Donna Albert

Comment by Donna Albert
Revised Draft EIS (RDEIS) for the Nov 2025 Proposed Chehalis River Basin Flood Damage Reduction Project

Here is a link to an article from the International Journal of Disaster Risk Reduction,"Managed retreat in the face of sea level rise: a multi-dimensional framework for climate resilience," Rashid and Sutley, Dec 2025. The article is focused on managed retreat from sea level rise, but also addresses other kinds flooding — the principles are the same. This article proposes longer-term planning, and frames managed retreat as a "realignment of human habitation with climate and ecological realities." In the case of the Chehalis River Basin, instead of exposing communities to recurring flood emergencies, managed retreat would be a long term plan that leaves room for the river, works with ecology, protects the salmon, is safer for people, and is more economical in the long term. The Venn diagram on page 4 is especially helpful.

Here are my comments on the RDEIS:

GENERAL

I am concerned that the RDEIS for the CRB Flood Damage Reduction Project does not carry planning out far enough, and that substantial and costly recurring damage by major flooding events cannot be prevented by the proposed Project.

If the rainfall estimates are based on staying below 2.7 degrees C of warming at 2100, they may be too optimistic.

Most of the substantial recurring damage from flooding experienced so far in the Chehalis River Basin is because so much infrastructure and development is already at risk because of where it was built. We didn't leave room for the river.

SALMON

No impact on salmon can be allowed. Salmon are already experiencing low summer stream flow and high water temperatures that are unacceptable. Climate change will make this worse. We cannot lose any more salmon. For this reason, the Flow Through Dam is not a viable option.

FLOW THROUGH DAM

3.3.3 Debris Management and 3.3.5 Sediment Management assume that more than 75 years from now, in 2100 and beyond, the State of Washington and local governments will have the capacity to execute expensive operations and management of the Flow Through Dam in the month immediately following a catastrophic flooding event. How much will that cost? Budgets are tight today, during good times. Climate change will be a much bigger drag on the economy after 2050 than it is today.

It is difficult to say what the global economy will be like in 2100. If the Flow Through Dam needs maintenance or expansion, will a future Washington State have the resources to to that? It is impossible to predict what our economy or our state budget will be like after 2100 if we fail to bring climate emissions down within the next 10 years (we are failing to do that, right now.)

3.3.4 Vegetation Management describes a process that will be disruptive and harmful to local biodiversity. We are not just in a climate crisis. We are also in a biodiversity crisis. We cannot afford such large scale disruptions to a river and nearby ecosystems.

COMPONENTS OF THE CHEHALIS BASIN STRATEGY LAND PROGRAM IN THIS RDEIS

5.1 Local Actions Alternative — I do not see any mention of heavy industrial logging in the WIllapa Hills, which does impact groundwater infiltration.

5.1.1 Components of Chehalis Basin Strategy LAND Program

On page 57, the RDEIS states that project components of LAND are preliminary and conceptual, therefore, impacts of components are not examined with the same degree of detail in this EIS as the Proposed Action. Because the LAND components are most "aligned with climate and ecological realities," this indicates that alternatives most likely to protect salmon, biodiversity and natural earth systems are not seriously considered in this RDEIS. This RDEIS is incomplete. This RDEIS is biased away from leaving room for the river and natural processes, and is biased toward protecting unviable development in the floodplain using a dam, while tolerating repeated worsening flood events in communities during the last half of the century and beyond — events that endanger people and are costly.

On page 61, the RDEIS says "detailed impact analysis in this EIS is limited by the current conceptual level of development of projects in the LAND program." This RDEIS is incomplete.

5.1.2.1, 5.1.2.2 and 5.1.2.3 - These land use measures seem to rely on existing processes that are currently failing to stop new construction in the floodplain.

5.1.2.2 Additional Flood Data seems to rely on the Flood Insurance Rate Map (Base flood Elevation) supplemented with flood-of-record data. Do these both use data from past floods?Are increasing future flood risks due to climate change quantified in the Base Flood Elevation through 2100 and beyond? Will these data sources ensure that new structures will not flood in their useful lifetime? Is infrastructure such as roads and sewers that serve the community also safe from flooding?

LOCAL REGULATORY STANDARDS

Table 1.4 Status of Improved Regulatory Standards

This table is enlightening. Commonsense regulatory standards save taxpayers money in the long run. These failures by certain cities and both counties must be corrected immediately to avoid further expense, loss, and endangering of people in floods. Kudos to Aberdeen, Cosi, Elma,

Hoquiam, Monte and Oakville. The RDEIS cannot assume in the No Action Alternative that these corrections are made by counties and cities.

CAPACITY OF SOILS TO HOLD WATER IN THE WILLAPA HILLS

5.1.5 Floodplain Storage Improvement - Abbe et al. 2019 found that restorative flood protection activities were not effective in reducing the peak flows of catastrophic floods downstream. The RDEIS says the Willapa Hills are too steep and rocky for this approach to be effective in reducing peak flood flows. Industrial logging continues on steep slopes in the Willapa Hills. Most of the Chehalis River Basin is subject to intensive industrial logging.

5.1.7 Groundwater infiltration improvement was considered but not evaluated.

The Chehalis River Basin is vast. If a change in how that land is used could slow the flow of water to the river, the effect could be substantial. We should study that and understand what is possible.

I can't speak to what the soils are like in the Willapa Hills in the Chehalis River Basin, but I walked through a legacy forest at the headwaters of the North River in the Willapa Hills in 2024. The forest floor was covered with fallen trees in various stages of decomposition, deep forest duff, mosses, ferns, and understory trees (it has since been clearcut by Department of Natural Resources, so the soils are now exposed and subject to erosion). On same the day I walked in that legacy forest before it was cut, I observed the erosion and exposed soils at another legacy forest that had already been harvested by DNR nearby.

Before the Willapa Hills were logged, they were covered with old growth forest. Old growth forest holds water and reduces flooding. Clearcut logging causes erosion and exacerbates flooding. Have we made flooding worse by logging nearly the entire Basin? Probably.

