Hybrid measures for flood risk management: combining hydrological investigation and public perception survey

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Introduction

Climate change is expected to affect the frequency, magnitude and seasonality of various precipitation-related hazards, including flooding as one of the costliest hazards in Europe. As natural hazards have a significant impact on infrastructure, human lives, and habitats, it is clear that adaptation measures aimed at both prevention and mitigation need to be considered to address climate change. Green (referred to as Nature-based) measures are currently being promoted by the European Union, but in some planning contexts these measures may not be fully capable of coping with predicted future climate hazards, especially in the case of extreme events. Furthermore, the implementation of such measures is often met with resistance from planning departments and decision makers due to institutional dependencies created by the use of grey infrastructure measures in the past. In addition, scepticism about the effectiveness of green measures goes hand in hand with a preference for grey measures. Hybrid measures do have a prevailing green visual look, they can fulfil some ecosystem services, but they require substantial technical equipment for implementation and may present a feasible complementary measure in planning context with limited space or already existing infrastructure. These solutions therefore combine parts of grey and green measures and present an alternative that can reflect the diversity of environmental conditions.
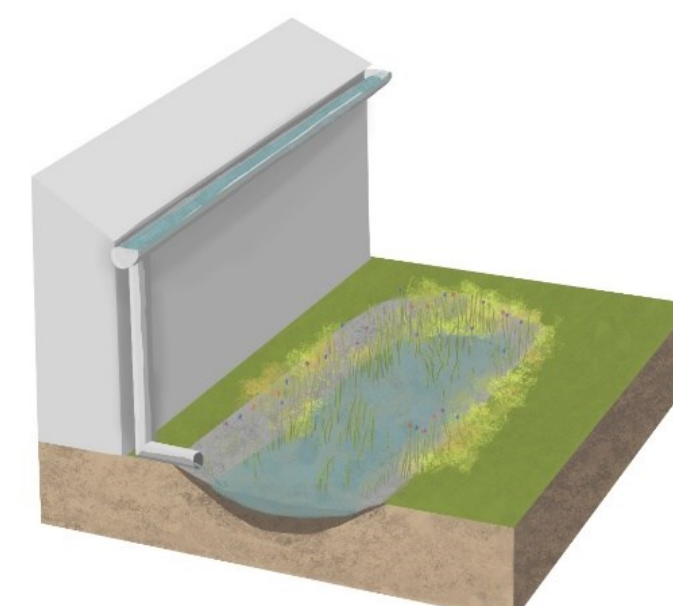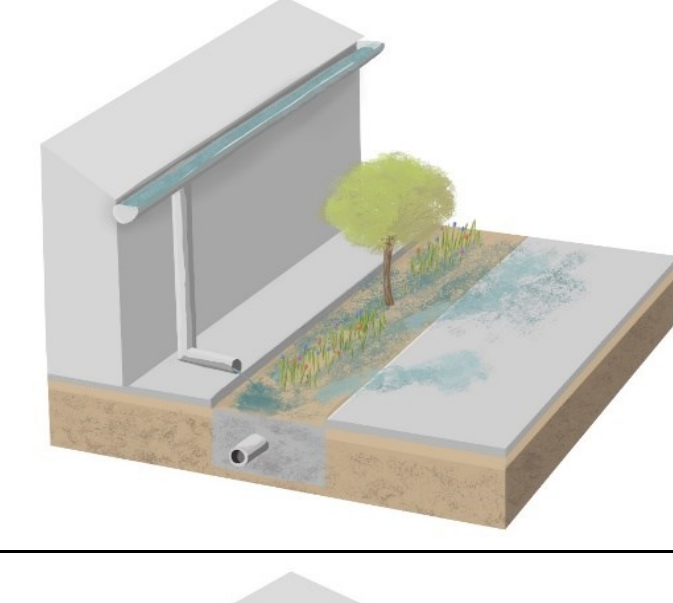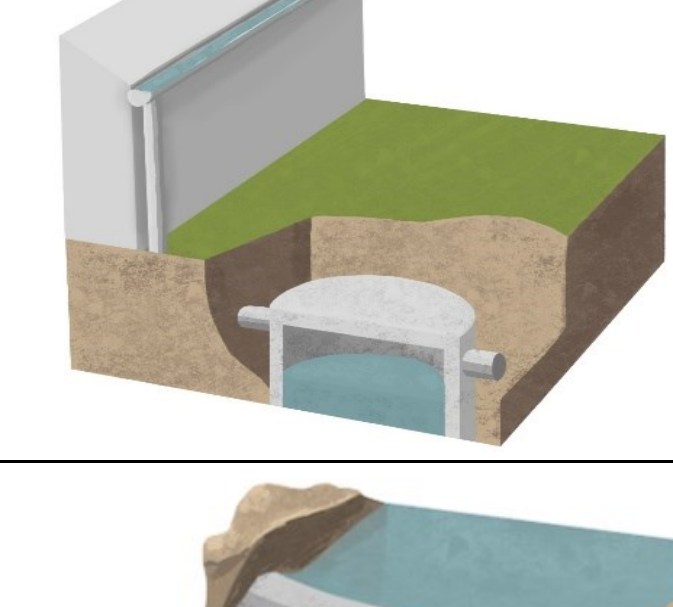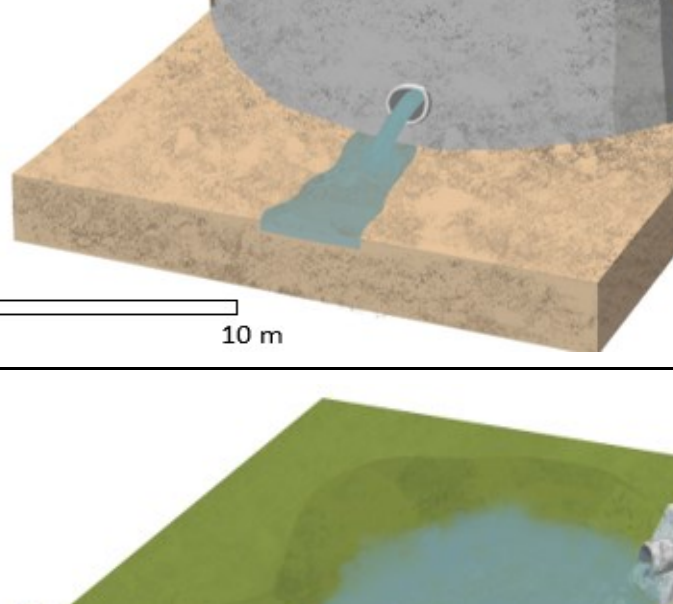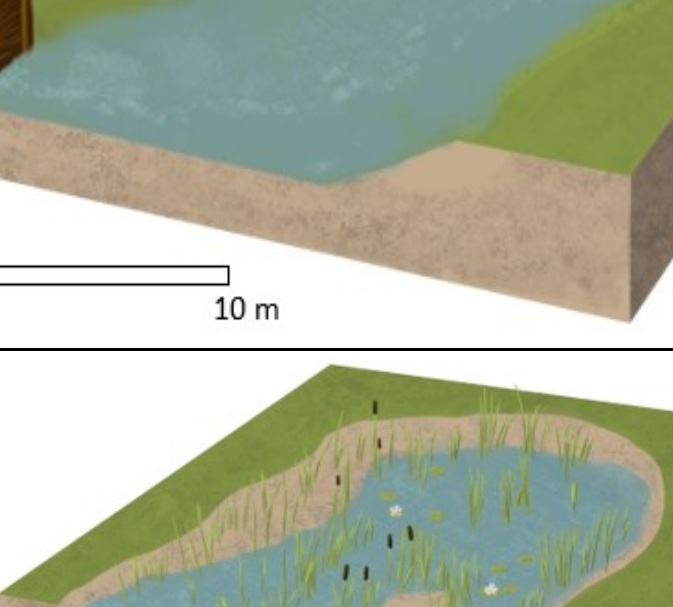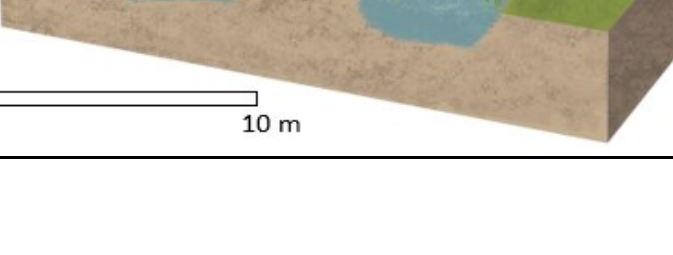
Aims

