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Social, economic, and legal aspects of polder implementation for flood risk management in Poland and Hungary

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Abstract

The implementation of nature-based solutions that involve natural processes to mutually decrease flood risk and protect natural ecosystems can be an answer to the demand for resilient flood risk management (FRM). As an example of a nature-based solution, flood polders have the potential to deliver those benefits; however, a need for innovation is observed in the field of redefining, combining, and reformulating existing approaches to improve the welfare and wellbeing of individuals and communities. This article aims to investigate polder implementation and management processes, perceived as a potential introduction of social innovation in Poland and Hungary, where social innovation in FRM is required but where the introduction of innovative solutions stalls at different stages. Based on a comparative analysis, a set of factors for effective social innovation was formulated regarding formal and legal conditions and economic and social aspects of polder management and implementation. Each of identified factors can either allow or hinder public engagement and successful social innovation.

KEYWORDS

floods, Golina polder, nature-based solution, social innovation, Tiszaroff polder

1 | INTRODUCTION

Although climate change has had significant implications for flood risk management (FRM) over the years, these have not induced actual action for flood risk mitigation (Wasko et al., 2021). At the same time, the vast majority of long-term FRM actions that have been undertaken have so far relied mostly on technical measures that have often been ineffective in combating increasing flood risk (Ellis et al., 2021). Flood damages, caused not only by the very nature of the flood events (Zwoliński, 1992) but also by negligence in the technical infrastructure of flood protection measures or the establishment of insufficient measures to cope with increasing flood risk, are predicted to increase and expand in the future (Alfieri et al., 2015; Hirabayashi et al., 2013; Jania & Zwoliński, 2011; Kreibich et al., 2022; Wing et al., 2018). While many initiatives emerge in the immediate aftermath of a flood event, there is still a general scarcity of substantial actions undertaken a priori to mitigate such risks (Albrecht & Hartmann, 2021).

The frequently observed post-factum approach to FRM action is characteristic of post-socialist countries influenced by their former centralized policies, resulting in certain specific kinds of flood risk perception among authorities as well as in society (Raška, 2015). Substantial transformations in established FRM systems are constantly required, especially in countries that have experienced floods on scales exceeding predictions of possible size of the disaster in the past (Matczak et al., 2018). Even in regions where actions to mitigate flood risk are actively undertaken, new innovative measures need to be implemented in response to social and environmental needs (OECD, 2016).

Due to dynamic societal transformation, more focus is usually dedicated to social innovations born out of new ideas that work to satisfy social goals (Mulgan, 2006) or to innovative services and activities aimed at meeting social needs (Cajaiba-Santana, 2014; Mulgan et al., 2007). An innovative approach to flood risk reduction can be expressed as a shift toward implementing solutions based on natural processes—that is, nature-based solutions (NbS)—to decrease flood risk while simultaneously preserving and maintaining geo-, bio-, and cultural diversity as well as the ability of ecosystems to evolve over time, thus, producing societal benefits in a fair and equitable manner (IUCN, 2021; Jakubínský et al., 2021; Raymond et al., 2017).

One example of an NbS in FRM is polders, which combine the potential of hydrotechnical engineering with nature-derived features and processes to mitigate floods (Daigneault et al., 2016). The effectiveness of polders in flood risk mitigation has been proven in several sites and under various conditions (Budiyono et al., 2017; Gao et al., 2018; Maczalowski, 2015; Mawandha et al., 2018; Novakova et al., 2014; Short et al., 2018; Wahyudi et al., 2019). However, despite their benefits, the implementation and management of polders is not straightforward and is limited by numerous factors and conditions.

This contribution aims to investigate polder implementation and management processes, perceived as a potential introduction of social innovation. A comparative analysis was conducted for two case study polders located in Central-European countries—Golina in Poland and Tiszaroff in Hungary—where similar background conditions were observed, such as their history of former flood events, increasing flood risk, and maladjusted FRM systems and their transformation. However, the implementation of these polders rendered different outcomes.

The research also addresses the questions of whether polders, despite their social and ecological benefits, may be assessed as social innovation and, if so, to what extent they contribute to the improvement of societal wellbeing.

To address these questions, a set of factors influencing the effectiveness of social innovation was identified.

