EIP-AGRI Focus Group
Nature based Solutions for water management under climate change

Minipaper Nature based Solutions as green infrastructures for agricultural water retention, treatment and availability

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INTRODUCTION – MOTIVATION

GREEN INFRASTRUCTURE AS NbS FOR AGRICULTURAL WATER MANAGEMENT

Our planet's freshwater sources are diminishing, and they are threatened by many factors. These include e.g. rapid population growth, conflicts and associated migrations, pollution, climate change as well as the degradation and loss of forests, wetlands, pastures, and arable land. This requires new solutions and approaches to water management, which are not based exclusively on the use of gray infrastructure (physical/built) and which stop fighting against nature and start working with it. Such an evolution promotes the concept of Nature-based Solutions (NbS), understanding as such the "actions to protect, sustainably manage and restore natural or modified ecosystems, which address societal challenges (e.g. climate change, food and water security or natural disasters) effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits" (IUCN).

In the case of agricultural water management the NbS consists of solutions that improve the availability of water and its quality, the efficiency of its use and/or the protection of the farm against flooding or excess water. These NbS: i) must be cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience and good water governance, ii) should bring more diverse natural features and processes into farms and landscapes, through locally or farm-level adapted, resource-efficient and systemic interventions, and iii) must benefit biodiversity and support the delivery of a range of ecosystem services.

Such solutions have been used for decades with a priority on reducing agricultural inputs (improving agricultural practices) and improving water quality (treatment of runoff water with green filters, natural and constructed wetlands, developing hedges or repopulating forestry to reduce sediment inputs to rivers). Given the evolving context mentioned above and since the agricultural sector is one of the most demanding ones for water, NbS should also play an essential role in improving water management for quantitative aspects in the present and in the future.

PROBLEM STATEMENT

Farms can sometimes be faced with either chronical excess of water, flooding, water scarcity, especially during the summer months. In addition, agricultural activities can lead to the transfer of contaminants to the water bodies: nutrients (nitrate, phosphorus), suspended solids, pesticides... Climate change is likely to increase these problems, with more frequent extreme events, higher evaporative demand, and less dilution of contaminants in water. In northern Europe, rainfall is expected to decrease during the vegetation period, but to increase during the autumn and winter, implying an increased risk of erosion and nutrient loading outside the growing season. The risk is especially high in mild winters, when the soil is not frozen. In southern Europe, summer precipitation is assumed to decrease, while evapotranspiration will increase due to higher temperatures, so that the lack of water will be more significant, and contamination dilution less effective.

Nature based solutions as green infrastructures, that slow or retain water inside or downstream of agricultural parcels or at the small agricultural watershed scale, can most often address several of these challenges. Slowing or retaining water can limit high flows, provide resources for irrigation, secure a minimal flow in watercourse, as well as allow contaminants to be degraded or leached nutrients to be used as fertilizers if harvested water is used for irrigation.

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Such infrastructures include structures that can increase groundwater recharge or water storage: infiltration ditches, terraced crops, infiltration ponds or wells, subsurface drainage (controlled or not), two-stage channels, natural ponds and wetlands, constructed wetlands, and reservoirs. Traditionally, these facilities were designed to deal essentially with a single problem: chronic or sudden excess of water, water scarcity, or poor water quality. The challenge now is to combine/adapt these solutions so that they are multifunctional and regulate both water availability and quality at the farm and small rural watershed (or irrigation district) scale. For example, drainage water can be stored in a multifunctional water reservoir or constructed wetland, whose one part can be dedicated to biodiversity preservation and water purification, and one part for water retention, infiltration or storage, to be used for irrigation in summer or be stored in the groundwater body itself.

To optimize their efficiency, some of these infrastructures should be designed at the scale of the group of farms (e.g., irrigation district) or the small watershed. This implies consultation/organization at the collective level, as well as financial aid, because these infrastructures, which consume agricultural land, can be expensive to set up and maintain.

Dissertation

This type of infrastructure can be reasoned at two scales:

- **At the plot scale**, where the issue is essentially to regulate the amount of water available for crops, so that they do not suffer from lack of water or excess water. At this scale, the solutions can rely on adapted agricultural practices (see minipaper 1 Nature based Solution at the field scale) or on drainage, especially tile drainage. This latter has traditionally be used to export soil excess water and reduce surface runoff, sometimes leading to too high discharges out of agricultural plots. Its development is now discouraged; yet in some contexts, existing tile drainage may be adapted in order to control drainage discharges, thereby reducing floods and nutrients exportation, and enhancing water availability for the growing period. The drainage network could also be used to perform irrigation from the soil (underwatering), but such a solution still needs to be further tested.
- **At the farm or the small watershed** (or irrigation district) scale. Here the issue is to keep water and contaminants it may transports in the relevant area. The advantages are twofold: on the one hand, excess water (floods) and exportation of contaminants to the river network are limited, on the other hand, water remains available for the summer period, either for irrigating crops, supporting biodiversity inside the area, or participating to the downslope river good status, for example by regulating low water flow. On top of that, it should be noted that slowing water in this way allows purification processes to take place. Here, essentially two types of solutions exist:
    - the first one is to enhance water infiltration in the soil or towards the underlying aquifer. This can be realized via infiltration ditches, terracing, or recharge reservoir, situated on permeable soils. Here water purification is mainly due to the filter effect of the soil: retention of suspended solids, adsorption of pesticides and phosphorus. Subsurface water can then be pumped for irrigation when necessary, and/or support the summer flow.
    - the second is to increase surface water storage, by building wetlands mimicking more or less natural ones. Depending on these constructed wetlands characteristics, water can be slowly released to the subsoil and contribute to the downslope flow, sustain biodiversity by providing favourable conditions for fauna and flora, contribute to purify water by favouring suspended matters settlement, phosphorus adsorption, denitrification, and pesticides adsorption and degradation. However, if such a pond is used for irrigation, the water level may drop drastically, and the conditions become less favorable for biodiversity.

