. The combined deposition of NOx ($p = 0.006$) and NHy ($p = 0.08$) explained the difference in the archeal community variance among the sites.
The results indicate that the peat bacterial community is robust and homogenously distributed among peatlands despite difference in edaphic factors. In contrast, the methanogenic archaeal community and activity seems to differ among and within peatlands. This variation may to some extent be explained by edaphic factors such as nitrogen deposition and temperature regimes. Thus, this specific functional group seems more vulnerable to changes in the environment.

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Impacts of Drought and Warming on Peatland Biogeochemistry and Ecology

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Abstract The impacts of summer drought and annual warming were studied on two raised bogs: Cors Fochno, Wales, and Whixall Moss, England as part of the BiodivERsA Peatbog project (www.sste.mmu.ac.uk/peatbog/). The Cors Fochno site receives low nitrogen deposition compared with Whixall which lies close to an agricultural ammonia point source. A key hypothesis of the project was that nitrogen deposition will affect the sensitivity of the ecosystem to climate change. The experiment consisted of twelve 2x2m plots per site. Plot treatments were: (i) passive warming with modified ITEX open-top chambers, (ii) summer lowering of the water table by an automated pumping system, (iii) combined warming and drought, (iv) control. Measurements were made of gas fluxes (CH4, CO2, N2O), pore water chemistry, litter-bag decomposition, chlorophyll fluorescence, plant growth and community composition. There were significant increases in vegetation cover at the Whixall site particularly in Vaccinium oxycoccus and Calluna vulgaris, but more subtle responses at Cors Fochno. Respiratory CO2 fluxes were higher at Whixall moss. Chlorophyll fluorescence showed drought induced stress effects on several species. Our results suggest that raised bogs damaged by pollution and peat-cutting may be more sensitive to climate change.

Part of the Peatbog symposium

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Impact of nitrogen deposition on the fate of nitrogen and carbon in mesocosms of five European peatlands

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Abstract Peatlands in Europe and North America have been affected by long-term nitrogen deposition at levels of 0.5 – 2 g N m^{-2} yr^{-1}, and in extreme cases up to 5 g N m^{-2} yr^{-1}. The consequences for the fate of nitrogen and carbon are poorly known. We investigated this issue with mesocosms from five European peatlands exposed to a range of 0.2 to 5 g N m^{-2} yr^{-1}. The mesocosms were incubated under controlled light and water table conditions for 160 days initial equilibration. We added a ^{15}N-NO_3 tracer with to determine how the allocation of nitrogen differed and also investigated the carbon exchange and productivity of the sites. The results show that the *Sphagnum* moss layer was not severely impaired and nitrogen still taken up by the moss layer albeit at reduced effectivity. Some breakthrough occurred, whereas nitrogen in the pristine sites seemed to be indirectly transferred into peat by vascular plant roots. Overall more nitrogen was taken up by vascular plants in the more polluted sites. Elevated nitrogen deposition lead to raised ammonium and DON concentrations even at lower deposition levels but strongly elevated nitrate concentrations only occurred at the most polluted site. Substantial differences in carbon cycling between sites did not occur in the experiments.

Nitrogen (N) is an important, growth-limiting nutrient in many peatlands and is supplied to the peat surface through dry and wet atmospheric deposition and furthermore fixed from atmospheric N_2 by microbes. Northern peatlands store large quantities of N, about 10 Pg N (Moore et al., 2004), and play an important role in the global biogeochemical N cycle. In the next few decades, global N deposition is anticipated to increase due to growing N emissions. Sphagnum-dominated peatlands are exclusively fed by wet and dry atmospheric deposition and are sensitive to increased atmospheric N input (Bragazza et al., 2005). It is thus important to examine the changes in N cycling induced by anthropogenic N input and the consequences for carbon cycling. We extracted peatland monoliths from five peatlands in Northern and Western Europe: Degerö Stormyr, Sweden; Lille Vildmose, Denmark; Fenn's Whixall and Bettisfield Mosses, United Kingdom; Cors Fochno, Wales, United Kingdom; and Frölichshaier Sattelmoor, Germany. All, but Cors Fochno are raised bogs. Cors Fochno can be best classified as a boreal mire. These five peatlands were chosen because their long-term background N deposition spans the full nitrogen pollution gradient in Europe (0.2–6 g N m^{-2} yr^{-1}). From each site, three intact peat monoliths (40 cm long, 30 cm diameter) were sampled and subsequently incubated under controlled conditions. All mesocosms were drained and then rewetted to a water table of ca. -28 cm below the moss layer. The experiment commenced after a two month acclimation period for 76 days at low water table level and 90 days at raised water level of ca. -8 cm. Mesocosms were watered twice a week using a synthetic rainwater solution adjusted for each of the sites. Throughout the experiment ^{15}N was applied as tracer in the form of $NH_4{}^{15}NO_3$ at 3 g of N m^{-2} yr^{-1} to each of the mesocosms. This deposition level was found by Blodau et al. (2006) to be almost fully

absorbed by mosses in mesocosms from unpolluted sites, whereas breakthrough of the tracer was expected in mesocosms from N polluted sites. We also investigated carbon fluxes using closed chamber techniques and gas chromatography.

