European RESPONSES to climate change

SEVENTH FRAMEWORK PROGRAMME

RESPONSES project

European responses to climate change: deep emissions reductions and mainstreaming of mitigation and adaptation

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Assessment of the costs, risks and benefits of selected integrated policy options to adapt to flood and drought in the water and agricultural sectors of the Warta River Basin.

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Introduction

The cost of floods, and the scale of droughts, continues to rise in the European Union despite more than a century of investments in levees, reservoirs, irrigation systems and other infrastructure (OECD 2010a,b). The International Panel on Climate Change (IPCC 2011) in its recent report titled "Managing the risks of extreme events and disaster to advance climate change adaptation (SREX)" noted the difficulties of determining the contribution of climate change to current flood and drought risk. Yet climate projections suggest significant increases in future risk across the EU (IPCC 2012), underlining the need for investing in drought and flood risk management today as a way of preparing for and, if possible, mitigating climate change in years to come. We examined the potential and challenges for mainstreaming flood and drought risk adaptation, with links to mitigation, into EU water and agriculture policies with a case study in the Warta river basin of Poland.

The research shows a wide mix of EU water and agriculture policies that contribute to flood and drought risk management. **To help prioritize EU policies and investments, we examined the cost-effectiveness and co-benefits of on-farm natural water retention measures (NWRMs) as an alternative to traditional investments in dams and reservoirs.**

The objective of NWRMs, such as natural ponds or wetlands, shelterbelts and changed tillage practices, is to slow down or reduce the flow of water downstream leading to a more natural flow regime within a catchment.

Many EU policies contribute to flood and drought risk adaptation

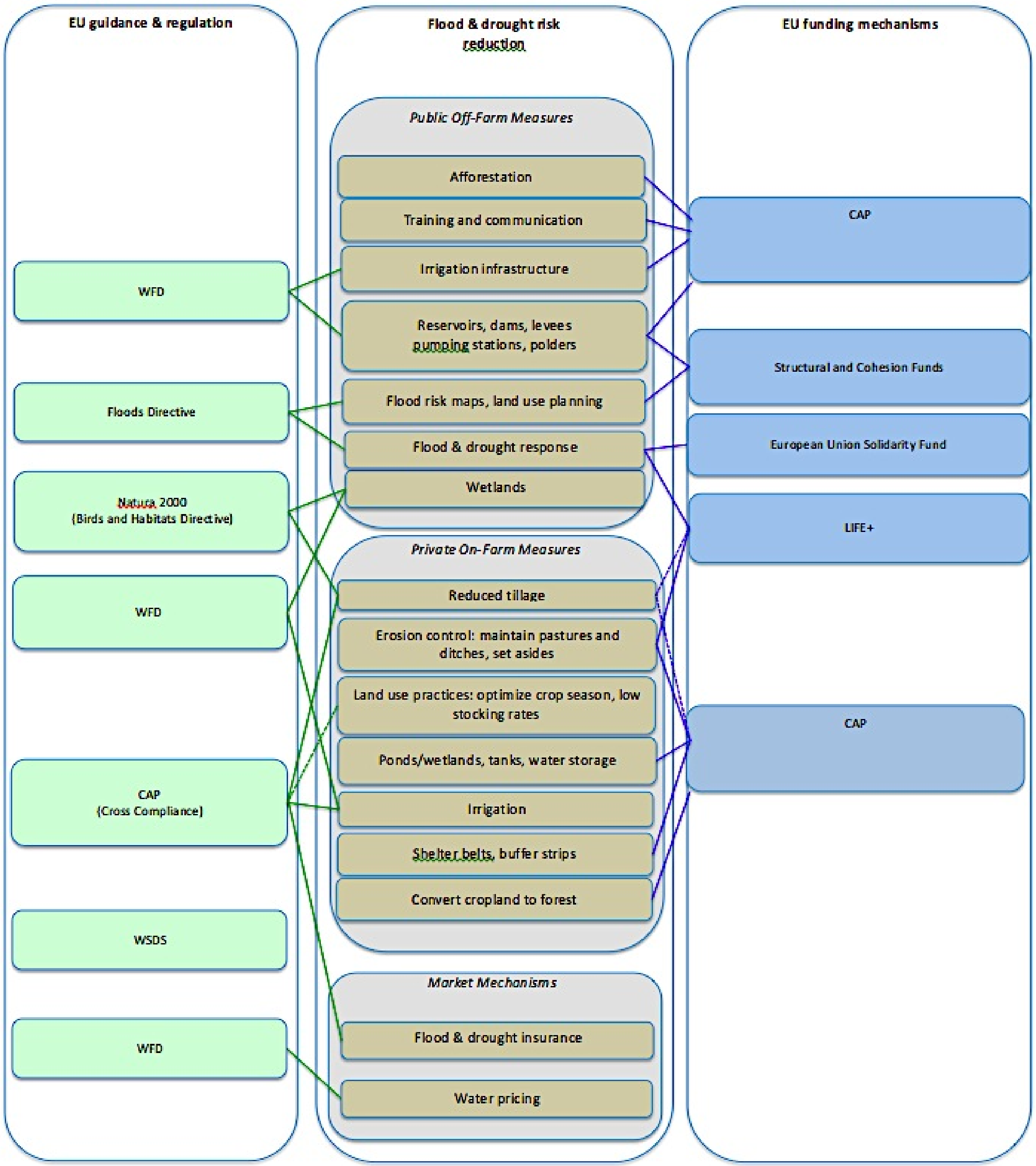
The EU has a comprehensive portfolio of policies addressing flood and drought risk. The most important are the (see Figure 1):

- EU Common Agricultural Policy (CAP),
- EU Water Framework Directive (WFD),
- EU Floods Directive (FD),
- EU Water Scarcity and Droughts Strategy (WSDS), and
- Structural and Cohesion Funds.

There are many examples of how flood and drought risk adaptation measures, with links to mitigation, are mainstreamed into EU policy. For instance, the WFD and FD require flood and drought risk management plans and flood risk assessments to take climate change into account, although without specific targets. While the CAP does not directly address flood and drought risks, recent reforms present mainstreaming opportunities. As one example, the CAP cross-compliance regulations can require on-farm measures, such as constructing small retention ponds, planting shelterbelts that reduce runoff, and changing tillage practices to hold moisture in the soil, which not only reduce flooding downstream and provide water in time of drought, but also contribute to mitigation by enhancing carbon sequestration. CAP's Agro-Environment Program (AEP) can compensate farmers for making on-farm water-retention and other "green" infrastructure investments. Off-farm "grey" infrastructure measures, such as large reservoirs, are eligible for co-funding from the European Agriculture Fund for Rural Development (EAFRD) and the Structural and Cohesion Funds.

As yet, these programs have not been linked into a unified EU policy for flood and drought risk management. A pressing issue facing the Commission with regard to mainstreaming adaptation to flood and drought risk, and linking adaptation with mitigation, is better integration of the patchwork of CAP, WFD, the Structural and Cohesion Funds and other policy instruments currently available.

Figure 1: EU policy instruments that mainstream flood and drought risk management



Cost-effectiveness of natural water retention measures (NWRMs)

In its recent publication, A Blueprint to Safeguard Europe's Water Resources, the European Commission suggested switching priorities from grey to green infrastructure, and especially from dams and reservoirs to NWRMs. In the Warta region, and throughout Europe, authorities have historically responded to flood and drought risk with large water infrastructure projects. These are increasingly facing budgetary constraints, environmental concerns, and public opposition. Many stakeholders recognize the need for new reservoirs in the Warta region, but suggest these should be supplemented by on-farm natural water retention strategies, especially those that promote climate change mitigation.

To address this transformation, powerful policy integration tools are proposed for the Commission's 2014-2020 Multiannual Financial Framework (MFF) that could greatly enhance the take-up of green infrastructure. The proposed commitment of 20% of the EU budget for climate mainstreaming in the MFF should increase support for all water measures related to climate adaptation. Elements of ecological focus areas envisaged by the Commission proposal on the greening of CAP Pillar I could promote NWRMs, in addition to CAP's Pillar 2 funds for regional development. The Blueprint also proposes that the Structural and Cohesion Funds as well as European Investment Bank support NWRMs.

But are NWRMs cost-effective? We compared the construction and maintenance costs of the Wielowies-Klasztorna reservoir with three on-farm measures: small and large ponds, shelterbelts, and conservation tillage. Preliminary estimates of the cost per cubic meter of water stored, along with non-quantified costs and co-benefits, are shown in Table 1. In viewing these estimates, it should be kept in mind that the extent to which retaining water in the landscape helps prevent runoff depends on, among other conditions, the available capacity of the water bodies and saturation of the soils.

Table 1: Cost effectiveness of selected NWRM in the Warta region with non-quantified costs and co-benefits (climate change costs and benefits marked in bold)

Water retention measures	Investment & maintenance costs/m3 water stored* or annual runoff reduced	Climate change mitigation and other significant non-quantified costs	Climate change mitigation and other significant co-benefits
Large reservoir (Wielowies Klasztorna) 49 million m3	€1.68 per m3 water stored	Increased CO2 emissions (deforestation for construction) Restriction of fish migration Reduction of groundwater levels downstream Social and psychological costs of displaced persons	Decreased CO2 emissions from electricity production Tourism Contribution to biodiversity Fisheries
Large on-farm pond (Warta data) 210,000 m3	€5.88 per m3 water stored	**Increased CO2 emissions (deforestation for construction)**	Contribution to biodiversity (including migration corridors) Landscape enhancement & recreation (also fishing)
Small on-farm pond (U.K. data) 140 m3	€558.00 per m3 water stored	**Increased CO2 emissions (deforestation for construction)**	Contribution to biodiversity (including migration corridors) Landscape enhancement & recreation
Shelterbelt (Warta data)	€6.86* per m3 annual runoff reduced	Reduced crop acreage Retards satellite monitoring	**Sequestration of CO2** Contribution to biodiversity (including pollination) Increased yield from remaining crops Reduction of land degradation

Switch to conservation Tillage (U.S data)	- €9.20 per m3 annual runoff reduced	Increased pesticide use	**Sequestration of CO2** **Less fuel use** Contribution to biodiversity, pollination & water quality Increased agricultural productivity Reduction of land degradation

* Among other assumptions (detailed in Deliverble 4.5), calculations are based on 30-year project life and discount rate of 5%. Estimates are preliminary and approximate.

Considering only investment and maintenance costs, preliminary estimates show that Wielowies Klasztorna is less costly for storing water in the landscape than on-farm ponds, with significant economic advantages over very small ponds. Moreover, it would require nearly 250 large ponds to store the equivalent water of the Wielowies Klasztorna reservoir.

Figure 2: An on-farm pond

The economies of scale suggest that ponds are less appropriate as a drought and flood measure, although they may be economically justifiable as fisheries.

The cost advantage of the reservoir, however, may lessen when compared to the runoff avoided from shelterbelts, and disappear altogether when compared to runoff avoided from conservation tillage.

Source: Oklahoma Forestry Department

Shelterbelts usually line roads and fields with trees and shrubs. Relative to cropland, shelterbelts have a higher potential to reduce runoff and retain water in upland areas.

Source:http://climatetechwiki.org/content/conservation-tillage

The term *conservation tillage* refers to management practices that minimize the disruption of the soil's structure, reduce erosion, degradation, and potentially water contamination. Conservation tillage techniques are designed to leave a minimum of 30% of crop residue on the soil surface (roughly 1,100 kg/ha) during the critical soil erosion period.

Not only does conservation tillage reduce runoff, but it also lowers labor and machinery costs.

Estimating the cost advantage of reservoirs over shelterbelts will require further research to compare "water stored" with "runoff prevented". The advantage of reservoirs may be reduced or eliminated altogether if climate change mitigation, as well as other non-quantified costs (like reservoirs restricting fish migration) and co-benefits (like contributions to biodiversity and reduced land degradation) are taken into account.

Valuing costs and co-benefits, including climate change adaptation

The non-quantified costs and co-benefits shown in Table 1 illustrate the necessity of valuing the full range of costs and benefits, including carbon sequestration, for mainstreaming flood and drought risk reduction into a unified EU policy program. Methods exist for pricing non-market costs and benefits and eco-system services, but they are difficult to implement, especially in the uncertain context presented by climate change.

The FD and WFD state that uncertainty related to climate change should be presented transparently in flood maps, with climate change scenarios included in planning processes. According to the EU's *Climate Change & Water Guidance*, climate change should be fully integrated into river basin management in future planning cycles. However, there continue to be great uncertainties in projecting climate change impacts on flood hazards over investment horizons relevant to water managers. This explains why climate change was not considered in assessing the flood risk in the cost-benefit analysis carried out for the Wielowies Klasztorna reservoir.

Making robust investments in light of climate change

Our estimates show that climate change increases flood hazards for the Warta region after 2070 (nearly doubling) and drought losses after 2030 (30-40% increase). The uncertainty surrounding these estimates and other model results is, however, significant, with even the sign of the uncertainty being in doubt (-17% to +85% for floods).

Robust policies that work well given a range of future scenarios are needed. For instance, water retention measures are robust for both growing flood hazard (increased precipitation) and for increased drought hazard (decreased precipitation).

Policy implications

Our preliminary results show that "green infrastructure," especially conservation tillage and (to a lesser extent) shelterbelts, are cost-competitive with "grey infrastructure" like dams and reservoirs for retaining water, and, in addition, that they contribute to climate change mitigation, biodiversity, pollination and reduced land degradation. Small and large on-farm ponds, alternatively, are hardly cost-competitive with large reservoirs, but have co-benefits like promoting corridors for species migration and creating income from fisheries. It would be important to compare the costs in terms of reduced runoff (in addition to water stored in the landscape) that takes account of soil saturation and other factors.

The *Water Blueprint* combined with the Commission's *2014-2020 Multiannual Financial Framework* could greatly enhance the take up of on-farm green infrastructure for managing flood and drought risk. The aim should be to prioritize investments and activities, taking account of future climate risk and the full range of costs and benefits. For this purpose, the Commission should consider providing guidance on valuing co-benefits of adaptation and mitigation measures in the agriculture and water sectors. There is also a need for risk assessors to be given concrete guidance on how to assess and value distant future climate change impacts in present-day infrastructure decisions. Irreducible uncertainties in climate and hazard projections mean that policymakers should consider the benefits of flexible, no-regret strategies, which as in the case of the Warta adds emphasis to the potential value of supporting on-farm green infrastructure, like shelterbelts and conservation tillage.

1 Introduction

The aim of the RESPONSES project is to identify and assess options for mainstreaming climate change mitigation and adaptation into European Union directives and other policy instruments. The reduction of flood and drought risk today can be important in anticipating future climate change, and thus an important part of an adaptation strategy, as well as contributing to climate change mitigation. This deliverable examines selected options for flood and drought risk reduction in Poland’s Warta river basin, and provides quantitative and qualitative estimates of their costs and benefits. It builds on Deliverable 4.3, which identified integrated flood and drought adaptation options that take account of mitigation in the Warta region Specifically, this deliverable responds to and reports on research carried out for Task 4.5:

> Task T4.5: *Integrated policy options appraisal, including adaptation and mitigation linkages:* Assessment of the costs, risks, benefits and trade-offs of selected integrated policy options with respect to socio-economic and ecological objectives, applying relevant methods from the RESPONSES research protocol. This analysis would be focused on options as they pertain to the Upper Warta river basin, but with the explicit aim of producing results that would be of more general relevance for national and regional modeling assessments.

Flood and drought risk reduction options were identified in Deliverable 4.3, which surveyed the full range of options relevant to the agricultural and water sectors. It showed how the Water Framework Directive (WFD), the Flood Directive (FD) and latest proposed Common Agricultural Policy (CAP) reforms have set the stage for funding, regulating and guiding agricultural/water policies relevant to flood and drought risk. Of particular interest is the potential for on-farm measures, such as changed tillage practices and shelterbelts, that would promote “green” objectives, including adaptation and mitigation to climate change.

The recent EC publication titled, *A Blueprint to Safeguard Europe's Water Resources* (hereafter Water Blueprint), has underlined the importance of exploring a range of options for reducing flood and drought risk. The Blueprint lays out a clear direction for water policies with an emphasis on green infrastructure:

> Pressure from agriculture and flood protection can be mitigated or prevented. Methods include developing **buffer strips,** which provide biological continuity between rivers and their banks and using, whenever possible, **green infrastructure** such as the restoration of riparian areas, wetlands and floodplains to retain water, support biodiversity and soil fertility, and prevent floods and droughts. This is a valuable alternative to classical grey infrastructure (e.g. embankments, dykes and dams). Particular attention should be paid to preventing the degradation of headwaters. These are small water bodies (nurseries to many fish species) which are frequently threatened, according to the EEA, by agricultural works (drainage, filling) and by dry-out. Fish ponds also play an important role in the retention and storage of water in the landscape, prevention of flooding and erosion.
>
> To address this, powerful policy integration tools are enshrined in the Commission proposals for the 2014-2020 Multiannual Financial Framework (MFF) that could greatly enhance the take-up of green infrastructure. The proposed commitment of 20% of the EU budget for climate mainstreaming in the MFF should increase support for all water measures related to climate adaptation. Elements of ecological focus areas envisaged by the Commission proposal

on the greening of **CAP pillar I**, such as buffer strips, could serve as Natural Water Retention Measures (NWRM), a type of Green Infrastructure.

The Water Blueprint proposes that the EC with Member States and stakeholders develop CIS Guidance on NWRM; that CAP Pillar I support NWRM; and that the Structural and Cohesion Funds as well as European Investment Bank support NWRM.

The strategy for NWRM laid out in the Water Blueprint flags the importance of understanding the costs and benefits of alternative measures for flood and drought risk mitigation. While cost-benefit analysis is required in many countries, including Poland, to evaluate large-scale reservoir projects, there are few analyses of on-farm measures that assess their benefits and costs. The objective of Deliverable 4.5 is to evaluate three EU agricultural/water policy options that have been identified as particularly relevant to climate adaptation and mitigation in Poland and throughout many Member States. These include:

- Off-farm large reservoirs
- Communal-scale middle-sized reservoirs
- On-farm small ponds
- On-farm shelterbelts; and
- On-farm conservation tillage.

These options are aimed primarily or secondarily at retaining water in the landscape (water retention measures) and reducing runoff with the primary or secondary benefit of reducing flood and drought risks, and with additional benefits and costs, including mitigation of climate change. The selected policy options include: (1) a continued policy of strong support for large reservoirs, and (2) increased and intensified support for on-farm water retention measures, including small and medium reservoirs, shelterbelts and conservation tillage.
The questions we will address in Deliverable 4.5 include:

- What are the relative costs of these measures with respect to retaining water in the landscape, and thus reducing drought and flood risk (cost-effectiveness analysis)?
- What are their co-benefits in terms of climate mitigation, reducing soil erosion, improving bio-diversity, electricity generation, tourism, etc.?
- How does (and should) climate change enter the cost and benefit estimates?
- Based on the costs and benefits of these measures, what advice can be given to the European Commission and Polish authorities on setting priorities with regard to off- and on-farm water retention policy options?

Our research methods include a literature search and stakeholder interviews at the national, regional and local levels, as well as a stakeholder workshop that elicited views on identified policy options and their costs and benefits. The interviews and workshop are reported in Appendices V and VI.