If it were possible to re-establish natural forests in the Willapa Hills, it would probably not help us in the next few decades. Could those forests become diverse enough and mature enough to mitigate flooding in the Basin during the 2100's? Probably. Could they become old growth? How much of the Basin would it take to make a difference?

GENERAL COMMENTS

Most of what is proposed in the RDEIS is a bandaid over our failure to get out of the way of the river and work with nature, instead of against it.

We must not do anything which harms the salmon, or reduces biodiversity.

We are in a climate crisis and a biodiversity crisis, both of which may be even worse in 2100. We are not doing much about either.

We are not planning far enough into the future.

Thank you for considering my comments.

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Managed retreat in the face of sea level rise: A multi-dimensional framework for climate resilience

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ABSTRACT

Sea level rise, intensifying coastal hazards, and climate driven catastrophes pose a growing threat to low lying communities. Managed retreat has emerged as a critical adaptation strategy involving the strategic relocation of people, infrastructure, and ecosystems. This study reframes managed retreat from a last resort measure to a proactive, socially equitable, and ecologically grounded strategy for climate resilience.

We offer a multidimensional approach that incorporates scientific estimates, disaster risk reduction, environmental assessment, community interaction, and economic evaluation. Using contemporary climate modeling and sea level rise estimates, we investigate threats to infrastructure, ecosystems, and vulnerable populations, emphasizing the limitations of constructed "hold the line" defenses.

We examined retreat's role in disaster planning, especially where hard protection is not viable, aligning it with the Sendai Framework. Through global and regional case studies, we highlight the importance of trust building, procedural justice, and participatory governance for policy accomplishment.

We explore how zoning and voluntary buyouts, among other legal tools, modular infrastructure, and adaptation based on ecosystems all work together to facilitate practical retreat plans. Finally, we weigh the costs of inaction against the long-term advantages of planned migration, identifying potential areas for reinvestment and transformation. This study provides a practical framework to aid policymakers, planners, and communities in developing context specific, equitable, and effective retreat strategies. Ultimately, we contend that retreat should not be interpreted as the abandonment of development, but rather as the realignment of human habitation with climate and ecological realities, thereby integrating sustainability, equity, and adaptation amid climate change.

1. Introduction

Anthropogenic climate change has increased the frequency and severity of extreme weather events, as well as accelerated sea level rise (SLR), driven by ocean warming polar ice melt. According to the IPCC Sixth Assessment Report, global mean sea level has already risen by approximately 0.2 m between 1901 and 2018 and is projected to rise between 0.63 m to over 1.01 m by 2100 under high emission scenarios [1,2]. These rising sea levels threaten approximately 680 million people who live in low lying coastal areas [3]

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potentially exceeding over a billion by 2050. Critically, newer elevation data suggests that the vulnerability of these individuals may be greatly underestimated [4].

To combat the growing coastal risk, proactive climate adaptation measures are gaining popularity. Although engineered solutions like flood barriers, levees, and seawalls have historically dominated adaptation planning [5,6], yet these defenses are often inadequate, expensive, and ecologically disruptive [7,8]. These "hold the line" strategies can unintentionally encourage continued development in hazard prone areas, deepen reliance on physical defenses, and postpone the adoption of more adaptive and sustainable strategies such as those associated with managed retreat [9–11].

In contrast, managed retreat, which involves the intentional relocation of populations, infrastructure, and assets from high risk regions, has been identified as a viable, long term adaptation strategy [9,11,12]. When planned inclusively, equitably and with strategic considerations of where to use other adaptation strategies, retreat can increase safety, decrease disaster losses, and pave the road to transformative resilience [8–10]. Retreat is especially critical in areas where the expense or practicality of protection is unsustainable, or when environmental deterioration renders in-place adaptation impossible [8,13,14].

However, retreat is not solely a technological or spatial decision. It entails significant political, legal, financial, environmental, and emotional factors. Relocation faces public criticism when it is perceived as unjust, forceful, or disconnected from local needs and involvement [15,16]. Even the best-intentioned initiatives can get derailed or delegitimized by problems including property tenure [17], historical injustices [15], displacement, and a lack of community involvement [18]. Thus, for retreat to be effective, it must be planned to use a multidimensional lens that considers both structural and sociocultural elements.

This study presents a comprehensive framework for managed retreat based on six interconnected domains: scientific analysis, disaster risk reduction, environmental assessment, community engagement, institutional and legal processes, and economic evaluation. Collectively, these domains provide a practical, evidence-based framework for the comprehension and direction of sustainable