2 | POLDERS AND SOCIAL INNOVATION

Ensuring flood safety is considered one of the basic needs of communities in flood-prone areas (Yusoff & Yusoff, 2021). As the negative consequences of flood events increase and expand over the years, new innovative solutions are required to cope with increasing flood risk and constantly changing background conditions (social, environmental, economic, and formal). In that context, polders, as regulated areas along rivers for the multiple goals of flood defense and a bundle of other public and private benefits, can be perceived as an innovation when compared to hydraulic infrastructure, such as dikes or dams (Bark et al., 2021; Moreau et al., 2022; Vingre, 2017). This reflects a general shift in FRM that emphasizes the role of protecting nature and human beings (Wesselink, 2016).

Polder implementation requires new arrangements, methods, and approaches, the introduction of which is both a necessity and an opportunity for different groups; land owners, land users, public administration, and indirect beneficiary groups activate themselves to defend interests or mobilize for new goals. As the role of citizens in decision-making processes gains importance (Guerriero & Penning-Rowsell, 2021), especially in post-communist countries (Raška, 2015), there is a strong need to investigate the process of designing and implementing new solutions that imply conceptual, process, product, or organizational change, ultimately aiming to improve the welfare and wellbeing of individuals and communities, defined as social innovation (OECD, 2016). Presented research perceives polders as an innovative solution with the potential to induce those changes, but the implementation and management of polders manifests as a host of intertwined and complex processes, and this potential is untapped.

The concept of social innovation provides an analytical perspective for these complex processes (Cajaiba-Santana, 2014). This approach acknowledges the proactiveness of all actors in decision-making processes and addresses the contingencies of historical and local situations while allowing the exploration of patterns across cases (Christmann et al., 2020; Mumford, 2002). The novelty of the concept of social innovation is expressed in its applicability to multiple socio-environmental problems that are not addressed by traditional innovation (Solis-Navarrete et al., 2021). Social innovation is however an answer for context-specific challenges as the background conditions determine the emergence and development of local social innovations (Brandsen et al., 2016, p. 8; Domanski et al., 2020) that can be upscaled and transferred to different applicable contexts (Thaler et al., 2019). Social innovation proposes new and better ways of solving

social problems and fostering positive social change (The Young Foundation, 2012). Presented study focus on process-oriented innovation that may however lead to an innovative results (EC, 1995).

The literature describes the preconditions of social innovation as the satisfaction of basic needs, reconfigured social relations (social transformation), and socio-political empowerment or mobilization (Moulaert et al., 2005). Transformation, leading to social innovation, can be triggered by deviations that create the need for a system to change (Thaler et al., 2019). Social innovation has its starting point in notions of social beneficence and public good that support people in organizations, communities, and society in general (Dawson & Daniel, 2010). A driver for change is a so-called window of opportunity, often referring to natural disasters (such as flood events) as a starting point of transformation (Few et al., 2017; Tortajada et al., 2021).

3 | CASE STUDIES

A comparative analysis of polders located in two purposively chosen Central European river basins in Poland and Hungary was performed. In recent decades, both countries have faced severe flood events (Kundzewicz et al., 1999; Kundzewicz et al., 2012; Szlávik, 2003). In Poland, floods endangered the majority of society, caused dozens of deaths, and induced significant economic losses estimated at billions of euros (Kundzewicz, 2014). In Hungary, apart from inducing significant defense operations, a series of major floods in the Tisza river basin resulted in a dike breach and, consequently, a large-scale inundation of settlements (Szlávik, 2003), which, until now, were considered events of the past and largely forgotten. For both regions, as well as for the whole of Europe, flood risk and flood damage are predicted to increase in the next decade due to the highly dynamic nature of climate change (IPCC, 2021). Because of the constantly increasing flood risk in both river basins, attempts are being made to find and implement innovative flood-protective measures. In both regions, polders play an important role in FRM. Although the background conditions for both regions appear to be similar, the processes adopted by the two countries to achieve the same goal, i.e. implementation of polders for flood risk reduction, were different and brought about different outcomes. The location of case study areas is presented in Figure 1 and all basic information are presented in Table 1.