This deliverable is organized as follows. First, we summarize the findings of Deliverables 4.2 and 4.3 to provide an overview of the challenges of adapting to the uncertainty of climate change impacts on flood and drought risk in the water and agricultural sectors and to provide a synopsis of the key adaptive practices in those sectors. In section 3, we discuss our choice of five on-farm and off-farm measures that serve as a basis for our analysis, and we follow in section 4 with a brief discussion of the pros and cons of cost-benefit analysis. We begin our analysis in the fifth section by examining the costs and benefits (and cost effectiveness for storing water) of a representative large reservoir in the Warta region, followed in sections 6,7,8 and 9 with an examination of the costs and benefits of communal reservoirs, small ponds, shelterbelts and conservation-tillage/no-tillage, respectively. Throughout we report on how practitioners and stakeholders in the Warta River Basin assess these options. We conclude by comparing the cost effectiveness of these options, and their broader costs and benefits. Finally, we discuss the implications for the European Commission and national policy makers, particularly in light of the recent *Blueprint to Safeguard Europe's Waters*.

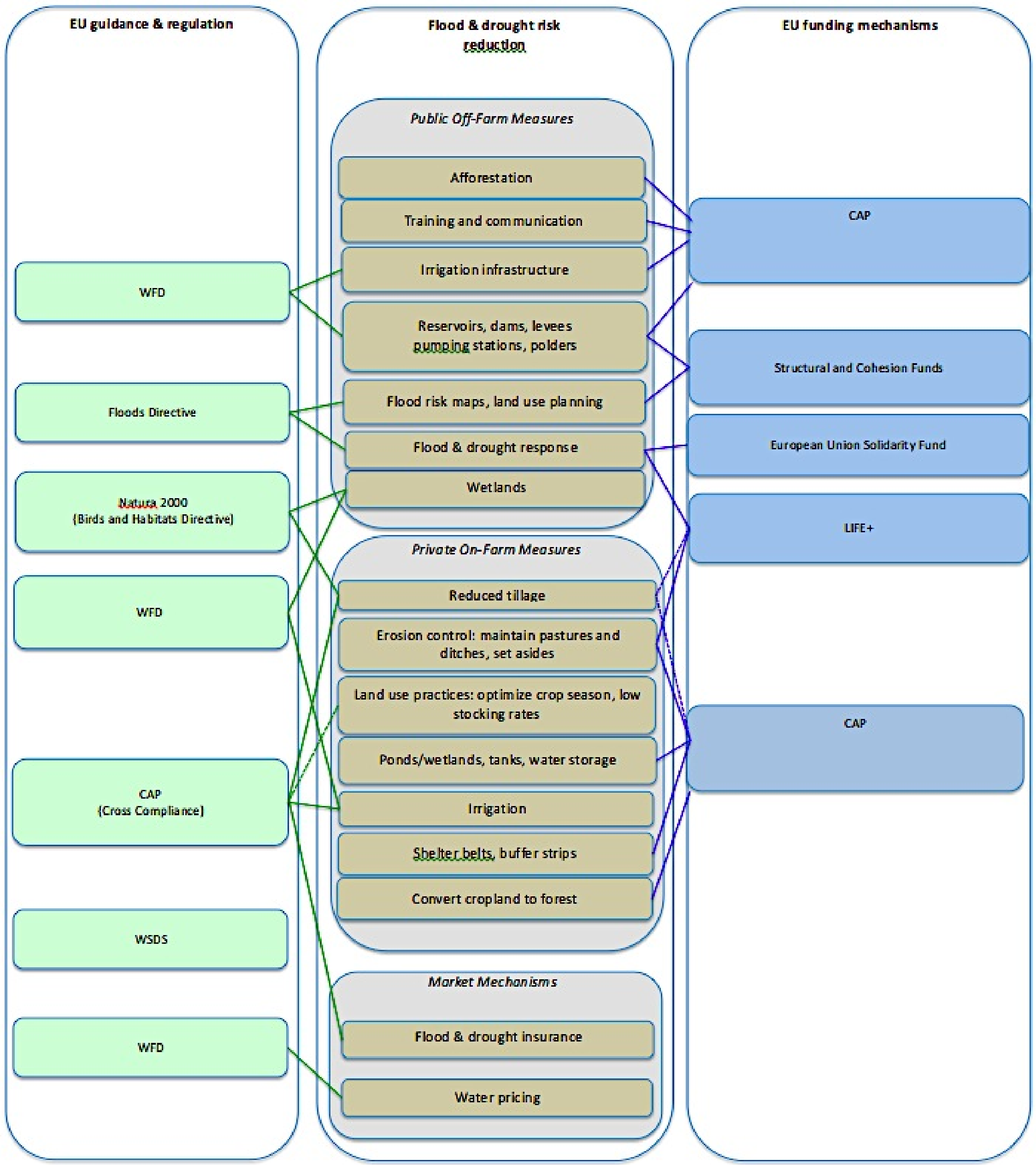
2 Background

2.1 Agricultural and water management measures for reducing flood and drought risk in the Warta region

A large variety of agricultural and water management measures can reduce the risks of flood and drought in temperate climates such as that found in Poland, and thus contribute to climate change adaptation. Deliverable 4.3 identified over 50 measures, which we classified as public "off-farm", private "on-farm" and "market" measures. Figure 2.1 shows those measures that are currently topical in the Warta region of Poland. Of particular interest is the past and current priority of investing in large and medium-scale reservoirs, primarily as a flood prevention measure, and the current interest in small reservoirs and other on-farm measures that retain water in the landscape. On-farm measures can contribute (perhaps significantly), not only to reducing drought and flood losses, but also to mitigating climate change, reducing soil erosion, protecting biodiversity and other environmental services.

As shown in Figure 2.1, the EU has a strong portfolio of instruments for funding, regulating, and guiding agricultural and water policy that are relevant for reducing the risks of floods and droughts, and thus supporting adaptation to climate change. In some important cases, most notably afforestation and conservation crop tillage, these measures can contribute to climate change mitigation. The recent Water Framework Directive (WFD) and especially the Flood Directive (FD) are giving strong signals for Member States to assess and manage flood risk. The Polish authorities have put little emphasis on the EU Water Scarcity and Droughts Strategy even given concerns in the Warta that existing water planning practices (mainly supply-oriented) may prove inadequate to cope with the adverse impacts of drought, leading to overexploitation of water bodies.

Figure 2.1: EU funding and guidance for on- and off-farm measures for flood and drought risk reduction



The Structural and Cohesion Funds and the CAP European Agricultural Fund for Rural Development (EAFRD) are the two largest sources for funding agricultural and water projects. A sizeable part of these funds has financed public, off-farm projects, like reservoirs, levees and polders, which have been targeted mainly to reducing flood risk, and which may have fewer co-benefits with regard, for example, to climate change mitigation, reduction of land degradation and the support of biodiversity and pollination, than their on-farm counterparts.

A number of EU policies and their implementation by Polish authorities provide disincentives for climate change adaptation and mitigation. Most notably, CAP's area farm payments, which subsidize arable land more than forested land, discourage such measures as shelterbelts and micro-reservoirs (greater than 100m2), both important for adaptation and mitigation. The Polish policy of exempting surface waters used for irrigation from water pricing (thus offering public waters free of charge) also discourages farmers from investing in water retention measures, such as small reservoirs and conservation tillage practices. As a final example, while the EU requires extensive crop insurance, the polish implementation of this requirement with heavy public subsidies also lessens incentives for farmers to take on privately funded risk reduction measures.

With the latest CAP "health check", an important opportunity exists to finance smaller, on-farm measures. The Commission's proposed reforms to CAP will eliminate the disincentives deriving from area farm payments, and shift more funds to so-called 'green payments' with great potential to support flood and drought risk management measures, like small reservoirs, afforestation and conservation tillage which contribute to adaptation by retaining water in the landscape and thus reducing flood and drought risk, to mitigation by sequestering CO_2 in soils and woodlands, and to biodiversity, the reduction of soil erosion and other ecosystem benefits.

The recent Blueprint (*A Blueprint to Safeguard Europe's Water Resources*) has added impetus to using CAP Pillar I funds to support Natural Water Retention Measures (NWRMs), which would include buffer strips around rivers, but also measures that support biodiversity, erosion control, small water bodies, among others. In addition to CAP, the Blueprint suggests funding from the 2014-2020 Multiannual Financial Framework (MFF) to enhance the take-up of green infrastructure. The proposed commitment of 20% of the EU budget for climate mainstreaming in the MFF should also increase support for all water measures related to climate adaptation. The Blueprint also prescribes that the Structural and Cohesion Funds as well as European Investment Bank support NWRMs.

2.2 Accounting for climate change in assessing flood and drought measures

The International Panel on Climate Change (IPCC 2011) in its recent report titled "Managing the risks of extreme events and disaster to advance climate change adaptation (SREX)" noted the difficulties of determining the contribution of climate change to current flood and drought risk, and even estimating attribution in the future. Notably, with respect to floods, even the sign of the future change may be indeterminable at this time. At the same time the SREX report showed evidence of decreased precipitation in many regions, and stated confidently that climate change would increase climate extremes in the future.

The Flood Directive and the Common Implementation Strategy (CIS) for the Water Framework Directive state that uncertainty related to climate change should be presented transparently in flood maps, and climate change scenarios included in ongoing initiatives and in planning processes. According to the EU's Climate Change & Water Guidance document, it is expected that climate change will be fully integrated into river basin management for the 2nd and 3rd River Basin Management (RBM) cycles. In the RBM Plans for the Vistula and Oder rivers, it is stated that for the first planning cycle the foreseen climate changes will be of very little importance to impacts for actions identified in the plans. This was reflected, for example, in the cost-benefit analysis carried out for the Wielowies Klasztorna reservoir (planned for completion in 2015), which did not take climate change into account. Moreover, this CBA did not consider the relation of the reservoir to climate change mitigation.

Although many analyses have been carried out for large infrastructure projects, we have identified only few analyses that examine on-farm measures for the purpose of retaining water. This is a serious gap given that in many cases on-farm water retention measures, some natural (NWRMs), have the co-benefit of sequestering CO2 and supporting biodiversity.

3 Selecting options for cost-benefit analysis

Because of uncertainty with regard to the impacts of climate change on flood and drought risk, it is important to explore robust solutions. One such solution is increasing water retention in rural areas, which is important both for increased dry periods (droughts) and, because it lowers risk to urban areas, it is important for increased wet periods (floods). In the case that there is no rise in flood or drought risk, increased water retention is needed since floods and droughts pose a current risk.

A host of studies has shown the importance of farm practices to the generation and discharge of farmland runoff (Evans 1990, Niehoff et al. 2002, Boardman 2003, Bronstert, 2003, Hall et al. 2003, O'Connell et al. 2004, Pfister et al. 2004). As reported for English and Welsh farms, some 14% of floods are attributable to runoff from farmland, mainly at the local level (Environment Agency 2002, OECD 2010). It follows that shifting farm practices to store water in the landscape would reduce flood risk. Practices that slow and store water on lands in and around farms do more than lower flood risk in downstream urban areas. They also lower risk from drought and water scarcity, especially in agricultural areas, and enhance biodiversity and (in some cases) contribute to climate change mitigation.

We have identified five water retention measures for analysis. These include:

- Off-farm large reservoirs
- Communal-scale middle-sized reservoirs
- On-farm small ponds
- On-farm shelterbelts; and
- On farm conservation tillage and no-tillage practices.

As will be described in more detail in this report, these measures differ in their costs with regard to retaining water in the landscape and preventing runoff; they also differ in their co-benefits, namely in their propensity for climate change mitigation, enhanced biodiversity, recreation, among others.

3.1 Informing the choice and analysis of the options

Information on flood and drought risk mitigation options at different scales, and their costs and benefits, were collected beginning with a literature review. Based on this review an interview protocol was designed and applied in semi-structured interviews with national and regional experts. See Appendix VII for the protocol and the list of experts interviewed along with their affiliation and expertise. The expert interviews helped to identify options as well as narrow the choice for cost-benefit analysis. They also elicited expert opinion on the costs and benefits of water retention measures.

The benefits and costs, as well as implementation issues, were discussed in an expert workshop at the Institute of Agricultural and Forest Environment of the Polish Academy of Science at Turew, Poland on 30 May 2012. See Appendix VIII for the workshop program and the list of participants along with their affiliation and expertise. Trained facilitators in cooperation with IIASA staff designed the workshop agenda and facilitated discussions. The aim was to identify how water managers and agricultural practitioners in the Warta river valley view policy options for flood and drought risk management, and especially the five options identified for further investigation. Expert opinions on the costs and benefits were elicited.

4 Cost-benefit Analysis

A cornerstone of risk management is access to knowledge on risks and cost-effective risk reduction measures. Cost-benefit analysis (CBA) has particular importance in this regard. Since the 1950s, CBA has been standard practice in the United States for the evaluation of risk reduction projects by organizations such as the Federal Emergency Management Agency and the Army Corps of Engineers. In the United Kingdom the Department for Environment, Food and Rural Affairs and the Ministry of Agriculture also generally advocate the use of CBA for this purpose (British Ministry of Agriculture, 2001). As a final example, France has used CBA for public investment and nuclear infrastructure projects since the 1970's.

CBA aims to assign monetary values to the costs and benefits of an investment, regulation or other public intervention. It is rooted in the theory of welfare economics and emulates the market in allocating scarce resources with the goal of enhancing human welfare. There are well known difficulties in assigning market-like monetary values, including the valuation of non-market costs and benefits and the assignment of a discount rate. CBA does not take account of the distribution of the costs and benefits, which is a separate consideration.

When evaluating the reduction of risks from floods, droughts and other stochastic events, CBA typically uses a deterministic approach based on past disasters in the region of concern. For example, a study might estimate the costs and benefits of a specified risk reduction measure if the catastrophe that occurred 10 years ago were to occur again tomorrow -- a form of a ”what if” scenario at a given point in time. An example of this approach for estimating flood DRR measures in Southeast Asia can be found in Dixit et al. (2009). As we will see in the following section, the Poles also took this approach in a CBA of the Wielowieś Klasztorna reservoir that is currently under construction.

Although CBA guidelines exist (Handmer and Thompson, 1997; FEMA, 2001; Navarro, 2005), there are no fully accepted and institutionalized methods for determining what a cost is, what a benefit is or how to discount the future. For this reason, CBA can be considered more of an organizing framework for understanding trade-offs than a fully objective method for evaluating the economic and social returns from a public intervention. The valuations depend heavily on the framing of the intervention, the accuracy of the data available, and the assumptions incorporated in the analysis. Benefit-cost ratios can be subject to misinterpretation in the absence of a full understanding of the factors on which they are based. (Risk to Resilience Study Team 2009 p.27).

Cost-benefit analysis is an established methodology in Poland for evaluating large-scale projects, but most experts recognize its limitations. According to a leading hydrology expert in Poland (Kindler 2012):

> ”... (In Poland) the CBA method is given and discussed by all basic academic textbooks in the country. Another issue is to what extent the CBA method has been applied to the main storage reservoirs built in the country. Before 1989 there were several "economic effectiveness" coefficients, taking into account the investment and maintenance costs and comparing them with usually very rough estimates of benefits (often characterized descriptively). Today, to my knowledge (but I will be happy to check again), it is a standard to use CBA method in case of the storage investments, but how good are estimates of both C and B I cannot guarantee. Here are two basic problems.
> First, financing of the large water storage investments (before as a rule from the state budget, now also to large extent) was and still is a serious problem. The Swinna Poreba reservoir in the Upper Vistula basin is being build already for more than 20 years and hopefully will be completed in 2014. It took more than 20 years to build the Czorsztyn reservoir on the Dunajec River. In my opinion even the best CBA will not help if the investment cycle is so long (in case of the above reservoirs it should be 5-6 years).
> Second, on the benefit side, it should be noticed that the main purpose of several large multi-purpose storage reservoirs built before 1989 have changed. Irrigation was often the main purpose, but now this is not any longer true (irrigation area has been dramatically reduced during the last 20 years).
>
> To summarize, under such circumstances, I am not surprised that it is very difficult to get the reliable data on the costs and benefits of water storage reservoirs. Dorota (Dorota Mirosław-Swiątek, a leading reservoir expert) is absolutely right that "CBA has not been a very important factor in policy decisions to build or not build reservoirs". (Kindler 2012)

In what follows, we do not attempt a comprehensive cost-benefit analysis of our selected measures, which would go far beyond the resources for this deliverable. It would entail estimating costs and benefits that are not priced in the market, which would require surveys that elicit willingness to pay or other measures to assess public preferences. Instead, we rely on analyses already carried out, and we do not attempt to quantify non-monetized costs and benefits. Where available, we discuss values for the non-monetized costs and benefits from similar analyses in the literature.

Instead of a comprehensive cost-benefit analysis of our selected measures, we carry out a quantitative cost effectiveness analysis by estimating the *capital investment plus maintenance costs per m2 of water retained in the landscape or per m3 of annual runoff avoided.*

5 Off-farm reservoirs

Poland is committed to increasing its water retention capacity, which currently stands at a level of about 6%, compared to several neighboring countries, where the level is around 10-12%. The strategy is to increase reservoir storage capacity at three different scales, which we define as follows:

Large reservoirs: 10 to 200 million cubic meters
Mid-sized reservoirs (river valley and lakes): 500,000 to 10 million cubic meters
Small (streams and ponds): Less than 500,000 cubic meters.

The construction of reservoirs to serve both flood and drought protection is a major and topical policy option in the Wielkopolska region, where reservoirs are considered to be the prime water retention instrument. The regional water management authorities are active in encouraging water storage at three scales across Wielkopolska. As shown in Table 5.1, currently three large reservoirs ((Jeziorsko, Jezioro Pakoskie, and Jezioro Porajskie) and some 67 mid-sized reservoirs provide 95% of the region's water storage capacity. The remaining five percent is provided by some 561 micro-scale ponds.

Table 5.1 – Water storage capacity (in 1000 m3) for reservoirs in Wielkopolska Voivodship

Reservoir Type			
	Large (10-200 million m3)	Mid-sized (0.5 – 10 million m3)	Small (micro) (less than 0.5 million m3)
Number	3	67	561
Total capacity (thousand m3)	316,000 (70%)	111,702 (25%)	23,665 (5%)
Average size (hectares)	2005	98	7
Average Perimeter distance (km)*	18	1	0.265
Average Volume	105,630	1667	42.03
STD DEV	90,080	1204	80.8
MIN	24,900	520	0.7
MAX	202,800	5800	486

* Assuming square area

Source: IIASA based on statistics from the *Bureau of Water Amelioration Projects and Environment Engineering (2005)*

From Table 5.1 we see that the storage capacity of the average large reservoir is approximately 63 times that of a middle-sized reservoir, and about 2,500 times that of a small reservoir or pond. This means it would take an average of 63 community reservoirs and 2,500 farm ponds, respectively, to provide the same capacity as one average large reservoir. In the following sections, we will compare the costs of providing water retention across these three scales. Also of interest, particularly for biodiversity, the perimeters of these different scale interventions differ non-linearly. To provide an equivalent storage capacity to the average large reservoir, the combined perimeters of the middle-sized reservoirs would be 3.5 times that of the large reservoir, and the combined perimeters of the small reservoirs, or ponds, would be 667 times that of a large reservoir. This could have relevance to evaluating biodiversity across the three options.

5.1 Workshop participants' views on costs and benefits of large reservoirs

A RESPONSES workshop was held in Turew, Poland on 30 May 2012 with 17 participants, including high-level officials, representatives from water research institutes, academics and private sector representatives. All agreed that reservoirs are a common measure for drought and flood risk management in the Warta region. Most agreed that new reservoirs are likely needed in the region, but other supplementary water-retention measures, like polders, ponds, shelterbelts and changed tillage practices, should be given consideration.
At this workshop, the participants expressed their views on each of the measures considered in this deliverable (communal and on-farm ponds, shelterbelts and tillage practices) and also on measures not considered in this deliverable. These include:

- Polders: Participants agreed unanimously that polders, which are not typical for the Warta region, are very promising and should be given serious consideration as a flood management measure;
- Regulation of rivers: Four of the 17 participants viewed this measure, which is seldom utilized in the Warta region, as a good candidate for flood risk management;
- Reducing soil sealing by limiting impermeable surfaces such as roads, huge parking places, dense infrastructure. Participants agreed this to be effective but costly if this means adopting materials that limit soil sealing.
- Irrigation and drainage (amelioration systems): Participants agreed unanimously that amelioration systems, which were commonly constructed in the 70's and 80's, should not be given priority in the Warta region. It was considered more important to maintain wetlands.