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- some intermediate solutions exist, as two banks ditches which slow down water, enhance its infiltration and the settling down of contaminants.

This farm or small watershed scale solutions rely on the same processes. The only difference resides in their governance: at the farm level, the farmer is the main decider-maker of what may be implemented on his lands; at the watershed level, decisions should be taken collectively, and solutions can be designed in order to be optimized at this scale. Anyway, in both situations, water is a common good which is also needed downslope.

Description of key issues

Given these main types of solutions, one of the key issues that arises is to choose and design the most appropriate NbS in order to optimize the expected services, taking into account the local context: climate, topography, soil, crops, farm structure, available land and funds, pre-existing infrastructures which may be used as NbS. Depending on the objectives, the NbS to implement won't be the same. For example, the design of a multifunctional reservoir should include a shallow zone with gently sloping banks to optimize purification and accommodate maximum biodiversity, but the "storage" part should be deep and with steep banks to limit evaporation and the surface area of the bank that dries up during the water withdrawal period. Such a relevant choice supposes to perform a thorough diagnosis, at the appropriate scale: farm or small watershed. This diagnosis should include a prospective phase, to take into account climate change and its possible implications on the hydrological functioning of the area under consideration and on the evolution of the services provided by the NbS.

Another key issue is to identify and value the ecosystem services provided by the NbS, both internally and externally of the farm or small agricultural watershed. It is also necessary to identify or elaborate the desirable organization on a collective scale (group of farms, irrigation consortia, small BV) to lead to efficient structures for both the farms and the aquatic environment downstream. This depends probably on the country, each country having its own organization for what concerns farm advisory service and small catchment management. A related issue is to identify the appropriate financial tools to enhance such infrastructures implementation. As a matter of fact, funding for NbSs is a key issue, both for their establishment and maintenance: the farmer must find benefits in the implementation of nature based solutions. If he or she benefits directly from the NbSs, there may be no need for an additional funding. This is the case, for example, when the implementation of NbS limits flooding or erosion on his plots, or if he/she can use the stored water for irrigation. On the contrary, when benefits are mainly or downstream farmers, or for the environment, the cost of the implementation and maintenance of the NbS should not be borne by the farmer, but rather for example by watershed authorities or an irrigation district.

Two other aspects, linked, must be considered: the maintenance of NbS should not be cost-expensive for the farmer. On top of that, the problem of land owning must be carefully taken into account: most of the time, NbSs consume land, sometimes agricultural land, and this point can hinder NbSs' implementation. Furthermore, depending on the country, the right-of-way of ditches and streams belongs either to the farmer or to the country, which can make it more difficult to schedule their evolution toward a NbS. Finally, farmers and hydrologists often known very little of the other knowledge: the first know little about water and contaminant transfers, in turn, the second know very little about the farmer's constraints. Ways have to be found in order to promote a better mutual knowledge.

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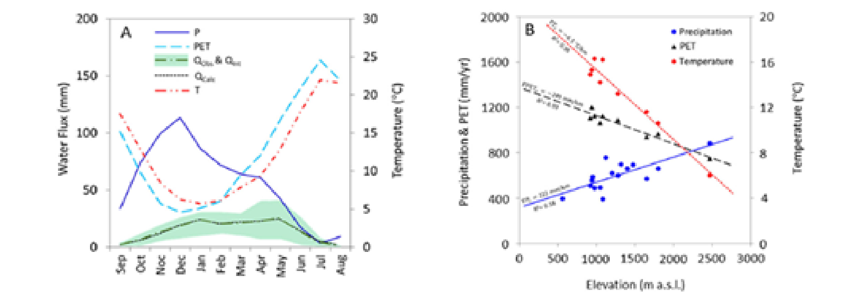
A few successful examples are given below, which will make it easier to identify research needs in a following part.

Infiltrations channels in Sierra Nevada

NbSaWM has been applied in southern Spain for more than one thousand years using the Water Sowing and Harvesting techniques (Martos-Rosillo et al. 2021). Rain and surface water are carried and infiltrated (sowing) in the subsoil to be collected (harvested) sometime later. In Sierra Nevada mountain range (Granada and Almería, southern Spain), since the 8th-10th centuries, farmers and shepherds infiltrate melting water in the upper slopes to recharge the aquifers and increase springs and river flow during the summer (Barberá et al., 2018; Martos-Rosillo et al., 2019).They use the "acequias de careo", long channels excavated in the soil, permeable, catching water from streams and snowdrifts to infiltrate it.

