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Overcoming Barriers and Fostering Adoption: Evaluating the Institutional Mainstreaming of Nature-Based Solutions in the Emilia-Romagna Region's Socio-Ecological System

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Abstract: International organizations like the EU and IUCN are advocating for nature-based solutions (NBSs) as green alternatives for climate change adaptation and mitigation, especially in disaster risk reduction and urban planning. The H2020 OPERANDUM project was designed to address the major hydro-meteorological risks (floods, droughts, landslides, storm surge, and coastal erosions) through the deployment and assessment of NBSs in different contexts and areas affected by specific hazards. Despite growing research and funding, NBSs are still in the early stages of mainstream adoption and face challenges in acceptance and dissemination. Although designed to benefit both social and ecological systems, they remain a niche area with low perceived effectiveness among technicians and decision-makers. Their uptake requires a paradigm shift that includes a change in cultural-cognitive institutions, a different and wider set of knowledge than traditional engineering (ecological, social), and an adaptive management approach, missing within the current governance system. Using a qualitative case study research method, this paper aims to identify barriers in mainstreaming NBSs for DRR (disaster risk reduction) in the Emilia-Romagna region—influenced not only by individual beliefs but also by variables tied to technical culture and local procedural norms—and emphasizing the importance of combining social and ecological indicators in socio-ecological system analysis.

Keywords: nature-based solutions; socio-ecological system; technical culture; qualitative research

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1. Introduction: NBS Definition and Their Role in the Social-Ecological System

Over the past two decades, a clear pattern has emerged: the rate of climate-related risk generation has outpaced risk mitigation efforts. This is evident from the considerable rise in the annual occurrence of documented natural disasters, predominantly attributed to climate change [1]. Hydro-meteorological hazards (HMHs) such as floods, droughts, and landslides pose persistent threats to socio-ecological systems (SESs) and human communities. Their frequency and intensity are already increasing due to climate change, a trend that is expected to continue in the foreseeable future [2]. The protection and preservation of ecosystems and biodiversity, which face imminent collapse, are also areas where current strategies fall short [3]. Recognizing the urgent need for action, major international organizations such as the UN, EU, and the World Bank have identified nature-based solutions (NBSs) as a viable approach to address these dual challenges. The IUCN in 2016 defined nature-based solutions as "actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits". The most recent NBS definition was formally adopted by UNEA-5 in 2022. This definition makes clear that NBSs aim to provide benefits at environmental, ecosystem, territorial, but also social, economic, and community levels [4].

The field of disaster risk reduction (DRR), and more generally, spatial planning and land management, has been dominated by the so-called "gray" or hard-engineering infrastructures that make extensive use of reinforced concrete, steel, iron, rocks, walls, and barriers of different heavy materials. This approach has served the purpose of economic development and risk mitigation but with a linear and deterministic view of the natural environment and its dynamics [5], and they have contributed to impairing the ecological status of river and coastal areas and reducing the provision of other ecosystem services. Moreover, longstanding urbanization processes have also significantly reduced the presence of green spaces in residential areas compromising ecosystem services such as water drainage, temperature regulation, mitigation of heat waves, and regulation of pollution and air quality and resulting in the reduction of recreational spaces [4]. NBSs instead have a dynamic nature that implies a more iterative process where the uncertainties and complexities of the socio-ecological system are considered [6], with a focus on co-benefits or additional ecosystem services [7] in addressing the challenges of climate change adaptation and mitigation [4,6]. A socio-ecological system refers to a complex system that reflects the relationship between ecosystems and social, economic, and cultural systems. It is defined as "a coherent system of biophysical and social factors that regularly interact in a resilient, sustained manner" [8]: this concept is helpful for the understanding and management of complex systems of human interactions with nature when addressing sustainable and climate-change-related issues [9].

Considering these characteristics, it is essential to recognize the intricate interconnections within and among ecological and social systems [10]. This entails integrating ecological understanding with anthropological, social, and economic insights [11]. Such an interdisciplinary approach draws upon a range of disciplines and theories, including Holing's new ecology [12], neo-institutionalism, and commons studies [13], as well as ecological and environmental economics [14].