The results show that the Sphagnum moss layer was not severely impaired at any site and that even under severely N polluted conditions nitrogen was still taken up by it. The effectiveness of the moss filter for the element declined, however, and some breakthrough occurred. This finding was reflected also by higher inorganic N concentrations in the peat pore waters (Figure 1) of the sites with higher long-term nitrogen deposition. Despite this fact even at the most nitrogen polluted site did peat mosses maintain a considerable ability to retain the applied nitrogen (Table 1), albeit at an increasing share of uptake by vascular plants.

Nitrogen in the pristine sites seemed to be indirectly transferred into peat by the root system of vascular plants, as ^{15}N content was elevated at intermediate depths at the end of the experiment, whereas content was higher and declined monotonously with depth in the more polluted sites. Elevated nitrogen deposition lead to raised ammonium and DON concentrations even at lower deposition levels but strongly elevated nitrate concentrations only occurred at the most polluted site. Substantial differences in carbon cycling between sites did not occur in the mesocosm experiments. The study thus suggests that long-term N deposition likely leads to substantial changes in N cycling but that C cycle as well as the ecosystem-level filter function can remain rather robust.

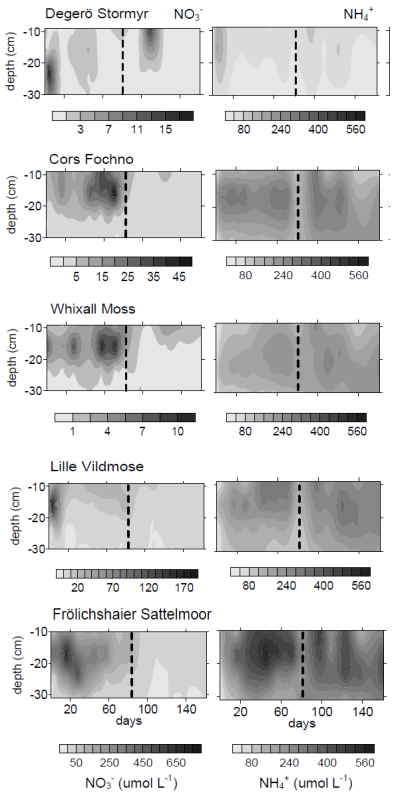

Figure 1 Concentrations of dissolved N in porewaters of the mesocosms (n =3). The vertical line indicates begin of wet conditions

Table 1 Recovery of the applied ^{15}N tracer from pools in mesocosms from the sites of differing long-term N deposition (n = 3, S.D.

Treatment/deposition (g N m^{-2} yr^{-1})	NO_3^- %	NH_4^+ %	Sphagnum %	Shrubs %	Grasses %	Peat %	Recovery (S.D.)
Degerö Stormyr (0.2)	0.011 (0.002)	0.003 (0.003)	65.6 (22.6)	3.8 (1.0)	1.8 (0.5)	59.8 (45.8)	131 (25)
Cors Fochno (0.8)	0.043 (0.045)	0.141 (0.030)	40.4 (15.0)	6.2 (3.4)	0.8 (0.3)	57.0 (18.7)	105 (12)
Whixall Moss (1.2)	0.014 (0.002)	0.284 (0.134)	23.6 (9.5)	5.4 (3.3)	0.4 (0.4)	66.1 (9.2)	96 (16)
Lille Vildmose (1.6)	0.031 (0.025)	0.661 (0.282)	57.8 (23.7)	5.7 (5.1)	1.4 (1.2)	21.9 (20.9)	87 (16)
Frölichshaier Sattelmoor (5.5)	0.051 (0.037)	0.207 (0.144)	45.5 (6.3)	12.4 (4.3)	1.2 (1.6)	36.2 (12.8)	96 (7)

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PEATBOG: A biogeochemical model for analyzing coupled carbon and nitrogen dynamics in northern peatlands

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Abstract Elevated nitrogen deposition and climate change alter the vegetation communities and carbon (C) and nitrogen (N) cycling in peatlands. To address this issue we developed a new process-oriented biogeochemical model (PEATBOG) for analyzing coupled carbon and nitrogen dynamics in northern peatlands. The model consists of four sub-models, which simulate: (1) daily depth profiles of soil moisture, temperature and oxygen levels; (2) competition among three plants functional types (PFTs); (3) decomposition of peat; and (4) production, consumption, diffusion and export of dissolved C and N species in soil water. The model is novel in the integration of the C and N cycles, the explicit spatial resolution belowground, the consistent conceptualization of movement of water and solutes, the incorporation of stoichiometric controls on elemental fluxes and a consistent conceptualization of C and N reactivity in vegetation and soil organic matter. The model was evaluated for the Mer Bleue Bog, near Ottawa, with regards to simulation of soil moisture and temperature and the most important processes in the C and N cycles. A simulation of the ongoing long-term nitrogen deposition experiments in the Mer Bleue Bog demonstrates the advantages of the PEATBOG model in tracking biogeochemical effects and vegetation change in the ecosystem.