Geographical and morphological context	• Southern Spain, Lat: 37.01765 N, Long: -3.192849 E, Elevation: 979-2913 m a.s.l. • Area: 68 km² • Geoogy: schists, soils: lithosols
Crops	• Pasture, vegetables (currently cherry tomato is the main one) and fruit trees, cultivated in small terraced fields.
Climate	• Cold climate, with mild and cool dry summers, together with significant altitudinal and thermal variations (classification of Köppen-Geiger). • Annual average temperature is around 13.3 °C (Bérchules meteorogical station. 1319 m a.s.l) • Annual mean precipitation 677 mm • Potential Evapotranspiration is around 1012 mm/yr • Average discharge flow at the Bérchules gauging station (1970-2015): 12.6 hm3/year



(A) Seasonal distribution of P, T, PET, average flow discharge measured at the Berchules gauging station (QObs)—represented with a variation interval associated to the 20% and 80% percentiles (QInt)—and total basin runoff from the HBV model (QCalc). (B) Altitudinal distribution of annual mean values of P, T, and PET on the southern face of the Sierra Nevada

Problems which have to be solved	• Enhancing aquifer recharge

Tableau 1: Idendity card of the Bérchules site (Spain)

Previous research in the Bérchules watershed (Granada) has confirmed that this artificial recharge allows duplicating the total aquifer recharge in the river watersheed and generate a storage surplus that will be discharged during the following hydrologic year (Jódar et al., 2022). These data explain the high efficiency of a "simple" system and its high resilience along -at least- 1200 years of operation (Martos-Rosillo et al., 2019). This NbSaWM system generate different ecosystem services, needed for drinkable water supply and local economy. In addition, this system is an example of a climate change adaptation tool that has already demonstrated its efficiency and resilience. Downhill of the "acequias", landscape effects of increasing water availability for vegetation are clearly visible: lush riverside forests and abundant drought-sensitive plant species (e.g., oak, and chestnut trees), rare in semi-arid mountains with predominant lithosols. These vegetation types, together with the irrigated terraced fields, are part of the hallmark landscape of this mountain, declared Reserve of the Biosphere by UNESCO in 1986, and National Park in 1999.

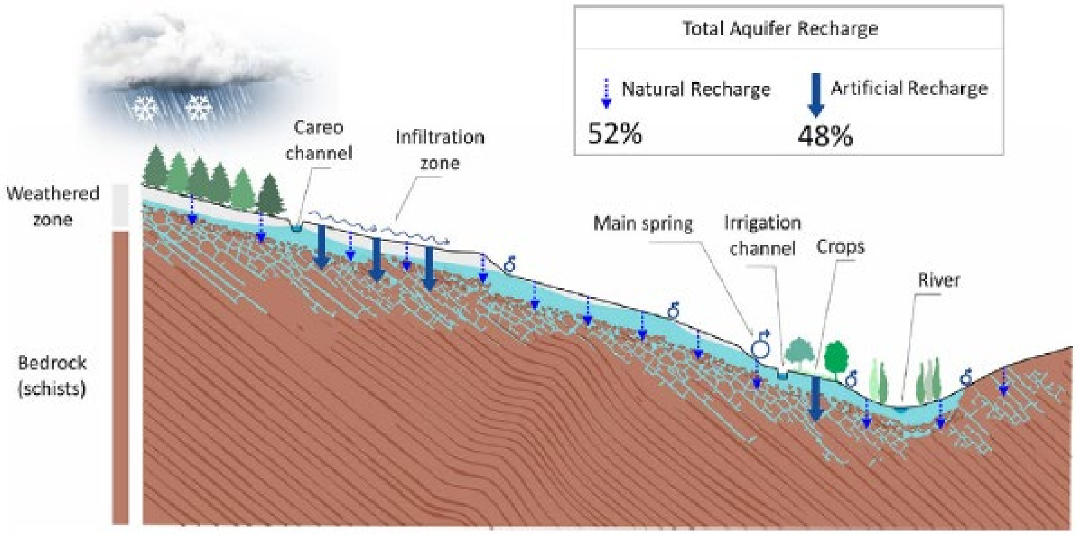


Figure 1: Idealized scheme of groundwater flowsystem on a hillside where groundwater is recharged with infiltration channels (acequias careo)

This system involves farmers, shepherds, inhabitants of rural populations, water users' associations, local and regional authorities, basin authority, National Park authority, environmentalist groups, research and academic institutions. The future plans are to restore abandoned "acequias de careo" and to rehabilitate functional ones. It is also planned to set water monitoring and to elaborate an accounting plan.

Terracing and natural resources management

Mediterranean areas are characterized by gullied hillslopes, stony colluviums, and torrential wadies which are related to extensive runoff and water loss, erosion and even desertification phenomena as affected by the climate change impacts. Terraced landscapes can be considered as an answer to these problems which create a dynamic balance between human and nature with multiple benefits for both sides.

These benefits include: (1) Water conservation: slows down and reduces water runoffs, improves rainwater harvesting, contributes to groundwater recharge through increased infiltration periods, (2) Prevention of soil erosion and decrease of rill formations, (3) Boosting of soil conservation and the formation of soil organic layers, (4) Reduction of sedimentation and water pollution, since water stays long enough for heavy particles to settle down and prevent downstream sedimentation and pollution of water bodies, (5) Increased farm land availability and land productivity of sloped fields, (6) Enhancement of landscape biodiversity and habitats creation, (7) Revealing of rural cultural heritage and supporting of agri-touristic activities. A characteristic example of terracing as Nature based Solution for the conservation of soil and water resources and the reverse of desertification is the case of SIGRI OLIVE MILL AND FAROS ESTATE in Lesvos island in Greece. The farm is established in the hilly area of Sigri, where agriculture was abandoned for decades, and shallow soils were suffering from desertification. For more than 20 years, the farm invested in the restoration of old traditional

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terraces as well as in the terracing of surrounding hills aiming for land regeneration and the establishment of a sustainable olive plantation.