The costs and benefits of these measures as viewed by the workshop participants are detailed in Appendix VIII.

Turning to the participants' views on large reservoirs, Table 5.2 lists the main costs and benefits arising from the discussions.

Table 5.2: Workshop participants' views on the costs and benefits of large reservoirs

Costs	Benefits
- Investment costs: legal, technical, social (compensation costs), environmental (unique species loss, nature compensation costs) - Maintenance (deepening of the reservoir, infrastructure maintenance, maintenance of the dam) - Management costs - Lost revenues due to reduction of agricultural land and forests areas - Loss of revenues from energy production and recreation due to flood protection needs - Loss of land and terrestrial habitats - The problem of water quality (cost of waste treatment, especially in urban areas) - Climate change (change of microclimate in the river valley) - Drying of the Warta river valley below the reservoir	- Flood protection (highest benefits for the cities); high potential for regulation of hydrological regime below the reservoir, - avoiding losses in big floods, management of medium/average flows - Power generation, - Recreation, - Water supply for irrigation and drinking, - Habitat for water birds and other animals - Multi-functionality: one solution many benefits (e.g. flood protection, power generation, recreation, water supply for irrigation and drinking, habitat for water birds and other animals). However those functions are sometimes conflicting limiting benefits potential. - Impact over a big area and possibility of high impact intervention - Increase in land values after construction of reservoir

5.2 CBA for a large reservoir (Wielowieś Klasztorna)

As an example of a cost-benefit analysis (CBA) for a large-scale reservoir, we consider the Wielowieś Klasztorna project that is planned for completion in 2015. As opposed to on-farm measures described later (ponds, shelterbelts and conservation/no-till agriculture) this measure is undertaken and managed by a public authority, the RZGW Regional Water Management Board. Relative to existing reservoirs in the Warta basin, Wielowieś Klasztorna will rank as one of the largest (see Table 5.1) with a dam height of nine meters, and an expected retention capacity of 48.8 million m^3 over an area of 20 km^2. The Wielowieś Klasztorna reservoir (WKR) has experienced a long planning period given the many hurdles for permits, analyses, purchase of land and procurement of funds. It has also encountered significant public opposition.

A requisite CBA was carried out by a consulting engineering firm in Pozńan, BBF, which showed the benefits and costs of the project (BBF 2003). The net present value of the investment was estimated within a range of -36.8 to 21.2 million euros, depending on the cost avoided from the selected flood scenario (ranging from zero to 90 million euros). For the purpose of the CBA shown in Table 5.3, the BBF selected one flood scenario, a loss of 71 million euro, which was experienced from a flood occurring in 2010.

Table 5.3: Costs and Benefits of the Wielowieś Klasztorna reservoir

	Quantified costs and benefits 1000 Euros		Non-quantified costs and benefits
	BBF 2003	IIASA (discount rate 5%)	
		Costs	
Dam construction	22 124		Barrier to fish migration
Infrastructure	13 528		Silting, river bed Erosion downstream
Housing/structure loss	14 418		Relocating inhabitants
Sewage treatment	not taken into account		Facilities to control organic effluents from humans and livestock
Development Fishery	not taken into account (see benefits)		Migratory fish decline
Agricultural production	not taken into account		Productivity decline due to terrain lost to pond
Documentation	919		
Maintenance	92	*1 274*	
Dredging		*15 821*	
Preparatory works	549		
Foregone Potential for climate mitigation (4)	1678	*1678(4)*	
Environmental Habitat, biodiversity			Loss of wetland habitat to filter runoff Loss of migratory fish species
Taxes	12 234		
TOTAL COST **CONSTRUCTION & MAINTENANCE COSTS / m3 water stored**	**64 988**	***81 992*** **1.68**	
Benefits			
Flood protection scenario s1	71 604		
Energy production	4 896		
Potable Water	17 840		

Recreation and tourism	11 592		
Irrigation	4 876		Increase potential to deliver water on demand to producers using irrigation
Fishery Development	916		Increase in lake fishing
TOTAL BENEFITS	**71,628**		

Source: BBF (2003) extended by IIASA

5.2.1 Quantified costs

5.2.1.1 BBF calculations

The costs to establish and operate a large-scale reservoir are dominated by expenses associated with construction (in this case more than 22 million euro), followed by supporting infrastructure (13.7 million euro), housing loss (13.1 million euro) and taxes (12.2 million euro). Considering only the reservoir construction (plus infrastructure) and maintenance costs (5% discount rate), including the IIASA estimates of additional maintenance (for comparability with other water-retention measures reported in the following sections), the C&M cost of the reservoir is about €**66 135 000**, or €1,35/m3. Adding dredging costs (IIASA calculations, see below), the total cost of the reservoir over a 24-year period is **€81 992 000**, or €1.68/m3. For the 10% discount rate the total cost of the reservoir over 24 years is about €**76 028 000**, or €1.56/m3.

5.2.1.2 Adding maintenance/dredging costs

The costs of maintaining a reservoir are significant. BBF (2003) reports maintenance costs, including labor costs of 9 staff members, of 92,300 euros annually, which translates to a present value of 1 274 500 euros over 30 years at a 5% discount. Additionally, IIASA has estimated the costs of maintaining adequate storage capacity by dredging incoming sediment. Assuming the sediment accumulating at the reservoir's bottom is not toxic, e.g. with dangerous concentrations of heavy metals and/or chemicals from industry or agriculture, the dredging and disposal costs in Poland currently run about 23,8 euro per cubic meter (D. Miroslaw-Swiątek, pers. comm). The costs of disposing of toxic sediments are four times higher (Ibid.), so any reclassification of benthic sediments as toxic could dramatically increase maintenance cost estimates over the reservoir's life. Assuming that dredging and disposal clears the annual inflow of sediment of 71 700 metric tonnes (Brański, J and K Banasik 1996, Table 1, Poznan gauging station) or 48 039 m3, and assuming 0.67 m3 per metric tonne (Hufschmidt and Srivardhana 1986) then total annual dredging costs are approximately 1.14 million euro, and the present value of dredging over 24 years at 5% discount rate is 15.8 million euro. Dredging and other maintenance costs then account for some 20% of all costs, assuming only safe sediments need to be disposed. Other social or ecological costs were not estimated in the report (BBF 2003, Hydroprojekt Poznań 2001).

5.2.1.3 Adding the reduced potential for climate change mitigation

Because construction of the WK reservoir require the clearing of forests and trees, it would reduce the area's potential for climate mitigation by reducing the capacity to absorb CO2. We calculated this cost, which was mentioned but not included in the BBF CBA, by estimating the sequestration of carbon by the cleared trees. The tree clearing was equivalent to 180 tons, which can absorb 180 tons of carbon over an assumed lifespan of 50 years. Assuming an average social cost of carbon of €48/ton (estimates from the RICE model, see Nordhaus 2011), which is likely a minimum value, we estimated the cost to be €333,000/year. Over 24 years, the present value at 5% discount rate is € 4,595,000.

Even with the IIASA additions of dredging and increased maintenance costs, the investment and maintenance cost per cubic meter of water storage of the Wielowieś Klasztorna reservoir (€1.7/m3 water stored) is significantly lower than the cost of water storage of larger reservoirs. For example storing one m3 of water in the larger Kąty Myscowa reservoir is estimated to be €5.76 (5% discount rate) and 4.72% (10% discount rate), and for the Włocławek reservoir the costs are estimated at €7.06 (5% discount rate) and €4.43 (10% discount rate) (see Appendix I).

We should point out that the storage capacity of these reservoirs is not equivalent to the amount of water they retain in the event of heavy precipitation. The full potential water retention capacity of the Wielowieś Klasztorna reservoir of 48.8 million cubic meters does not reflect the actual capacity of the reservoir to retain water in the case of a flood. The difference between the full capacity and active storage capacity, called 'dead tank' capacity, is about 10.75 million cubic meters, lowering the active capacity of the Wielowieś Klasztorna reservoir to 38.05 million cubic meters (Wawręty and Zielazinski 2006). Besides flood control, a reservoir maintains a reserve to provide for multiple needs (drought, water supply, fishing, energy production, sport and recreation). The requisite reserve for the Wielowieś Klasztorna reservoir is 16.9 million cubic meters. Accounting for dead tank and other reserve requirement the active storage capacity is reduced to 21.5 million cubic meters or 43% of the flood storage capacity reported by the BBF (2003). Taking this into account, the cost of storing a m3 of *flood water* in the Wielowieś Klasztorna reservoir rises to that of the Kąty Myscowa reservoir, or around 3.88 euros per cubic meter water retained (3,59 euros by 10% discount rate).

5.2.2 Non-Quantified costs

A variety of environmental and social impacts are difficult to estimate and have yet to be quantified for this reservoir. According to Panasiuk (2010) the incomplete Wielowies Klasztorna CBA is further evidence of the lack of detailed and comprehensive cost benefit analyses for reservoirs in Poland. For example, environmental costs were only qualitatively described rather than quantified and incorporated in the financial analysis. To name specific examples, the costs of losing the opportunity to visit the oak forests, as well as the loss of CO2 sequestration potential, were calculated but not taken into account in the final calculations.

Damming the river to build the reservoir changes the timing and duration of water dynamics (hydrological regime) over significant reaches of the river downstream of the reservoir. The elimination of pulses of river level results in changes in the distribution and composition of flora and fauna in river-influenced habitats (Junk et al. 1989). It should be noted that 527 species and 37.8% of flora in Wielkopolskie are on a red list of endangered species (Zukowski and Jackowiak 1995). The dam also inhibits the migration of fish populations upstream from the reservoir. While the diversity of species using aquatic and wetland habitats (flora, amphibians, reptiles and mammals) may increase, this can result in declining fish biodiversity, a pattern documented worldwide from North America (Brown et al. 2012) to Africa (Gourène et al., 1999). For example, Kocovsky et al. 2009 note that dams are the principal reason for declines and extirpations of a number of anadramous fish species, including the shad (alosines) in the eastern United States (Jenkins and Burkhead, 1994; Beasley and Hightower, 2000), and the salmonid stocks in the Pacific Northwest (Nehlsen et al., 1991) and scores of other fish species (reviewed in Pringle et al., 2000). Similar declines in a range of migratory species, e.g. diadromous European eel *Anguilla anguilla* (L.) and vimb *Vimba vimba* (L.), and potamodromous nase *Chondrostoma nasus* (L.) and barbel *Barbus barbus* (L.), were noted in the Warta river following construction of the Jeziorsko reservoir in 1986 (Kruk 2004). These declines continued despite improvements to water quality in the 1990s, so the dam's impoundment remains the most likely and significant cause.

The reservoir's alteration of habitat and hydrological regime creates increasing environmental costs over time. Loss of wetland habitat lowers the capacity to filter sediment and chemicals from the river channel, and the relatively still reservoir waters cause these elements to accumulate in the reservoir bottom sediments (benthos). If the benthos saturates with nitrogen and phosphorus, these nutrients can increasingly saturate the water column and cause massive algal blooms that damage or eliminate fishing and swimming recreation (Scheffer 1998). The movement of inorganic material (silt and sediment) downstream is also slowed or halted by the dam. As a result sedimentation can fill the reservoir basin, effectively eliminating its storage capacity and starving downstream portions of sediment. This can result in erosion of the river bed and, hence, reduce downstream groundwater below the dam. Lowered groundwater levels in the floodplain results in long-term succession from wetland to more dryland ecosystems as well as reduced productivity of floodplain agriculture. Furthermore, the cumulative effects of river pooling due to loss of pulsing river dynamics and loss of wetland habitat lowers the capacity for self-purification of runoff and of the water column (Junk et al. 1989).

5.2.3 Quantified benefits

The Wielowieś Klasztorna reservoir (WKR) is expected to contribute to climate adaptation by reducing the risks of drought, and especially floods. In fact, over 50% of the benefits from the reservoir are attributed to flood protection of downstream urban areas (about €71 million flood losses avoided in Scenario 1 (BBF 2003). By such estimates flood protection appears to be a major benefit of the project, dwarfing energy production, which is estimated at about 5% of the benefits or about €5 million annually. It is instructive to understand how flood risk reduction was estimated, and whether climate change was taken into account. We already noted that the cost efficiency of the WKR in storing flood water declines if the actual, not potential, storage capacity is used. Similarly, the actual benefits of flood protection realized by the active storage capacity is less than that estimated by BBF (2003).

The Wielowieś Klasztorna CBA takes a deterministic approach for estimating the benefits of reducing flood risk by choosing one historical flood with a loss of about 71 million euros. The estimated probability of this flood is one in 100 years. However, for the BBF CBA, it was assumed that the flood would occur in the first year of the completed project. This has been criticized by Wawręty and Zielazinski (2006), who note that flood losses for the entire Warta basin from the great flood of 1997 amounted to only 52.1 million euro or 68% of the benefits claimed for the WKR CBA.

In addition to this flood scenario (S1), the report also discussed four additional scenarios with associated internal rate of returns for the investments:

S1: the reservoir is expected over thirty years to reduce the losses from one selected major flood (2010) equal to 71.6 million EUR;
S2: the reservoirs allows for flood losses avoided in the year 2020 at the level of 71.6 million EUR.
S3: the reservoirs allows for flood losses avoided in 2010 at the level of 85.9 million EUR.

S4: the reservoirs allows for flood losses avoided in 2010 at the level of 57.3 million EUR
S5: no flood;

For the S2 scenario (flood in 2020) the Cost/Benefit ratio becomes less than one. Note that more advanced methods are available for including flood risk in CBA calculations by considering the whole range of flood risk probabilities (Mechler 2008).

In making these calculations, the analysis did not consider climate change. The reason suggested in expert interviews was that in the planning period for water investments, it is not expected that climate change will have a significant influence on flood risk. (Dubel 2012a).

In addition, this diversity of scenarios does not consider the financial implications of a flood occurring late in the planning period. Our calculations show that the net present value (NPV) of flood avoidance benefits declines with time from roughly 71 million euro in 2010, to 42.5 million euro in 2020 to 26 million euro in 2030, at which point the costs outweigh the benefits. Furthermore, if NPV is calculated probabilistically, with an equal likelihood of a 1 in 100 year flood occurring in any year, then the NPV of flood avoidance benefits declines further to 10.5 million year.

5.2.4 Other quantifiable benefits

As described by BBF (2003), the net present value of other benefits of the WKR includes fish cultivation (916,21 million euro) and increasing the availability of water resources for society and industry (estimated at 17,84 million euro). Some (Panasiuk 2009, Wawręty and Zielazinski 2006) question whether the water recipient city of Kalisz needs to increase the amount of available potable water when the existing delivery capacity (1700 m3 per hour) is already three times higher than current water needs (5 million m3 per year). Despite the potential for climate-related water scarcity, these critics argue that water consumption trends in the EU currently move downward (EEA 2012), and as Poland continues to modernize it should follow that pattern as well. Other benefits include: agriculture from irrigation (4,87 mln euro) and hydro-energy production estimated to reach 3050 MWh/year with a yield 4,9 mln euro. Use of hydro-energy entails the benefits of avoiding the costs incurred by society from gaseous (SOx and NOx) and particulate emissions from burning wood.

5.2.5 Non-Quantified benefits

The engineering study that justified construction of this reservoir documented a variety of benefits and costs associated with its establishment and operation (Hydroprojekt Poznań 2001). However, not all benefits were described or quantified (Panasiuk 2010). Among others, the non-quantified benefits include: regulation of thermal fluctuations both in the river channel and adjacent wetland habitats, habitat for water birds that can potentially be linked to aesthetic values, and aquatic sports.

6 Communal-scale ponds

In contrast to the large Wielowieś Klasztorna reservoir, many villages in Poland have or are considering investments in medium-sized ponds, generally ranging from about 0.5 to 10 million m3 water storage capacity. Communal ponds serve various purposes: recreation, fishing, biodiversity and also flood and drought protection. They are usually constructed as wetlands with a perimeter of aquatic plants to retain and treat runoff from relatively small surrounding drainage areas. Such reservoirs are located within a community or within one, sometimes very big, farm. This off-farm measure can be part of a series of small reservoirs on a river, managed by a local community.

In the period 2011-2015 almost 6 million cubic meters of middle size reservoirs were and are planned in Wielkopolskie for construction. A total of €63 million of EU funds are targeted for these reservoirs, and also for the planned 356 km of levees, 66 km of levee reconstruction after floods, 130 km of rivers/streams regulation and 121 200 cubic meter increase in floodplain retention.

6.1 Workshop participants' views on costs and benefits of a communal-scale pond

For the most part, the workshop participants (see Appendix VIII) were positive about the option of constructing communal-scale ponds as a measure for reducing flood and drought risk; however, they noted the high construction and maintenance, among other, costs. They recognized that communal ponds are common in this area, and four of the participants thought they should be increased in number. Table 5.3 records the participants' listing of costs and benefits.

Table 6.1 Workshop participants' views on the costs and benefits of a communal-scale pond

Costs	Benefits
- Land purchase for creating a reservoir - Removing remaining facilities and structures (e.g. electricity lines, roads) - Construction / reconstruction - Maintenance - Investments in sewage treatment facilities - Designating and maintaining buffer zones - Loss of areas for agricultural land use	- Protection against drought and possibility to secure minimal water flows - Potential irrigation function - Natural irrigation of soils near the reservoir - Drinking water reserve - Flood protection - Fish harvesting - Positive impact on microclimate, more rainfall (in case of many small reservoirs) is especially beneficial for dry areas - Recreation - Biodiversity - Diversity of landscape (aesthetic values) - Creation of jobs caused by the construction, maintenance and use of the reservoir - Land value appreciation (five times)

6.2 Costs and benefits of a selected communal-scale (on-farm) pond in the Warta region

For our analysis we selected an existing pond in the Warta region covering 14 hectares with a storage capacity of 210 000 cubic meters. As such, it qualifies as a small reservoir, but in many ways it functions at the same scale as the medium-sized reservoirs described in Table 5.1. The pond is located on a relatively large (1500 hectares) private farm but with the size and functions typical of communal ponds. The costs of installing and maintaining the pond, as reported by the farmer (but not verified), as well as the non-quantified benefits, are reported in Table 6.2.

Table 6.2: Costs and Benefits of a communal-sized pond

	Quantified costs and benefits **(Euros)**	Non-quantified costs and benefits
Costs		
Pond preparation	59,600	
Pond excavation	954,720	
Maintenance (NPV)	220 146	
Environmental		Sewage treatment for inhabitants of all tributary catchments.
Agricultural productivity		Productivity decline due to terrain lost to pond (this would be reflected in the value of the land, which was not estimated)
TOTAL COST	1,234,466	
Construction and maintenance cost per m3 water stored	5.88	
Benefits		
Flood protection		Pond is drained in Autumn to make the full storage capacity available or the annual flood in early Spring.
Energy production		Micro-hydro power generation possible
Biodiversity		Enhance avian, amphibian, fish and mammal biodiversity; Facilitate animal migration by reducing landscape fragmentation
Irrigation		Water for irrigation increases crop yield
Recreation and tourism		Enhanced biodiversity and landscape diversity attracts tourists
Fisheries		Sport fishing potential

Source: Interview with ponds owner, Stefan Jankowiak 2012

6.2.1 Quantified costs

As with large reservoirs, the costs of the acreage used for the pond, and its preparation and excavation, dominate the costs of communal-size ponds. In this case this totaled over €700,000 or about €5.9 per cubic meter of water stored. Note that the pond lifespan is 20 years, so we doubled the cost of preparation and excavation to cover the 30 year period (which slightly overestimates the cost). This is substantially less than recorded for two comparative reservoirs (Murowana Goślina and Kleszczewo) in the Warta region, both of which are somewhat larger, with construction costs of €1.21 and €1.23 million, respectively, or about €10.1 per cubic meter of water stored. In the case of the far larger Odolanów reservoir, increasing storage capacity by 25-fold (2 600 000 m3) only doubles the construction costs (€2.36 million), effectively lowering the average water stored cost by an order of magnitude to €0.90 per cubic meter.