Moreover, the NBS approach is grounded in distinct scientific assumptions, knowledge bases, and technical practices, marking a significant technical and technological shift. Efforts toward mainstreaming NBS can be characterized as a socio-technical change or transition [15], emphasizing that it would represent both a technical shift but also a new holistic approach to spatial planning, water and land management, and biodiversity conservation, carrying substantial social and ecological implications. The term mainstreaming is sometimes used interchangeably with concepts like "diffusion", "social acceptance", "market acceptance", "technological transition", "community acceptance" [12], and even "adoption", "attitude", or "support" [16]. In the context of NBS, attention has predominantly focused on local community acceptance [17,18]. This variable is widely recognized as very relevant. However, since we are dealing with a socio-technical transition, the level of acceptance among technicians and policymakers should also be considered to foster mainstreaming and obtain impacts on a significant scale. In the past two decades, research on climate change adaptation strategies and management practices has increasingly emphasized transdisciplinary approaches. The complex nature of the NBS approach, which amalgamates diverse knowledge, novel technical expertise, and social practices, has underscored the necessity to cultivate co-creation practices. This has led to a higher demand of stakeholder engagement in NBS planning and implementation [17–19] and a shift in methodological perspective [6,20]. This has been the approach adopted by the Horizon 2020 OPERANDUM project [21,22], which aimed to address major hydro-meteorological risks through the design, deployment, and assessment of NBSs. Grounded in a co-creation framework, the project has established seven open air laboratories (OALs) [23,24] to facilitate a user-centric approach, wherein stakeholders actively participate in the planning, implementation, and evaluation phases of NBS initiatives. OALs, as complex biophysical and socio-economic systems, extend the concept of living labs to rural contexts. They represent a suitable place to analyze and study the socio-ecological system: a physical space where it is possible to analyze and address issues related to social and rural dynamics, guiding the collection and management of pertinent data and information to increase social acceptance and strengthen policies at the local level.

This paper offers insights from a case study conducted in the rural areas of the Italian region, Emilia-Romagna, where OPERANDUM OALs have been implemented. These insights hold relevance beyond rural contexts, extending to diverse peri-urban and urban settings. While acknowledging the significance of garnering positive attitudes and support from administrators and public decision-makers, attention must also be directed towards ensuring technical acceptance and fostering collaboration across professional cultures, extending beyond the horizon of decision-makers. The research idea stems from a combination of constant and shared reflections among social science researchers and members of OALs during the project, coupled with the growing necessity to generalize case studies for wider applicability, especially in urban contexts pertaining to wild or emergent natural settings. This aims to contribute to the transdisciplinary research field, recognizing the need to increasingly integrate social and ecological variables when addressing the numerous challenges posed by the effects of climate change on socio-ecological systems and the populations inhabiting them. The social sciences are tasked with scrutinizing the social and cultural ramifications of environmental technological innovations, avoiding the trap of "quantophrenia" [25–27], which confines sociological analysis to statistical and numerical realms. Sociology must instead embrace qualitative methodologies and techniques to thoroughly delve into the multifaceted aspects of social practices intertwined with technical and technological changes.

2. Materials and Methods

This research employed a qualitative case study methodology [28–30], particularly in its exploratory sense, aiming to capture the comprehensive and significant essence of real-life events [28] and to explore the underlying causes of complex phenomena [29]. This method fosters the exploration of diverse perspectives and facilitates the development of rich relationships between social and ecological variables and how they interact within socio-ecological systems within which NBS implementation initiatives develop.

This research focused on the governance system of Emilia-Romagna and its associated socio-ecological system as the case of analysis. The Emilia-Romagna region faces a high level of risk with respect to different hydro-meteorological hazards [31,32], and NBSs would therefore be a strategic tool to reverse this trend and mitigate risks.

The research field was explored via interviews and focus groups, together with constant participant observation linked to the active involvement of the authors in project activities within the OAL Italy, located in two areas of Emilia-Romagna. From November 2020 to July 2022, 19 semi-structured interviews and 3 focus groups were carried out with researchers, local government and administration technicians, practitioners, and planners involved in the project in various roles. Respondents were anonymized, with only their organizational affiliation, focus area, field of action, and educational background disclosed (Appendix A).

The selection of interviewees was based on their involvement in the OPERANDUM project. They participated in various capacities during the project's phases, acting as stakeholders in the co-design phase and collaborators during the implementation phase. Initially involved in focus groups, the participants were later invited to take part in individual in-depth interviews to delve deeper into three thematic areas that emerged during the collective discussions. These thematic areas are detailed and discussed in the results section. All interactions were recorded and transcribed verbatim. The findings from the interviews and focus groups were subsequently analyzed through content analysis, in which the statements obtained were broken down, divided into thematic areas, and examined in their main components to understand and detail the knowledge of the phenomenon researched. The types and classifications of the thematic areas were identified in the focus group and served as the "unit of measure" useful for producing inferences and arguments that represent the main findings of the interviews. The analysis was carried out without the use of analysis software, instead proceeding with repeated readings of the transcriptions to identify considerations related to each thematic area over time. This also allowed for the highlighting of recurrences and inferences that had not been initially coded and enabled a more integrated analysis, exploring aspects and issues not immediately detectable.