Climate change and elevated N deposition are likely to alter the structure and functioning of peatlands through interactive ways that are incompletely understood. Ecosystem modeling has become an important approach in analyzing the interacting effects of climate and N deposition on peatlands and in making long-term predictions. In the PEATBOG model, we focus on the integration of C and N cycling through vegetation, soil organic matter and soil water, the coupling of C and N throughout the ecosystem, and the consistency of mass movements between pools. We first highlight the structural design and principles that governed the modeling process, and then explain the components of the model by focusing on the individual submodels. To improve readability of the text the equations are listed in the appendix. We subsequently present an evaluation of the simulated WT dynamics, C fluxes, depth profiles of CO_2 and CH_4 in soil water, and C and N budgets. The model output is compared against observations for the well characterized Mer Bleue Bog (MB), Ontario, Canada. We also present sensitivity analyses for environmental controls, such as temperature, precipitation, and N deposition, and for some calibrated key parameters. Finally we demonstrate the potential of the model for analyzing the effects of experimental long-term N deposition and climate change. The PEATBOG (Pollution, Precipitation and Temperature impacts on peatland Biodiversity and Biogeochemistry; see acknowledgements) model version 1.0 was implemented in Stella® and integrates four submodels: environment, vegetation, soil organic matter (SOM), dissolved C and N (Figure 1). The environment submodel generates daily WT depth from a modified mixed mire water and heat (MMWH) model

(Granberg et al., 1999) and depth profiles of soil moisture, peat temperature and oxygen concentration. The vegetation submodel simulates the C and N flows and the competition for light and nutrients among three plant functional types (PFTs): mosses, graminoids and shrubs. Most of the algorithms of plant physiology were adopted from the Hurley pasture (HPM) model (Thornley and Verberne, 1989; Thornley et al., 1995). Modifications were made for mosses and for the competition among PFTs in the nutrient poor environment. Litter and exudates from the vegetation submodel flow into the SOM submodel and are decomposed into dissolved C and N. The dissolved C and N submodel tracks the fate of dissolved C and N as DOC, CH_4, CO_2 and DON, NH_4^+, and NO_3^-. PEATBOG consistently emphasizes mass balance principles and the dynamic interplay of production, consumption and translocation of materials throughout the ecosystem. It is able to generate soil physical conditions and plant composition internally and thus requires only a few site specific parameters on geological location, local climate and initial vegetation composition for simulations. The PEATBOG model was effective in reproducing current C and N cycles in a northern peatland with some weaknesses in displaying correct short-term dynamics of C cycling during extreme meteorological periods. It was adequately sensitive to broader changes in climate and N deposition and reproduced a considerable range of empirical findings related to effects of inter annual meteorological variability and N deposition. In terms of application, the model is suitable for investigating the mechanisms of observed changes in peatland C and N fluxes due to changes in meteorological drivers and N input. Alternatively, the model could be a tool for assessing long-term scenarios of global change. The multi-layer structure of the soil submodel also allows for the integration of other belowground processes in the future, such as SO_4^{2-} reduction, to explicitly model CH_4 production on account of the competition among electron acceptors.

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Landscape-scale impacts of nitrogen deposition: new insights from the PEATBOG project

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Abstract Most of the developed world is exposed to elevated levels of reactive nitrogen deposition derived from industry and intensive agriculture. Experimental studies since the 19th Century have shown that elevated nitrogen inputs can lead to major changes in biodiversity and ecosystem function; however, we have only recently begun to understand the landscape-scale consequences of N deposition. In this presentation we will summarise results from Work Package 5 of the PEATBOG project. Using national- and European-scale datasets from peatlands, grasslands, heathlands and sand-dunes we show that N deposition exerts a pervasive influence on plant communities and biodiversity. N deposition impacts may be mediated by important interactions with other pollutants, particularly base cation deposition. Impacts on individual plant species may be present at very low levels of N deposition, often below the current critical load, suggesting that the current regulatory regime may be insufficient to prevent ecosystem impacts. Extrapolation into the future shows N deposition impacts intensifying and extensifying into currently unaffected regions. Plants are not the only organisms to be affected by increasing N deposition with experimental studies showing widespread impacts at the microbial level. N deposition is, and will continue to be a key challenge to the conservation of biodiversity and ecosystem services in European ecosystems.

Peat Fires and Resultant Air Pollution in Indonesia

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Abstract Wildfires are not a part of the natural processes in humid and wet environment of the tropical, but fires on peatland have a long history such in Indonesia. The most famous air pollution occurred in Southeast Asia including Indonesia during the devastating 1997-1998 El Nino event. In August 2010, Indonesia formally admitted to producing about 2.1 billion tons of carbon dioxide (CO2), which is a very high amount, mostly as a result of peatland fires and deforestation (DNPI 2010). Thus, Indonesia remains as one of top emitter for carbon and pollutant matters. One of the areas where fire often occurred in Indonesia (Yulianti et al., 2012) with severe pollution is in the Mega Rice Project (MRP) area in Central Kalimantan. Pollutant Standard Index (PSI) in Palangkaraya (capital province of Central Kalimantan) tends to increase from July to September, in accordance with the fire season in Southern Kalimantan and Sumatra. The hazardous level of PSI caused two pollutant indicators: CO (carbon oxide) and PM10 (particulate matter up to 10 micrometers in size). These air pollution indicators come from not only surface fire but also long lasting peat fire. The project of JST-JICA "Wild Fire and Carbon Management in Peat-Forest in Indonesia" has been carried out at the site of the Mega Rice Project (MRP) as the research associated with peat and fire. This project consists of four main research groups: (1) Fire Detection and Fire Prediction. (2) Carbon Assessment. (3) Carbon Management. (4) Integrated Peat Management. Peat decomposition and response of water quality and aquatic community to water level was investigated in our research group. Kuramitz et al., (2012) reported that in burnt area, organic matter of surface soil (0-20 cm depth) have been disappeared, however in more deep soil (30-50 cm) was still found the organic matters with more variety and quantity. Peat fire also have decomposed humic acid in peat soil, and lead to decrease the molecular weight and increase the aromaticity of humic substances.