Adding the annual maintenance costs to the Jankowiak pond from repairing and mowing the levees (€14 320) and discounting this annual sum at 5% over 30 years, yields a present value of €220 146, thereby raising the total costs to €727 306 and the cost per cubic meter water stored to €3.46. This is less than that of two large reservoirs, and Katy-Myscowa, where the cost/m3 is estimated at €7.06 and 3.63, respectively (see Appendix I). The low costs of the Jankowiak pond is explained by the observation that the pond was built in a very suitable place (in the stream valley) using the farmer's own labor, while the commercial prices of constructing the reservoir in the more difficult places are on average three times higher.

6.2.2 Non-Quantified costs

Middle to small reservoirs incur many of the non-quantified costs as large reservoirs. These include: loss of agricultural land that is converted to the pond and adjacent buffer strips and the resulting loss in agricultural productivity may not be severe if the pond location is chosen because it is already low-lying and wet. Protecting the pond's water quality may involve investments in vegetative buffer strips to filter runoff inflowing into the reservoir or sewage treatment facilities to handle effluents from humans and livestock living in close proximity to the reservoir. Failure to remove sediment can mean long-term permanent loss of storage capacity, and failure to maintain water quality can eliminate such ancillary benefits as recreation (fishing and swimming) in reservoirs of any size, but these can be most acutely and immediately felt in smaller water bodies.

6.2.3 Non-Quantified benefits

Communal reservoirs provide the same non-quantified benefits as large reservoirs. Of course, because of their smaller scale they have a smaller impact in providing land value appreciation in the reservoir's vicinity, urban flood protection, irrigation water, regulation of the thermal micro-climate of the river valley, fish for commercial and sport fishermen, recreation, potable water for human settlements, habitat for birds, and regulation of the hydrological regime downstream of the reservoir.

In comparison with mid-sized and small reservoirs and ponds, large reservoirs may be less effective at slowing the speed and volume of the flood crest, especially flood volumes arriving in inhabited areas at elevations higher than the main river valley where most large reservoirs are situated. For example, the incidence of "muddy floods", e.g. walls of brown water laden with farm sediment, has been greatly reduced in regions in Northern England where farmers installed small temporary ponds and bunds that held the water in farm fields (Wilkinson and Quinn 2010a, Wilkinson et al. 2010a,b). *In addition, because their small size allows them to be located in a diversity of upland habitats closer to farms far from the main river valley, mid-sized and small reservoirs may be better suited for supplying irrigation water to upland farms, cooling field micro-climates, and providing habitat for amphibious, aquatic and migratory bird species.*

As opposed to one large reservoir, a network of ponds and associated habitats and buffer strips provides a greater diversity of migration pathways for avian, amphibian, mammal and reptile species that migrate across large distances. The advantage conferred by pond networks is especially apparent during periods of water scarcity. Finally, depending on where they are constructed, mid- and small-scale ponds may result in less deforestation in terms of removing forest habitats with sufficient area far from the edges to provide habitat that supports "interior" species, e.g. "shy" species that require undisturbed forest to isolate them from the stresses of more rapidly changing edge and open habitats.

The smaller dimension of ponds enhances the potential for natural, riparian habitats. In addition, communal reservoirs and small ponds can serve domestic water needs and by raising groundwater levels, increase crop yield (reported in China by Mushtaq et al. 2009). Small ponds can improve water quality by trapping sediment. Run-off retention is sufficiently long to allow particles to settle and dissolved pollutants to be biologically treated (Scottish Environment Protection Agency 2012). Extra income from vegetable and fruit production boosted by ponds has also been observed in Thailand (Wangkahart et al. 2005a,b).

7 Small on-farm ponds

Small reservoirs or ponds can be located both within the floodplain and in higher elevations of the catchment as a means to retain water, especially for agricultural purposes. Currently, over a ten-year period (2005 to 2015) some 284 **off-farm** ponds, averaging about two hectares (20,000 m2) in size and covering up to 80 (800,000 m2) hectares in area, have been or will be constructed in the Wielkopolska Voivodship under the jurisdiction of the Amelioration and Water Facilities Management Board (WZMiUW) and supported by the EU Rural Development Programme, Regional Operational Programme for Wielkopolskie (under the Programme for the Oder), among other smaller contributions (Amelioration and Water Facilities Management Board (WZMiUW 2011). These ponds in total would provide over 12 million cubic meters of water storage capacity (compared to 48.8 million expected from the Wielowieś Klasztorna reservoir). They would contribute importantly to water retention in higher zones beyond the hydrological influence of the major rivers (BIPROWODMEL 2005).

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Ponds can be classified as Runoff Attenuation Features (RAFs), a category that includes bunds, drain barriers, runoff storage features (both online and offline), woody debris dams, buffer strip management, and willow barriers (Wilkinson et al. 2010b). If a typical farm or small catchment can sacrifice 2-10% of the landscape to runoff storage and mitigation features, then the properties of the runoff regime can be radically altered (Quinn et al., 2007a). However, after a few years these features can fill with sediment, reducing their water retention capacity (Verstraeten and Poesen, 1999). Therefore the management of these features is an important issue (Wilkinson et al. 2010).

7.1 Workshop participants’ views on small ponds (up to 0.5 mln m3)

Table 7.1 shows the costs and benefits of small ponds as viewed by workshop participants. The participants acknowledged that small ponds are a frequent feature of the Warta landscape, and seven of the 17 participants were of the opinion that they should be applied more frequently. Costs of the ponds were roughly estimated at the level of 12.000-24.0000 euro per reservoir or 28.000 euro per ha.

Table 7.1: Costs and benefits of small ponds as viewed by workshop participants

Costs	Benefits
– Construction / reconstruction – Maintenance – Mowing slopes - preventing overgrowing plants, sediment clogging – Investments in sewage treatment facilities – Designating and maintaining buffer zones – Loss of areas for agricultural land use – Quick eutrophication processes	– Wildlife habitat, increase of biodiversity – Increase of retention in the catchment – Positive impacts on microclimate – Possibility of irrigation and water reserve in case of fire – Increase of groundwater level leading to higher agricultural yields – Integration of local community – pond construction near village brings people together (recreation) – Increased attractiveness of the area

7.2 Costs and benefits of small ponds with examples from the UK

Lacking empirical data for small ponds in the Warta region, we have found publications on their costs and benefits for the UK and China (for details see Appendix II). In the UK (Wales) Ockenden et al. (2012) record the costs of 16 ponds. In Table 7.2 we show the average estimates of these ponds, and we supplement these quantified costs with the main un-quantified costs and co-benefits as found in the literature and as reported by the workshop participants.

Table 7.2: Quantified and non-quantified costs and benefits of ponds in the UK

	Quantified costs & benefits (Euros)	Non-quantified costs & benefits
Costs		
Pond Construction	1666	
Maintenance (PV)	3800	
Agricultural productivity		Productivity decline due to terrain lost to pond
TOTAL COST	5466	
Construction and maintenance costs per m3 water stored	558	
Benefits		
Flood protection		Pond is drained in Autumn to make the full storage capacity available or the annual flood in early Spring.
Irrigation		Water for Irrigation
Biodiversity		Enhance avian, amphibian and mammal biodiversity
Agricultural productivity		Pond water raises groundwater level thereby increasing crop area and yield in areas adjacent to pond during drought.

Source: Adapted from Ockenden et al. 2012

7.2.1 Quantified costs

Over the past decade a series of experiments with very small ponds (volumes ranging from 2 to 62 m3) established that they are effective in trapping sediment and reducing runoff (Ockenden et al. 2012, Deasy et al., 2009). The costs to establish and maintain small ponds, as reported in Wales, include expenses to excavate, drain, fence and vegetate the pond. From Ockenden et al we estimate the construction and maintenance costs to average about €558 per cubic meter storage capacity when the present value of maintenance costs are discounted at 5% and €382 per cubic meter when discounted at 10% (see Appendix II for calculations). These costs are significantly higher than the costs estimated for the communal-size and large reservoirs. It appears there are strong economies of scale for constructing and maintaining reservoirs (see Appendix III). In Wales, the ponds must be fully dredged and the sediment redistributed on the fields about every four years on average. Such maintenance costs are therefore relatively high, averaging about 62% of construction costs (Allyson Bailey, pers. comm. 2013).

7.2.2 Non-Quantified costs

The non-quantified costs of small ponds are generally the same as those of medium-sized reservoirs (see Section 5.2.2).

7.2.3 Non-Quantified benefits

Small field ponds can lower flood and drought risk by increasing the capacity to store water in the field before it runs off into the network of water channels leading eventually to the main river arteries. Small ponds retain both surface water and groundwater of the soil surrounding the pond, and the latter may provide more water retention capacity than the former. In addition to boosting groundwater levels, these effects raise soil humidity and decrease soil erosion due to drifting. A major benefit of a mosaic of small farms is that they provide corridors for migration of amphibians and other (often) endangered species.

8 Shelterbelts

Reservoirs are not the only option for retaining water in the landscape and thus reducing flood and drought risk. In addition, farmers can increase forests, plant shelterbelts and change tillage practices. In this section, we focus on shelterbelts and conservation tillage practices, and provide estimates of the costs and benefits for water storage, and also co-benefits, such as enhancing biodiversity and crop production.

Figure 8.1: Shelterbelts in Oklahoma

Source: Oklahoma Foresty Services. forestry.ok.gov

8.1 Workshop participants' views of costs and benefits of shelterbelts

The participants of the RESPONSES workshop (see Appendix VIII) viewed shelterbelts as positive, and seven of the 17 participants were of the opinion that they should be increased in the Warta region. Eleven participants viewed them as already typical for the landscape. In Table 8.1 we list the costs and benefits as expressed by the participants.

Table 8.1: Costs and benefits of shelterbelts as expressed by workshop participants

Costs	Benefits
– Lower yields from agricultural production close to the belt – Costs of construction (material, man-months) – Costs of maintenance: equipment, amortization, man-months, protection against animals (10 years), conservation of trees – satellite monitoring of fields becomes more difficult due to obstacles like trees – education of local communities in shelterbelts management – renaissance of invasive species of trees, cost of their elimination	– Increase of average agricultural yields on the fields – Positive impact on microclimate, amelioration of water balance – Lowering a speed of wind leading to decreasing soil erosion due to wind – Reduction of nitrogen, phosphorus loads – Source of wood/biomass – Biodiversity increase 5 times (haven for small animals and insects) – Nicer landscape – Positive impact on bees leading to increase of agricultural yields and bee owners profits increase – Recreation (bike routes) – Sequestration of CO2

The participants viewed the benefits of afforestation, more generally, as similar to those of shelterbelts; yet , more participants (10) were of the opinion that they should be a higher priority for the region. There may be several reasons for this, including their commercial value as well as the availability of EU subsidies. They can also be planted where soils are poor, which contrasts to shelterbelts that typically replace agricultural land.

8.2 Costs and benefits of shelterbelts

Shelterbelts are linear landscape structures composed primarily of trees and shrubs that line the margins of roads, agricultural fields and waterways. Relative to cropland, shelterbelts have a higher potential to reduce runoff and retain water in upland areas. Shelterbelts are part of Polish efforts for creating more forest areas on farmland. They provide enough vertical structure to lower wind speed (by 35-40%) on the intervening agricultural fields, thereby increasing relative air humidity, decreasing potential evapotranspiration of crops, reduce the ambient air temperature in the intervening crop fields, increasing snow depth, and reducing the melting rate of snow in spring (Silgram et al. 2005). The shelterbelts themselves have higher evapotranspiration (128,6%) and infiltration (117,5%) rates and lower runoff (7,1%) rates than adjacent cropped fields (Figure 2, Kedziora 2004). These factors combine to increase the percolation rate in areas covered with shelterbelts compared to open areas by a substantial amount – estimates vary between increases by 300 m^3/ha (Zalewski and Wagner-Lotkowska 2004: pp 137 – 153, UNEP 2004 pp 137 – 153), 650 m^3/ha (Kedziora and Tamulewicz 1990), or even 1300 m^3/ha in more recent measurements (Kedziora 2004). Even larger differences in infiltration rates are reported for shelterbelts vs. grazed areas: Carrol et al. (2004) report 60 fold increase in infiltration rates in areas planted with young trees versus grazed grassy fields.

Table 8.2 Costs and benefits of shelterbelts in the Warta river basin and Wales

	Quantified (Euros/ha/yr)		Non-quantified
	Warta1	**Wales**	
Costs			
Shelterbelt establishment	4,315	18 041	Transaction costs of planning and implementing policies at landscape to regional scales
Maintenance	5.624 (4 yrs)	5,624 (4 yrs)	
Agricultural productivity foregone		1,306	Productivity decline due to terrain lost to shelterbelt; restricts satellite monitoring
TOTAL COST per hectare	**9,939**	24,971	
Investment & maintenance costs per m3 water stored	6.86	6.07	
Benefits			
Flood protection			Retains water in the landscape
Soil protection			Reduced losses through erosion
Soil fertility maintenance			Increased nutrient retention
Water protection			Reduced leaching of water polluting elements.
Crop production			Increased net primary production of annual and perennial crops.
Biodiversity			Enhanced avian, amphibian, fish and mammal biodiversity; Facilitated animal migration by reducing landscape fragmentation.
Pollination			Increased abundance of wild pollinators.
Pest control			Increased abundance of pest predators.
Recreation and tourism			Enhanced biodiversity and landscape diversity. Improved regional aesthetics.
Carbon sequestration			Increased amounts of carbon stored in biomass and soil
Production of timber, fuel woods and edibles			Increased supply of timber, fuel wood and edibles
Decreased erosion Increased air purification			Air filtration through trees and shrubs, as well as less wind erosion through the combined effect of increased soil moisture and reduced wind speed.

Notes: 1 – Andrzej Kedziora (pers. comm.), 2- Workshop of regional experts.

8.2.1 Quantified costs

The costs of establishing a shelterbelt in the Warta river basin total some 4262 4,315 euros per hectare based on the costs of planting trees (67 trees per 100 m) and bushes (20 per 100 m) in a 5-meter wide strip. These costs per 100 m include: tree purchase (ca. 104 euros), soil preparation (ca 6 euros), labor (ca 11 euros), fence purchase and installation (ca. 93 euros) (see Appendix III). This contrasts with higher establishment costs per hectare of 6500 7,930 euros for New Zealand (Appendix III) and 18 041 euros in Wales (Appendix III). Note that in Wales a critical function of shelterbelts is to control the movement of grazing livestock, mostly sheep. This extra security requires high fence construction costs per hectare (14 246 euros per hectare or some 79% of construction costs.)

To ensure tree survival newly established shelterbelts must be carefully maintained for about 4 years until the trees are robust enough to survive and grow despite animal browsing, if any. We applied costs from shelterbelt maintenance in New Zealand: 1,586 euros per hectare of shelterbelt and derived present value figures for 4 years maintenance of 5,624 euros (5% discount rate) and 5,027 euros (10% discount rate). In Wales, one substantial cost is the income foregone because productive land is converted to a shelterbelt (16,579 euros per hectare over a 15 year period). These foregone income costs are currently carried by the Welsh government in the form of grants (D. Jenkins (pers. comm.).

8.2.2 Non-Quantified costs

Shelterbelts are normally established as linear agro-forestry elements on the margins of agricultural fields, but the net spatial impact can be much larger than individual fields or farms. Adoption and implementation of elements like shelterbelts can be hindered by the transaction costs of negotiation at two scales, e.g. regional and landscape. A lack of regional capacity at landscape planning makes it difficult to integrate such land uses between and across farms at scales in which shelterbelts can yield significant benefits. The regions of eastern Germany immediately adjacent to the Warta river basin share the same challenges of water scarcity and drought potential, and considerable research was invested there to demonstrate the benefits of shelterbelts. Yet, despite this evidence, existing land use planning has to date proven incapable of incorporating shelterbelts into integrated landscape schemes (J. Dauber, pers. comm. 2012). Similarly, in Western Poland, especially the Warta river basin, only managers of large-scale farms, e.g. the former collectivized socialist farms, will even consider adopting measures like shelterbelts (A. Kędziora, pers. comm. 2012). Where average farm size is much smaller it has so far proven to be an insurmountable challenge to garner the agreement of multiple small farmers to incorporate shelterbelts in their portfolio of land management practices.

8.2.3 Quantified and Non-Quantified benefits

Besides water retention, shelterbelts provide a number of ecosystem services on the farm as well as landscape scale. It remains rare to find measurements of such benefits of ecosystem services (E. Bennett, pers. comm.). However, a systematic assessment of monetary values of some of the many ecosystem services related to shelterbelts concludes that the most valuable ecosystem service provided is **soil maintenance**, followed by **increased crop yield**, then **biodiversity protection** (e.g. vertebrates like bats and birds, but also **pollinating** insects and **pest controlling** species), then **carbon sequestration** and **air purification** (Chen et al. 2012; the cost estimates underlying this ranking were based only on the literature, not on site-specific measurements). Another, more comprehensive study of a related planning measure, a floodplain forest in Luznice, Czech Republic, estimated the benefits from ecosystem services at a similar magnitude, with biodiversity a top contributer (ProAct 2008).

Shelterbelts help **maintain soils** because they are a shelter for wind, they reduce and slow runoff, trap snow, enhance organic content of the soil, and keep moisture in the field – all of these processes reduce soil erosion (Silgram et al. 2005, 2007, 2009, Nisbet et al. 2011). Measurements of annual rates of sediment retention have been higher at sandy sites (0.5–6 t ha^{-1} yr^{-1}), compared to silty sites (0.02–0.4 t ha^{-1} yr^{-1}) and clay sites (0.01–0.07 t ha^{-1} yr^{-1}; Ockenden et al. 2012). Shelterbelts can reduce erosion and sedimentation by as much as 70% at field level, yet by only ca. 20% at catchment level because of the diverse ways, e.g. ditches, sewers and road surfaces water can flow around buffers in landscapes (Verstraeten et al. 2006). Shelterbelts can greatly reduce nutrient leaching (Silgram et al. 2005), thereby protecting **water quality** of ground- and surface waters. A study across 86 catchments in Denmark showed a 33% reduction in nutrient leaching which paralleled a similar decline in nitrogen levels measured in streams (Nisbet et al. 2011).

Increased moisture, due to reduced evapotranspiration, a cooler microclimate, reduced soil compaction and surface sealing, as well as enhanced organic content and nutrient cycling contribute to **increased agricultural yields** (Nisbet et al. 2011). It is as yet unclear under which conditions the beneficial effects on the microclimate on the farm level scale up to the landscape level.

Biodiversity is enhanced through shelterbelts in various ways: simply by providing habitat, e.g. to birds, bats, and insects, but also by functioning as corridors for the movement of wildlife through the landscape. Ryszkowski, (1995) found that a mosaic of landscape structures including small, cultivated fields, shelterbelts, meadows and small ponds maintained biodiversity of mammals, amphibians, reptiles, and insects. In particular, the number of bird species was positively correlated with the diversity index of the landscape. The added biodiversity includes species that provide essential services to agriculture, such as **pollination and pest control** (Kremen et al. 2004). The service of pollination has recently entered the spotlight due to a puzzling pollinator decline ("the pollination crisis" according to the US Department of Agriculture) and due to the fact that it cannot efficiently be replaced by technical or other means (Schröter 2009).