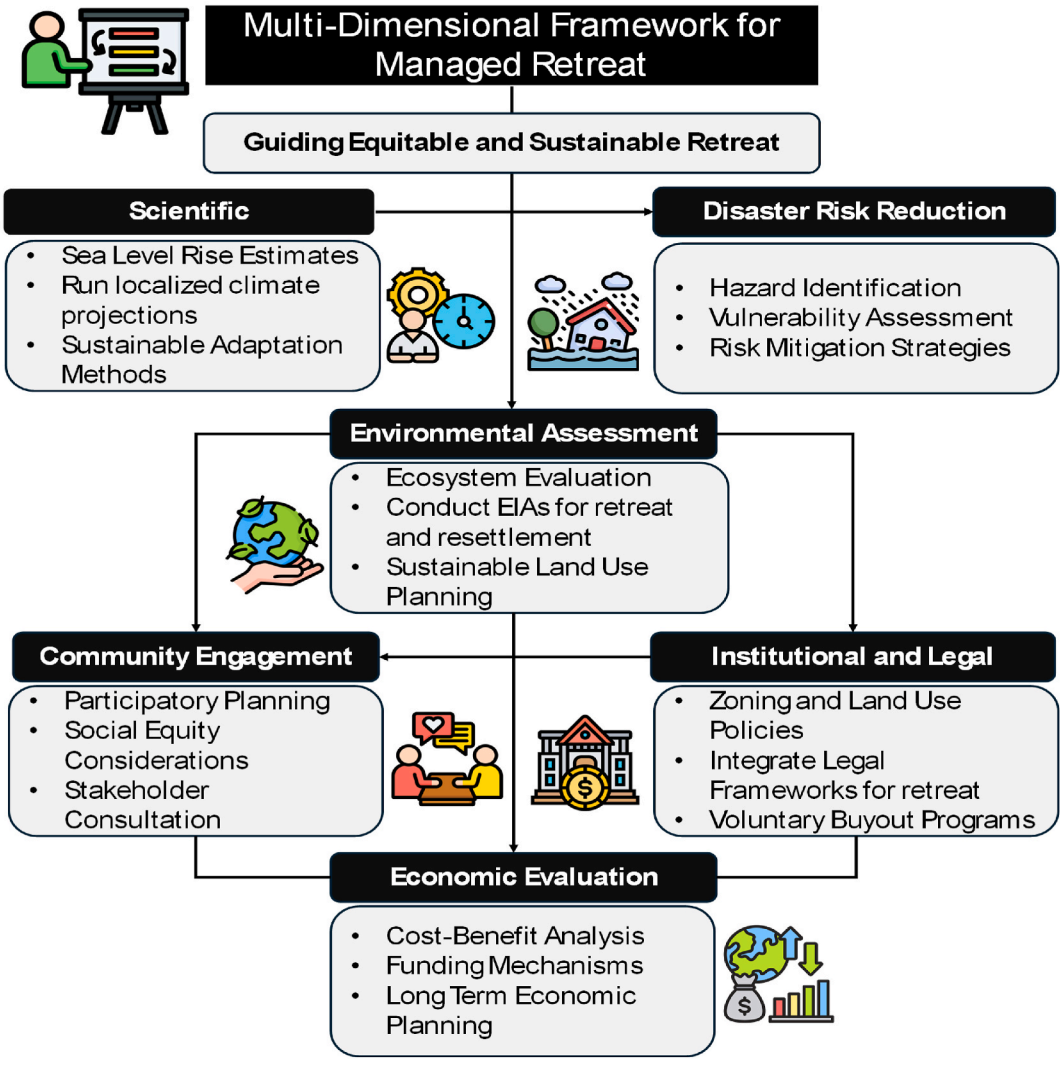

Fig. 1. Multi-dimensional framework for managed retreat.

and equitable retreat across different geographies and contexts. As the framework is developed mainly by case studies and data from the United States and other developed countries, it is intended primarily for application in these contexts. Although the lessons may be of interest to a broader audience, their application in other contexts will necessitate adaptation to unique social, political, and institutional realities. This framework is designed to encompass both proactive retreats undertaken in anticipation of future hazards and reactive retreat implemented in the aftermath of disaster events. The novelty of this work is the integration of all six domains into a single structured framework. Previous studies have made substantial progress by examining particular elements, such as institutional conditions and governance [19,20], adaptive pathways [21], innovations and constraints in governance [22], or quantitative evaluation methods [23], whereas this study synthesizes across these strands to provide a multidimensional framework that bridges technical, governance, economic, and community perspectives.

The following sections elaborate on this concept and analyze its implementation using case studies from around the world. We aim to move beyond the notion of retreat as a last resort and instead reframe it as an important part of the climate adaptation toolkit providing strategic realignment of human settlements with shifting climate realities. When well executed, managed retreat transforms from just an act of surrender into a tool for adaptation, resilience, and rejuvenation.

2. Multi-dimensional framework for managed retreat

This study presents a six-part framework for managed retreat, emphasizing the core dimensions that guide equitable and forward-looking implementation. This multi-dimensional framework includes.

- scientific analysis to assess climate threats and exposure;
- disaster risk reduction to embed retreat into broader hazard mitigation;
- environmental assessment to align actions with ecological systems;
- community engagement to ensure inclusive and just decision making;
- institutional and legal mechanisms to provide the governance tools and coordination necessary for implementation; and
- economic evaluation to examine cost effectiveness, long term benefits, and the fair distribution of resources.

As illustrated in Fig. 1, successful managed retreat strategies integrate governance, environmental, and infrastructural capacities to ensure resilience and equity. Successful retreat requires addressing concerns such as land tenure, insurance, compensation, public involvement, and historical injustices [15–17]. Disregarding any of these elements often leads to resistance and failure [12,14,15]. This framework is not prescriptive and is adaptable to different geographies, risk levels, community contexts, and institutional settings. Community leaders, residents, and other stakeholders can use the framework as a roadmap of elements to incorporate when considering managed retreat as a potential climate adaptation strategy.

Retreat is also a complex governance challenge, entangled with inequality, housing dynamics, and institutional fragmentation [12,14,24]. In the following sections, each dimension is examined in detail to highlight its core functions, planning considerations, and relevance for effective and context specific retreat implementation.

3. Scientific foundation: sea level rise and risk projections

It is imperative to comprehend the scientific foundation of sea level rise (SLR) to substantiate managed retreat as a rational and essential adaptation strategy. SLR projections are contingent upon the latest developments in climate modeling, improved observations, and new insights into the dynamics of ice sheets. This section consolidates the most recent discoveries regarding SLR projections, with a particular emphasis on their scientific foundations, uncertainties, and potential implications for policy and planning.

3.1. Climate models and emissions scenarios

Projections of sea level rise are derived from Coupled Model Intercomparison Project (CMIP) simulations particularly CMIP5 and the more recent CMIP6 which model the Earth's climate response under different Representative Concentration Pathways (RCPs) or Shared Socioeconomic Pathways (SSPs) [25,26].

The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report [1] projects that, depending on emissions scenarios, the global mean sea level might rise anywhere from 0.28 to 1.01 m by the year 2100. The contributions from thermal expansion, dissolving glaciers, and mass loss from the Greenland and Antarctic ice sheets are combined in these projections [1,27]. Under high emissions, sea level rise exceeding 2 m by 2100 is now considered plausible [28]. This could result in the loss of approximately 1.79 million square kilometers of land, including critical food producing regions, and potentially displace up to 187 million people, posing severe implications for food security, migration, and infrastructure resilience worldwide [29]. In a complementary analysis using improved elevation data, Kulp et al. [4] show that up to 630 million people could be living on land below annual flood levels by 2100 under high emissions, significantly revising earlier exposure estimates upward due to errors in standard elevation models.