The restoration potential of degraded blanket bogs in northern England

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Abstract The blanket bogs of the southern Pennines are heavily degraded due to a history of industrial pollution, poor land management and wildfire. Sensitive bog species were all but eradicated from these areas, and in the most severe cases, vegetation was completely lost leaving large areas of bare and eroding peat. Over recent decades, conditions have slowly improved with changing air quality and land management policy now focused on protecting and enhancing these rare habitats.

Landscape-scale restoration efforts have been underway since 2003, adapting and up-scaling methods developed in the 1980s. These have focussed on stabilising the bare and eroding peat, greatly reducing further losses. Applications of lime, fertiliser, heather (Calluna) brash and grass seed serve to knit the surface together. Lime and fertiliser acts to raise the pH of these very acidic peats and support rapid growth of the grass nurse crop. Heather brash acts as a physical restraint whilst providing heather seed and other propagules. Over time (5-6 years), dominance shifts from these grasses to typical bog species, as cotton grasses (Eriophorum angustifolium and E. vaginatum) and dwarf shrubs (Vaccinium myrtillus, Empetrum nigrum, etc.) recolonise these areas.

The approach outlined has been implemented over large areas to great effect, restoring cover to previously bare areas, benefiting both ourselves and nature through a host of ecosystem services. Despite these successes, Sphagnum mosses remain largely absent from affected areas. These species provide much of the form and function of blanket bogs, and are an essential component. Natural recovery is painfully slow, and appears to be limited to expansion of remnant hummocks and lawns. Large-scale spontaneous recolonisation appears unlikely in the short-term, given the vast degraded expanses and isolated fragments remaining. Hence, the next stage of restoration seeks to actively reintroduce Sphagnum into these areas.

Sphagnum reintroduction in upland blanket bogs is underway across bogs of the southern Pennines and other parts of the UK using various techniques. The latest approach is through spreading of micro-propagated Sphagnum moss encapsulated in beads, dubbed "Beadamoss", and in early trials these plants successfully established in the moorland environment. Here, we assess the outcomes of field trials, which aim to answer the "how, what, where and when?" of Sphagnum reintroduction.

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Restoration constraints for aquatic invertebrates of raised bog landscapes

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Abstract Raised bog landscapes are degraded by loss of natural gradients between bog massifs and surrounding minerotrophic landscapes, peat extraction, and nutrient enrichment. To restore degraded bogs rainwater is retained, aiming at *Sphagnum* recovery. We hypothesized that nutrient enrichment enables aquatic macroinvertebrates absent from pristine bog massifs to become abundant in nutrient enriched bog remnants. Our second hypothesis was that macroinvertebrates characteristic of bog gradients hardly profit from restoration focusing on ombrotrophic conditions solely. Macroinvertebrate abundance was higher in bog remnants in the Netherlands, where nitrogen and phosphorus concentrations are increased, than in pristine bog pools in Estonia. This increase was indeed primarily due to species absent from unpolluted ombrotrophic bog pools. In pools created by restoration the abundance of species preferring nutrient poor ombrotrophic pools was higher than in pools remaining after historical use of bogs, such as peat cuttings. The cumulative richness and abundance of species preferring minerotrophic parts of bog gradients were decreased in Dutch bog remnants. Further reduction of nitrogen and phosphate availability in bogs and restoration of transitional habitats in and adjacent to remaining bog remnants, as well as in fen reserves currently including relict populations of species typical for bog gradients is recommended.

Raised bog landscapes are characterised by both ombrotrophic bog massifs that are acid and extremely nutrient limited as well as gradients from bog massifs to the more minerotrophic surroundings, where these harsh conditions are gradually attenuated. Both elements are threatened by drainage, peat extraction, cultivation, afforestation and increased nutrient availability. Bog restoration includes rainwater retention (Wheeler and Shaw, 1995). To assess the effects of nutrient enrichment, loss of natural bog gradients, and restoration measures on aquatic macroinvertebrates we compared the species composition of pristine raised bog systems in Estonia and degraded and rewetted raised bog remnants in The Netherlands that show a dramatically increased availability of nitrogen and phosphate (Van Duinen, 2013).

Differences in the macroinvertebrate abundance and species composition between pristine Estonian bog landscapes and Dutch bog remnants show that both degradation and restoration have acted as filters (*cf*. Poff, 1997) on the invertebrate community (Figure 1). Loss of natural bog gradients caused loss of species characteristic of transitional mires and laggs, including endangered species (Van Kleef et al., 2012). This loss calls for conservation and restoration of heterogeneity and gradients in environmental conditions typical for complete raised bog landscapes.