Other benefits of shelterbelts are **carbon sequestration** (contributing to climate mitigation), the **production of timber (**for on farm and off farm uses, e.g. woodchips for animal bedding (Carroll et al. 2004) or construction wood), **fuel woods and edibles (**e.g. fruit, mushrooms), and **landscape aesthetics**. Finally, shelterbelts contribute to **air purification**, directly through the living tree biomass, and inderctly through reduced sediment erosion, due to decreased wind speeds and increased soil moisture content (Silgram et al. 2005).

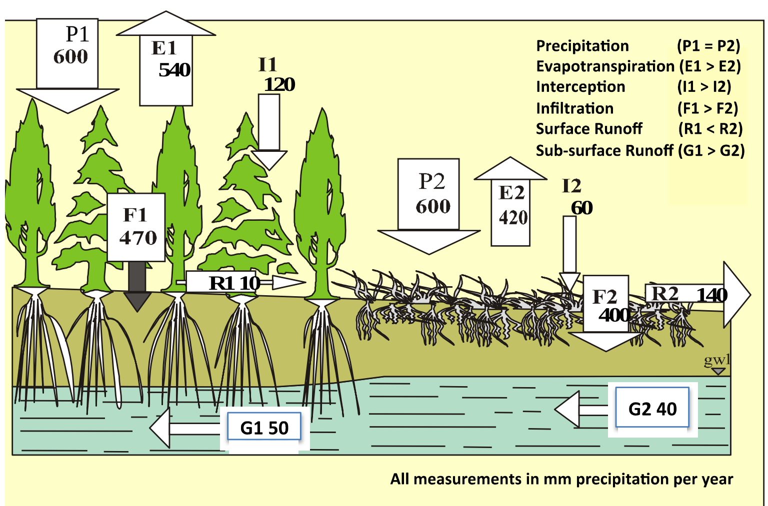

Figure 8.1 – Comparison of water balances of two land uses: coniferous forest and arable land in Poland. (K�dziora 2004)

9 Conservation tillage

Within conventional agriculture, tillage is a root (main?) cause of agricultural land degradation (Huggins and Reganold 2008). In response, conservation agriculture has emerged as an alternative to conventional agriculture, aimed at sustaining soil productivity by reducing soil erosion and compaction (FAO 2001). The term *conservation tillage* refers to management practices that minimize the disruption of the soil's structure (Holland 2004). Conservation tillage techniques are designed to leave a minimum of 30% of crop residue on the soil surface (roughly 1,100 kg/ha) during the critical soil erosion period. No- or zero-tillage is an extreme case of conservation tillage and aims for 100 percent vegetation cover prior to seeding.

Conservation tillage in general aims at avoiding negative effects associated with conventional tillage, such as erosion, compaction and hardening of the soil that reduces the infiltration and percolation rate (rate at which water moves to groundwater level; Wikipedia 2012). Thus, conservation tillage contributes to flood protection by reducing total runoff from agricultural land (Uri et al. 1999, Schmidt et al. 2001). However, introducing conservation tillage practices is complex. Careful planning and practice is required to achieve positive outcomes for the farmer and the environment. Some studies have found that concentrations of nitrate and herbicides in runoff can be higher under conservation tillage practices, leading to potential contamination of groundwater (e.g. Sims et al. 1994). Others stress the potential benefits of conservation tillage for water quality by reducing runoff of sediment, nutrients and pesticides (Uri et al. 1999, Holland 2004, FAO 2004, Huggins and Reganold 2008).

Conservation tillage is now wide-spread around the globe, although it is hardly practiced in our Warta case. The primary reasons producers switch from conventional to conservation tillage are (1) labor and fuel savings (by 30-50% and 50-80% respectively; Huggins and Reganold 2008) by reducing the number of passes across a field, (2) equipment cost savings (mainly through reduced machinery wear), and (3) yield increases (Nowatzky et al. 2007). The widespread switch to conservation tillage in Australia, for example, was indeed facilitated by a focus on the on-farm benefits, with the many environmental benefits as a welcome, but not primarily targeted co-benefit (Ian Prosser, CSIRO, personal communication 2013). The spread of conservation tillage systems on more than 110 million ha world-wide shows the great adaptability of the systems to all kinds of climates, soils and cropping conditions (Derpsch et al. 2010). In the U.S., roughly 41 percent of all planted cropland was farmed using conservation tillage systems in 2004, compared with 26 percent in 1990 (Huggins and Raganold 2008). Similarly, as of 2006, more than two thirds of farmed land in Canada was managed with some form of conservation tillage, which practically reversed the situation as it had been in 1991 (Statistics Canada 2013). In Europe, two nations rank in the global top-20 in terms of implementing conservation tillage management: Spain (650 000 ha) and France (200 000 ha) (Derpsch et al. 2010). However, conservation tillage practices have yet to become widespread in Poland. One regional expert in soil science (Weber 2012) estimates that conservation tillage is practiced on less than 1% of agricultural land under cultivation in Poland. Huggins and Reganold explain the relative slowness with which conservation tillage is adopted in Europe mainly by an absence of government policies promoting conservation tillage, along with elevated restrictions on pesticides (including herbicides), leaving farmers with little incentive to adopt the approach (Huggins and Reganold 2008).

Wielkopolska is characterized by intense agricultural production, including conventional tillage practices on light soils. This leads to increased wind and water erosion and contributes to increased drought risk by contributing, among other things, to a net loss in the region's water balance. As an area of highly erodible soils, Wielkopolska could benefit from introduction of conservation tillage practices in multiple ways.

Figure 9.1: No-till machinery

9.1 Workshop participants' views of the costs and benefits of changing tillage practices

The participants of the RESPONSES workshop (see Appendix VIII) acknowledged that farmers in the Warta region and throughout Poland have not changed their tillage practices towards conservation tillage. Yet, most viewed conservation tillage practices as positive, and the majority (12 of the 17 participants) were of the opinion that they should be increased in the Warta region (see Appendix VIII). In Table 9.1 we list the costs and benefits as expressed by the participants.

Table 9.1 Costs and benefits of changed tillage practices

Costs	Benefits (after 5 years)
– Cost of special equipment[1] – Higher costs of means (also chemical) to fight weeds, plants illnesses and pest – Social: less work -> loss of jobs in agriculture – Pollution due to chemicals used against weeds, plants illnesses and pest	– increase of agricultural yields – yields more stable – higher soil retention – increase of decay in the soil (fertilizer for future crops) – increase of CO_2 sequestration (of about 36 Mg CO_2/ha) – saving fuel and man-months costs – increase of jobs in equipment production – increase of biodiversity (especially soil organisms) – increased biologic activity of soil

9.2 The costs and benefits of conservation tillage

Usually cost benefit analysis of conservation tillage focuses on water quality aspects or overall profitability. Here we look at costs and benefits of conservation tillage in terms of water retained in the landscape, i.e. reduction of runoff, and hence contribution to flood protection. The costs and benefits are shown in Table 9.2.

[1] In follow-up phone calls to detail this statement, farmers could not specify these presumed costs, reporting that they did not know how high they would be.

Table 9.2 – Overview of costs and benefits of switching from conventional tillage to conservation tillage*

	Quantified costs and benefits		Non-Quantified costs and benefits
Costs and cost savings	Euros ha^{-1}	Euros m^{-3}	
Machinery wear and fuel	-39	-0.38	
Pesticides	19	0.19	
Labor	-42	-0.40	Social costs of increased unemployment in the agricultural sector due to reduced labor requirements (or benefits if high employment and opportunities for absorbing labor in higher productive activities.
Total annual Tenant costs	-61	-0.60	
Total Discounted Costs (5%over 30 years)	**-944**	**-9.2**	
Total Discounted Costs (10% over 30 years)	-579	**-5.6**	
Benefits			
Flood protection			Retains water in the landscape
Soil protection			Reduced erosion.
Soil fertility maintenance		-	Reduced compaction, increased organic content, increased nutrient content of the soil.
Water protection			Reduced nutrient leaching, reduced silting.
Crop production			Reduced fuel, labour, irrigation and machinery costs (included in reduced costs above). Potenially increased crop yield.
Biodiversity			Increased.
Pollination			Increased shelter and fodder is very likely to increase the abundance of wild pollinators.
Pest control			Reduced abundance of pests like slugs etc., enhanced abundance of pest controlling soil organisms.
Climate protection			Increases albedo which has a net cooling effect.
Carbon Sequestration			Enhanced storage of carbon in soil

* The additional costs of conservation tillage in comparison to conventional tillage

Source: Adapted from FAO 2001, Jordan et al. 2000

9.2.1 Quantified costs

Switching practices from conventional tillage to conservation tillage can reduce costs – with the possible exception of the extreme case of no-tillage (which will require the purchase of new types of machinery). For reduced or conservation tillage no new equipment may be required (Leys et al. 2007). The same or smaller tractor could suffice, and in any event (conservation or no-tillage) machinery wear will be reduced, as will fuel and labor costs (Table 9.2), by reducing the number of times that heavy farm equipment travels over a field (from seven or more to four or fewer; Huggins and Raganold 2008). The costs for pesticides will be increased, since weed management relies on herbicides (Table 9.2).

In the extreme case of transforming practices to no-tillage, investment in a new type of seeder may be required, which could be subsidized by the government (or from CAP funds). For example in some regions of Australia the purchase of such a seeder is eligible for a refundable tax offset, one of the factors that led to widespread and successful implementation of no-tillage. Huggins and Reganold (2008) report that a sophisticated seeder for no-tillage is priced at ca. 80,000 Euros; however operating and maintaining other tillage equipment is no longer necessary, lowering the total capital and operating costs of machinery required for crop establishment by up to 50 percent (Huggins and Raganold 2008).

9.2.2 Non-Quantified Costs

We have not quantified the social costs of potentially more unemployment due to reduced labour costs of conservation tillage practices.

9.2.3 Non-Quantified Benefits

Many physical environmental impacts of switching to conservation tillage are well recognized but seldom evaluated in economical terms (Sanders 2000). Here we summarize such benefits using the concept of ecosystem services (Millennium Ecosystem Assessment 2005).

Switching from conventional tillage to conservation tillage increases the ecosystem service **flood protection** on a landscape scale. The higher crop cover densities slow water movement by reducing direct water impact on bare soil, by slowing water movement on the surface and encouraging greater rates of infiltration to the soil and percolation down to the groundwater level, and by increasing the density of organic material both above and below ground and thereby enhancing water absorption and retention in the soil itself. Jordan et al (2000) report that the transition from conventional plowing to conservation tillage reduced runoff per hectare from 213 to 110 m^3, for a net retention of 103 m^3ha^{-1}, or 48% (we based our cost estimates on this number, see also Appendix IV). Other estimates on runoff reduction due to changed tillage lie in the same range (e.g. Leys et al. 2007; UNEP 2004 p.147).

As water permeability of the soil is improved, and aggregates are stabilized, the soil is also substantially better **protected against erosion** (Jordan et al. 2000; Uri et al. 1999; Holland 2004). Deasy et al. estimate that conservation tillage can lower soil losses through erosion by between 24 –79%, depending on the specific practice (Deasy et al. 2008).

Conservation tillage systems also benefit farmers by reducing soil compaction and therefore better **maintaining soil fertility.** Further factors contributing to soil fertility maintenance are increased organic and nutrient content and recycling of the soil (Holland 2004), as well as improved soil structure and microbial activity (Jordan et al. 2000).

Conservation tillage may also decrease the risk of runoff and pollution of surface waters with sediment, pesticides and nutrients (FAO 2001; Holland 2004), thereby contributing to **water protection.** For example, the proportion of farmland in Ohio's Maumee and Sandusky River watersheds under conservation tillage rose from 5 to 50% between 1985 and 1995 (Lok 2001). At the same time, nitrogen levels in these rivers dropped by around 15% and phosphorus fell by about 48% (Lok 2001). It should however be noted that the overall usage of pesticide is likely enhanced in conservation tillage cultivation, since weed control relies solely on herbicides (Blevins et al. 1983). Therefore careful management is needed to realize the full water protection potential (Gebhardt et al. 1985).

Crop yields under conservation tillage are more stable and crop production profitability tends to increase over time relative to conventional agriculture (FAO 2001). Conservation tillage conserves soil moisture and reduces extremes of water logging and drought (Holland 2004). Thus **crop production** under conservation tillage is potentially enhanced, due to enhanced soil moisture and overall reduced soil degradation (Lafond et al. 1992; Jordan et al. 2000). Where water availability limits crop production, greater water conservation can mean higher-yielding crops or new capabilities to grow alternative crops (Huggins and Reganold 2008).

Conservation tillage increases soil and terrestrial **biodiversity** (FAO 2001), as well as habitat for wildlife (Uri et al. 1999). Aquatic wildlife will also profit due to increased water quality through less sediment and pollutants in agricultural runoff (see above; Holland 2004). A richer soil biota under conservation tillage improves nutrient recycling (Holland 2004) and leads to better **pest and disease control** (Jordan et al. 2000, Holland 2004). The greater availability of crop residues and weed seeds improves food supplies for birds and small mammals. In a study published in 1986, researchers in Iowa found 12 bird species nesting in no-till fields, compared with three species in tilled fields (Huggins and Reganold 2008). Insects also profit from conservation tillage (Holland 2004), with likely benefits for **pollination**. Pollination is a vital ecosystem service currently in decline worldwide (Potts et al. 2010). However, since herbicide use under conservation tillage is increased with potential harmful effects, and insecticide use may be decreased through natural pest and disease control, further studies are needed to examine the net effect on wild and domestic pollinators.

As conservation tillage slows water movement, reduces soil erosion, and increases the amount of organic material both above and below ground, **carbon sequestration** is enhanced, thus contributing to climate mitigation (Reicosky, 1997; Veseth, 1998, Holland 2004). Moreover, conservation tillage increases the albedo of the land and leads to a net cooling effect (Lobell et al. 2006), which contributes to **climate protection**.

10 Comparing on-farm and off-farm water retention measures

In this section, we summarize and compare the main costs and benefits of selected on-farm water retention measures – ponds, shelterbelts, and reduced tillage practices – with off-farm large and communal reservoirs. We compare the investment and discounted maintenance costs of the five different measures for storing or retaining a cubic meter of water in the landscape or preventing a cubic meter of runoff over 30 years. Finally, we list the un-quantified costs and benefits of these measures.

10.1 Cost efficiency of selected water-retention measures

Table 10.1 shows a wide range of estimates across measures and also within measures (see appendix VI for more details). The uncertainties around these estimates result from differing contexts (for example, the different costs of shelterbelts in Wales versus New Zealand) and also the different assumptions surrounding these estimates (detailed in Appendices I-V). Comparisons cannot at this writing be made between reservoirs/ponds and shelterbelts/conservation tillage because we cannot compare storage capacity with the reduction of annual runoff. Still, the figures suggest ***that there are cost-effective natural water***

retention options that could complement or replace large reservoirs as a flood and drought protection measure. Because of its reduction in farm costs, one cost effective measure for storing water in the landscape is switching to conservation tillage practices. The numbers also show large economies of scale in storing water in reservoirs.

Table 10.1: Summary of costs for averting runoff and storing water

Flood & drought management practice	Costs (Euros)		Investment + maintenance costs /m3 water stored or annual runoff averted	
	Discount Rate		**Discount Rate**	
	5%	10%	5%	10%
CONSERVATION TILLAGE (30 years)	Total cost/ha		**Construction and maintenance costs/m3**	
Conventional tillage	6,369	3,906	-9.2 *	-5.6 *
Conservation tillage	5,426	3,327		
SHELTERBELTS (4 years maintenance)				
Wales	24,971	24,236	6.07	5.91
Elbe	2,979	2,888	2.29	2.22
NZ	13,554	12,957	10.43	9.97
Warta	9,939	9,342	6.86	6.47
SHELTERBELTS (10 years maintenance)				
Wales	33,133	30,050	7.77	7.12
Elbe	3,990	3,608	3.07	2.78
NZ	20,177	17,675	15.52	13.60
Warta	16,562	14,060	12.74	10.82
PONDS (20-30 yr lifetime)	**Total costs**		**Construction and maintenance costs/annual**	
China (26,167 m3)	17,124	12,783	0,60	0,46
UK (33 m3)****	5,466	3,871	558.00	382.00
Warta (210,000 m3)	1,234,466	1,149,321	5.88	5.47
RESERVOIRS (30 yr lifetime)				
Wielowies Klasztorna (48.8 million m3)	81 992 000		1.68	1.56
Katy Myscowa (65.5 million m3)	377,200,000	309,050,000	5.76	4.72
Wloclawek (376 million m3)	2,654,755,833	1,666,306,264	7.06	4.43

*Cost for switching from conventional to conservation tillage ** 409 m3 per hectare per year; *** 130 m3 per hectare per year; **** average of 16 cases. Note, pond lifespan can be as short as 20 years, which would require major costs not included in these calculations.

One important result shown in Table 10.1 is that the most cost effective measure for reducing runoff is switching to conservation tillage practices. The reason is that this switch reduces machinery and labor costs in addition to reducing water runoff. This measure is not directly mentioned in the Water Blueprint. Our preliminary estimates show that it deserves more analysis and attention as a flood mitigation measure.

The most important message from these estimates is that they show the importance of carrying out full cost-benefit calculations. While the primary benefit from the large Wielowies Klasztorna reservoir is flood control, this is not the case of the other reservoirs documented in Table 10.1, nor is it the case of on-farm ponds, shelterbelts and conservation tillage. In the next section, we discuss additional costs and co-benefits of water-retention measures as they are applied in the Warta region.

10.2 Costs and benefits of water-retention measures in the Warta region

Table 10.2 summarizes our calculations on the cost effectiveness of on-farm and off-farm water-retention measures with the most important non-quantified costs and co-benefits. Those costs and benefits related to climate change mitigation and adaptation are marked in bold.

Table 10.2: Cost effectiveness of selected NWRM in the Warta region with non-quantified costs and co-benefits (climate change costs and benefits marked in bold)

Water retention measures	Investment & maintenance costs/m3 water stored* or annual runoff reduced	Climate change mitigation and other significant non-quantified costs	Climate change mitigation and other significant co-benefits
Large reservoir (Wielowies Klasztorna) 49 million m3	€1.68 per m3 water stored	Increased CO2 emissions (deforestation for construction) Restriction of fish migration Reduction of groundwater levels downstream Social and psychological costs of displaced persons	Decreased CO2 emissions from electricity production Tourism Contribution to biodiversity Fisheries
Large on-farm pond (Warta data) 210,000 m3	€5.88 per m3 water stored	Increased CO2 emissions (deforestation for construction)	Contribution to biodiversity (including migration corridors) Landscape enhancement & recreation (also fishing)
Small on-farm pond (U.K. data) 140 m3	€558.00 per m3 water stored	Increased CO2 emissions (deforestation for construction)	Contribution to biodiversity (including migration corridors) Landscape enhancement & recreation
Shelterbelt (Warta data)	€6.86* per m3 annual runoff reduced	Reduced crop acreage Retards satellite monitoring	**Sequestration of CO2** Contribution to biodiversity (including pollination) Increased yield from remaining crops Reduction of land degradation
Switch to conservation Tillage (U.S data)	- €9.20 per m3 annual runoff reduced	Increased pesticide use	**Sequestration of CO2** **Less fuel use** Contribution to biodiversity, pollination & water quality Increased agricultural productivity Reduction of land degradation

* Among other assumptions, calculations are based on 30-year project life and discount rate of 5%. Estimates are preliminary and approximate.