Choosing qualitative methods captures the importance of individuals' contributions and their process of assigning meaning to specific objects or events. This approach is essential for generating insights and conducting critical analyses of such multifaceted phenomena. It is therefore necessary to move beyond mere quantitative data and delve deeper into the experiences of those directly engaged in decision-making processes and procedural dynamics that underpin the research focus. This approach facilitates the potential comparison with challenges associated with NBS adoption in urban settings. By using SES case study methodology as our analytical framework and socio-technical transition as our theory of change, we aim to elucidate the critical factors for successful project or plan design and implementation related to resource management, territorial planning, and, in our specific context, the acceptance, adoption, and effective implementation of NBS.

3. Case Study

The EU Horizon 2020 OPERANDUM project carried out on-site research implementing OAL, based on the living lab concept defined by Westerlund and Leminen [33] as "physical regions or virtual realities, or interaction spaces [. . .] for creation, prototyping, validating, and testing of new technologies, services, products, and systems in real-life contexts". The OAL Italy was entirely located in the Emilia-Romagna region on the Panaro River (Figure 3) and the Bellocchio beaches (Figure 1). The first site tested deep-rooted plants (Figure 4) to strengthen river embankments; the second tested artificial dunes with special sandbags (Figure 2) to protect the beach and the surrounding ecosystem from storm surges and coastal erosion.

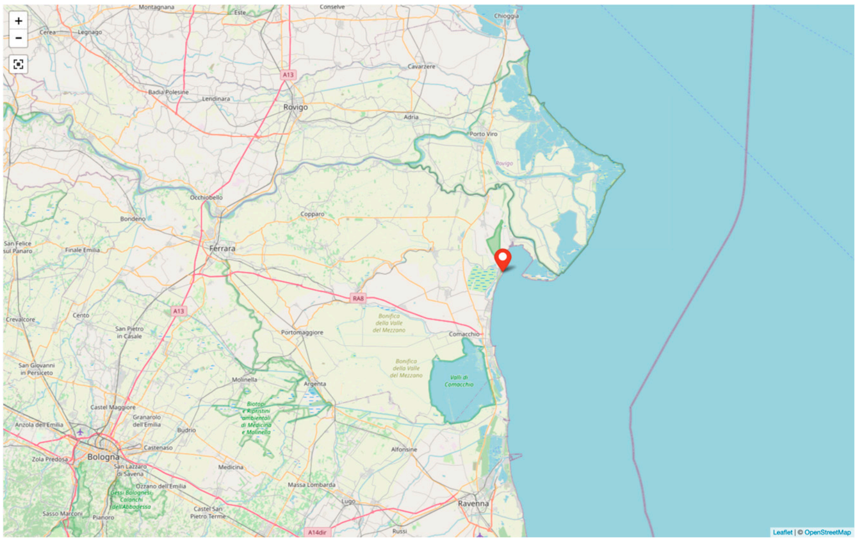

Figure 1. Map of the Bellocchio Beach, Comacchio (Ferrara).

Bellocchio Beach is located on the Emilia-Romagna coast of Adriatic Sea (Figure 1). The Bellocchio Beach is situated between a very active touristic hub (Lido di Spina) and the mouth of the Reno River. The site is very interesting from a naturalistic point of view. The beach is located close to a vast pine forest and is strongly affected by marine erosion. In case of storm surges, sea water floods the lagoon, threatening the freshwater ecosystem and biodiversity. The sites, embedded in one of the main touristic systems of Europe, preserve natural heritage and historical records, and in the inland area, they host industrial activities like fish farms.

Figure 2. Artificial dune built on Bellocchio Beach.

The Panaro River is a tributary of the Po River and flows for the greatest part in the province of Modena in the Emilia-Romagna region (Figure 3), with a basin covering 1775 km^2, 45% of which is in a mountain environment. The main hazard here is river flooding since the area is a natural floodplain. The basin is densely populated, with numerous industrial and agricultural activities, including livestock farming, resulting in a significant level of exposure. Vulnerability is further heightened by insufficient wetland management, inadequate flood protection for properties and structures, and diminished water retention capacity. Consequently, the region faces risks such as the potential loss of human life, infrastructure damage, property loss, and harm to agricultural crops and livestock. The chosen NBS is designed to alleviate the risk of flooding caused by soil erosion along the inner edge of the riverbank by planting deep-rooted shrub vegetation (twelve species of perennial cespitose and Leguminosae graminoid grasses) (Figure 4) to reinforce the embankment.