In case of small-scale traditional exploitation of bogs several characteristic species were able to persist as relict population in mosaics of peat cutting pits. Here, rewetting may result in an unsuitable habitat for characteristic and endangered species for a short or long

period. Re-colonisation capacity of these species is limited due to habitat fragmentation and limited dispersal ability. Therefore, conservation of relict populations of characteristic species currently present in bog remnants, fen reserves and moorland pools is recommended. Gradual changes over longer periods of time are recommended to avoid shock-effects and to enable species to move within the restoration site, if necessary (Van Duinen, 2013).

In case of industrial exploitation, hardly any species could live at the drained peat fields. After rewetting invertebrate species, including characteristic species, colonized the new water bodies, depending on the regional and local species pool, species' dispersal abilities, and habitat conditions (Van Duinen, 2013).

Increased nutrient availability enabled invertebrates naturally absent from extremely nutrient limited bog massifs to invade and to become abundant. Several species preferring ombrotrophic water bodies in pristine bogs declined, either due to changed abiotic conditions or biotic interactions with species invading polluted bogs. Changes in food plant quality affect growth of herbivores (Turlure et al., 2012). High nutrient availability limits restoration of invertebrate communities of bog landscapes, like it hampers recovery of bog vegetation. Therefore, a further reduction of atmospheric nitrogen deposition and phosphate concentration in bog remnants is required.

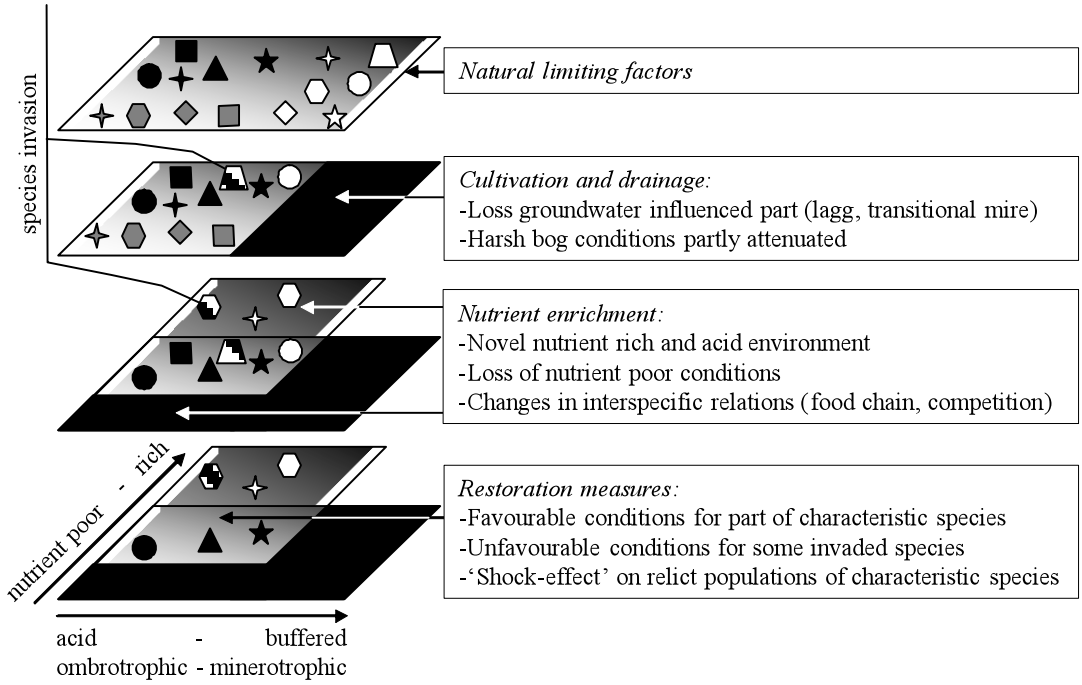

Figure 1 Schematic representation of species filters acting on the aquatic invertebrate community of raised bog landscapes. Different species are represented with different symbols. Short description of the filters in the text boxes at the right side of the figure

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Impacts of Air Pollution and Climate Change on Peatlands: Challenges for Management and Policy

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Abstract: Ombrotrophic peatlands are in part highly sensitive, and in part surprisingly robust, to the impacts of air pollution and climate change. Biogeochemically, peatlands react to nitrogen (N) inputs by progressive nutrient enrichment, including enhanced foliar uptake of N, accelerated nutrient cycling and transformations, and breakthrough of N into lower peat layers. However, the above- and below-ground ecological communities appear relatively resilient, perhaps due to the dominant role played by hydrology. Despite this overall elasticity, Sphagnum and some components of the microbial community appear sensitive to high concentrations of reduced N, and some plant species show threshold-like declines in abundance at low levels of N deposition. In addition, nutrient enrichment could 'prime' the ecological community to respond rapidly to changing climate. Finally, unlike other vulnerable habitats, options for mitigation of pollution damage through management of peatlands are limited. These characteristics of peatlands pose challenges for their conservation and management, and for developing effective policy for peatland ecosystems in the arenas of air pollution control, biodiversity preservation, and climate change mitigation. The presentation will highlight some of these challenges, and propose specific recommendations to better protect these distinctive ecosystems in the face of current and future environmental change.