Figure 2: Terrace induced landscape evolution between 1990 and 2021

Today, in a 200-hectare sea-front peninsula, 40.000 olive trees are cultivated in a certified organic plantation using environmentally friendly practices that transformed the area into a healthy and productive ecosystem. The application of certified organic agriculture in terraces and the rehabilitation of biodiversity improved the water use efficiency and the water balance of the agricultural watershed, while effectively contributed to the control of erosion. Furthermore, the entire effort had a positive effect on the regeneration of the local society and rural economy through olive and high-quality oil production, with multiple environmental benefits for natural resources, native flora-fauna as well as climate since the plantation counterbalance the carbon footprint created by 2.000 people (Takavakoglou & Pana, 2020).

Two-stage channels

Conventional ditching and dredging of ditches and streams to ensure agricultural drainage can have negative environmental impacts, so that drainage methods like two-stage channels (TSCs) are needed. Their structure mimics the features of a natural stream and is therefore more sustainable. TSCs improve water retention capacity and prevent flooding; they may also reduce nitrogen, phosphorus, suspended solids, and carbon loading and have positive impacts on biodiversity. The retention and removal of suspended sediment and nutrients improves the water quality in streams and in downstream water bodies.

TSCs consists of a main channel, where water flows when discharge is low, and of floodplains where water has more room to flow in times of increased water volume. Vegetation in floodplains prevents erosion and may remove nutrients from the water. With TSCs, natural processes reducing nutrient loads from the water are also possible.

There are a few challenges associated with the TSCs. They need more space, and they are more expensive to construct than traditional ditches. Losing of productive field area under floodplain also means yearly losses of yields and area-based CAP subsidies. To increase more expensive drainage structures, financial support are needed.

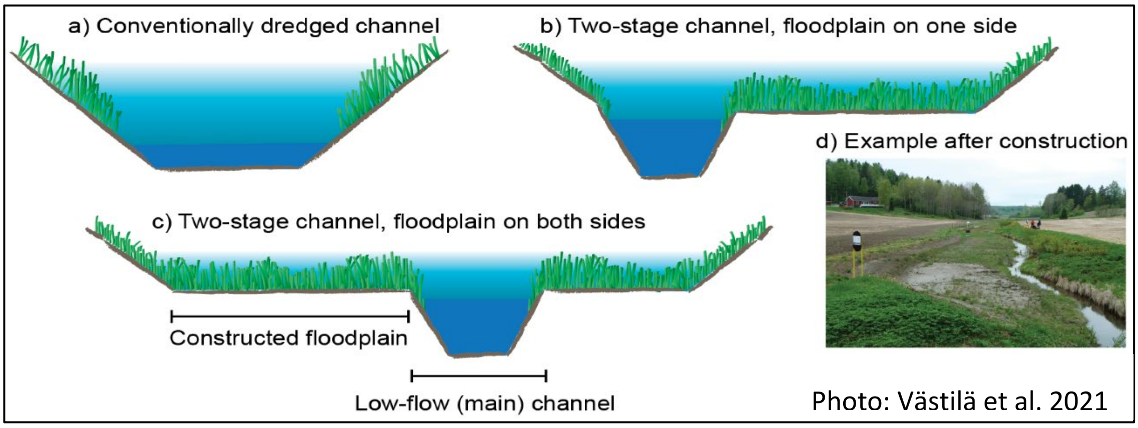

Figure 3: Different kind of managed ditches

On the other hand, TSCs require less maintenance than common ditches and thus maintenance costs are lower. Farmers also profit from well-functioning drainage and flood mitigation through improved crop security and crop yields.

It is possible to construct TSCs on a wide variety of environments. In Finland they are used both on clay and fine sandy soils. They are especially suitable if the ditch has already returned close to the natural state or if there are endangered or protected species. Flood risk areas or areas where erosion material accumulates on ditches are other recommended places. In terms of water quality benefits, they should be placed where concentrations of solids and nutrients are the highest. TSCs can also be constructed only in part of the channel network: they can show verifiable benefits even when used on only 10-20% of the channel length.

Lifting of subregions' water levels by lifting of natural or artificial water courses bottoms

In many (German) landscapes natural as well as artificial watercourses' beds were mechanically deepened with the upcoming of large maintenance machinery in the last century's late 50s. Those activities induced the descent of the surrounding areas' ground water levels to a new deeper and from today's point of view too deep state.

Figure 4: Lifted watercourse bottom in Germany

For rewetting the affected landscapes and achieving today adequate water levels in the connected land, the watercourse maintenance organizations have been experimenting with reduction of maintenance activities as well as with active inserting of local materials such as local stones. It is crucial to handle the elevation as an iterative process in close calibration with adjacent landowners, in order to find the accepted individual higher water level including sufficient functioning during wet periods. Such a solution avoids too much drainage of the area, and thus increases its retention capacity: more water is available for the farmers and the aquatic environment during low water periods. Eventually, these elevated water courses' reaches will become more favorable to biodiversity.