Importantly, these models are probabilistic, accounting for uncertainty in physical processes, future emissions, and socioeconomic developments. Nevertheless, with rapid mitigation, sea levels will continue rising for centuries due to climate system's inertia [30,31].

3.2. Underestimations and ice sheet dynamics

Recent research indicates that conventional projections may underestimate future SLR as a result of uncertainties in ice sheet processes, particularly marine ice sheet instability and marine ice cliff instability in Antarctica [28,32]. These nonlinear mechanisms have the potential to substantially increase SLR beyond central IPCC estimates by causing rapid, irreversible ice loss.

For instance, under futures with high emissions and limited adaptation, structured expert judgment assessments show that, albeit improbable, sea level rise surpassing 2 m by 2100 is physically possible [28,33]. As a result of feedback loops such air blocking and reduced albedo, the Greenland Ice Sheet is also seeing faster surface melting and runoff [34,35].

The "deep uncertainty" associated with SLR projections is underscored by these emerging insights, which require planners to implement adaptable, resilient frameworks [36]. Under such circumstances, managed retreat becomes more than just a preventive measure, but a reasonable response to unknown thresholds. Because this uncertainty propagates all six dimensions of the framework, from community engagement to infrastructure planning, adaptive methods like dynamic adaptive policy pathways and robust decision making are crucial for predicting a variety of futures [37].

3.3. Regional variability in sea level rise

Globally, the rate of sea level increase varies. Glacial isostatic adjustment, vertical land motion, ocean dynamics, and gravitational changes all contribute to both local and regional fluctuations [38,39]. SLR happens much faster in deltas that are sinking, like those in Bangladesh or Louisiana, than the average rate around the world [40,41]. These regional differences underscore the need for site-specific risk assessments to inform managed retreat. Adaptation must be locally grounded, even as it is globally informed.

4. Managed retreat as a resilience strategy

Managed retreat is becoming more widely acknowledged as a fundamental element of disaster risk reduction (DRR) as well as a climate change adaptation strategy. As climate related catastrophes become more frequent and severe, incorporating managed retreat into disaster risk reduction frameworks is critical for minimizing exposure, reducing susceptibility, and improving long term resilience.

4.1. Framing DRR and vulnerability reduction

Disaster Risk Reduction (DRR) strives to prevent new and reduce current catastrophe risks using structural and nonstructural interventions, with a focus on reducing hazard exposure, susceptibility, and societal fragility [42,43]. Managed retreat directly contributes to this objective by relocating individuals and assets from hazard prone regions, thereby eliminating risk rather than merely managing it.

Unlike traditional DRR methods that focuses on physical defenses, retreat can collectively address issues like marginalization of social groups, unsustainable land use, and unsafe housing in flood zones [14,44]. Retreat promotes spatial and social resilience by

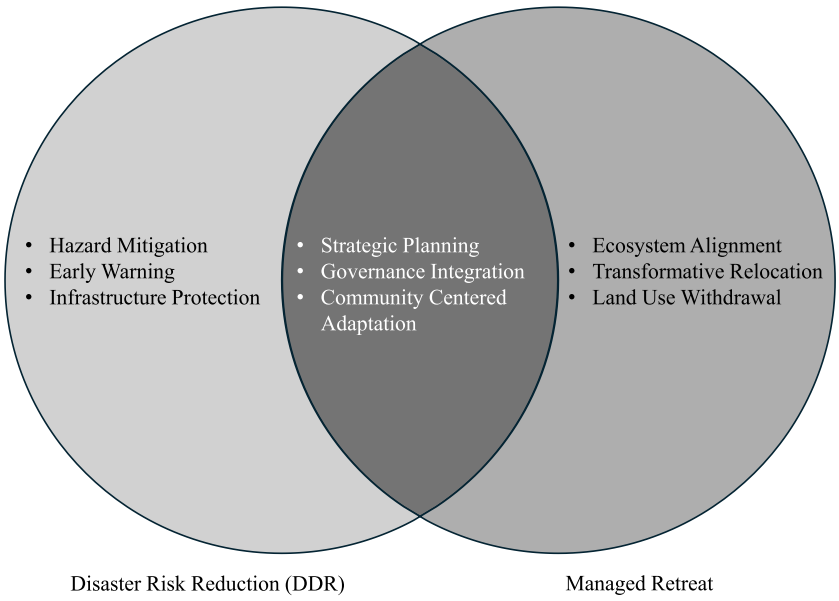

Fig. 2. Relationship between Disaster Risk Reduction and Managed Retreat, highlighting their overlap in strategic planning, risk reduction, and governance integration.

limiting long term exposure and allowing communities to rebuild in safer locations [9,12]. As illustrated in Fig. 2, managed retreat expands upon traditional DRR by emphasizing long term planning and governance integration.

Furthermore, managed retreat is consistent with the Sendai Framework for Disaster Risk Reduction, which promotes forward thinking, inclusive, and integrated risk governance that recognizes non-economic losses and encourages transformative change [11, 42]. Additionally, it helps with both adaptation and mitigation by keeping natural buffers like dunes and wetlands, which naturally prevent flooding and storm surge impacts. However, their effectiveness is contingent upon temporal and contextual factors, fluctuating with the rates of sea-level rise and vertical land displacement, including subsidence, which may restrict their protective capacity [45].

4.2. Rising disaster frequency and managed Retreat's role

Disasters, such as hurricanes, coastal floods, and inundations caused by rising sea levels, have become more common and destructive as a result of climate change [1]. Over the past two decades, economic losses from weather related disasters have escalated significantly. According to the World Meteorological Organization (WMO) [46], from 1970 to 2019, there were over 11,000 reported disasters attributed to weather, climate, and water hazards, resulting in $3.64 trillion in global economic losses. Furthermore, socioeconomic inequalities have been identified as factors that amplify the human toll of such disasters. Research indicates that high levels of income inequality within countries can exacerbate human losses from natural hazards [47].