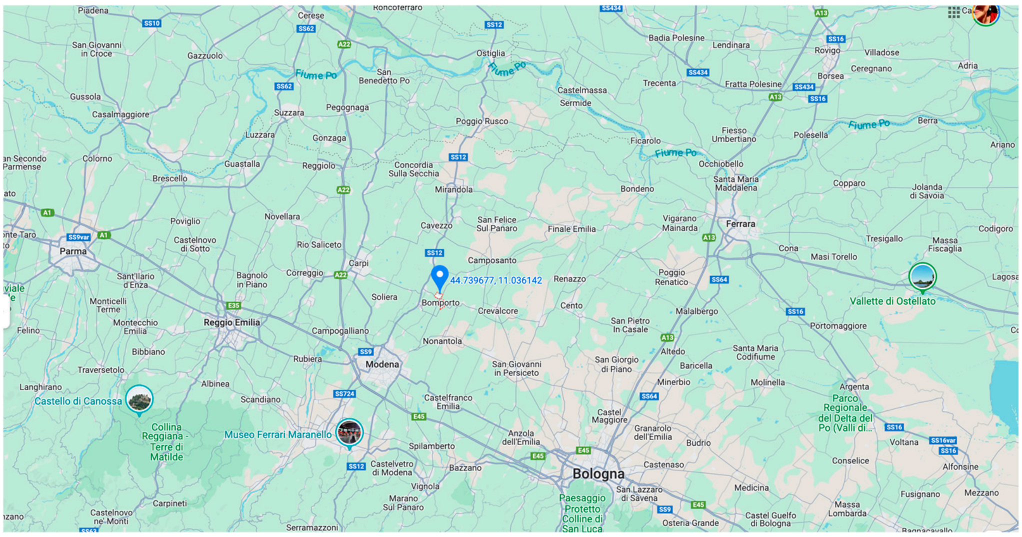

Figure 3. Map of the Panaro River close to Bomporto (Modena).

Figure 4. Deep-rooted plant planted on the Panaro River embankment (left side).

4. Results

This section offers a qualitative content analysis of insights gleaned from interviews and focus groups, aimed at pinpointing three overarching variables identified as impediments to the expansion of the NBS niche, hindering its progression to becoming a recognized standard and effecting a substantial socio-technical transformation. By examining interviews and focus groups, we seek to uncover dimensions crucial for evaluating this process, along with social variables essential for comprehending the adoption and mainstreaming processes of NBS.

4.1. Technical Culture and Professionals

Cultural factors appear to play a significant role in explaining the inertia within the system, the lack of innovation, and the preference for conventional solutions. Among the most commonly cited is the background of technicians, who are predominantly trained to adhere to the prevailing management paradigm, focused on simply managing water flow to mitigate risk without considering broader impacts. This prevailing management approach promotes hyper-specialization but lacks cross-disciplinary integration and fosters a deterministic view of risk, resulting in low-risk acceptance and limited inclination to innovate.

> *"Around the issue of resilience, we have learnt this new term [. . .] to refer to when dealing with the issue of hydrogeological risk. Before, there was resistance, and we had to resist and counteract, and nullify the risk. Now we are learning that it is not possible to nullify the risk. This is a concept that is maturing even at an institutional and social level. In the face of such striking changes our efforts are almost useless, complicated, and we must learn to act in different ways with different objectives, perhaps by accepting a degree of risk [. . .], including the ecological one" (Respondent 6, Civil Engineer 2022).*

> *They (decision-makers) have a very old-fashioned mentality which is very deterministic, it is all black and white, and there is a certain resistance to accepting probabilistic approaches with a broad quantification of uncertainty (Respondent 17, Physicist 2022).*

> *We would never be able as a country to hold all the mountain sides and banks of the country together, but we are able to do planning" (Respondent 12, Geologist 2022).*

Highlighting the importance of these cultural aspects, the statements collected strongly indicate the necessity for a new type of training and education characterized by multidisciplinary and adaptive skills. It is crucial to raise awareness among all stakeholders, including technicians, about the need to adapt to changing paradigms and embrace innovative approaches. High-level technical skills, including expertise in fields such as hydraulics and geology, are essential for DRR efforts. However, there is a notable scarcity of ecological skills in both the Italian and Emilia-Romagna DRR contexts. The absence of hybrid professional profiles and medium/large engineering firms with multidisciplinary teams further exacerbates this issue. Public administrations lack naturalistic engineers, biologists, and ecologists, and external collaborations are sporadic.