Groundwater recharge with cleaned wastewater

In a pilot project in Northern Germany (between Hamburg and Hannover) cleaned wastewater of a 6.000 inhabitant communities wastewater purification plant is pumped for seepage to a forest situated ca. 6 kilometers from the original dumping-into-the-creek site and ca. 25 meter uphill. The criteria for selecting the seepage location were: **1-** absence of drinking water formation areas and **2-** presence of agricultural irrigation wells within the subterranean downstream area. The cost for uphill pumping and maintenance of the seepage facilities are born by the local irrigation waterboard. In return its members are allowed to extract 85 percent of the percolated water through their downstream wells (in addition to the conventionally permitted volume). A well for control of water quality was installed at the seepage site. This solution provides farmers with more water for irrigating their crops.

Figure 5: Groundwater recharge site, feeded by cleaned water

Local Measures for Managed Groundwater Recharge (MAR) with water from Drainage Pipes

In the west areas of northern and central European Lowlands, which were shaped by several sequential glacial periods, you encounter loamy hilltops next to sandy bottoms. Typical are local heterogeneous soil and subsoil conditions (e.g. sand near stagnant moisture) with at the same time deep groundwater tables. These loamy parts often are artificially drained with buried perforated plastic tubes (drainage pipes).

Searching for solutions to increase groundwater availability for irrigation, two crop farmers in the northern German landscape Lüneburger Heide (between Hamburg and Hannover) developed the idea to stop leading this drainage water into nearby ditches or natural watercourses. Instead, they changed the directions of two main collective tubes and lead the drainage water into two (in one case newly created) seepage ponds at a sandy bottom. In that climatic area, a mean loss from drainage of 100 mm of seepage may be very roughly estimated, while the mean use of irrigation water is 80 mm.

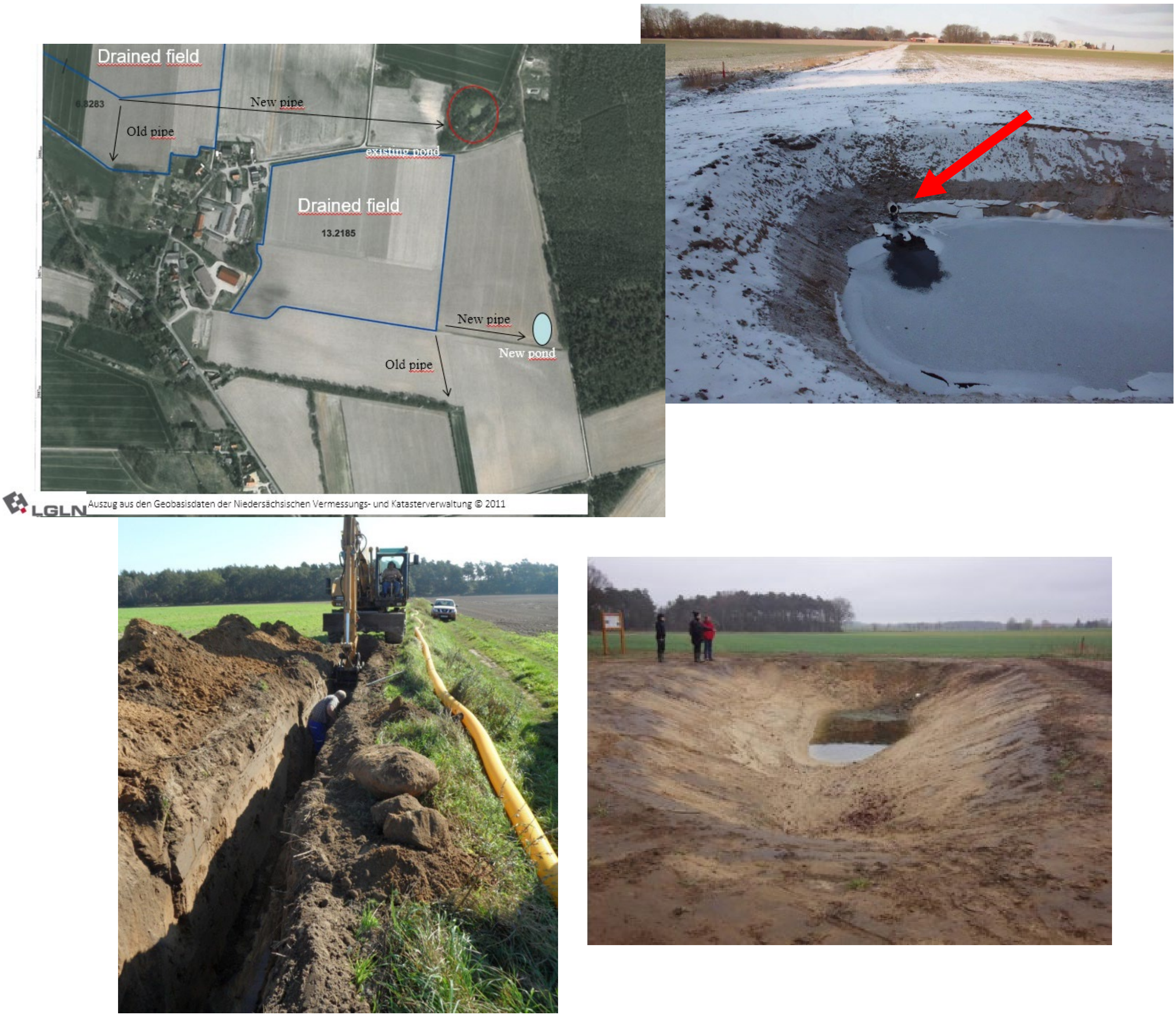

Figure 6: Construction of alternative collection drain before leading into a creek and now leading into a newly created seepage pond (see red arrow) in 2010/11. The pond meanwhile is completely hidden by shrubs and young trees. *Pictures by J. Martens, Waterboard Uelzen*

Important to know is that the nitrate, which is typically contained in the drainage water, will be reduced to nitrogen gas due to the anaerobic conditions in the seepage pond in combination with organic material from surrounding shrubs on its bottom. Probes of seepage water under the pond were practically free of nitrates.