In such contexts, managed retreat emerges as a strategic DRR option when other measures repeatedly fail. For instance, buyouts in New Jersey following Hurricane Sandy cleared flood zones of thousands of homes, allowing for the creation of buffers of open space [48]. Table 1 provides a selection of MR examples.

In high risk areas, retreat also provides a financially sensible substitute for recurring reconstruction and insurance payouts [6]. It has the potential to reduce displacement cycles and facilitate dignified relocation when implemented in conjunction with long term planning, equitable governance, and ecological restoration [9].

4.3. Migration and justice dimensions

Climate change is not only a threat to the environment and people, but it is also a problem for social justice. Rising sea levels,

Table 1
Global case studies of managed retreat.

Case	Country	Timeline	Trigger	Instruments Used	Success Factors/Barriers	References
Soldiers Grove	Wisconsin, United States	1976–1983	Repeated flooding	Community-led relocation, floodplain zoning, solar energy ordinance	Successful early retreat model; sustainable town design; first U.S. "solar village"; strong local leadership and planning vision	[61]
Medmerry	United Kingdom	2011–2013	Coastal flooding	Realignment, land purchase	Strong public support, ecosystem restoration, stakeholder involvement	[125]
Isle De Jean Charles	United States	2016 - Present	Land loss, sea level rise	Federal/state buyouts, planned relocation	Cultural dislocation, slow implementation, tribal sovereignty issues	[126,127]
Vunidogoloa	Fiji	2014	Coastal erosion flooding, SLR	Government-led planned relocation	Cultural continuity, funding support, participatory design	[89,124]
Ocean Beach Master Plan	California, United States	Planning (2016), Design (2019), Construction (Late 2026) and Open to Public (2031)	Coastal erosion	Coastal highway removal, dune restoration, hybrid protection (partial seawall + sand replenishment)	Multi-agency consensus: lawsuits delayed start; infrastructure constraints shaped hybrid strategy; long term phasing plan guided by SPUR and CCC support	[128]
Oakwood Beach (Staten Island)	United States	2013–2015 (first buyouts)	Hurricane Sandy flooding	FEMA buyouts	High buy in, fast track funding post-disaster	[48,129]
Matatā	New Zealand	2005 to 2018	Debris flow hazard, flood, coastal erosion	Local government led withdrawal, rezoning	Legal barriers, lack of national policy backing	[67]
Surfer's Point	California, United States	1995–2011 (Phase -I), Phase – II ongoing	Coastal erosion, receding shoreline	Infrastructure relocation (bike path, parking lot), natural beach & dune restoration	Community led opposition to seawalls; support from Surfrider Foundation, multi-agency coordination, use of natural systems over hard armoring	[128]
Newtok	Alaska, United States	1994–2019	Permafrost thaw	Community led relocation, grants	High costs, statutory and institutional barriers, logistical delays, tribal coordination,	[130,131]
Blackwater National Wildlife Refuge	Maryland, United States	2000s - Present	Sea level rise, tidal erosion	Marsh migration planning	Habitat preservation, long term resilience planning	[132]

storms, and continuous coastal erosion increasingly force either voluntarily or involuntarily migration, raising concerns around governance, equity, and human rights protection.

4.3.1. Climate migration

Climate induced migration is predicted to rise dramatically in the next decades. According to the World Bank [49], approximately 216 million people could be relocated by 2050 as a result of gradual climate impacts such as rising sea levels and diminishing agricultural production. Most of this movement will be internal, with regional hotspots in Sub-Saharan Africa, East Asia, and South Asia. These Internal migration creates complex challenges for local authorities in managing services, land rights, and resettlement [50].

4.4. Climate justice

Disparities in access to resources exacerbate the difficulties of displacement caused by climate change. Low income people, Indigenous communities, and racial minorities frequently face the brunt of managed retreat without receiving adequate benefits or support [14,51]. Furthermore, recent studies have revealed that retreat programs tend to favor populations with greater political and legal power, reinforcing systemic disparities [12,52]. To maintain climate justice, adaptation plans should be designed to guarantee equitable treatment, protect traditional land ties, and prevent forced relocation [2,53]. Ethical retreat must uphold self-determination, fair compensation, and procedural justice to be restorative rather than reactive [9,11]. Neglecting these factors increases resistance and risk of failure. Thus, justice must be inherent to effective and legitimate retreat planning rather than an auxiliary concern.

Despite its potential benefits, managed retreat also carries considerable risks and drawbacks. Numerous studies have demonstrated that poorly planned or inadequately supported relocation can result in additional forms of social, cultural, and psychological trauma, and in some cases may be perceived by affected communities as a "second disaster." Research on post-disaster resettlement indicates that relocation may disrupt livelihoods, weaken social bonds, undermine place attachment, and create prolonged stress when communities feel excluded from decision making processes or receive inadequate compensation [54,55]. Further evidence demonstrates that top down or poorly coordinated relocation procedures might lead to unequitable outcomes and limit recovery [56]. Therefore it is critical in application to acknowledge these potential risks for averting unintended adverse consequences and ensure that retreat initiatives are perceived as socially equitable, culturally appropriate, and aligned with community defined objectives.

5. Multidimensional capacities for retreat

5.1. Governance and management approaches

5.1.1. Governance for equitable and effective retreat

For managed retreat to be implemented in a way that is both environmentally responsible and socially equitable, effective coastal governance is essential. Coastal Zone Management (CZM) offers a framework for the integration of stakeholder input, land use planning, and scientific data to achieve a balance between long term risk reduction and development. In numerous regions, regulatory tools, including hazard zoning, shoreline setbacks, and rolling easements, are employed in CZM initiatives to redirect growth away from high risk areas while simultaneously safeguarding ecosystem services [57,58].

Managed retreat within Coastal Zone Management frameworks is most effective when supported by robust institutional coordination, transparent decision-making processes, and active public participation. However, fragmented authorities especially in decentralized or politically contentious planning systems often hinders implementation [11,14]. The framework therefore assumes a degree of institutional capacity typical of developed contexts, and where such capacity is limited, additional governance strengthening would be required before application. Examples from the Netherlands, New Zealand, and California show how stronger institutional capacity, climate informed design and adaptive coastal governance may legitimize retreat as an adaptation strategy instead of a measure of last resort.