If the sole intent of these investments is to retain water in the landscape, we could conclude that conservation tillage and reservoirs are more attractive investments than communal/small ponds and shelterbelts. We cannot, however, draw this conclusion without valuing the non-quantified costs and co-benefits of these investments.

The main costs and co-benefits, as discussed by stakeholders in the Warta region, are listed in Table 10.1. For large reservoirs, it is important to consider their costs in terms of increased CO2 emissions (deforestation for construction), restriction of fish migration, reduction of groundwater levels downstream, and the social and psychological costs of displaced persons. At the same time, large reservoirs have added benefits including, among others, electricity production decreasing CO2 emissions, tourism, contribution to biodiversity, and fisheries.

A main benefit derived from complementing or replacing large reservoirs with smaller communal or on-farm ponds is their additional contribution to biodiversity by providing a mosaic of water bodies supporting corridors for migration. Shelterbelts also have large benefits outside of their contribution to flood and drought risk management. In fact, a main benefit is reduction of wind erosion, and they also contribute to the sequestration of CO2, increased crop yields, pollination and landscape enhancement.

Finally, switching to conservation tillage appears to be a win-win strategy across a range of costs and benefits. The net additional economic costs for this switch appear to be negative, that is, there is a net gain to the farmer in terms of additional equipment and labor costs, which compensates for the additional (economic) costs for pesticide use. The benefits are primarily in terms of natural water retention, and also sequestration of CO2, contributions to biodiversity and increased agricultural productivity.

For the Warta region, this analysis appears to confirm a conclusion from the Stakeholder Workshop (see Appendix VIII), where stakeholders agreed that the Warta region would benefit from a mosaic of natural water retention measures, or green infrastructure, in addition to the grey infrastructure in the form of existing and planned large reservoirs. Given that it would take an average of over 60 community ponds or 2,500 small on-farm ponds, respectively, to provide the same capacity as one average large reservoir, a mixture appears to be needed. This mosaic could change, however, with extensive investments in other green infrastructure, such as shelterbelts (examined here) and also buffer strips, and with a change of farmer practices to conservation tillage.

11 Conclusion

This analysis shows the importance of carrying out more extensive cost-benefit estimates across on-farm and off-farm measures for tackling drought and flood risk in the context of a changing climate. While concrete recommendations for supporting water retention measures will depend on a more detailed investigation of their costs and benefits, this deliverable highlights the potential of natural water retention measures as a complement to conventional investments in large reservoirs.

One important result is that a cost effective measure for reducing runoff, possibly the most cost effective measure, is switching to conservation tillage practices. The reason is that this switch reduces machinery and labor costs in addition to reducing water runoff. This measure is not directly mentioned in the recent

European Union Water Blueprint (A Blueprint to Safeguard Europe's Water Resources). Our preliminary estimates show that it deserves more analysis and attention as a flood mitigation measure.

Although shelterbelts that reduce annual runoff cannot be directly compared to ponds and reservoirs that store water, our estimates show that they likely compare favourably as a natural water retention measure, especially when taking account of their co-benefits in terms of erosion control, biodiversity and pollination.
Another useful result is our demonstration of the economies of scale among reservoirs and ponds for storing water. Small ponds are two orders of magnitude more costly to construct and maintain as a flood and drought prevention measure than large reservoirs. Here, again, there are large co-benefits that should be factored into the cost-benefit equation, including especially the value of small ponds in promoting corridors for migration.

Our results should prove useful for assessing measures discussed in the European Commission Blueprint (A Blueprint to Safeguard Europe's Water Resources), which emphasizes the importance of Natural Water Retention Measures (NWRM) that support biodiversity, erosion control and small water bodies.

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APPENDICES

Appendix I: Cost-benefit estimates for two reservoirs: Wloclawek and Katy-Myscowa

Appendix II: Cost-Benefit estimates for ponds

Appendix III: Cost-benefit estimates for shelterbelts

Appendix IV: Cost-benefit estimates for conservation tillage and no-till

Appendix V: Summary of costs for runoff averted and water stored

Appendix VI: Interviews

Appendix VII: Workshop

Appendix I: Cost-benefit estimates for two reservoirs: Wloclawek and Katy-Myscowa[2]

A detailed description of the cost-benefit analysis for the Wielowies Klasztorna reservoir can be found in the text. For comparative purposes, the intent of this Appendix is to provide estimates of the costs and benefits for two additional reservoirs: Wloclawek (constructed in 1970 to give an historical account) and Katy-Myscowa (planned).

The two cases are based almost entirely on two reports (Wawrety and Zelazinski 2006 and 2007) published by the Green Network http://zielonasiec.pl/en/ (a national alliance of ten non-governmental environmental and sustainable development associations and foundations) and the Society for Earth (TNZ) http://www.tnz.most.org.pl/en/ (a Polish non-governmental organization acting to preserve, protect and recover the natural heritage and to protect human health and life from the consequences of pollution).

All values are in euro 2012 using the Consumer Price Index (CPI):

- for values in euro (Source: http://fxtop.com/en/inflation-calculator.php?A=1&C1=EUR&INDICE=EUCPI2005&DD1=01&MM1=01&YYYY1=2000&DD2=19&MM2=03&YYYY2=2013&btnOK=Compute+actual+value;
- for values in polish PLN (Source: http://krzysztofsikora.pl/kalkulator-inflacji.php)
- for chinese yuan (Source: http://www.inflation.eu/inflation-rates/china/historic-inflation/cpi-inflation-china-2012.aspx and http://www.measuringworth.com/chinacompare/result.php)
- for New Zealand dollar (Source: http://fxtop.com/en/inflation-calculator.php?A=1&C1=NZD&INDICE=NZCPI2006&DD1=15&MM1=06&YYYY1=2005&DD2=15&MM2=06&YYYY2=2012&btnOK=Compute+actual+value)

[2] The currency conversion is 1 PLN=0,23868 Euro(http://themoneyconverter.com/PLN/EUR.aspx) The assumed lifetime of the reservoir is 30 years. Present value calculations are based on 5% and 10% discount rates.

The Wloclawek reservoir

The Wloclawek reservoir was constructed in 1970. It has an area of 70.5 km2, a maximum and minimum depth of 15 and 5.5 meters, respectively, and a total water storage capacity of 376 million m3 (Wawrety and Zelazinski 2006). The benefits and costs shown in Tables I.1 and 2. were estimated in 2000 PLN and converted to 2012 euro (Conversion: 1PLN in 2000 = 1.46PLN in 2012).

Table I.1: Estimated benefits of the Wloclawek reservoir

Benefits	A priori Estimates	PRESENT VALUE (30 years) Million EURO	
	Million EURO	5,00%	10,00%
Power plant, internal[3]	477.45/yr	7,339.62	4,500.91
Power plant, external[4]	120.77/yr	1,856.53	1,138.49
Recreational profits (additional to those of unregulated river)[5]	0	0	0
River transport[6]	0	0	0
Dam serving as a bridge[7]	14.38	14.38	14.38
	Total benefits	9,210.53	5,653.78

Source: Adapted from Wawrety and Zelazinski 2006

Table I.2a: Estimated costs of the Wloclawek reservoir

Costs[8]	Estimation[9],	PRESENT VALUE (30 years) Million EURO	
	Million EURO	5,00%	10,00%
Building barrage (initial and subsequent investments in strengthening the barrage)[10]	106.32	106.32	106.32
Building power plant[11]	126.28	126.28	126.28
Submerged land[12]	11.33	11.33	11.33

[3] Sale of electricity – price was assumed as 121,5 PLN/MWh (price based on tariff of Energy Regulatory Office for Polish Electro-energetic Networks), energy production was assumed to be 1/3 during peak and 2/3 outside peak

[4] The repot added in the avoided external cost of fuel consumption in power plants assumed at 94 PLN/MWh (Bartczak, 2000, Environmental and economic analysis of the enterprises financed by the National Fund for nature's protection. Final report. Warsaw Ecological Economics Center). However, this value is double counting the value of electricity.

[5] Survey of mayors of municipalities in the vicinity of the tank

[6] Unfavorable conditions for navigation

[7] Assumed value based on half of costs of building bridge in Wyszogrod (information from Dromex webpage)

[8] Ecological costs were not taken into account in the report because of methodological problems (Panasiuk D., 2010 'Value of the Environment in the analysis of costs and benefits of water reservoirs in Poland ', p. 6)

[9] Values have been discounted, discount rate 3% to the level from 1970

[10] Hydroprojekt 2000, Analysis of cost division of maintenance of water degree in Wloclawek; costs of land purchase were excluded and were calculated in position 'Submerged land'

[11] Hydroprojekt 2000, Analysis of cost division of maintenance of water degree in Wloclawek

[12] Review of local land prices - survey of mayors of municipalities in the vicinity of the tank

Production and distribution of electricity[13]	81.69	1 255.81	770.11
Maintenance of the dam and reservoir[14]	79.82	1 227.10	752.50
Flooding costs[15]	20.42	20.42	20.42
Losses for fishing[16]	4.95	76.07	46.65
Dredging safe sediment[17]	86.43	1,328.58	814.73
	Total costs	**4,151.91**	**2,648.33**

Source: Wawrety and Zelazinski 2006

Table I.2 b: Estimated construction, maintenance (+dredging) costs of the Wloclawek reservoir for flood control per m3 water stored

Costs	Million EURO	PRESENT VALUE (30 years) Million EURO	
		5,00%	10,00%
Building barrage*	88.14	88.14	88.14
Road infrastructure * **	4.10	4.10	4.10
Facilities ******	6.84	6.84	6.84
Dredging safe sediment *****	86.43	1,328.58	814.73
Maintenance of the dam and reservoir[18]	79.82	1,227.10	752.50
	Total costs	2,654.76	1,666.31
	Cost / m3 water stored	**7.06**	**4,43**

Source: Adapted from Engel J, M Kaczynska, M Wisniewska 2001 (Tab. 3)

* The front dam, weir, sluice, pillar, side dam and shafts, river regulation on the lower position, channel A and drainage works, protection of the edges of the reservoir ** Additional drainage construction and land redemptions *** Road crossing on the degree, Roads and Bridges **** Operational facilities of the degree, shipping facilities, protection of other facilities ***** See SEDIMENTS COMMENTS

Calculating sedimentation and dredging costs

The reservoir resulted in a reduced flow rate and the deposition of material lifted and dragged by the river (sedimentation)

[13] Based on tariff of Energy Regulatory Office where price for energy from hydro plant in Wloclawek was set for 17,11 PLN/MWh (this price is supposed to be approximation of cost of production of energy)
[14] Operating costs have been adjusted for the costs of maintaining the river in situation when barrage would not exist (Engel J, M Kaczynska, M Wisniewska 2001)
[15] Costs of flooding in 1982 times flooding probability equal to 1%
[16] Based on data on fishing of vimba bream, trout and common bream before 1968 and in subsequent years (price of trout and vimba bream was assumed to be 25 PLN/kg, and common bream – 9 PLN/kg)
[17] See SEDIMENTS COMMENTS
[18] Operating costs have been adjusted for the costs of maintaining the river in situation when Wloclawek barrage would not exist (Engel , Kaczynska and Wisniewska 2001)

- It is estimated that in the 30-year period, (1970-2000) 45 million m3 of sediments was deposited in the reservoir. While maintaining the current rate of sedimentation (approximately 1.7 million m3/yr) the reservoir will fill in about 80 years (2080).
- The chemical composition of deposits can present additional problems in the future.
- The lack of sedimentation in the river below the dam has caused erosion and the need to refill it with the sedimentation extracted from the reservoir and transported down the river.
- It would be best to carry 1.7 million m3 per year of sedimentation, however this operation is very expensive and time consuming. For this reason, the authorities have proposed that about 300,000 m3 of sediments be transported per year.

Source: WWF Poland 2001

Table I.3: Estimated dredging costs for the Wloclawek reservoir

Action	COST per m3	Sed. Rate	Total Annual Cost	PRESENT VALUE (30 years), Million EURO	
	EURO	m3 yr-1	Million EURO	5,00%	10,00%
Dredging toxic sediment	203.36	1,700,000	345.70	5,314,32	3,258.92
Dredging safe sediment	50.84	1,700,000	86.43	1,328.58	814.73

Source: IIASA based on: I. Engel J, M. Kaczynska, M Wisniewska 2001. II.Brański J. and Banasik K. 1996

Table I.4: Sedimentation Rates in the Vistula River

Gauging Station	Drainage Area	Sediment Yield		Discharge	Period	Sediment Yield	
	(km2)	/yr	Units	(m3 s-1)		30 yrs accum.	units
Wloclawek	172,389	1720	1000 t	934	1956-1990	51,600,000	t
		1152.4[19]	13 sand			34,572,000	sand

Source: Brański, J and K Banasik 1996

Note: there is a discrepancy between the sedimentation accumulated as predicted by measured sediment yield (Branski and Banasik 1996) and by engineering estimate above.
Conversion rate for sediment tons of sand to cubic meters:

- 1 m3 sand = 2.08 metric tons (1 metric ton = 0.48077 m3) (Source: Online Conversion.com (http://www.onlineconversion.com/forum/forum_1122501366.htm).
- 1 ton sediment = 0.67 m3 (Source: Hufschmidt. M.M. and Srivardhana. R. 1986).
- 1.5 ton sediment = 1m3 (1 ton = 0.66667 m3). (Source: Helcom Monas 9/2006)

Conversion factors between cubic meters (wet volume) and tons (dry weight) of dredged material that can be used in the absence of analytically determined values (type of dredged material (silt)):

- The wet weight: 1 m3 water- saturated sediment (wet volume) above water surface = 1,6 tons
- The dry weight: 1 m3 sediment = 1,1 tons

[19] 1720 x 0,67

(Source: Cato 1977)

The Katy-Myscowa reservoir

The Katy-Myscowa reservoir is still in the planning stages. It is estimated to cover an area of 4.27 km2 with a total storage capacity of 65.5 million m3 (The Regional Water Management Board in Krakow (RZGW) http://www.krakow.rzgw.gov.pl). A cost-benefit study on the project was carried out by the Polish Green Network and Society for Earth (TNZ) (Wawręty R and J Zelazinski 2007; 2006).

The estimated benefits and costs are shown in Tables I.5 and I.6. The estimates were originally reported in 2001, 2003 and 2007 PLN, and have been converted to 2012 euro (Conversion: 1PLN in 2001 = 1.41PLN in 2012; 1PLN in 2003 = 1.38PLN in 2012; 1PLN in 2007 = 1.25PLN in 2012).

The costs shown in Tables I.8 have been estimated in 1996 PLN and converted to 2012 euro (Conversion: 1PLN in 1996 = 2.13PLN in 2012)

Table I.5: Estimated benefits of the Katy-Myscowa reservoir

	Hydroprojekt Million EURO		Lemtech 2007 Million EURO		Average Million EURO	PRESENT VALUE (30 years) Million EURO	
	(2001)	(2003)	(MIN)	(MAX)		5,00%	10,00%
Flood protection	1.5	8.3	13.7	25.5	12.25/yr	188.25	115.44
Recreational profits	3.0	4.2	4.3	7.1	4.63/yr	71.16	43.64
Increase in land price in area near reservoir	One-off increase	One-off increase	9.6	17.9	13.78/yr	211.89	129.94
Annual alignment of the river flow in order to obtain the required water quality classes	0.2	2.6	-	-	1.39/yr	21.29	13.06
Increasing the supply of drinking water in Jaslo and area	10.8	1,3	18.6	33.5	16.04/yr	246.53	151.18
Production of electricity (operational income)	0.3	0.4	0.8	1.4	0.72/yr	11.05	6.78
Increase / maintain jobs and capital absorbed by the local market goods and services during construction (2008-2016)	-	-	3.6	10.8	7.22/yr	110.99	68.06
Benefits for employees (from 2017)	-	-	0.1	0.2	0.16/yr	2.52	1.55
Environmental effects associated with the production of renewable energy	-	0.2	0.2	0.4	0.26/yr	4.07	2.50
Total benefits						**867.6**	**532.14**

Sources: Wawręty R and J Zelazinski 2007; 2006

Table I.6. Estimated costs of the Katy-Myscowa reservoir

Costs	Hydroprojekt, Million EURO		Lemtech 2007, Million EURO		Average, Million EURO	PRESENT VALUE (30 years), Million EURO	
	(2001)	(2003)	(MIN)	(MAX)		5,00%	10,00%
Investments	167.2	214.9	211.0	211.0	201.00	201.00	201.00
Operational costs	0.4	0.2	0.4	0.7	0.43/yr	6.55	4.02
Dredging safe sediment[20]	-	-	-	-	-	169.65	104.07
Total cost						377.20	309.05
					EURO / m3 water stored	**5.76**	**4.72**

Source: Wawręty R and J Zelazinski 2007; 2006

Table I.7. Sedimentation Rates in the Vistula River

Gauging Station	Drainage Area	Sediment Yield	Discharge	Period	Sediment Yield		Storage Capacity Remaining
	(km2)	1000 t / yr	(m3 s-1)		m3 sand / yr[21]	30 yrs accum.	%
Krajowice	2,092	236	23	1956-1990	158,120	4,743,600	99.93
Mielec	3,915	324	34.4	1956-1990	217,080	6,512,400	99.90

Source: Brański, J and K Banasik 1996

Table I.8 Estimated dredging costs for the Katy Myscowa reservoir

Action	COST per m3	Sed. Rate	Total Annual Cost	PRESENT VALUE (30 years), Million EURO	
	EURO	m3 yr-1	Million EURO	5,00%	10,00%
Dredging safe sediment	50.84	217,080	11.07	169.65	104.07

Source: IIASA based on: I. Engel J, M. Kaczynska, M Wisniewska 2001; II. Brański J. and Banasik K. 1996

[20] Calculations in the Table III.3 Estimated dredging costs for the Katy Myscowa reservoir

[21] Sediment yield x 0,67 (from the table Conversion rate: Sediment tons to cubic meters, as above)

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Appendix II – Cost-Benefit estimates for ponds

In this Appendix, we show the calculations for the cost-benefit estimates of the on-farm pond in the Warta. For purposes of comparison, we also report estimates of selected costs and benefits for ponds in China and the UK.

On-farm pond in the Warta

The figures reported for the on-farm pond in the Warta were recorded from an interview with farmer Stefan Jankowiak (October 2012). The numbers have not been validated. The pond covers 14 hectares with a depth of approximated 1.5 meters and volume of 210,000 m3. The economic life of the pond is assumed to be 20 years, although the calculation (for comparison)were done for 30 years like in other cases. In order to obtain a 30 years time scale, the construction costs (pond preparation and excavation) were calculated twice, and the maintenance costs discounted over 30 years.