The limitations of this approach against water shortage are resulting from expenses for material and planning work. In this example, they were covered by public funding for climate change adaption pilots. However, these costs could be compensated alternatively, if the involved farmers would be rewarded by additionally permitted groundwater abstraction quota, for example additional 50 mm of the estimated 100 mm mentioned above, the other half being for groundwater dependent ecosystems (waterbodies, wetlands). However, this rewarding system can only work if the additional groundwater coming from the seepage pond is indeed flowing towards the irrigation wells of those farmers who paid the investment. Otherwise, these improvements must be thought, and associated costs and benefits shared at a collective level. The part of the recharged amount of water would increase groundwater supply.

If the local water authority could be won for promotion of compensating single MAR measures with additional groundwater abstraction quotas, that would mean a powerful incentive for a Bottom-Up process, in which irrigation farmers (or irrigation boards) check their individual possibilities to "seed" water. A strong argument is that after the initial investment, there is no further running costs. Related regional technical authorities need to contribute non-bureaucratically the necessary geohydrological information concerning the involved small watershed. In addition, knowledge needs in some cases to be spread concerning the successful nitrate reduction in the seepage ponds (i.e., non-aerobic conditions combined with energy for reducing bacteria coming from the organic material (mud)).

Constructed wetlands

Wetlands are covered by water for a most part of the year and are moist at other times. Typical aquatic and wetland vegetation alternate with open water areas. Many natural wetlands have been drained for decades to meet the needs of agriculture and forestry. Agricultural drainage water that has seeped into ditches or other drainage systems can cause load of nutrients (nitrogen and phosphorus) and pesticides into the surface water bodies, as well as increased floods. Constructed wetlands (CW), built at the farm or the small catchment scale, can help mitigate the effects of agricultural diffuse load and remove different pollutants from drainage water. Furthermore, CWs have several additional benefits since they can retain/store/infiltrate drainage water that could be reused for irrigation and/or groundwater/soil moisture recharge, as well as reduce water excess during extreme precipitation events. These properties will become increasingly important in the future, as both heavy rainfall and drought are predicted to increase with climate change. To retain nutrients as much as possible the residence time of water in wetland need to be long enough. In addition to structure that slow down the velocity of water it is important to dimension wetland relative to upstream catchment area. The right sizing is also important from the point of flow and flood control.

Constructed wetlands increase biodiversity by providing suitable habitats for many plants and animals. The fauna of wet environments is diverse and abundant, and it can be promoted by the proper management. Wetlands also bring variety to the middle of fields that can be otherwise rather monotonous landscape. Constructed wetlands also have recreational value. A well-maintained aquatic environment can promote e.g., hiking, bird watching, hunting, and fishing.

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Farm Wetland in Italy

The example consists of a non-waterproofed surface flow CW located on an experimental agricultural farm in Emilia-Romagna region, Italy. The CW treats tile drainage water coming from a 12.5 ha experimental farm that grows different crops (e.g., fruit trees, vegetables, and cereals) throughout the year. The area of the CW represents around 3% of the total farm surface, and it is divided into four 8–10 m wide meanders that create a 470-m-long water course. The total capacity of the wetland is about 1,500 m^3 when the water level reaches 0.4 m, which is the maximum water height below the discharge level. The whole farm area is drained to a main ditch from which water is conveyed into the CW by means of two pumps. The CW effluent is discharged into a canal, which collects excess water from the fields of other neighboring farms. The CW has been continuously inhabited by different aquatic plant species, such as common reed (*Phragmites australis*) or cattail (*Typha latifolia*, *T. angustifolia*).

Figure 7: Position and design of the farm wetland in Italy.

The CW has been under operation and monitored since more than 20 years and its capacity to remove/retain pollutants and water was proved within several studies and research projects (Lavrnić et al., 2018; 2020a; 2020b; Braschi et al., 2022). The main purpose of this CW is to mitigate pollutants and water flows to the downstream. Secondary purposes are to enhance water storage/retention, plant biodiversity inside the CW and water infiltration in the subsoil.

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Multifunctional constructed wetlands in Finland

Multifunctional wetlands provide several environmental benefits. The main goal of constructed wetlands is often to protect waters, a secondary purpose is to protect fields and other areas from floods. They may also provide water for irrigation. They slow down the inflowing water thus promoting settling and deposition of suspended particles. Wetland vegetation and micro-organisms uptake nutrients which reduces nutrient content of water. Microbes can convert nitrate dissolved in water into nitrogen gas. The dissolved P can be adsorbed into the wetland soil. CW can be constructed damming or digging. Suitable locations include, e.g., hollows, flooded areas, and other moist areas that might be difficult to cultivate. If the CW is established on a cultivated field, it is important to remove phosphorus-containing topsoil from the area that will be covered by water. There should be suitable area around the wetland that can be used for the maintenance purposes.