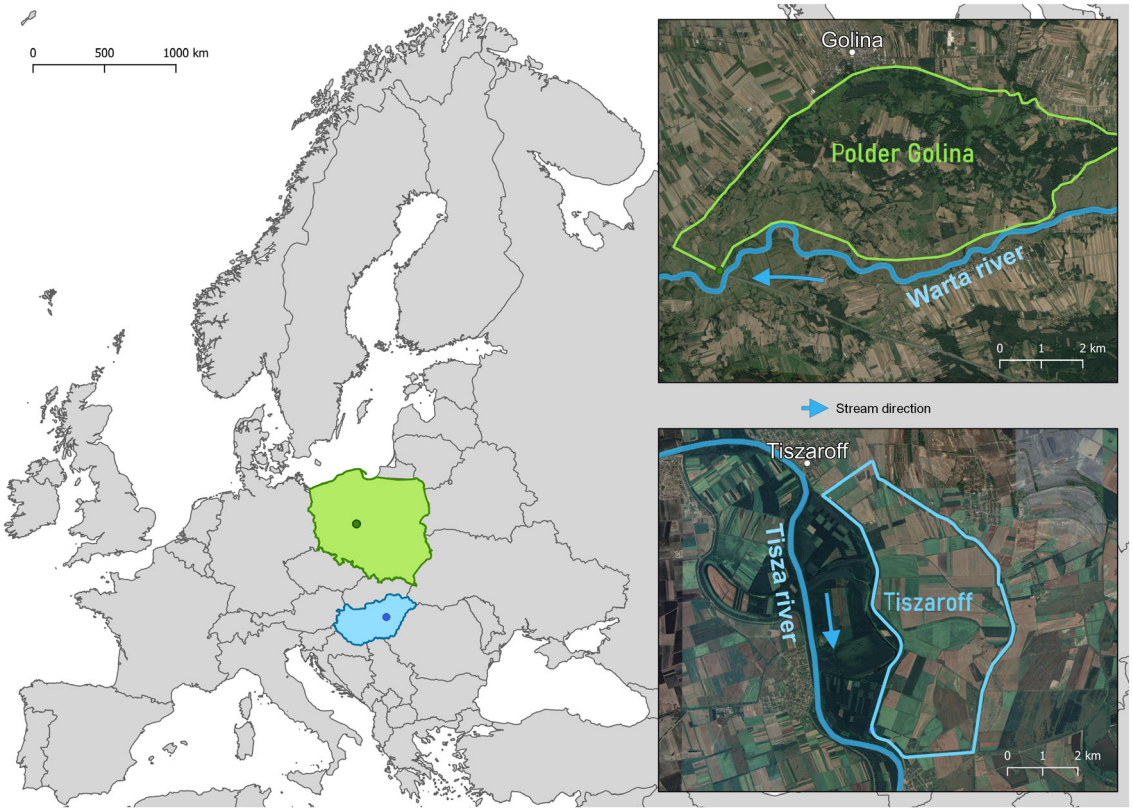

FIGURE 1 Location of selected case studies—Tiszaroff and Golina polder.

TABLE. 1 Description of Tiszaroff and Golina polders.

Feature	Golina	Tiszaroff
Location	Warta river (Poland)	Tisza river (Hungary)
Area (ha)	2678,5	2336
Retention capacity (mln m^3)	37	97
Water level reduction (cm)	29	38
Land cover	95% of agricultural areas 4% artificial surfaces 1% forests	95% of agricultural areas 3% forests 2% water bodies
Share of private land (%)	78	94

3.1 | Golina polder

The Polish polder Golina is located in the central part of the country, on the right bank, between 385 and 398 km of the Warta River. The polder was constructed as part of a project to develop the widely spread, natural Konin-Pyzdry valley. This complete project involved the construction of embankments that would divide the valley into nine polders with dedicated hydrotechnical structures designed to protect areas in the lower section of the Warta, particularly the city of Poznan (Laks, 2017). Due to limited financial resources and the construction of another flood retention reservoir named Jeziorsko upstream, the initial development plan for Golina was abandoned for almost 40 years, and then narrowed down to two polders (Golina and Zagórów) instead of a complex polder system (Laks & Lewandowska, 2017). Ultimately, only Golina was designed for flood protection purposes, with its area intended for agricultural use and optional flood retention (Laks, 2017). The legal and formal framework for establishing polders in Poland did not specifically define the conditions to set up operational polders and manage water retention during flood events. Hydrotechnical infrastructure (consisting of embankment spillways, weirs, pumping stations, and sluices) was built in 1980 to enable the flood water to uncontrollably flow into the polder and mitigate the flood wave peak. However, due to unsettled ownership relations and lack of formal regulation, the retention potential of the polder was left untapped and social conflicts emerged (Laks, 2017).