Table II.1. Investment and maintenance costs of Warta on-farm pond

Costs	Average (estimation)	PRESENT VALUE (30 years), EURO	
	EURO	5,00%	10,00%
Pond preparation *	29,800	59,600	59,600
Pond excavation **	477,360	954,720	954,720
a.Pond maintenance (mowing dikes twice per year)	10,741/yr	-	-
b.Pond maintenance (fixing and conserving dikes)	3,580/yr	-	-
Total annual Pond maintenance (a+b)	**14,321/yr**	**220,146**	**135,001**
Total costs		**1,234,466**	**1,149,321**
	EURO / m3	**5.88**	**5.47**

Source: Anna Dubel interview with farmer Stefan Jankowiak (October 2012)

* Dikes, digging bypass, irrigation and drainage from fields **digging when natural landform not sufficient to retain water

Ponds in China

Below we show adjusted estimates for the costs and benefits of small ponds in China, primarily constructed for the purpose of fisheries, but also used for drought management by irrigation. The analysis is based on Mushtaq, S, Khan, S, and Hafeez M (2009). The benefits and costs shown in Tables II.2 and 3 have been estimated in 2009 Yuan, then converted to 2012 euro (Conversion: 1Yuan in 2009 = 1.12Yuan in 2012).
In making our estimates we assumed the following:

1. The conversion factor used in all calculations is 1 Yuan=0.1216 Euro (Date valid: 31 Dec 2012, Data source: http://www.currency-converter.org.uk/currency-rates/historical/table/CNY-EUR.html)
2. The original data were expressed in the Chinese unit called "mu", where 15 mu = 1 hectare (1 mu = 0.067hectare). The tables below present data converted to hectares.
3. The time scale adopted in the calculations is 30 years. The time horizon (life expectancy of a pond) is 20 years, after this period a pond must be totally refurbished. In order to obtain a 30 years time scale, the construction costs were calculated twice, and the maintenance costs discounted over 30 years. (Source: Mushtaq, S, Khan, S, and Hafeez M. 2009.)
4. Two different average pond volumes were used for Cost/m3 water stored calculations:
    - 36,993 m3 (see Table II.4 and 5)- as effect of calculations from the area served by pond (hectares) and the median value of water per ha (liters)
    - 26,167 m3 (see Table II.6)- as effect of a visual inspection

Table II.2. Costs of constructing ponds in China

Costs	Costs	PRESENT VALUE (30 years), EURO	
		5,00%	**10,00%**
Capital	Construction	3,538.81	3538.81
Capital	Pump set	1770.50	1770.50
Capital	Piping, hose, wires	590.17	590.17
Variable	Pumping cost	4198.38	2574.59
Variable	De-siltation	1110.31	680.88
Variable	Channel clearing	1129.85	692.86
Variable	Repair Maintenance	461.29	282.88
Variable	Pond Mgr. wage	1779.56	1091.29
Variable	Other expenses	509.44	312.41
Variable	Miscellaneous costs	628.08	385.16
Total 30 years		**15,716.39**	**11,919.54**
	Cost/ m3 over 30 years **	0.42	0.32
	Cost/ m3 over 30 years ***	0.60	0.46

Source: Mushtaq, S, Khan, S, and Hafeez M. 2009

* The Zhanghe Irrigation System (ZIS) accounts for most of the irrigated area in Zhanghe Irrigation District (ZID) where the study was conducted, located in Hubei Province, in the Yangtze River basin of China. The Zhanghe basin has an area of 7740 km2, including a catchment area of 2200 km2. ** for the average volume of 36,993 m3 *** for the average volume of 26,167m3

Table II.3. Benefits of ponds in China by volume

Benefits	*Volume (m3)*	< 1000	1.000 to	> 10.000
	Median Volume (m3)	500	5.000	10.000
Tangible	Fish harvest (kg yr-1)	100	225	2,134
Tangible	Fish harvest (euro)	15.91	22.85	333.74
Tangible	Incremental benefits from crop production*			
Intangible	Improved groundwater recharge			
Intangible	Domestic water supply			
Intangible	Reduced flood risk			

* increased cropped area, yields, changes in cropping patterns

Small-size ponds (< 1000 m3) show diseconomies of scale (1.19). The medium (1.000 to 10.000 m3) and the large ponds (> 10.000 m3) show moderate economies of scales (0,76 and 0,66). The large ponds that serve an area of about 6.70 ha, imply that if area and fish harvest increase by 10%, cost would increase no more than 7.7%.

Table II.4. Distribution of area served by ponds, by pond size, by village

Village	Area served by pond (hectares)									Overall		
	Small			Medium			Large					
	N	Mean	S.D	N	Mean	S.D	N	Mean	S.D	N	Mean	S.D
Shuangbie	1	1.33	--	7	2.00	1.07	2	4.33	2.36	10	2.40	1.57
Wuba	3	0.76	0.54	3	4.00	1.15	3	7.33	3.05	9	4.03	3.29
Huangyan	2	0.43	0.14	5	4.40	1.80	3	8.89	6.94	10	4.95	4.69
Sundian	3	1.86	0.17	3	2.93	1.54	3	5.47	2.47	9	3.42	2.17
Overall	**9**	**1.12**	**0.68**	**18**	**3.16**	**1.66**	**11**	**6.70**	**4.05**	**38**	**3.70**	**3.20**

Source: Mushtaq S. (2004)

Volume of ponds

To convert the area served by the pond to the pond volume, we assume the following[22]

1. Since 98% of land around these ponds is irrigated for rice production, which varies from 8 ML to 12 ML per ha, we use the median value of 10 ML (10 million liters per ha = 10.000 m3 per ha)
2. We assume all the land served by the pond requires watering multiple times per year but adds up to the avg. of 10 ML ha-1 yr-1. So we estimate pond volume from the land area served
3. Using overall figures, we derive pond volumes for small, medium and large ponds

Table II.5. Pond size calculations

Village	Pond Size						Overall	
	Small		Medium		Large			
	N	m3	N	m3	N	m3	N	m3
Overall (average)	**9**	11,167	**18**	31,553	**11**	67,000	**38**	**36,993**

Source: IIASA based on Mushtaq S. (pers. comm. per email 14 Dec 2012)

Table II.6. Pond size estimates

	l	w	d	Vol. (m3)
Small	100	50	1,50	7,500
Medium	150	70	2	21,000
Large	250	100	2	50,000
Overall (average)				**26,167**

Source: visual inspection of Fig. 7 a-c in Mushtaq S. (2004)

Ponds in the UK

General notes:

1. The Pound/Euro conversion rate used in all calculations is 1,2025. (source: http://www.currency.me.uk/convert/gbp/eur)
2. Maintenance costs include dredging sediment from pond and dispersing it on the field. For most of these ponds, dredging must be done every 4 years. Assumption: Dredging and dispersal costs are 62 to 64% of construction costs in the case of Gully Trap, so we apply that ratio across the board. All maintenance costs except n 13 and 14 were derived using the 62% of construction costs criterion
3. Time horizon: 30 years. After 30 years a pond must be totally refurbished.

Table II.7: Costs to establish and maintain small ponds (euro) - excavation, drainage, fencing and vegetation

Costs		Dimensions				PRESENT VALUE (28 years) 5% discount		PRESENT VALUE (28 years) 10% discount	
Site	**Name**	**Area (ha)**	**Area (m2)**	**Volume (m3)**	**Con-struction**	**Main-tenance**	**Total Costs**	**Main-tenance**	**Total Costs**
Loddington	Upper Ponds	10	100	38	1443	3092	4535	1794	3237
Leicester-shire				18	1792	3840	5631	2228	4019
	Paradise	4	20	6	1804	3866	5669	2243	4046
				8	2249	4819	7068	2796	5044
	Little Owl	9	22	11	553	1185	1739	688	1241
Crake Trees Manor,	Bill & Ted	20	200	51	1203	2577	3780	1495	2698
Cumbria				51	1491	3196	4687	1854	3345
	William	10	50	26	1804	3866	5669	2243	4046
	India	50	125	63	3247	6958	10205	4037	7283
Whinton Hill	Shelduck	30	320	96	3728	7989	11717	4635	8362
Cumbria				128	4642	9947	14589	5771	10413
	Yellow-hammer	20	50	26	601	1289	1890	748	1349
	Gully Trap	1,5	7,5	2	337	2379	2715	1380	1717
				2	421	2907	3328	1686	2107
Newton Rigg	Willow Coppice	1	5	4	601	1289	1890	748	1349
Cumbria				1	746	1598	2343	927	1672
Average		**16**	**90**	**33**	**1666**		**5466**		**3871**
						Cost/m3	**558**		**382**

Source: Ockenden, MC, Deasy, C, Quinton, JN, Bailey, AP, Surridge, B, and C Stoate, 2012.

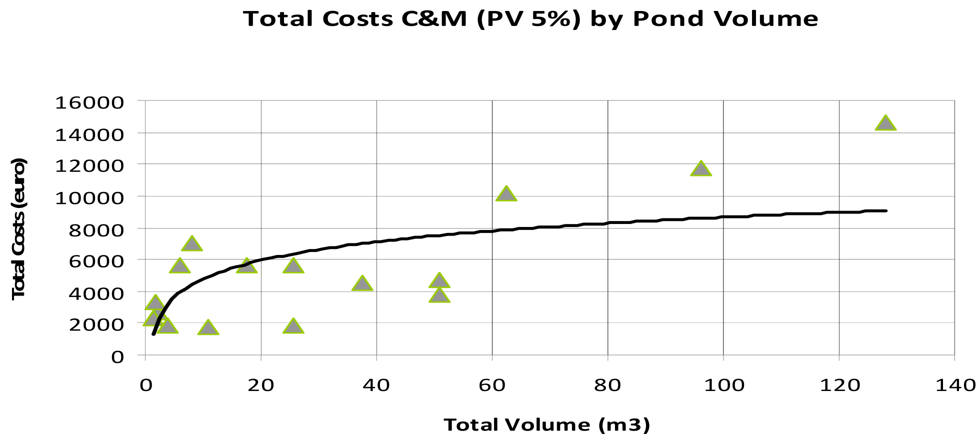
Example: The Upper Ponds in Loddington

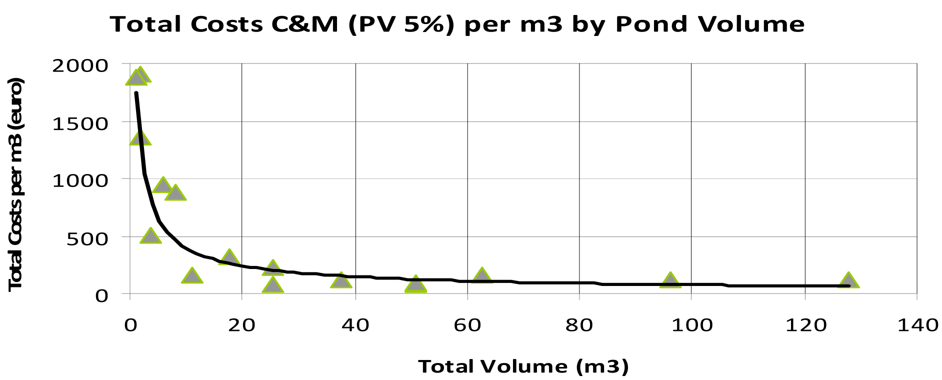
A shallow paired-cell field wetland was created in summer 2008.

Design: This two-cell pond allows most of the sediment to be trapped in the first cell, while the second shallow cell contains less sediment. Thus, there is more vegetation to filter pollutants from the water.
Size: The wetland is 100 m^2 in area, and occupies approximately 0.1% of the contributing catchment area. The wetland is irregularly shaped, but is approximately 15 m long by 7 m across.
Depth: Both cells are around 0.5 m deep and are unlined, though soils contain clay and were compacted during construction.
Cost: This field wetland was created by contractors in September 2008.The work involved:
Excavating the shallow wetland cells.
Drainage – diversion of existing drainage pipes leading into the field corner was needed.
Profiling the site – the excavated spoil was spread around the wetland and used to create a bund at the field edge to prevent surface runoff entering the wetland except at the inlet.
This field wetland cost around £1200 to create, including drainage.

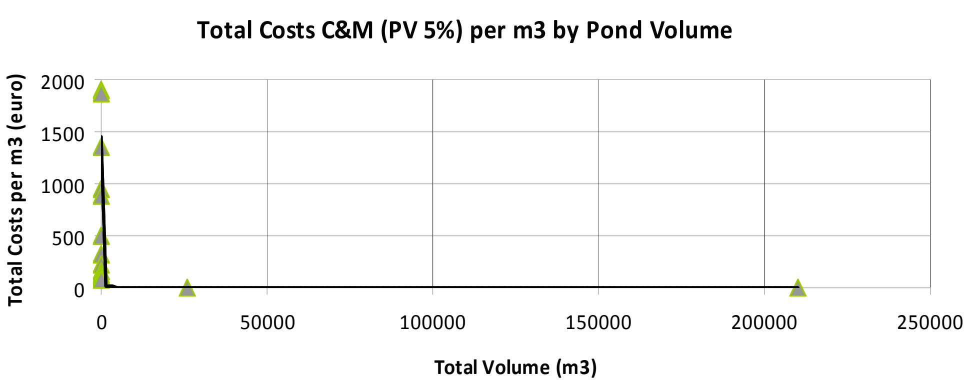
Source: http://mops2.diffusepollution.info/research/sites/loddington-leicestershire/upper-ponds/?nggpage=2

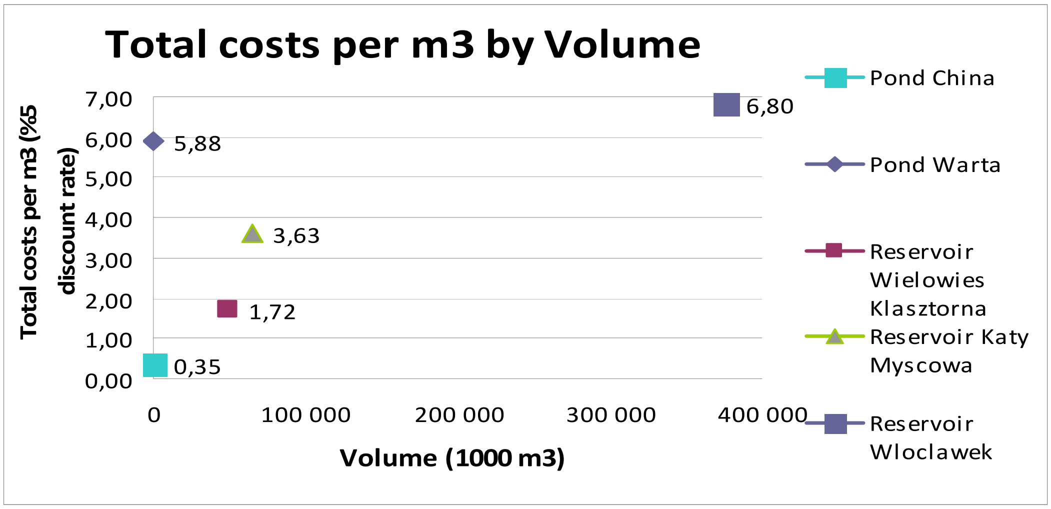
Figure II.1. Construction and maintenance costs according to pond volume

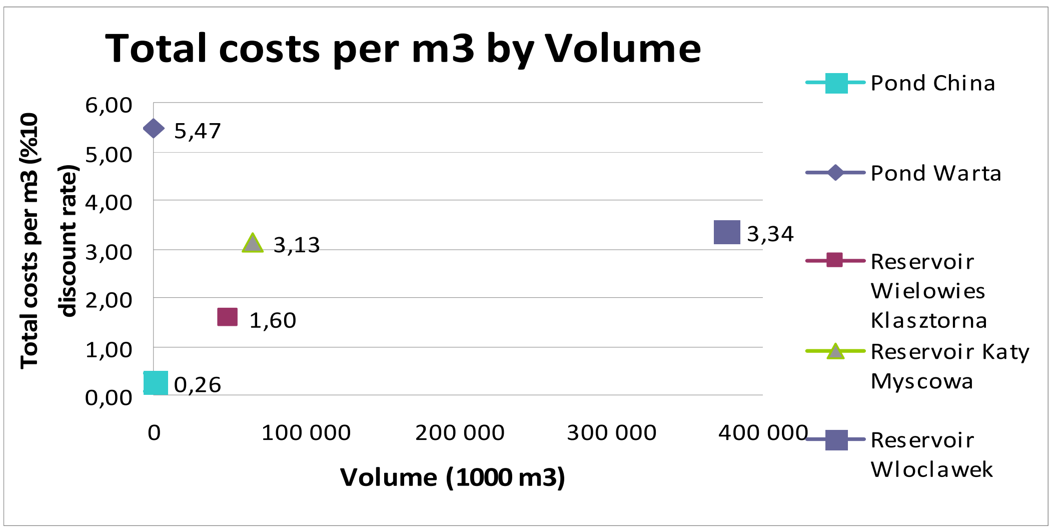




The Regression for all 3 cases of ponds (China, 16 ponds UK, Warta)







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Appendix III: Cost-benefit estimates for shelterbelts[23]

In this Appendix, we show how we calculated the quantifiable costs and benefits of shelterbelts. We begin by reporting on published calculations, and our estimates for shelterbelts in the Warta. We then compare with estimates in New Zealand, Germany and Wales.

For calculating water retention, or the reduction in annual runoff, we use the following comparison of runoff from coniferous forests and cultivated fields.

Table III.1: Difference in Total Annual Runoff- Comparing Coniferous Forest and Cultivated Fields

mm ha-1 yr-1	cm ha-1 yr-1	cm3 ha-1 yr-1	m3 ha-1 yr-1	m3 m-2
65	6.5	650,000,000	650	**0.065**
130	13	1,300,000,000	1,300	**0.13**

Source: I.Kedziora, A. and Tamulewicz, J. (1990). II.Kedziora, A. (2004)

Shelterbelts in the Warta

The currency conversion is: 1 PLN=0.23868 Euro; NZ $ =0.65 Euro (Source: http://themoneyconverter.com/PLN/EUR.aspx)

For our calculations, we assume a shelterbelt that is 100 meters in length and 5 meters in width (area = 50 m2). The distance between the trees in each row is assumed to be 3 meters, and the distance between rows is assumed to be 2 meters. The number of planted trees is thus 67, and of planted bushes, 20.

Table III.2: Costs of shelterbelts in the Warta region

Costs		PRESENT VALUE (4 years*), EURO		PRESENT VALUE (10 years*), EURO	
	EURO	5,00%	10,00%	5,00%	10,00%
Construction	215.77				
Cost (/ha)	4,315.33	4,315.33	4,315.33	4,315.33	4,315.33
Maintenance costs/ha**	1,586/yr	5,624	5,027	12,247	9,745
Total costs / ha		9,939	9,342	16,562	14,060
Cost/m2	0.432	0.43	0.43	0.43	0.43
Maintenance cost/m2 NPV		0.56	0.50	1.20	0.97
Total costs / m2 Shelterbelt		0.99	0.93	1.65	1.41
Total costs / m3 runoff *** averted (65 mm/ha/year)		13.72	12.95	25.48	21.63
Total costs/ m3 runoff **** averted (130 mm/ha/year)		6.86	6.47	12.74	10.82

Sources: Kedziora, pers comm (2012); Department of Agriculture, Fisheries and Forestry (2012); Meurk, C.D. (2012).

23 The currency conversion is: 1 PLN=0.23868 Euro; NZ $ =0.65 Euro (Source: http://themoneyconverter.com/PLN/EUR.aspx)

* there are maintenance costs only for 4 years until the trees are robust enough to survive without maintenance. **Assumption – New Zealand and Poland maintenance costs are similar and can apply to Poland *** (Total costs / m2 Shelterbelt) / (m3 m-2 value from the Table 1: Difference in Total Annual Runoff- Comparing Coniferous Forest and Cultivated Fields) ****(Total costs / m2 Shelterbelt) / (m3 m-2 value from the Table 1: Difference in Total Annual Runoff- Comparing Coniferous Forest and Cultivated Fields). Source: Kedziora 2004) ***** Average price of planted tree, costs of planted trees, preparation of the soil, labour cost of planting, cost of protection (fence), cost of protection of one tree

Shelterbelts in New Zealand

General notes:

- The conversion factor used in all calculations is 1 NZD = 0.65 Euro (Data source: http://www.currency.me.uk/convert/nzd/eur (15 June 2012)
- The costs shown in Tables III.4 were estimated in 2005 NZD (New Zealand dollar) and converted to 2012 euro(Conversion: 1NZD in 2005 = 1.22NZD in 2012).
- In making our estimates we assumed the time scale adopted in the calculations is 4 and 10 years.