> *"One cannot [. . .] realize or design NBS works without talking about living organisms that have the "flaws" that are not linear over the course of a year [. . .], so I have to design and think about how they develop over time" (Respondent 11, Biologist/Ecologist 2022).*

> *"Let's agree on terminology. Between engineers, economists, and biologists, there are different terminologies. You can't go around talking about NBS that only a few people know exactly what they are" (Respondent 11, Biologist/Ecologist 2022).*

> *"For the implementation of specific interventions or to increase knowledge we still do not have sufficient knowledge of what are, for example, the ecological or ecosystem aspects when doing an intervention" (Respondent 2, Environmental Engineer 2022).*

> *"Site management is always entrusted to technicians with a certain training and never supported by agronomists, forestry experts, or botanical experts. Renaturation works are managed in a marginal way or are not carried out correctly, and this then leads to a failure of the intervention" (Respondent 1, Civil Engineer/Hydrologist 2022).*

The relevance of ecological expertise varies depending on the type and ecological intensity of nature-based solutions [34]. Some practitioners express concerns about potential "ecosystem disservices", such as unforeseen impacts like attracting undesired species, operational complications, and challenges in managing new habitats. To address these challenges, there is a growing demand for more experimental spaces to test NBSs, which would facilitate better knowledge sharing, risk assessment, and learning from both results and lessons. Respondents stress the need for a greater integration of knowledge and that a more adaptive and flexible management approach is crucial for effectively implementing NBSs and navigating uncertainties in ecosystem management.

> *"What the decision-makers are looking for is data, whether it has been done this way and has been successful and why, or if there have been critical issues, how they can be solved" (Respondent 4, Coastal Geologist 2022).*

> *"What is certainly missing is dissemination of positive experiences that give courage and confidence to those who make plans and those who make interventions, that these things can really be done, that they work and that they are therefore worth the risk. There is a need for more examples of interventions that went well" (Respondent 6, Civil Engineer 2022).*

> *"This culture can only be changed by disseminating pilot interventions, and by training both technicians and administrators (Respondent 1, Civil Engineer/Hydrologist 2022).*

4.2. Governance and Policy Dimension

Another significant issue brought to light is how to move beyond the experimentation phase and scale up the transition. This involves considerations regarding governance structures and processes, policy instruments, and the development of comprehensive planning and operational strategies for risk mitigation. It has been noted that risk mitigation efforts are typically underfunded, with funds often arriving after disasters occur or through large-scale master plans rather than on a structural basis. This approach overwhelms administrative and technical offices, limiting the opportunity to explore new solutions. Furthermore, when funds become available, and there is a strict timeline for implementation, such as in the case of the NRRP [35], traditional "ready-to-go" projects are prioritized over the design of new and innovative ones.

One of the most recurrent and significant factors is attributed to the so-called legal barriers, in terms of the absence of technical standards on NBSs established by the relevant ministries. The lack of well-defined technical standards with legal value undermines the confidence of technicians in adopting innovative and less certain approaches.

> *"If something happens with an alternative approach, then you risk being blamed precisely because you have made a different choice, even if it is perhaps less risky. In the last 20 years, legal procedures have become more complex, sensitivities and responsibilities have increased a lot, and there are many more trials" (Respondent 3, Naturalistic Engineer 2022).*

> *"If one makes a mistake, they cannot be hanged. Here, part of the public administration difficulty in being transparent is linked to the fact that if I make a mistake they put me in jail and throw away the key" (Respondent 12, Geologist 2022).*

> *"It is very brutal and pragmatic, but my responsibility is to save it from flooding. If you tell me it can be saved in a different way but I have never done it, and because there is a risk, as an engineer I go on the safe side" (Respondent 10, Environmental Engineer 2022).*

> *"Why do I personally have to go and risk not having sufficient guarantees that in my river, when there is a flood, the water will pass without causing damage, which is the task given to me by the laws and regulations. I do not have sufficient guarantees for doing something different" (Respondent 6, Civil Engineer 2022).*

Furthermore, a more precise codification and procedural framework for NBS would improve certainty in authorizing projects. Particularly noteworthy is the absence of explicit inclusion of NBSs in the annexes to the Environment Code and in the Environmental Impact Assessment Regulation, which delineate project types and their authorization processes based on specific thresholds.