Despite the lack of agreement between the local community and the authorities (lack of formal regulations for land reclamation and managing the polder), the Golina polder was flooded several times between 1997 and 2020. During the last severe flooding in 2010, owners of the land located within the polder tried to block the water flow with sandbags, which led to a loss of flow control and severely damaged the hydrotechnical infrastructure of the polder. Damages were also caused by a lack of maintenance. Analysis performed on the impact of the Golina polder on the transformation flood wave revealed that, despite its considerable distance, the polder influenced the water level in the gauging station in the city of Poznań (Laks, 2017; Malinger et al., 2023). During the flood event in 2010, uncontrolled polder retention reduced the water level by 17 cm and water flow by 37 m^3/s, thus, significantly decreasing flood risk, although normal operating conditions would have caused a reduction of 29 cm and 65 m^3/s, respectively. This indicates a necessity for clarification of legal relations, particularly with regard to land ownership and renovation of infrastructure (Laks, 2017).

A concrete decision to build a fully operational flood retention polder was made in 2015, in which implementation of the Golina polder was included in a FRM plan for the Odra river basin as a technical strategic investment for flood risk mitigation (Rozporządzenie, 2016). Multi-criteria analysis performed for the purpose of the FRM plan included a comparison of three scenarios: (i) building the Golina polder, (ii) embankment relocation in the Golina municipality, and (iii) embankments removal in the Golina municipality. Based on economic, social, environmental and flood criteria, the first scenario was selected for implementation.

Due to the fact that the whole area of the Golina polder intended for inundation is protected in various forms, such as Natura 2000 birds and habitat directive sites as well as protected landscape areas, its implementation was preceded by detailed environmental impact analysis. The scope of analysis and environmental monitoring have been defined in detail in the decision on environmental conditions taken in the project involving the construction of a polder (RDOŚ, 2020a). During the environmental impact assessment, different variants of flow control were compared to select the most effective method for polder inundation that would not negatively influence the environment. Decisions on environmental conditions in relation to the Golina polder also included conditions of land use during the implementation and operation phases.

The environmental impact assessment procedure provides public participation in whole decision-making process (Ustawa, 1960; Ustawa, 2008) and local communities actively exercised their rights submitting reservations that were further included in the assessment. However,

extensive and detailed environmental impact analyses, constrained by numerous formal defects, led to a significant delay in the factual establishment of the fully operational polder. An environmental conditions decision was issued in 2020, where a specific variant of flow control was settled (RDOŚ, 2020a). However, in 2022, the appeal proceedings are in progress and polder implementation is still withheld (GDOŚ, 2022; RDOŚ, 2020b).

3.2 | Tiszaroff polder

The Tiszaroff flood peak polder is located in the middle section of the river Tisza in the Hungarian Plain, on the left bank at 375–380 km of the river section. It was completed in 2009 and was inundated during the 2010 flood.

The unprecedented series of major floods on the Tisza river between 1998 and 2001 as well as the dike breach in 2001 at the Hungarian upper section triggered a reconsideration of the prevailing flood defense strategy that had focused on heightening dikes to cope with flood peaks (Szlávik, 2003), albeit the height requirements were not fulfilled along the whole length of the river (Somlyódy & Aradi, 2002). The revision that concluded in the 2004/67 Law (named The Further Development of the Vásárhelyi Plan—VTT by its Hungarian acronym) combined three approaches: (i) strengthening the dikes, (ii) decreasing the roughness of the river corridor and (iii) creating flood peak polders. Notably, the Tiszaroff polder was the first element of the VTT development program. This polder system provides a total storage volume of 1.5 billion m^3 (Dobó, 2019) along the upper and middle sections of the Tisza River. Its flood wave reduction effect, albeit in a decreasing manner, lasts across the whole Hungarian stretch of the river.

The Tiszaroff polder was built adjacent to an existing dike line on an already protected part of the former Tisza floodplain, dominated with croplands, with no significant environmental value. It is a controlled inundation site where the operation of floodgates controls the timing and discharge volume of the inundation. This technical feature, based on a flood wave forecast simulation, provides the most effective flood peak reduction in what a given storage volume can reach.

During the initial planning phase of the polder development program according to the 2004/67 Law, it aimed for intertwined land usage based on nature-related floodplain farming activities that would be less exposed to damages in case of inundation and would form high natural value areas. Background documents of the VTT planning process estimated that nature-based farming activities would have higher public benefits than crop-dominated ones. However, the support provided by the EU CAP system for such activities (tailor-made for these flood polders) was not attractive enough to trigger land-use adaptation. The bias, induced by the EU-CAP subsidies' crop-friendly preferences was a major driver of sustaining a rigid crop-dominated landscape.