Situation of Peat Fire Combustion on Southern Kalimantan, Indonesia

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Abstract Recently, Indonesia was recognized as one of most carbon emitting country, from its peatland fires. Four large fires occurred in the first decade of the present century, giving an average interval of only about 2.5 years. This study carried out in the Mega Rice Project (MRP) area, Southern Kalimantan, an area of the pilot project of REDD+ (Reducing Emissions from Deforestation and Forest Degradation plus). The three objectives are to elucidate combustion properties of the most combustible materials, to clarify recent fires occurrence, and to notice the air quality conditions. Samples from various depths of peat and dominant surface vegetation analysed using the Bomb Calorimeter, Thermogravimetry-Differential Thermal Apparatus, and a CHNS/O analyzer. Fire activity was observed during active fire years using thermal camera. Ambient air pollution analyzer measured the air pollutant indicators. The results showed that peat at surface (<50cm) has the highest calorific value, and most considered as high-risk fuel. Under dry condition, surface peat fire could be occurred long lasting (months) with thick smoke release. The highest concentration of CO and PM10 reached 13,61 ppm and 1,171 μg/m^3 in September 2009, respectively. As a result, Pollutant Standard Index (PSI) was holding on the unhealthy until hazardous levels nearly two-months in 2009.

In 1996/1997, more than one million hectares of peat swamp forest (PSF) of the southern of Central Kalimantan has drained by drainage channels for agricultural land under the MRP. The effect was a lowering of ground water levels (GWL), mainly in the following dry season that are a cause of severe wildfires (Putra & Hayasaka 2011). Page et al. (2002) showed that as much as 70% of the PSF destroyed by the fire in 1997. Since then, the highest numbers of fires in Kalimantan recorded in the years 2002, 2004, 2006, and 2009 (Yulianti and Hayasaka, 2013). The peatland fires produce toxic smoke and release the large amounts of carbon. However, the study on tropical peat fires is not particularly active in comparison to the boreal. Here, to clarify the combustion properties of fuels and tropical peat fire situation, this preliminary study collected samples of peat, fern, and local wood from the MRP Block C north, six months post to the 2009 fire. Samples dried on certain temperature, and analyzed by using the Bomb Calorimeter, Thermogravimetry-Differential Thermal Apparatus, and a CHNS/O analyzer. During highest fire events on 2002~2012, fire behavior and temperature changes of peat fires were observed by thermal video system and other suitable equipment. The indicator pollutant parameters during fire season measured by ambient air pollution analyzer system in Palangkaraya (capital province of Central Kalimantan). A comparison of analysis calorific result for peat and vegetation showed surface peat layer is about 25 kJ/g, contrary to the water content as shown in Table 1. It could be explained by carbon content of peat than the other materials (R^2 = 93.56%). The highest ignition temperature was also indicated by the peat samples with more than 260ºC. In Table 1, the three ferns species have a similar rate to that surface peat, suggesting both of material will be burn

faster than wood and peat layer at depths above 50 cm. As a result of peat fires (Figure 1), there are elevated concentrations of CO and PM10 from July through September in 2009 under the influence of fire season drought. The highest concentration of CO and PM10 were 13,61 ppm in September 29 and 1,171 μg/m3 in September 5, respectively. Both pollutants were leading as critical parameter of Pollutant Standard Index (PSI) during the fires season. The study concludes that a study related peat fires in more detail needed to design an effective fire prevention method. Final goal is to reduce carbon emission and haze problem from Indonesian peatlands.

Table 1 The properties related to combustion of peat and vegetation

Combustible material		Carbon content (%)	Calorific value (kJ/g)	Water content after dried 105° (%)	Ignition temperature (°C)	Max combustion rate	
						mg/min	(g/h)
Peat	0-20	61.93	25.82	84.44	273	2.03	0.12
	20-50	62.69	24.72	84.61	294	2.88	0.17
	50-80	58.41	22.66	87.09	284	1.80	0.11
Stenochlaena palutris		45.08	17.62	9.97	253	2.40	0.14
Pteridium aquilinum		47.62	18.14	11.83	258	2.82	0.17
Osmunda cinnamomea		44.15	16.29	12.51	259	2.52	0.15
Combretucarpus rotundatus		40.43	17.00	14.9	264	1.22	0.07
Shorea balangiran		39.39	17.00	9.4	253	1.33	0.08

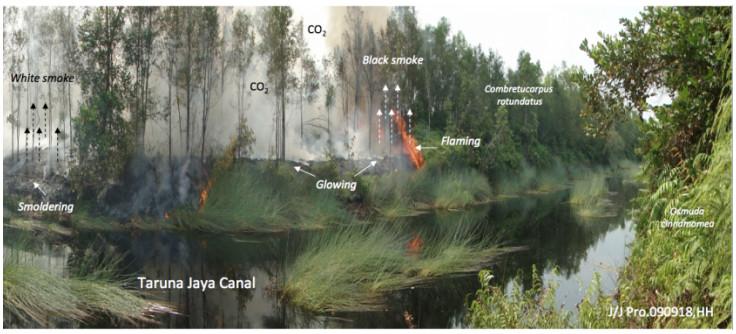

Figure 1 Peatland fire incident in one of the MRP canals in 2009

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Effects of Forest Fire on Characteristics of Humic Acid, Extracted from Peat Soil in Central Kalimantan, Indonesia