Table III.3. Leaching rates according to crop in New Zealand

	Land Use						
	Woodland	Winter Cereals	Spring Cereals	Sugar Beet	Potatoes	Peas	Oil Rape Seed
Mean Annual flux (Leaching rate) in kg N/ha)	18	40	40	23	67	75	48
Leaching rate as % of Woodland rate in %	100.00	222.22	222.22	127.78	372.22	416.67	266.67
Woodland leaching rate as % of crop's rate in %	100.00	45.00	45.00	78.26	26.87	24.00	37.50

Source: Nisbett et al. 2011 (p. 26, Fig. 4, after Silgram et al. 2005)

Table III.4. Costs of shelterbelts in New Zealand

Costs		PRESENT VALUE (4 years), EURO		PRESENT VALUE (10 years), EURO	
	EURO	5,00%	10,00%	5,00%	10,00%
Construction Cost/ha	7,930	7,930	7,930	7,930	7930
Maintenance costs/ha[24]	1,586/yr	5 624	5,027	12,247	9 745
	Total costs per ha	13,554	12,957	20,177	17,675
Construction cost/m2	0.79	0.79	0.79	0.79	0,79
Maintenance cost/m2	0.16/yr	0.56	0.50	1.22	0,97
	Total costs per m2	**1.36**	**1.30**	**2.02**	**1.77**
	Total costs per m3 runoff * averted (65 mm/ha/year)	**20.85**	**19.93**	**31.04**	**27.19**
	Total costs per m3 runoff * averted (130 mm/ha/year)	**10.43**	**9.97**	**15.52**	**13.60**

Source: Nisbett et al. 2011 (p. 26, Fig. 4, after Silgram et al. 2005)

* (Total costs / m2 Shelterbelt) / (m3 m-2 value from the Table 1: Difference in Total Annual Runoff- Comparing Coniferous Forest and Cultivated Fields)

[24] Assumption - maintenance costs are similar and can apply to Poland

Shelterbelts in the Elbe river basin, Germany

Table III.5. Shelterbelt costs in the Elbe river basin, Germany (Energy Plantation Strip or Kurzumtriebsplantage)

Item	***Costs (€)***	***Dimension***	**PRESENT VALUE (4 years), EURO**		**PRESENT VALUE (10 years), EURO**	
			5,00%	10,00%	5,00%	10,00%
Terrain Preparation	*195*	*per ha*				
Plants *	*1,500*	*per ha*				
Planting	*426*	*per ha*				
Total preparation costs	**2,121**	**per ha**	**2,121**	**2,121**	**2,121**	**2,121**
Care & Maintenance **	**242**	**per ha / yr**	**858**	**767**	**1.869**	**1.487**
	TOTAL COSTS per ha		**2,979**	**2,888**	3,990	3,608
	Total costs per m2 Shelterbelt		**0.298**	**0.289**	**0.399**	**0.361**
Total costs per m3 runoff *** averted (65 mm/ha/year)			**4.58**	**4.44**	**6.14**	**5.55**
Total costs per m3 runoff *** averted (130 mm/ha/year)			**2.29**	**2.22**	**3.07**	**2.78**

Source: Uckert and Grundmann 2012
* Price per plant (0.15 euro), 10 000 plants per ha ** extra 30 euro per ha for each harvest *** (Total costs / m2 Shelterbelt) / (m3 m-2 value from the Table 1: Difference in Total Annual Runoff- Comparing Coniferous Forest and Cultivated Fields)

Other costs:

	Euro	**Dimension**
Harvest*	25	per tonne
Storage (ventilation)	3	per tonne
Transport of sold goods	5	per tonne
Recultivation	1000	per ha

* Rotation: 40% smaller harvest

Shelterbelts in Wales

General notes:

1. The conversion factor used in all calculations is 1 Pound = 1,22811 Euro (Data source: http://www.xe.com/ucc/convert/?Amount=1&From=GBP&To=EUR (accessed 16 Dec 2012)
2. Ponds. "Soft Engineering" to prevent river bank erosion is paid at £81.30/m. A water gate to allow water through but prevent stock access is £100. Pond restoration is paid at £3.07/m2
3. Budget to plant shelterbelts and corridors on 3 ha (3%) of a 100 hectare farm. For the comparison reason, all values in Table III.6 are (/ha)

Table III.6. Shelterbelt costs in Wales

COSTS	Euro/ ha/yr	PRESENT VALUE (4 years), EURO		PRESENT VALUE (10 years), EURO		PRESENT VALUE (15 years), EURO	
		5,00%	10,00%	5,00%	10,00%	5,00%	10,00%
Fencing	14,246						
Watergates	246						
Plants	3,549						
Total construction costs	18,041	18,041	18,041	18,041	18,041	18,041	18,041
Maintenance costs[25]	1,586/yr	5,624	5,027	12,247	9,745	16,462	12,063
Income foregone [26]	368/yr	1,306	1,168	2,845	2,264	3,824	2,802
TOTAL COSTS over 30 years		24,971	24,236	33,133	30,050	38,327	32,906
TOTAL CONSTRUCTION AND MAINTENANCE (C&M)COSTS		23,665	23,068	30,288	27,786	34,503	30,104
TOTAL C&M COSTS/ha[27]		7,888	7,689	10,096	9,262	11,501	10,035
TOTAL C&M COSTS/ m2		0.79	0.77	1.01	0.93	1.15	1.00
Total C costs/ m3 runoff * averted (65 mm/ha/year)		12.14	11.83	15.53	14.25	17.69	15.44
Total costs per m3 runoff * averted (130 mm/ha/year)		6.07	5.91	7.77	7.12	8.85	7.72

Source: Jenkins 2013

* (Total costs / m2 Shelterbelt) / (m3 m-2 value from the Table 1: Difference in Total Annual Runoff-Comparing Coniferous Forest and Cultivated Fields)

BENEFITS (unquantified): Shelter, erosion protection, biosecurity from neighboring flocks, more wildlife and game, easier stock management.

[25] Assumption - maintenance costs are similar and can apply to Poland

[26] There is an annual payment for income foregone for farmers of £300/ha/yr for 15 years after planting and for non farmers of £68/ha/yr. Income foregone payments £300 x 3 x 15 = £13,500 (=16.579 Euros)

[27] Sum of Fencing, Watergates, Plants divided by 3 (The budget to plant shelterbelts and corridors are on 3 ha (3%) of a 100 hectare farm)

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Jenkins D (2013) Head of the NGO Coed Cymru in Wales. Contact: davidj@coedcymru.org.uk, +44 1686 650 777. All this can be verified from www.wales.gov.uk . All of the figures which are included here are derived from the Glastir scheme. This is the Welsh Government agri-environment scheme supported by EU funds.

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Appendix IV: Cost-benefit estimates for conservation tillage and no till

Cost estimates are taken from FAO 2001. Conversion: 1$ in 1979 = 3.33 $ in 2012. We took the cost estimates for the case of maize calculation, since they contained the cost of insecticide. Additional amount of water conservation tillage stores, compared to conventional tillage: 103 m3 per ha (Jordan et al. 2000). Present value costs discounted over 30 years.

Table IV.1 Costs of conventional and conservation tillage (Maize and Soybeans averages, 1979data)

	Per hectare cost (2012 Euros)	Per hectare cost (2012 Euros)	Annual additional cost per ha	Annual additional cost per m3 averted	PV of additional cost per m3 averted over 30 years	PV of additional cost per m3 averted over 30 years
	Conventional tillage	**Conservation tillage**	**(2012 Euros)**	**(2012 Euros)**	PRESENT VALUE (30 years), EURO 5%	PRESENT VALUE (30 years), EURO 10%
Machinery wear & fuel	272.8	233.6	-39.2	-0.4	-5.9	-3.6
Pesticides	58.4	77.8	19.5	0.2	2.9	1.8
Labour	83.2	41.6	-41.6	-0.4	-6.2	-3.8
Total selected costs	414.3	352.9	-61.4	-0.6	**-9.2**	**-5.6**
PRESENT VALUE (30 years), 5%	**6,369**	**5,426**	**-944**	**-9.2**		
PRESENT VALUE (30 years), 10%	**3,906**	**3,327**	**-579**	**-5.6**		

Source: FAO 2001, Leys et al 2007

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Appendix V: Summary of costs for averting runoff and storing water

Flood & drought management practice	Costs (Euros)		Investment + maintenance costs /m3 water stored or annual runoff averted	
	Discount Rate		**Discount Rate**	
	5%	10%	5%	10%
CONSERVATION TILLAGE (30 years)	**Total cost/ha**		**Construction and maintenance costs/m3 annual runoff averted**	
Conventional tillage	6,369	3,906	-9.2 *	-5.6 *
Conservation tillage	5,426	3,327		
SHELTERBELTS (4 years maintenance)				
Wales	24,971	24,236	6.07	5.91
Elbe	2,979	2,888	2.29	2.22
NZ	13,554	12,957	10.43	9.97
Warta	9,939	9,342	6.86	6.47
SHELTERBELTS (10 years maintenance)				
Wales	33,133	30,050	7.77	7.12
Elbe	3,990	3,608	3.07	2.78
NZ	20,177	17,675	15.52	13.60
Warta	16,562	14,060	12.74	10.82
PONDS (20-30 yr lifetime)	**Total costs**		**Construction and maintenance costs/annual m3 water stored**	
China (26,167 m3)	17,124	12,783	0,60	0,46
UK (33 m3)****	5,466	3,871	558.00	382.00
Warta (210,000 m3)	1,234,466	1,149,321	5.88	5.47
RESERVOIRS (30 yr lifetime)				
Wielowies Klasztorna (48.8 million m3)	81 992 000		1.68	1.56
Katy Myscowa (65.5 million m3)	377,200,000	309,050,000	5.76	4.72
Wloclawek (376 million m3)	2,654,75,83 3	1,666,306,264	7.06	4.43

*Cost for switching from conventional to conservation tillage ** 409 m3 per hectare per year; *** 130 m3 per hectare per year; **** average of 16 cases

Note, pond lifespan can be as short as 20 years, which would require major costs not included in these calculations.

Appendix VI: Interviews

Interview protocol

Farmers

General

1. Tell me about your farm (size, what you grow, etc.) Do you have children – do you want them to stay in this area and farm?
2. What challenges make farming difficult in this area?
3. Do you consider droughts and/or floods a real challenge?
4. From your experience, do you think floods and droughts are increasing in this area? Why or why not.
5. What do you see as important causes?
6. (If they don't mention climate change) Do you think climate change is playing a role today or in the future?
7. What in your opinion should be done to mitigate flood and drought risks?
8. What are the most important on-farm measures for reducing flood and drought risk? What are you doing?
9. What are the most important off-farm measures for reducing flood and drought risk?
10. (Try to get an idea of how they rank these)
11. Supplementary questions: What are in your opinion the main costs and benefits of the reservoirs? How is the water quality? Are managers worried about water quality?
12. What are you doing on your farm? Why? Who do you receive information from on farm practices?
13. What do you think of following specific measures? (eg, ponds, changed tilling practices, shelterbelts,…)
14. How much would it cost you in time and other expenses to (eg build a pond of X size; change your tilling practices (time per hectare))?
15. What programs are you aware of on the part of the EU for agriculture and water?
16. What programs are you aware of for dealing with flood and drought risk?
17. Do you receive payments from the EU, explain?
    1. Do CAP funds support this kind of activity, and, if not, should they? Do you receive cap funds. What are the main requirements you must fulfill? Are you aware of the good agricultural practices specified for those receiving CAP funds?
    2. What is your opinion of the EU programs, how could they be improved?
    3. Do you have insurance against flood and drought losses? Why or why not? Is it a good idea?
    4. (If they have insurance) Does your insurance policy have any conditions that require you to take preventative measures?
    5. Are your losses compensated by the government after floods/droughts? How do you finance your losses (e.g. relatives, bank loans, savings??)
    6. If so, should farmers be compensated? How much? What do you think of current policies for this purpose?
    7. Should farmland be flooded to protect downstream cities?

Water Managers (River Basin Authority)

1. Can you tell me about your position and responsibilities?
2. What is your opinion on the content and implementation of the Oder river basin management plan?

3. The decision, as we understand it, was not to consider climate change in these plans since it will have little impact during the current planning period (till 2027). Do you agree? If not, how would you include climate change?
4. What measures do you think are most effective in controlling flood/drought risks?
5. What measures have been implemented or are planned to be implemented?
6. Can you tell me about how the decision has been made to build the ……. reservoir? (collect any documentation?)
7. What are in your opinion the main costs and benefits of the reservoirs? How is the water quality? Are managers worried about water quality?
8. Were alternatives, like building smaller reservoirs, also evaluated? (collect)
9. Follow up – what on-farm measures would be cost-effective?, not cost effective?
10. How effective do you feel off-farm measures are?

    (Try to get an idea of how they rank)

11. What role does the EC (via CAP, WFD, structural funds, etc.) play in the building of reservoirs, or on-farm measures? (obviously via national legislation/programs)
12. (more specifically, try to find out funds and how much is being allocated?)
13. How effective are EU measures, and how can they be improved?
14. Do CAP funds support this kind of activity, and, if not, should they? Do you receive cap funds. What are the main requirements you must fulfill? Are you aware of the good agricultural practices specified for those receiving CAP funds?
15. Do you have insurance against flood and drought losses? Why or why not? Is it a good idea?
16. (If they have insurance) Does your insurance policy have any conditions that require you to take preventative measures?
17. Are your losses compensated by the government after floods/droughts? How do you finance your losses (ie relatives, bank loans, savings??)
18. Should farmland be flooded to protect downstream cities?
19. If so, should farmers be compensated? How much? What do you think of current policies for this purpose?
20. If so, should farmers be compensated? How much? What do you think of current policies for this purpose?
21. What, in your opinion, would be done differently if climate change was taken into account?

Research institutes

1. Tell me about your research on floods/droughts as it intersects with climate change
2. What research articles/documents can you point me to? Especially on costs and benefits of on- and off-farm mitigation measures?
3. What do you think are main causes of increasing flood/drought losses in the UW?
4. How does climate change fit into this picture?
5. Is climate change taken account of in these documents?, how? (If climate change not considered)
6. What measures do you think are most effective in controlling flood/drought risks?
7. What measures have been implemented or are planned to be implemented?
8. Can you tell me about how the decision has been made to build the …. reservoir? (collect any documentation?
9. Were alternatives, like building smaller reservoirs, also evaluated? (documentation)
10. Follow up – what on-farm measures would be cost-effective? not cost effective?
11. How effective do you feel off-farm measures are?
    (Try to get an idea of how they rank)
12. Who bears the burdens?
13. How useful/effective are current insurance arrangements (crop and property)? Should it be mandatory? What role can the EU play?

14. (If they have insurance) Does your insurance policy have any conditions that require you to take preventative measures?
15. Are your losses compensated by the government after floods/droughts? How do you finance your losses (e.g. relatives, bank loans, savings??)
16. Should farmland be flooded to protect downstream cities?
17. If so, should farmers be compensated? How much? What do you think of current policies for this purpose?
18. What is the role of CAP, WFD, structural funds, and other EU funding/policy in mitigating flood and drought losses?
19. Do CAP funds support this kind of activity, and, if not, should they? Do you receive cap funds. What are the main requirements you must fulfill? Are you aware of the good agricultural practices specified for those receiving CAP funds?
20. How effective are EU measures, and how can they be improved?
21. What are the problems and what reforms are needed?
22. What, in your opinion, would be done differently if climate change was taken into account?

List of interviewees

1. Prof. Janusz Kindler – prof. Emeritius, Warsaw Polytechnic
2. Prof. Janusz Zalewski – European Regional Ecohydrology Center, UNESCO
3. Ms Katarzyna Marks – WWF Polska, specialist in energy and climate policies
4. Dr Marzena Osuch – Institute of Geophisics Polish Academy of Science in Warsaw
5. Mr Ryszard Jaworski – Regional Agricultural Advisory Board, Director
6. Prof. Janusz Jankowiak - Institute for Agricultural and Forest Environment (IAFE) of Polish Academy of Sciences in Poznań, Director
7. Prof. Piotr Kowalczak - Institute for Agricultural and Forest Environment (IAFE) of Polish Academy of Sciences in Poznań
8. Mr Wojciech Białek - Regional Water Management Board in Poznan, Director of Water Resources Department
9. Mr Dariusz Krzyżański - Regional Water Management Board in Poznan, Director
10. Mr Stefan Jankowiak – farmer, Jagrol Prezes
11. Mr Arkadiusz Błochwiak – Amelioration and Water Facilities Management Board, Director
12. Mr Henryk Ordanik – farmer, Kowalewo
13. Mr Andrzej Szumski – Department of Agriculture Forestry and Environmental Management of Local Government , Powiat Gostyń
14. Mr Ryszard Sziwa - Institute of Meteorology and Water Management, Division in Poznan, v-ce Director
15. Dr Jerzy Kozyra - Institute of Soil Science and Land Cultivation, State Reseach Institute, Puławy, researcher

Appendix VII: Workshop

Workshop at Turew, Poland on 30 May 2012

Workshop Program

9:00-9:15	Welcome, presentation of the project and goals of the workshop
9:15-10:45	First session: Cost-benefit analysis of flood and drought adaptation measures
10:45 – 11.00	*Coffee break*
11:00- 12:30	Second session: Prioritization of selected off- and on-farm flood and drought adaptation measures
12.45 – 13.30	*Coffee break*
12:45 – 13:45	Third session: Recommendations for the EU an national policy makers
13:45 – 14:00	Summary and conclusions
14:00	*Lunch*

Workshop participants

Name	Function	Institution
Mgr Arkadiusz Błochowiak (represented by Michał Szmiński)	Director	Wielkopolski Zarząd Melioracji i Urządzeń Wodnych [Amelioration and Water Facilities Management Board]
Mgr Henryk Ordanik	Head of an agricultural Corporation	Agricultural Corporation Karolew [farmer]
Mgr Andrzej Szumski	Head of Department	Department of Agriculture Forestry and Environmental Management of Local Government (Powiat Gostyń)
Mgr Paweł Kurosz	Director	Department of Crisis Management and Social Security of Local Government (Powiat Poznań)
Mgr Dariusz Krzyżański (represented by Wojciech Białek, Jacek Smusz)	Director	Regional Water Management Board in Poznan
Piotr Łykowski	Director	Agency of Restructuring and Modernization of Agriculture
Dr Tadeusz Przybecki	Head of Department	Agricultural Advisory Center for Wielkopolska in Poznan
Mgr Mariola Górniak	Director	Marshall Office, Department of Environment
Dr Jerzy Kozyra	Researcher	Institute of Soil Science and Land Cultivation, State Reseach Institute, Puławy
Mgr Ryszard Sziwa	Vice Director	Institute of Meteorology and Water Management, Division in Poznan
Prof. Andrzej Kędziora	Vice Director	Institute for Agricultural and Forest Environment (IAFE) of Polish Academy of Sciences in Poznań
Prof. Janusz Jankowiak	Vice Director	Institute for Agricultural and Forest Environment (IAFE) of Polish Academy of Sciences in Poznań
Dr Marzena Osuch	Researcher	Institute of Geophisics Polish Academy of Science in Warsaw
Mgr inż. Agnieszka Banrowska	Researcher	Institute of Geophisics Polish Academy of Science in Warsaw
Dr Monika Kaczała	Researcher	Department of Insurance, University of Economics in Poznan
Dr Łyskawa Krzysztof	Researcher	Department of Insurance, University of Economics in Poznan
Dr Piotr Mańkowski	Researcher	Department of Insurance, University of Economics in Poznan