Ex-post simulations showed that the inundation of the Tiszaroff polder in 2010 resulted in a 38 cm decrease in the flood peak at the gates and a 36 cm decrease at the nearby downstream city of Szolnok (Kötivizig, 2010). The impacts of these reductions were felt in a diminishing manner along the whole section of the Hungarian river. The peak level reduction also nullified the need to build temporary defense structures against extreme pressure from the city section of the river in Szolnok. From an economic perspective, the balance of the 2010 intervention was positive—the flood risk reduction outweighed the damage compensation paid for sacrificing agricultural produce (Ungvári, 2016). A subsequent analysis (Ungvári & Kis, 2018) demonstrated that the 20-year return frequency flood is the breakeven one. In the case of more extreme floods, the use of the polder would be justified from an economic point of view. It is important to highlight that this breakeven flood peak level is much lower than the 100-year return frequency flood that was designed to be the trigger for polder use, based only on the hydrologic conditions outlined by the law under the VTT development program (Ungvári & Kis, 2022). It was concluded that flood risks alone do not provide enough additional benefits, compared to the actual operation, to justify the investment. Financially robust results on additional environmental benefits of a major land management change are necessary to be in the position to investigate whether such a step is justifiable—whether it is worth investing in the socio-economic improvement of the site and whether its users will be able to live up to the expectations of managing a site with higher performance on all three—environmental, social and flood risk reduction—aspects (Ungvári, 2022).

4 | COMPARATIVE STUDY OF POLDER IMPLEMENTATION

For this study, a comparative case study analysis was applied (Coletta et al., 2021). The analysis relied on content analysis of technical literature and reports and an extensive review of legal frameworks and administrative procedures. The research also includes the results of media coverage analysis and field visits. Data and information were analyzed to identify procedural steps and conditions in the polders' establishment. Moreover, thematic analysis methods were used to identify and report patterns in the themes obtained (Liamputtong, 2010;

Pertanika, 2021). Qualitative data and information were studied descriptively and then presented in the form of descriptions and tables to facilitate the reporting of findings. The analysis was performed in three thematic groups relating formal, economic, and social aspects as they overlap in innovation processes (Mumford, 2002).

4.1 | Formal and legal conditions

A significant factor hampering the implementation of polders is related to legal background and institutional settings (Raška et al., 2022; Warachowska & Zwoliński, 2023). A sufficient legal basis (including land acquisition, compensation and incentives) as well as efficient administrative systems and structures support NbS implementation and management (Brokking et al., 2021; Han & Kuhlicke, 2021; Neumann & Hack, 2020). The above factor is of particular importance in the implementation of polders, because NbS requires significantly more land than hard engineering constructions (Hartmann et al., 2019). Another crucial factor related to implementation is the fact that polder retention is also highly dependent on ownership structures (Brokking et al., 2021). Moreover, if precise methods for land reclamation agreements are not formulated and established, land acquisition and its further management would appear as both time- and money-consuming activities.

Regarding the factors mentioned above, FRM systems in Poland and Hungary are characterized by numerous common features. In both countries, due to the introduction of Directive 2007/60/EC for the assessment and management of flood risk (the Floods Directive) by the European Commission, frameworks for FRM and flood impact reduction have been implemented (EC, 2007). The implementation of the Floods Directive played a role in stimulating discussions and FRM planning in many member states that lacked a pre-existing national framework, thus positively influencing the creation of legal instruments for FRM (Priest et al., 2016). Also, the implementation of Directive 2000/60/EC of the European Parliament as well as the framework established by the Council for community action in the field of water policy (EC, 2000) had significant impacts on the water management systems in both countries, while introducing the rules for water management in cross-national river basins.

Issues related to FRM in Poland are regulated by the Water Law Act (Water Law, 2017), in which obligations related to the Water Framework Directive and Floods Directive have been implemented. The amendment to the Water Law Act in Poland in 2017 introduced a definition for a flood-protective polder (Water Law, 2017), which focused only on its flood protection function, regardless of the fact that the hallmark of such a measure lies its multifunctionality. This substantially narrowed down the definition of a polder, together with the lack of specific rules for land reclamation and flood damage compensation, directly caused significant social difficulties in polder establishment and its subsequent management.

First, the hydrotechnical infrastructure of the Golina polder was partially built in the 1980s during the realization of a project to embank the widely spread, natural valley for agricultural purposes in the Konin-Pyzdry section. After 1989, the project was re-prioritized. After this, although the polder was never finished as a fully operational flood-protective measure, existing infrastructure enabled flooding of the Golina polder area during the flood events in 1997 and 2010 (Ministerstwo Środowiska, 2012; Przybyła et al., 2011). Because of the lack of formalization in managing the polder and unfinished infrastructure for flood water flow control, the Golina polder could neither be qualified as a flood-protection polder nor could the land located within it be eligible for compensation for flooding (Sąd Administracyjny, 2011a, 2011b), according to the Polish Water Law Act (Water Law, 2001, 2017).