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Abstract Almost every year, forest fires occurred in peatland area in Central Kalimantan, Indonesia. When fire happened, there were not only trees but also peat soil burnt. The major constituent of peat soil is humic substances, consisting of humic acid, fulvic acid and humin. Therefore, the chemical changes in peat soil as impact of peat fires was investigated through the characterization of humic acids extracted from peat soil at burnt and non-burnt sites. The characterization of extracted humic acid (HA) was performed by elemental analysis, molecular weight by HPSEC, FTIR and pyrolisis GC-MS. The effect of fire on the elemental composition of HA was observed through the value of H/C and O/C. Heating process for HA made the aromaticity increased and released functional groups containing oxygen of HA to decrease the H/C value and the O/C value. HA extracted from burnt peat soil showed the lower value of H/C and O/C than that from non burnt peat soil. Molecular weight of HA from burnt site was slightly lower (3380- 3612 Da) than from non-burnt sites (3934-4368 Da). Pyrolisis-GCMS data indicated that the number and intensity of peaks from the pyrolisis products decreased after the heating process.

Peatland area in Central Kalimantan, Indonesia is reported to be about 3,010, 640 ha. In 1996, Indonesian Government initiated to develop the peat forest in Palangka Raya, Central Kalimantan as a paddy field. The peat forest about 1,700,000 ha was used for Mega Rice Project (MRP) and then long irrigation canals to exclude water from peat forest were constructed for new paddy field. The total length of canal have been about 5,956 km. However, MRP was discontinued and some environmental problems such as the deforestation and the decrease in water table level are remaining. Consequently the dry peat soil triggers forest fires in dry season. When forest fire happened and then peat soil was burned, the peat will release huge amount of carbon dioxide to the atmosphere and also some organic materials in soil as the degraded compound will release to the aqueous environments.

Most part of organic matter in soil consists of humic substances (HSs) that include humic acid, fulvic acid and humin. Humic substances play a significant role in environment and enhance the fertility of soil by improving their physical and chemical properties. In this study, the chemical changes in peat soil as an impact of the peat fires was investigated through the characterization of humic acids extracted from peat soil which were collected

from burnt area and non burnt area in Central Kalimantan. Humic acids were extracted and purified according to the method recommended by International Humic Substances Society (IHSS) and Stevenson (1984). The characteristics of humic acid were measured by elemental composition, molecular weight, FTIR Spectrum and GCMS-Pyrolysis data. Elemental composition of humic acids were measured by JE. Science Micro Corder JM 10, molecular weights were analyzed by high performance size exclusion chromatography with TSK-Gel Colomn, modified from Asakawa et al., (2000), FTIR spectrograms were measured by FTIR spectrometer JASCO FT/IR 4100 and pyrolisate compound were determined by pyrolysis-GCMS, Shimadzu GC-17A/QP 5050 type GC/MS system (Fukushima et al., 2011).

Effect of the fire on humic acids would be observed through the value of H/C and O/C that calculated from the elemental analysis data. The higher value of H/C indicates higher aliphatic group and the lower O/C indicates the higher aromaticity. The ratio of O/C indicates the amount of the functional group containing oxygen. After heating experiment to humic acids at 200, 300, 400 ºC, it indicated that the value of O/C and H/C decreased gradually corresponding to the different heating temperature. The molecular weight of the humic acids decreased after heating process, however the different in molecular weight between burnt sites and non burnt sites was not so large. FTIR spectrogram indicated that heating process were increasing the absorbance intensity at 1650-1630 cm^{-1} and 1280-1230 cm^{-1} which attributed for C=O stretch (amide), aromatic C=C, hydrogen bonded C=O, C-O ester, phenolic C-O. GCMS-pyrolisis data showed that pyrolisate compounds of HA extracted from unburnt sites consisted of aliphatic alkanes, alkenes, ketone, aldehyde, phenolic compound and fatty acid, whereas pyrolisate compounds of HA extracted from burnt soil were dominated by phenolic compounds.

The impacts of burning process on characteristics of humic acid showed that the value of H/C and O/C of humic acid from burnt soil were lower than that from non-burnt soil. The molecular weight analysis showed the burning process decreased the molecular weight of humic acid. However, FTIR spectrums of HA did not show the large differences between burnt and non burnt sites. Pyrolysis-GCMS data indicated that burning process have changed the composition and quantity of organic substances containing in extracted humic acid.

Acknowledgements This research was supported by JICA-JST Project "Wild Fire and Carbon Management in Peat-Forest in Indonesia".