5.1.2. Local government roles and community led engagement

Local governments play an important role in implementing managed retreat because they have authority over land use, construction standards, emergency management, and community outreach. Their proximity to communities positions them to build trust and enable participatory planning [59]. Involving residents in decision making, particularly through visual modeling, multilingual workshops, and neighborhood planning committees, builds legitimacy and incorporates local knowledge into retreat designs [60].

Examples such as Soldiers Grove, Wisconsin, where the business district was relocated following a flood, demonstrate how community led planning can align retreat with values such as renewable energy and resilience [61]. Similarly, Fairbourne, Wales implemented public engagement and multi-agency coordination strategies; however, the necessity of early and candid engagement is underscored by persistent apprehensions regarding legitimacy and fairness [62]. In contrast, in many coastal jurisdictions in the United States, continued investment in public facilities such as schools, fire stations, and utilities in hazard-prone areas has unintentionally encouraged additional development. These practices exemplify the "safe development paradox," in which efforts to provide critical services in vulnerable areas legitimize ongoing growth while increasing long-term exposure [63]. In contrast, policy approaches like the United States Coastal Barrier Resources System show how removing federal investment incentives in specific areas can significantly reduce development pressure and associated disaster costs [64].

This emphasizes the critical importance of establishing inclusive and transparent engagement from the outset of retreat planning. To guarantee procedural justice, local authorities must co-develop retreat standards, ensure equitable compensation, and protect

vulnerable groups such as renters and undocumented populations. Without inclusive and participatory governance, retreat efforts risk being neither equitable nor effective.

5.1.3. Policy instruments

Various policy instruments can be utilized to back managed retreat, each with its own unique purpose of easing the transition to new land uses, decreasing risks, or restoring damaged ecosystems. These tools can be broadly grouped into financial, regulatory, nature-based, and infrastructure-focused strategies. Fig. 3 depicts a typology of instruments often used to achieve managed retreat. These include financial methods like voluntary buyouts, regulatory techniques like zoning changes and setback laws, nature-based tools like ecosystem restoration, and infrastructure focused relocation initiatives. Successful retreat programs often combine tools that compliment one another.

Successful managed retreat depends on robust policy tools and clear planning frameworks. Planning frameworks are also essential. Voluntary property buyouts, transfer of development rights (TDRs), rolling easements, and zoning revisions have all been utilized to implement retreat tactics in both high and low risk areas [9,10].

Most used are voluntary buyout schemes, in which governments acquire properties in danger and transform them into open space. Nevertheless, their success is contingent upon equitable access, transparent communication, and fair compensation [48,65]. In the absence of these measures, buyouts may exacerbate social inequalities and contribute to the fragmentation of communities. Rolling easements provide a dynamic legal strategy by enabling coastal movement while prohibiting new development. However, they face resistance from regulatory and political interests [66]. Furthermore, redevelopment authorities can facilitate the coordination of land repurposing and acquisitions following retreat, while clear property-rights tools, such as standardized compensation and transferable development rights, help to ensure equity and feasibility [67]. Strategic use of policy instruments can make retreat feasible, fair, and locally appropriate [22].

5.2. Ecosystem based adaptation and environmental sustainability

Strategies that complement, rather than disrupt natural systems are widely recognized as more important for managed retreat

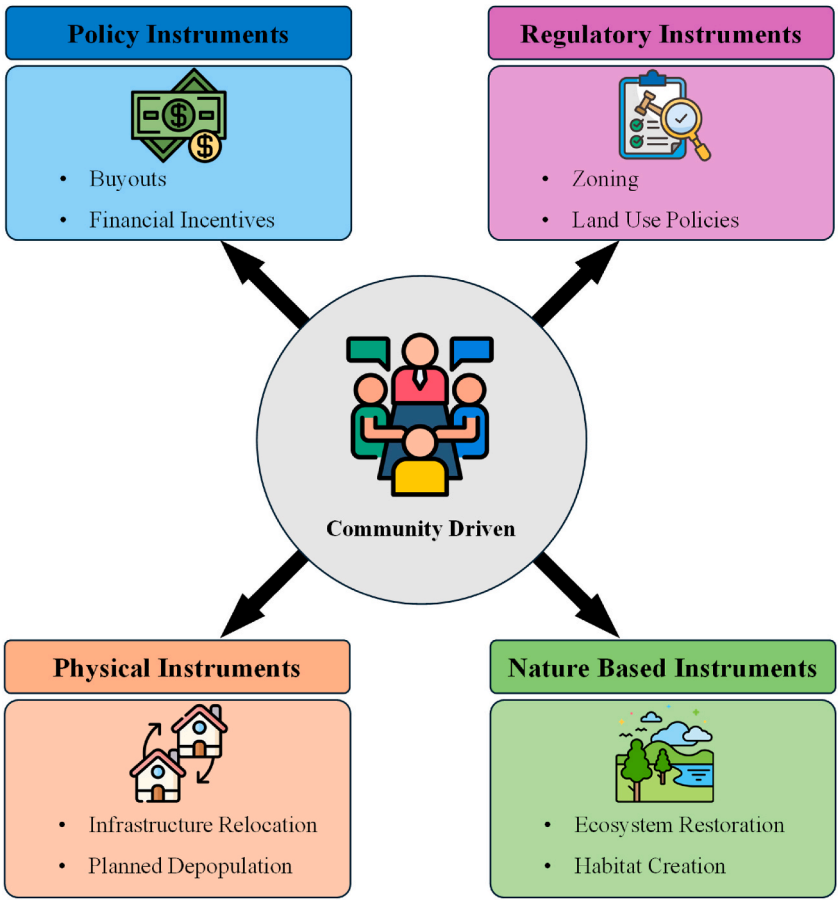

Fig. 3. Typology of managed retreat instruments.

planning. Ecosystem based adaptation (EbA) can attenuate risks in the near term by drawing on the buffering and regenerative functions of ecosystems, such as wetlands, mangroves, and dunes. However, these functions are not permanent, their protective capacity is strongly time-dependent and will diminish as sea level rise accelerates [68,69]. More recent studies reinforce this point, showing that while EbA effectively reduces near-term risks, its protective capacity is not indefinite and may decline as sea level rises accelerates, particularly where projects are not calibrated for future climate risk [70,71]. This underscores the importance of integrating EbA with long-term adaptation strategies such as managed retreat. EbA enhances long-term co-benefits by restoring ecosystems, enhancing biodiversity, sequestering carbon and improving community well-being [72,73]. Effective ecosystem-based retreat requires aligning ecological, infrastructural, and community goals, as seen in Fig. 4.