> *"The main issue in the design phase has been which kind of procedures and documentation should be followed" (Respondent 16, Physicist 2022).*

Policymakers should recognize that relying solely on regulatory policies to mainstream NBSs may encounter resistance from the prevailing cognitive-cultural structures within the governance system. Therefore, the policy cycle needs to integrate learning cycles to facilitate system adaptation and yield results. Alongside regulatory efforts, there is a need to promote social learning to reshape knowledge, skills, and values within the system. This shift in competences and investments in the field could be supported by a significant uptick in interest in NBSs by large corporations, driven by the potential to enhance their sustainability reporting indicators. While the extent to which this interest represents genuine commitment or greenwashing is debatable, the convergence of private funds toward NBSs could contribute to mainstreaming these solutions.

> *"Private companies exhibit greater willingness to embrace innovations compared to public bodies" (Respondent 8, Civil Engineer/Construction Sustainability 2022).*

4.3. Socio-Economic Dimension: Land Use Conflict and Economic Interests

A potential barrier identified is when NBSs require more space to be effective compared to their gray counterparts. Land property rights and conflicting interests emerge as critical contextual factors, especially within the DRR system. This scenario may occur, for example, during actions such as widening riverbeds or canals, excavating floodplains (golena), or constructing dune cordons. In highly anthropized socio-ecological contexts like Emilia-Romagna, this could lead to conflicts with local interest groups such as farmers, tourist operators, or individual citizens who, for various reasons, prefer the status quo.

These reasons may include feeling safer with higher embankments, attachment to the area, or economic interests. The predominantly private regime of land ownership necessitates ongoing interaction with stakeholders, such as landowners, farmers, and residents, which impacts decision-making and potentially influences the mainstreaming process of NBSs for interventions beyond riverbeds and canals.

> *"It seems that there is a need for keeping the situation unchanged because it is the safest and quietest way rather than going to tell people about these practices that may be more effective, but that entail sacrifices for someone. For instance, losing the possibility of using a floodplain and instead planting an orchard there. Taking it down and making it a water expansion area becomes complicated from this point of view. It is easier to raise the embankment than to make a setback and give land to the river so everyone is safer (Respondent 13, Civil Engineer/Hydrologist 2022).*

> *"Whenever I have heard talk of interventions to reduce risk in the river area, I have always and consistently observed the opposition of agricultural interest organisations, especially when it comes to biodiversity conservation practice and protected areas" (Respondent 5, Physician/Data Analyst 2022).*

Trade-offs may emerge between navigational interests, such as the need for higher riverbanks and renaturation objectives, both central to the Po River renaturation project. Similarly, recreational and tourism interests along coastlines may clash with efforts for ecological management and risk reduction.

> *"This (Posidonia, seagrass, dunes) is the ecological beach approach. We remove the Posidonia to sell the tourist a product that does not exist. We have to start selling the real Mediterranean beaches which are made by this system. Because in winter it protects us from erosion" (Respondent 4, Coastal Geologist 2022).*

> *"For us (in Italy), the concept of public good, having privatised the beach, is somewhat less and this is reflected in decision-making. Owners of seaside facilities, hoteliers and all those who have an interest are important lobbies" (Respondent 4, Coastal Geologist 2022).*

Understanding the forces at play within the socio-ecological system, including interest groups and organizations, is therefore crucial. Interviews highlighted that interest groups often act as barriers to NBS mainstreaming, and convincing stakeholders of the benefits of ecological practices, such as river restoration, can be challenging but necessary. Some respondents pointed out that individual entrepreneurs and companies are more receptive to accepting ecological approaches when there is proper engagement and effective communication. They suggested that compared to interest organizations, these entities demonstrate a greater willingness to participate. Moreover, among the individual aspects considered crucial by the interviewees, dealing with private or contested areas in NBS planning requires careful consideration of various interests involved from the outset. Addressing conflicting interests and balancing private interests with the public good is imperative, and improving communication is vital to convey the long-term benefits of NBSs to stakeholders and the general public, potentially leveraging climate change adaptation discourse to elevate NBSs on the political agenda.

5. Discussion

The acceptance and adoption of NBSs in DRR policies are influenced not only by individual beliefs but also by variables tied to technical culture and procedural norms. It is essential to recognize that alongside the variables we have identified, there are additional factors linked to the environmental and morphological context, particularly concerning high-risk events like hydro-meteorological disasters.