This study evaluated the effectiveness of selected green (e.g. urban trees, rain gardens), grey (e.g. drywells, permeable sidewalks) and hybrid (e.g. green roofs, stormwater tree tranches) measures on flood risk using hydrological modelling with the HEC-HMS software. This study was carried out in order to define the most effective and suitable flood protection measures for the selected case study, the Glinščica river basin in the municipality of Ljubljana in Slovenia. Based on the hydrological modelling performed, rain gardens were found to be the most effective measure in terms of reducing peak runoff and runoff volume for the Glinščica river model. Both green roofs and stormwwater cisterns also showed relatively good results compared to the other measures. The hydrological study was combined with a public perception survey in which we investigated the acceptance, feasibility and effectiveness from the public perception perspective in Slovenia, Czechia and the Netherlands. Therefore, we were interested in whether there are differences in the perception of the selected green, grey and hybrid flood risk management measures. We were also interested in which of the contextual (e.g., flood exposure and experience) and compositional (e.g., socio-demographics) factors influence public perception of the acceptability, feasibility, and effectiveness of these measures.
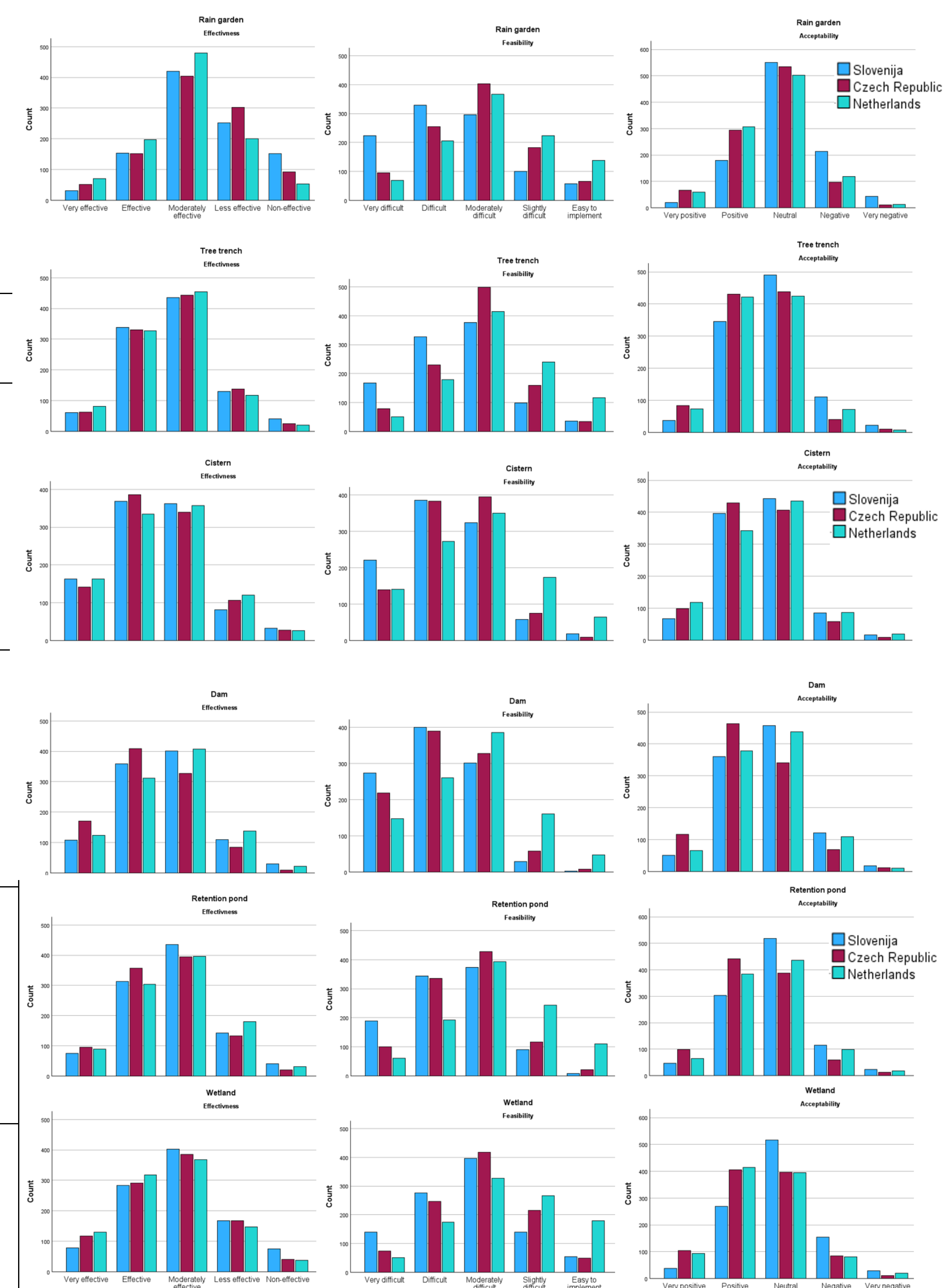
Public perception survey