5.2.1. Nature based solutions

In coastal areas that are susceptible to extreme weather events and sea level rise, nature based solutions (NbS) are increasingly recognized as essential scalable strategies for enhancing coastal climate resilience. Healthy ecosystems such as wetlands, woods, reefs, dunes and coastal mangroves act as natural buffers that reduce storm surges, erosion, and flooding while simultaneously supporting biodiversity and carbon storage [74,75].

By integrating ecosystem services into adaptation planning, governments and communities can reduce reliance on costly gray infrastructure. Coastal wetlands in the U.S. have demonstrated a capacity to mitigate property damages during hurricanes by absorbing wave energy, thereby serving as a natural coastal defense [72,76]. Recent research confirms that NbS are cost-effective, provide various co-benefits, and can increase both ecological and social resilience [70,77].

NbS also offer broader sustainability benefits that extend beyond hazard protection. They improve water quality, support fisheries, and provide recreational and cultural opportunities, making them particularly essential for disadvantaged coastal populations that rely on ecosystem services [75,77]. Also, “blue carbon” ecosystems like mangroves, salt marshes, and seagrasses help the world reach its carbon reduction targets by storing a lot of carbon [78].

However, NbS have limits. Modeling indicates that numerous coastal wetlands will be unable to adapt to significant sea-level rise as time passes. Nevertheless, this result is not unavoidable: the prevention of large-scale wetland loss is possible through the provision of adequate accommodation space through the implementation of meticulous nature-based adaptation and coastal management

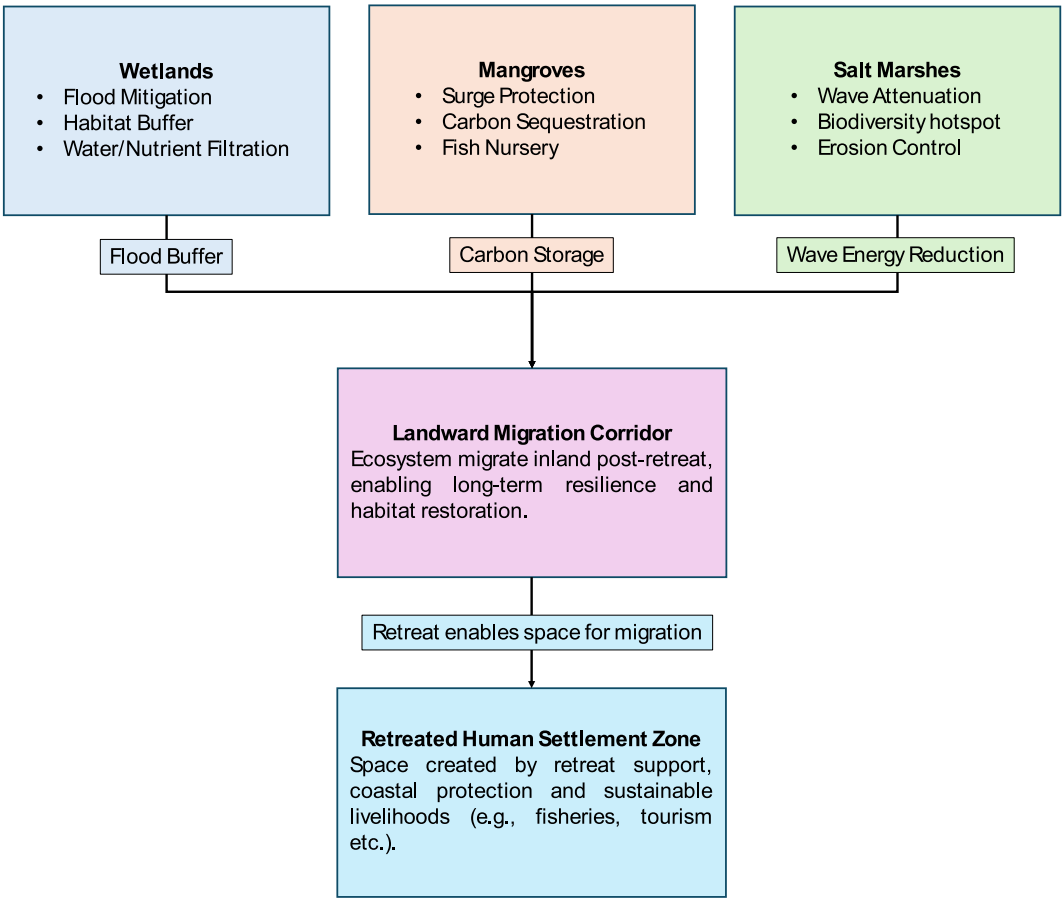

Fig. 4. Conceptual interaction of natural ecosystems, infrastructure, and communities in ecosystem based retreat planning.

strategies [79]. Further research has demonstrated that the efficacy of NbS is context-specific and restricted, particularly in cases where projects are not calibrated for future climate hazards [71]. As sea levels rise, ecosystems may degrade, drown, or shift landward as space allows, lowering their buffering ability [78]. This emphasizes the significance of including NbS into a broader set of adaptation strategies, such as managed retreat, zoning reforms, and infrastructure redesign, rather than regarding them as standalone solutions.