The wetland should contain deep water areas where particles settle and where sediment can be easily removed. Different kind of islets, shallow water areas, ridges, dams, flood-areas, and vegetation affect water flow and water level and increase diversity.

Constructed wetlands need maintenance. Vegetation around the CW should be mowed and removed regularly. Sometimes grazing is possible. Plant material can be utilized, e.g., as feed or for biogas production. If wetland vegetation is overgrown, it should be also thinned. Maintenance also includes inspection of dams and edges and repairing of collapsed structures as well as removal of sediment.

Geographical and morphological context	• Inkoo, Southern Finland; 60°04'24"N 23°50'54"E; rather flat landscape with agriculture and forestry; fields cover 22 % of the area • Hemiboreal zone; Dominant clay soils dominant (2/3), < 5% organic
Crops	• Mainly cereal cultivation, but also, e.g., grasslands • Average farm size in Inkoo is 62 ha; average parcel size in Finland is around 2,5 ha
Climate	• Annual average temperature is around 6,5 °C and precipitation 650 mm • The duration of snow cover varies widely from about a week to 2-3 months each year • Evaporation is around 400–500 mm/yr • Growing season is around 185 days • In the southwestern Finland, the effective temperature sum during the growing season is around 1,300°C, and precipitation is around 340 mm • In Inkoo, annual water erosion is around 450 kg/ha, which is very close to the average erosion in Finland
Problems which have to be solved	• Flooding and erosion of channels • High load of nutrients into the watercourses With climate change, winters are predicted to warm more than summers; in winter rainy days increase and there will be less and less frost and snow cover time; already now most of the agricultural water load comes outside the growing season in southern Finland, and climate change increases this risk

Table 1 : Identity card of the finish site

Photos: WWF Finland/Viivi Kaasonen

Figure 8: Position and design of a multifunctional wetland in Finland

Some practical points about this example:

The scale of action: These 2.6 hectares wetland is situated in a 0.64 km^2 forest-dominated catchment. The mean annual discharge is 0.006 m**3**/s. wetland area is 2.6 hectares.

The characteristics of the NbS: The wetland consists of deeper and shallower areas. The deeper areas act as settling basins. The shallower areas are, e.g., good rooting sites for plants. Diverse wetland is a good habitat e.g., for waterfowl. The quality of incoming water has not been measured. There is an animal farm, agriculture, and forestry in the catchment area. It is estimated that this wetland works well after the peak of the load during construction, as it is large in relation to the catchment area (2.8%). In Finland, it is possible to get support (CAP) to construct the wetland. To be eligible, the area of the wetland needs to be, including floodplains, at least 0.5% of the area of the catchment area above.

Governance and financial aspects: The construction started at the request of the landowner. WWF took care of the coordination of planning and construction as well as paid the costs. They also take care of all the bureaucracy. The landowner took part in the planning. It was important that the result was good also from his point of view. The planning and construction of wetland was carried out by contractors because WWF does not have the capacity for this work. The landowner is responsible for the management of the site in coming years.

Multifunctional reservoirs in Sweden

Historically executed and ongoing water projects have been created, designed, operated and followed up from a, largely, strictly ecological perspective. If the perspective is broadened so that future water projects can be driven to achieve both ecological benefits for the environment, and at the same time economic benefits for the landowner as well as social benefits, there is an opportunity for water projects to have a larger and broader impact.

Natural wetlands have always existed and this term has, by many people, a bearing on ecology and the environment. On the contrary, the term "Irrigation ponds" is associated with the possibility of irrigation outlets being created and not whether or how much environmental benefit is created. In order not to get caught up in historical and habitual thought patterns, it is proposed that the term Constructed Wetland is introduced.

Geographical and morphological context	• Southern Sweden, 55°24'54.2"N 13°24'4.8"E (WGS84), • Intermediate clay in flat agricultural landscape
Crops	• 1000 ha farm with rape, wheat, barley, grass seeds, sugar beets and vegetables
Climate	• Annual precipitation of 650 mm, evenly distributed over the year. • Normal temperatures between 0-20 degrees. • Summer in Jun-Sep with peaks up to 30 degrees with evaporative demand and winter Dec-Feb with peaks down to minus 15 degrees.
Problems which have to be solved	• Periods of water excess (floods) and water scarcity (droughts). • Water courses transports high amounts of nutrients to the Baltic Sea (eutrophication).

Table 2 : Identity card of the Swedish site

The Tullstorp stream project recently performed an overall pre-study (Bonthron, 2020) to investigate the benefits of a combined concept system of multifunctional water reservoirs, recirculating water with irrigation & customized drainage as a potential mitigation action to face ongoing climate change. The basic idea behind the pre-study is that water is stored in a multifunctional water reservoir when there is excess of water. When there is a drought, the water is "harvested" from the storage and used in a recirculating irrigation system and a system of customized drainage. During 2022 a pilot project of the combined concept system is started to being constructed at a landowner within the catchment area of the Tullstorp stream. The main purpose here is to store water and nutrients for irrigation; secondary purposes are to control flood, to enhance biodiversity in the water ponds, and to allow more food to be produced and new crops to be introduced.