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Characterization of Humic acid and Fulvic Acid Extracted from River Water in Tropical Peatland, Central Kalimantan, Indonesia

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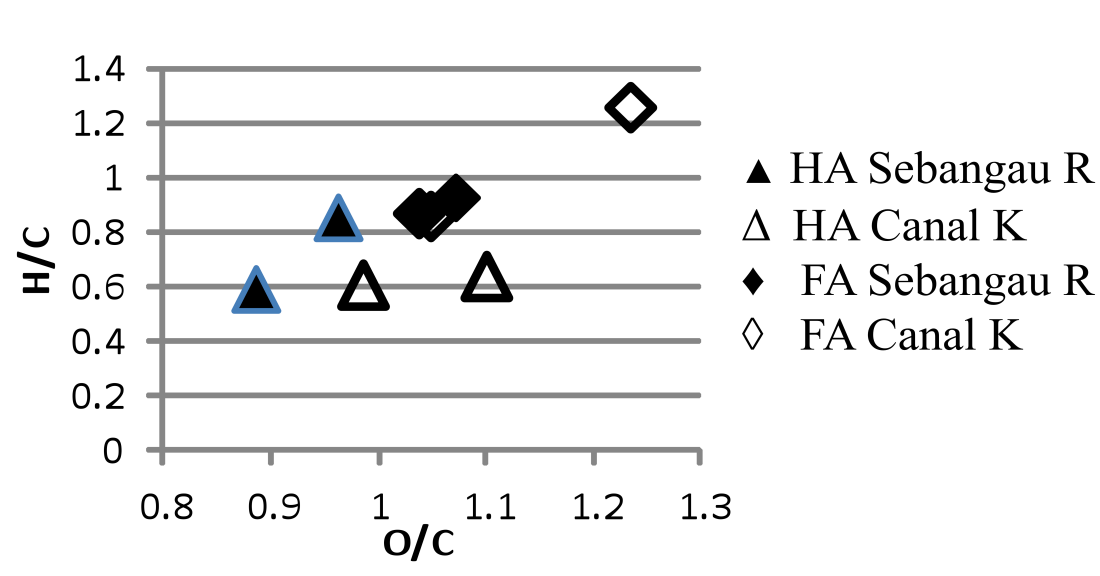
Abstract Humic acid (HA) and fulvic acid (FA) were extracted from 20-40 L of river water that located in peatland area in Central Kalimantan, Indonesia. The rivers are Sebangau River as a representative of natural river and Canal Kalampangan as an artificial river. The DOC concentration of the Sebangau River was in the range 36.6-43.17 mgC/L and 40.7-45.53 mgC/L for Canal Kalampangan. The characterization of the extracted humic acid and fulvic acid was performed by elemental analysis, molecular weight by HPSEC and FTIR data. The carbon content of HA from both rivers was higher than carbon content of FA, on the contrary, the oxygen content in FA was higher than in HA. The values of H/C and O/C indicated that the extracted HA contained more aromatic group than FA, and the extracted FA has more functional groups containing oxygen. The molecular weight of HA in both rivers was in the range 3664-4360 Da, and was 3248-4348 Da for FA. Generally, the characteristics of HA extracted from natural river and artificial river was not significantly different, and FA extracted from both rivers also shows similar chemical structure and physical.

Aquatic humic substances are a major fraction of dissolved organic material in natural water, especially in peatland area. According to Frimmel (2001) reported, humic substances enter to aquatic from two main sources, first is terrestrial that origin from plant and soil (allochthonous substances) and second is materials that results from biological activities within the water body itself (autochthonous substances). On the basis of their solubility in acid-base, humic substances can be divided in three fractions: humic acid is a fraction of aquatic humic substances (AHS) that is soluble at higher pH but insoluble at low pH. The other fractions of AHS are humin, a fraction which is insoluble in all pH; and fulvic acid, a fraction which is soluble at all pH (Greenberg et al., 1992). The characteristics of humic substances generally depend on their origin. Almost all fractions of humic substances have similar elements composition but the differences are in molecular weight and functional groups. This study was conducted to know whether there are some impacts of forest and peat fire on characteristics of humic substances in river and canal in peatland area of Central Kalimantan, Indonesia. The water samples were collected three times from the Sebangau River and the canal in Kalampangan. The Sebangau River flows in Sebangau National Park where its vicinity is surrounded with peat forest, whereas the canal in Kalampangan is an irrigation canal that was constructed to make paddy field in Mega Rice Project (1996-1999) which failed to attempt to convert about 1 millon hectares of wetland (mostly peatland) to paddy field (Muhamad and Rieley, 2002).

Humic acid and fulvic acid were extracted and purified from 20-40 L river or canal water, according to Thurman and Malcolm's method (1981). The dissolved organic carbon (DOC) was measured by TOC analyzer (Shimadzu A-5100). The elemental

composition of humic acid and fulvic acid were measured by JE. Science Micro Corder JM 10. The molecular weights were analyzed by high performance size exclusion chromatography with TSK-Gel Colomn, using a modified method by Asakawa et al., (2000), FTIR spectrograms were measured by FTIR Spectrometer JASCO FT/IR 4100.
In peatland area, it seems the sources of organic matters in river water mostly origin from autochthonous substances. The DOC concentration of the Sebangau River as natural river and canal Kalampangan as a constructed river, there was no significant different each other. The carbon content of HA from both rivers was higher than carbon content of FA, on the contrary oxygen content in FA was higher than in HA. The values of H/C and O/C indicated that the extracted HA contained more aromatic group than FA, and the extracted FA has more functional groups containing oxygen as shown in fig 1. The molecular weight of HA extracted from the Sebangau river (4242-4360 Da) was higher than that from the canal in Kalampangan (3664-3738 Da), FA also showed similar behaviour. Whereas the molecular weight of FA from the Sebangau river was 3883 -4348



Da and from the canal in Kalampangan was 3248-3303 Da.

Figure 1 H/C and O/C value of HA and FA extracted from River water

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