In Hungary, the legal bases of polder establishment and management were steered by a law (2004/67) that declared its development to be of fundamental public interest. It established the hydrological goal (1 m decrease in extreme flood peaks along the river) and the legal framework for polder implementation and exploitation that was applied in the Tiszaroff case. The land trail for the new defense infrastructure was expropriated, but the area inside the new polder could still be owned privately. The authorization of polder inundation initiated an upfront payment for the landowners, based on land quality, as compensation for future constraints on land development. It also offered full damage compensation in the case of any future inundation event. Landowners who would decline the offer faced expropriation.

The aforementioned legal instrument (Law 2004/67) called for the multipurpose use of polders as an integration of the flood mitigation function with the agricultural cultivation of the land. It also established that the financial burden of maintenance of the floodplain farming water management infrastructure within the polder lies on the state budget and the connecting water uses are exempted from the Water Resource Fee.

4.2 | Economic aspects of establishing polders

Financial barriers related to polder implementation are perceived mostly during the land acquisition process

(McCarthy et al., 2018; Raška et al., 2022), while negotiation with private actors appears to be difficult, especially in large-scale projects (van Dijk, 2003).

In the case of both polders investigated in this study (Golina and Tiszaroff), the land is mostly a private property. Using private land to decrease the downstream flood level is an intervention to pursue public benefits for a wide range of citizens while imposing its costs on a small group of people situated upstream. With the increasing distance between the two groups (beneficiaries and cost bearers) in terms of localization and communality, there is an urgent need to establish a clear contractual term for such service provisions (Thaler et al., 2016).

From an economic point of view, establishing and exploiting a polder for flood risk reduction purposes is worthwhile if its overall risk reduction impact is higher than the cost of establishing the infrastructure and management of the land within the polder. The public benefits of polder use (expressed as flood risk reduction) must be compared to the total cost related to polder implementation and management in monetary terms in order to justify the use of public financial resources. Also, the largest element of performed economic analysis was expenses related to land expropriation what emphasizes the role of economic analysis in FRM bargain.

In the Polish case, the inherited legal definition of polders can be viewed as an ambiguous allocation of property rights concerning the boundary of state responsibilities on protection against floods. Overcoming competitive interests between the state and local communities was attempted through legal actions based on the definition of polder delineation, without accounting for its full economic impact on landowners and their real impact on flood protection in the region. The state tried to limit its financial burden of buying flood risk reduction services by using ambiguous delineations, but the lack of economic bases thwarted the unequivocal execution of what the law authorized. In the Tiszaroff polder case, a cost minimization approach was applied where the expected cost of initial and event-based payments over several decades of polder operation was verified by a threefold difference between the investment cost of the polder system and the large-scale dike height increase along the impacted river stretch downstream from the polder (Ungvári & Kis, 2022). It was assumed that the development alternatives were identical—both fulfill the defined hydrological goal, and the difference between their investment costs provided a basis to verify the decision and the compensation commitments as part of the polder development program that took shape with the law (Law 2004/67). Up to the mid-2010s, the Golina site was never analyzed with similar economic accuracy (KZGW, 2015a, 2015b).

4.3 | Social aspects of FRM using polders

Several factors that influence polder implementation and management are perceived in knowledge distribution and share among stakeholders (Brokking et al., 2021; Chou, 2016; Małecka-Ziembińska & Janicka, 2022). People's knowledge about NbS effectiveness and their awareness of increasing flood risk can influence their general acceptance of NbS (Gray et al., 2017; Han & Kuhlicke, 2021; Martinez-Juarez et al., 2019; Raška et al., 2022). Furthermore, transdisciplinary knowledge transfer between specialists and stakeholders is necessary for the sustainable management of these measures (Neumann & Hack, 2020). Common awareness of flood risk and well-established knowledge can foster the involvement of local communities and communication during the entire NbS management process (Neumann & Hack, 2020).