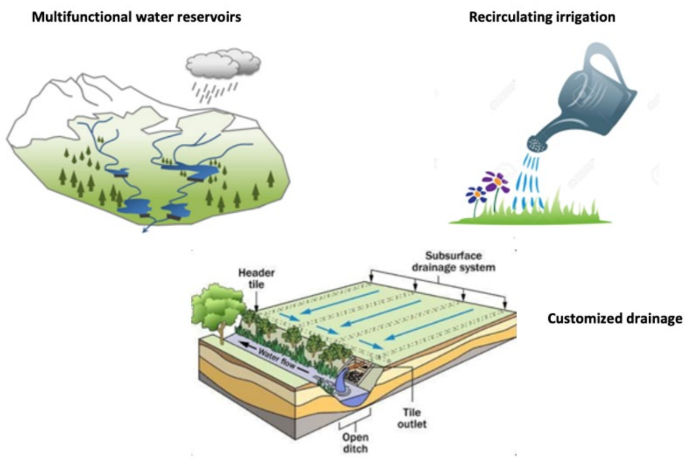

Figure 9: Tullstorp stream project principles. *Pictures – Energiforsk, MAHER SH och SlideShare*

Figure 10: Different water dams of the former old sugar beet factory

Some practical points about this example:

Scale of action: The NbS system consists of a water dam infrastructure of an old sugar beet factory (sediment dams and cooling water dams) transformed to water reservoirs for 200 000 m^3 at an area of 6,5 ha, irrigation systems to 500 ha and initially 50 ha of pilot system for customized drainage. The scale of action is that of the farm.

The characteristics of the NbS: The old sediment dams are 5 meters deep and have steep slopes and banks dividing the system into several ponds. The old cooling dams are 2 meters deep and have gentle slopes. Spontaneous vegetation of bushes, trees and reed.

Incoming water is pumped from nearby river during wintertime when there is an excess of water and the nutrients contents is at highest levels (N - 10 mg/l, P – 0,2 mg/l). The water also has high contents of suspended matters due to upstream problem of surface runoff from fields. The NbS system is efficient for reducing problems with floods, droughts and eutrophication. Besides this the water reservoirs have a positive impact to the biodiversity in the area and is used for recreation and hunting. Water for irrigation is positive for the farmer in

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terms of new crops can be introduced and higher yields are anticipated. From a social perspective agriculture gains better resilience for extreme periods of wet and dry conditions with customized drainage an irrigation.

Governance and financial aspects: The group of farmers behind the Tullstorp stream project initiated a pre study of the NbS system. The most appropriate and cost-efficient area for the pilot system, with reusing the old sugar mill infrastructure, was the reason for placing the pilot system at one of the farms - Jordberga estate.

The three components in the system – water reservoirs, irrigation and drainage were designed in cooperation with different suppliers of equipment and specialists. Jordberga estate is the main financer with co-finance from WWF and BSAP fund. Jordberga estate is also responsible for maintenance of the NbS.

This pilot system will be used as demonstrator and dissemination site. There is a plan to spread the concept to other farmers in the catchment area, taking into account the water balance/budget in the stream, meaning how much water can be harvested from the stream during winter without effecting the ecosystem in the stream.

Further upscaling in the region, in Sweden and to other countries is possible due to the fact that many areas and countries face problems with water excess (floods) and water scarcity (droughts).

Research needs

Assessment of effectiveness of NbS for agricultural water management requires deep understanding of the involved natural and artificial processes, which are characterized by their complexity and interlinks. Therefore, state-of-the-art site-specific research is imperative before promoting their adoption. Furthermore, given the multidimensionality of NbS, this research should be interwoven into the innovation process, thus it should be science-based participatory action research.

Spatially distributed modelling of the fluxes of water and substances transported in it is a first step in developing operational tools to assess the effects, benefits and costs of NbS for agricultural water management. On-site monitoring of natural or managed processes is the basis for analytical research and essential for models' development. Monitoring techniques are therefore key components of the required research. Living-Labs (i.e., full-scale demo sites) are probably the most appropriate research infrastructure for this purpose. Fundamental research of specific processes may be also necessary. In this case, laboratory or field-controlled experiments might be needed.

Ideas for Operational Groups

Problem:

Periods with excess of water (flooding) and water scarcity (drought), both impacting water quality (suspended matters, nutrient, pesticides).

Main activities and results:

- Elaboration of a grid/decision tree to choose the right NbS according to the context, the targeted problem, and the expected evolutions.
- Optimized design of these kind of NbS depending on the local context and its expected evolution, understanding also their hydraulic and hydrologic behaviour, as well as their treatment capacity
- Assessment of the cumulative impact (i.e., removal efficiency and water retention capacity) of these NbS at farm as well at the small catchment scale, in order to balance water availability for farmers and good ecological status for rivers

- Assessment of carbon sequestration or release and greenhouse gases emissions from natural and constructed wetlands, depending on their characteristics
- Assessment of biodiversity enhancement, other ecosystem services, and of the associated costs and benefits.

Potential partners:

- Farmers
- Experts
- Advisors
- Researchers

Ideas for innovations

We understand that innovation with NbS for agricultural water management is a process necessarily interlinked with research, policy and education. Above we advocate for Living-Labs and Participatory Action Research to respond to research needs. The innovation process should be embedded in this research. However, policy measures that incentivize participation in the innovation process and adoption of NbS are likely necessary to ensure progress in the adoption process. EU common agricultural policy conditionality measures might be a means to facilitate the innovation process. Education at all levels, from university to the farm, passing by agricultural practitioners, should ensure that NbS for agricultural water management are funded and justify as alternative or complementary to conventional solutions.

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