The survey was conducted online in Slovenia, Czechia and the Netherlands with the support of the company Valicon. The survey was prepared and translated in Slovenian, Czech and Dutch, and the local language was in the respective country (e.g. Slovenian language in Slovenia). A representative sample (general public, n = 1000) was collected in all three countries, taking into account spatial and socio-demographic characteristics at different levels. The aim of the survey was to assess the effectiveness, feasibility and acceptance of selected flood protection measures. During the survey, respondents were only shown the drawing of the measure and not the description or the name of the measure. Respondents therefore had to answer three questions about the effectiveness, feasibility and acceptance of each measure. The survey was launched on February 1, 2024 and completed on February 12, 2024.

Table: Overview of the flood protection measures and question used in this study.

How effective is, according to your opinion, this flood protection measure in terms of reducing the eventual flood damage?	Very effective (1), Effective (2), Moderately effective (3), Less effective (4), Non-effective (5)
How difficult (e.g., obtaining all the permissions, financial sources) it is to implement, according to your opinion, this flood risk measure in Slovenia / Czech Republic / Netherlands?	Easy to implement (1), Slightly difficult (2), Moderately difficult (3), Difficult (4), Very difficult (5)
According to your opinion, what is the public perception about this flood protection measure?	Very positive (1), Positive (2), Neutral (3), Negative (4), Very negative (5)

Measure	Scale and measure type	Short description	Drawing used
Rain garden	Small, green measure	A rain garden is a small garden covered with vegetation, usually positioned in low-lying areas to store rainwater runoff. Rain gardens are designed to collect excess water (e.g., from roofs), with the water infiltrating into the soil. They provide additional ecosystem services and have a green appearance.	
Tree trench	Small, hybrid measure	Stormwater tree trenches represent a series of trees connected underground by a trench system to manage the excess amount of rainwater that can be infiltrated. Visually, the combination of grey and green appearance is mixed and some ecosystem services are provided.	
Cistern	Small, grey measure	A cistern (also known as a rainwater retention tank) is a water reservoir (above or below ground) that is used to store rainwater runoff (usually from roofs). Water can be reused. They do not provide any ecosystem services and usually have a predominantly grey appearance.	
Dam	Large, grey measure	Dams are hydraulic structures that regulate the flow of water in a river and are usually built perpendicular to the river. They do not provide any significant ecosystem services, are made of materials that are difficult to degrade and have a grey appearance.	
Retention pond	Large, hybrid measure	A retention pond (reservoir) (dry or wet), is a special type of water storage infrastructure that is mainly used to reduce runoff peaks. Special hydrotechnical equipment is used for water storage, a combination of grey and green appearance is mixed and some ecosystem services are provided.	
Wetland	Large, green measure	A wetland is a riverine area with a unique ecosystem that is either permanently or seasonally flooded for a short period of time during high water. Visually, wetlands have a green appearance.	

Preliminary results of public perception survey

Effectiveness, feasibility and acceptability of selected flood protection measures in Slovenia, Czechia and the Netherlands.

Modelling

Based on the hydrological modelling performed, rain gardens were found to be the most effective measure in terms of reducing peak runoff and runoff volume for the Glinščica river model (Slovenia). Csterns also showed relatively good results compared to the other measures tested.

Based on the preliminary analysis some interesting results can be made:

-the most effective measures in the public perception perspective in all three countries are cisterns and dams.

-the least effective measure in all three countries is the rain garden.

-The most difficult measure to implement in the public perception is the dam, followed by the cistern in all three countries.

-Wetlands are the easiest to implement in all three countries.

-In the Netherlands, the average feasibility of all six measures analysed may indicate that flood protection measures are easier to implement compared to Slovenia and Czechia.

-The general acceptance of rain gardens is the most negative in all three countries. Dams are more readily accepted than wetlands or retention ponds.

-Cisterns in Slovenia and wetlands in Czechia and the Netherlands are the most optimal solution according to the general preference (considering effectiveness, feasibility and acceptability at the same time).