The lack of awareness about flood risk, deficiency in the availability of information on polders—including their real impact on private property—as well as the absence of clear and consistent formal and legal conditions for polder implementation and management (Sosnowska, 2016) may directly lead to the emergence and proliferation of social conflicts. When water flowed into the Golina polder area uncontrollably during the flood events in 1997 and 2010, the local community decided to block the overflow shaft with sandbags to prevent further inundation and protect the private property located inside the polder. Later, as intended, the provisional protection was removed and the polder area was filled with water. However, because of unscheduled water flow, flood peak attenuation was unsuccessful and the polder did not play a significant role in the flood protection system.

Social tensions in Poland were also observed regarding land acquisition, substantial decisions on establishing polders were taken after decades of hesitation and specific rules for land expropriation were not formulated. Also, flood damage compensation rules were unclear, as they referred to an ambiguous formal definition for a polder (Sąd Administracyjny, 2011a, 2011b; Sąd Najwyższy, 2020; Water law, 2017).

The lack of administrative response toward social needs resulted in bottom-up initiatives—several interpellations were addressed at the municipal and national levels, formulating key questions for landowners, such as the course and rules for land expropriation, financial security for eventual claims and possible land use and cultivation of areas intended for inundation.

Polder management and establishment in the Tisza river basin did not induce such social tensions and protests because the VTT law created simple *take-it-or-leave-*

it rules for landowners to cooperate. With no other viable solution in sight, strong political support for the development plan was observed. From the perspective of the landowners, the rules for compensation were advantageous—a significant upfront payment and full compensation in the case of uncertain future events (in the case of average or below-average quality land, the imposed cultivation constraints were not effectively binding on the actual agricultural activities).

5 | DISCUSSION

A comparative analysis of case studies revealed several factors influencing effective social innovation. However, the polder implementation process is complex. It can be observed in the development of both the physical infrastructure and the institutional framework that incorporates agreements between public agents of the beneficiaries (downstream communities) and landowners, who are the service providers for flood risk reduction (upstream communities) (Warachowska et al., 2021). Ultimately, the influence of all formulated factors is ambiguous; they can have both positive and negative influences depending on the context.

5.1 | Formal and legal conditions

The evidence from both case studies indicates that the establishment and effective management of polders is impossible unless their formal and legal backgrounds are substantially settled and a set of clear rules for the land negotiation process is formulated and directly communicated. However, it should be noted that the above instances do not prejudge the success of the implementation process of a fully multipurpose, nature-based solution, as shown in the Hungarian case study.

In both case studies, institutional FRM is characterized by several common features, such as geopolitical history, the legacy of centralization, and the dominant role of the state hampering social participation. In both polder implementation processes, the role of local communities was limited. In Hungary, landowners were restricted to choosing between two pre-designed options: participating in a compensation scheme or expropriation of the land. In Poland, complaints from local communities opened a window of opportunity at the beginning but were considered only minimally in the later stages of polder implementation.

A strong legal and formal background can serve as a basis and support for social innovation, but if too strong, it can deter people from undertaking actions.

5.2 | Economic aspects of social innovation

Comprehensive economic analysis can significantly enhance the process of polder implementation (Ungvári & Kis, 2022), helping to justify the use of public finances and formulate an acceptable financial scheme for landowners. In the Hungarian case, as the land was accessed to fulfill a public goal, seemingly the legitimacy of the compensation was sufficiently established. The case shows that the simple *take it or leave it* rule limited the role of the people in the decision-making process.

NbS implementation processes require economic justification, but negotiation processes supported by the results of economic analysis (especially land expropriation) hold great potential for innovation. Any agreement with landowners that makes them accept transitional water cover on their land results in nullification of payment of the full price of the land. This arrangement is a reasonable and usual aspiration for implementing nature-based FRM solutions. It is also the preferred option from a social point of view, since expropriation decreases the livelihood prospects of inhabitants, which goes against other development initiatives, such as countryside development strategies.

The implementation of NbS invokes agreements that encourage positive actions instead of obedience to imposed rules. This requires skills, adequate approaches, and perceptions that institutions are yet to acquire, but citizens should demand as well. Implementing these approaches has an indirect positive effect on the social cohesion of the areas concerned, which is also of great importance.

5.3 | Social aspects of FRM using polders

The analysis showed that facing the disastrous consequences of flood events is a strong driver for undertaking flood risk mitigation actions, yet the responses in local communities differ.