The results of the interviews indicate that factors influencing the acceptance and integration of NBSs into mainstream practices, especially among skeptical technicians or those lacking specific training, is their perception of risk and what is considered a valid solution to face it. Regarding NBS acceptance, the perceived effectiveness emerges as a central theme. This perception is considered a socio-ecological index, encompassing hazards, exposure, and vulnerability. It is noted that individuals' risk perception may not always align with the actual level of risk. The adoption of NBSs is influenced by the risk context; higher risk lowers the likelihood of adoption compared to traditional solutions. Therefore, a high-risk context and the uncertainties regarding the effectiveness of NBSs are an obstacle, as both the technical planners and decision-makers do prefer the solutions they know better and have relied on so far. Stakeholders, accustomed to traditional gray solutions, express uncertainty about the effectiveness of NBSs due to its socio-technical novelty. Many stakeholders in DRR lack direct experience with NBS implementation, further underscoring the importance of addressing perceptions and socio-technical readiness in NBS integration. Increasing awareness of the benefits of NBSs can be achieved through the active involvement of stakeholders in all phases of design and implementation, using creative methods to inform and disseminate the results obtained at the local level (field trips, talks, videos, and booklets) or by connecting successful experiences at the national and international levels (In this regard, it should be mentioned that the OPERANDUM project has produced a GeoIKP platform specifically for this purpose, to facilitate the connection and exchange of knowledge about NBS and their role in mitigating hydro-meteorological risks worldwide. The platform can be explored at the website: https://geoikp.operandum-project.eu/, accessed on 28 July 2024).

Furthermore, the examination of documents and interviews reveals a pivotal concern: the need to clarify the concept of NBS for all stakeholders engaged in disaster risk governance. NBS, although resembling naturalistic engineering or eco-engineering, aims to adopt a more ecological perspective. To be categorized as NBS, an intervention must be seamlessly integrated into the socio-ecological context, enhancing both social aspects (such as risk reduction and ecosystem services) and ecological elements like ecosystem connectivity, reduction in fragmentation, habitat expansion, and the reactivation of natural morphological dynamics.

Respondents frequently mention their apprehension about legal proceedings, the liability associated with involvement in DRR activities, and the lack of incentives for change within the existing normative framework which maintains the formal strategic objective of "letting the water flow". This fear of legal consequences, coupled with concerns about liability and a regulatory environment that supports the status quo, contributes to resistance toward adopting NBSs.

All respondents believe that NBSs can be valuable tools to address the challenges of the coming decades including adaptation to and the mitigation of climate change and a more balanced relationship with the natural environment, conservation, and improvement of ecosystems. However, they are aware that NBS cannot always be decisive and are more effective in some contexts than in others where they can still complement more traditional gray solutions. A complete transition from the previous regime to solely NBS is unlikely, and instead, a hybrid approach combining NBS and gray solutions should be pursued. The research indicates that awareness of this issue is gradually increasing among technical actors within the system, but it is not yet sufficient to challenge the prevailing regime. More importantly, this awareness lacks support from an adequate policy framework and a comprehensive set of skills.

The fear of failure and a perception of ineffectiveness stem from a lack of knowledge and skills, the system's inability to experiment with alternative solutions, and an excessive reliance on the old system. The policy framework, often referred to as "regulative institutions" by Ostrom [11], which has the potential to influence the behavior and choices of actors, has instead acted as a barrier. Thus far, it has encouraged actors to adhere to the old apparatus, favoring traditional engineering approaches, rather than facilitating the mainstreaming process of naturalistic engineering and NBSs.

The interviews highlighted the intricacies of the socio-ecological system in Emilia-Romagna and the myriad variables at play in socio-technical change, particularly regarding the integration of NBSs. They indicate a tendency within the system to favor continuity and path dependency due to various factors, including cultural, legal, social, economic, and technical considerations. These barriers are unlikely to shift in the short term without decisive political and regulatory action facilitating the widespread experimentation and implementation of NBSs. Cultural cognitive institutions and a lack of understanding of ecological approaches are prominent among these factors. Nonetheless, integrating governance and policy dimensions into this discourse has proved to be a highly intricate effort, yet one deemed essential to foster an academic dialogue capable of influencing public discourse and policy development. While the developed framework may possess complexity and pose challenges in application, it remains adaptable, open to refinement, and potentially transferable to other contexts, such as urban areas, especially with collaborative efforts from a multidisciplinary research team. Research into complex systems, particularly within socio-ecological frameworks, relies on specific indicators and variables to assess how the system adapts and redirects itself in response to actions and interventions within its ecological and social spheres.

The case study presented underscores the importance of adopting a qualitative approach to construct a comprehensive analytical framework that enables cohesive interpretations through meaningful connections. Assessment for dimensions such as trust, cultural barriers, and attitudes could be organized more effectively by first understanding, through a qualitative study, the relevant aspects of these dimensions for the participants themselves. Subsequently, they could be operationalized with the (well-known but acceptable) limitations that come from using scaling techniques. Embracing these multifaceted perspectives is crucial for fully understanding and estimating acceptance rates and levels. A primary challenge encountered during this research was structuring an analysis capable of encompassing the numerous variables inherent in such a complex system. While some sections may be challenging to grasp, they were considered a vital initial step in laying the groundwork for future, more targeted investigations into specific variables and outcomes related not only to environmental or ecological aspects but also to social and cultural factors influencing the acceptance and adoption of NBS in DRR policies. In future research, exploring the development of quantitative research methodologies to evaluate the impact of specific barriers on the mainstreaming process may be worthwhile, enabling comparisons with other factors.

6. Conclusions

The qualitative case study methodology has several inherent limitations: findings from case studies typically offer limited generalization, as they are deeply rooted in the unique context and conditions of the case being studied. The primary objective of a case study is particularization—understanding the complexities and nuances of the specific case in detail—rather than producing broad, universally applicable insights. Consequently, while case studies provide rich, contextualized understanding, their results are not easily transferable to other settings or populations. Nevertheless, the study presented revealed three overarching barriers in mainstreaming NBSs that can be further studied and broadly researched: technical culture and professionals, governance and policy dimensions, and socio-economic factors. This exploration illuminates the deeply entrenched technical culture that predominantly favors conventional solutions over innovative NBS approaches. Cultural factors, such as deterministic risk perceptions and a deficiency in interdisciplinary training among technicians, loom large as significant obstacles in this landscape. Governance and policy dimensions emerge as pivotal determinants in the process of mainstreaming NBS. The absence of established technical standards, coupled with insufficiently funded risk mitigation efforts and regulatory hurdles, hampers the scalability and acceptance of NBS initiatives. Moreover, socio-economic factors add another layer of complexity to the equation. Conflicts arising from land use issues and competing economic interests pose formidable challenges to the seamless integration of NBSs into disaster risk reduction policies. The divergent interests of various stakeholders, ranging from farmers to private corporations, introduce complexities that demand sustained stakeholder engagement and effective communication strategies to navigate. In conclusion, addressing the identified barriers requires a comprehensive and collaborative effort involving socio-ecological frameworks focusing on specific indicators and variables to assess how the system transforms and reorients itself taking into consideration specific actions and interventions within its ecological and social domains.

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Appendix A

	Organization	Sector	Functions	Background
1	High-level public technical body	Hydraulic Risk Management	Planning	Civil Engineer-Hydrologist
2	High-level public technical body	Water quality and ecological status	Planning	Environmental Engineer
3	Private firm	Risk mitigation and biodiversity conservation	Design	Naturalistic Engineer
4	Regional body	Water protection–coastal areas	Planning and design	Coastal Geologist
5	Environmental NGO	Ecosystem and biodiversity conservation	Research and advocacy	Physician and Data Analyst
6	Regional body	Risk mitigation	Design and implementation	Civil Engineer
7	Private firm	Risk mitigation and NBS	Design	Architect and Construction Engineer
8	Private firm	Risk mitigation and NBS	Design	Civil Engineer construction sustainability
9	Irrigation and drainage consortia	Water management and risk mitigation	Design and implementation	Environmental Engineer
10	Park authority	Biodiversity and ecosystem conservation	Planning and design	Environmental Engineer
11	Private consultant	Disaster Risk and biodiversity conservation	Design and implementation	Biologist/Ecologist
12	Civil Protection	Risk mitigation	Planning, risk prevention and response	Geologist
13	Interregional operative body	Water management and risk mitigation	Design and implementation	Civil Engineer–Hydrologist
14	Research Organization	Forecasting and risk mitigation	Research	Physicist
15	Research Organization	Modeling and risk mitigation	Research	Civil Engineer–Hydrologist
16	Regional agency	Modeling and forecasting	Research	Physicist
17	Research Organization	Modeling and forecasting	Research	Physicist
18	Private firm	Risk mitigation and biodiversity	Implementation	Agronomist
19	Municipality	Spatial planning and urbanistic	Design and implementation	Construction Engineer/architect

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