In the Polish case, strong social conflicts emerged after the flood event, and communities actively participated in the initial phase of polder implementation. Then, the bottom-up action collided with the insufficiency of the administrative system and ambiguous rules for polder implementation, resulting in further limitation of public participation. Social conflicts, initially perceived as a problem to be solved, can become a window of opportunity to initiate change in contrast to the status quo. Conflict, in this case, can be seen as an inevitable part of social innovation processes (Schumpter, 1911). The environmental impact assessment on polder

implementation involved public participation during the whole decision-making process, yet active engagement appeared only at the beginning and strong trust in local and national authorities has stopped further efforts. The environmental impact assessment was also a protracted process due to the ambiguity of legal regulation and the complexity of the negotiation process.

In the Hungarian case, the status quo flood defense strategy prevailed for decades due to there being no apparent reason to change track. The disastrous flood event triggered a feedback process, but the reaction of the state was so firm in its invocation of a regional-scale implementation that it also limited public participation—the role of citizens was limited to choosing between two options. This corresponds to a phenomenon often observed in post-communist countries: people mostly rely on the state for long-term flood risk mitigation, and people's engagement, if it extends beyond ensuring their own wellbeing at all, is rather limited (Raška et al., 2020).

5.4 | Social innovation

Social innovation can refer to such a changes that aim to improve the welfare and wellbeing of individuals and communities (OECD, 2016). This approach to social innovation is reflected in the concept of NbS, meaning actions and technologies that are established to protect, sustainably manage, and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously benefiting people and nature (IUCN, 2021). The implementation of NbS, involving natural processes to simultaneously protect natural ecosystems and provide human wellbeing (Cohen-Schacham et al., 2016; Fernandes & Guiomar, 2018), seems to be an answer to meet the demand for resilient FRM. Yet, polders, as NbS in FRM, satisfy social needs on the one hand, but on the other hand, their implementation and management require innovation in redefining, combining, and reformulating these approaches to induce successful change.

Assembling multi-purpose land management schemes that include flood risk reduction, among other public and private benefits, in places where it is necessary to maintain a steady and dynamic balance between competing interests requires institutional skills that only states with advanced governance capacities possess. Central-European countries (even after over 30 years since the transition) struggle to restructure governance culture toward such capacities (Dąbrowski & Piskorek, 2018; Gorzelak, 1996; Sykora & Bouzarovski, 2012). Without such a shift in governance culture, negotiating NbS solutions is bound to be an uphill struggle. The primary issue here is not the choice of innovations to foster flood risk reduction agreements; rather, it is whether the challenges to FRM can create a pilot field to cultivate better governance solutions.

The case study analysis proved that polders can be perceived as an innovative and effective measure in FRM. Moreover, the implementation of polders meets the preconditions of social innovation. In the implementation of polders to mitigate flood risk, basic needs were satisfied, significant transformative processes were induced to implement polders, and local communities and institutions were mobilized to induce change. However, substantial and long-lasting change in society has yet to be induced.

6 | CONCLUSION

The dynamic nature of climate change, together with intensive floodplain development, have resulted in flood damage of an enormous scale. This has fueled discussions on the implementation of innovative flood-protective measures capable of coping with constantly changing environmental, social, formal, and economic conditions.

Depending on context polders can be seen as an innovation, especially when compared to hydraulic engineering solutions in FRM. They also bring benefits to the environment by protecting natural ecosystems, as well as to people by decreasing flood risk and ensuring safety. Although their innovativeness and effectiveness seem evident in terms of flood risk mitigation, the potential in introducing social innovations is untapped. The evidence from the comparative analysis shows that facing the disastrous consequences of flood events is a strong driver for undertaking flood risk mitigation actions. Yet this does not always evoke a change aimed at improving the welfare and wellbeing of society. Effective introduction of social innovation is bounded by several factors that are full of contradictions—the same aspect can either allow or hinder public engagement and successful social innovation. Furthermore, there are hardly any necessary conditions, while several combinations of sufficient conditions can lead to success.

Lack of systematization of the formal and legal frameworks precludes the introduction of innovation in FRM systems and at the same time significantly complicates the flood damage compensation process. Moreover, clear and simplified rules for land reclamation and polder implementation can help people engage in decision-making processes but can also significantly limit their factual active engagement. Furthermore, formal and legal ambiguity, along with its consequences, leads to social conflicts, which can be seen as a complication in FRM

measure implementation but often becomes a window of opportunity as well. The implementation of polders was induced in response to the context-specific challenges such as social pressure to undertake effective flood risk mitigation actions. Local communities anticipated innovation in FRM that the authorities were expected to deliver. Social transformation is a continuous process, and as flood risks increase dynamically, constant adjustments in the formal, economic, and social variables are required. Thus, the introduction of social innovation requires the optimization of those variables as they overlap in the process of innovation.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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