5.2.2. *Ecosystem restoration and retreat zones*

In managed retreat plans, ecosystem restoration is an important aspect, especially in areas where land is designated for environmental rehabilitation after humans leave. Mangroves, salt marshes, and dune systems are some of the best habitats for mitigating coastal impacts. Recent research has demonstrated that mangroves, salt marshes, and dune systems can reduce storm surge and erosion while promoting biodiversity. However, their protective capacity is significantly influenced by time. Mangroves are unlikely to develop vertically after sea-level rise surpasses ~7 mm yr^{-1} [80], and U.S. tidal wetlands may drown between 2020 and 2060 under intermediate-high SLR scenarios [81]. This suggests that restoration improves resilience; however, there are thresholds beyond which these ecosystems will be overwhelmed [71].

Managed retreat can allow tidal ecosystems to migrate inland, where they would otherwise be trapped by increasing sea levels and hard infrastructure. The Medmerry Managed Realignment project in the United Kingdom restored 183 ha of intertidal habitat, thereby reducing flood risk and enhancing biodiversity. While this project indicates near-term flood attenuation and biodiversity improvements, subsequent reviews advise that the benefits of managed realignment fade as sea-level rise increases and even reverses on small scales. Consequently, these projects have the potential to purchase time, however, they necessitate long-term planning and ample space to remain effective in the face of elevated SLR trajectories [68,82]. Therefore, infrastructure planning and governance frameworks that are more retreat-oriented must incorporate ecosystem restoration. For this, designating retreat zones guarantees that ecosystems have the adequate accommodation space to migrate inland, thereby preserving their protective functions and ensuring that ecological adaptation is in accordance with community safety and long-term resilience [71,78].

5.3. *Infrastructure resilience in retreat planning*

As climate hazards grow, infrastructure resilience has become a top priority in managed retreat planning. Critical infrastructure, such as transportation networks, energy grids, water systems, and social services, must not only be protected but also reimagined, relocated, or redesigned for long term community resilience. These decisions shape the equity, scope and outcomes for retreat.

5.3.1. *Hard and soft infrastructure systems*

Hard infrastructure includes critical physical systems such as highways, bridges, levees, sewage networks, power plants, and communications, many of which are located in low lying coastal areas that have been subjected to salinization, erosion, and recurrent floods owing to past development patterns. Retreat planning must phase out, reinforce or relocate these systems. Without coordinating

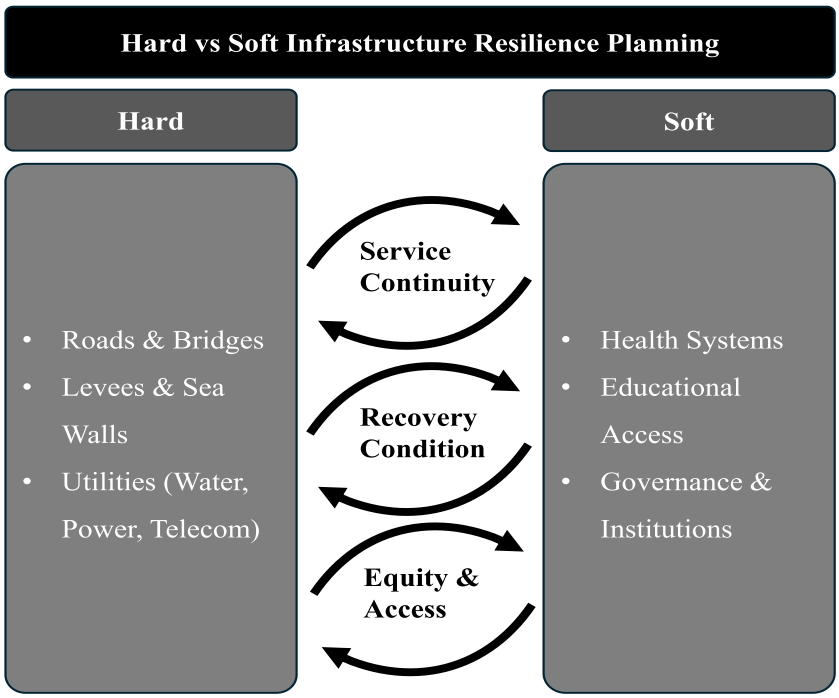

Fig. 5. Interdependence of hard and soft infrastructure in managed retreat.

infrastructure withdrawal with residential buyouts can lead to "stranded assets" or service deserts, which can impede the recovery process and worsen existing disparities [9]. However, sustained investment in major transport corridors, ports, and energy hubs can result in "lock-in" conditions that restrict retreat pathways, making them highly challenging. This illustrates the safe-development paradox, which occurs when the expansion of protective infrastructure or services in vulnerable regions promotes further settlement, thereby exacerbating long-term exposure [63,83]. Recognizing these dynamics is essential in order to prevent infrastructure decisions that limit future retreat options.

In contrast, soft infrastructure encompasses the social, institutional, and ecological systems that promote human well-being, such as healthcare, education, governance, and emergency response. These systems are essential for sustaining communities during and after retreat. Investment in mobile clinics, decentralized education, and local water systems can provide adaptable solutions, particularly in rural or underserved areas [84]. Hard and soft infrastructure must function in tandem to support effective, equitable retreat (see Fig. 5). For example, relocation without adequate healthcare or evacuation plans undermines safety. Furthermore, relocating sites with soft infrastructure in mind will help smooth transitions. When possible, retreating to locations that still enable residents to use the same healthcare and educational facilities as before, can also help maintain identity and place attachment while removing risk.

5.3.2. Rethinking infrastructure design

Managed retreat requires rethinking static, centralized infrastructure and considering a wide range of alternatives, including modular, decentralized, hybrid and adaptive pathways approaches [60,85]. Modern infrastructure must be able to do more than simply withstand threats; it must also allow systems to absorb, change, rebound, or retreat.

Today, resilient design emphasizes relocatability, redundancy, and flexibility. For instance, modular homes that are already built can be adapted or relocated inland, and elevated roadways and transport routes can provide transitional connectivity. However, these designs are not intended to justify additional exposure to hazardous regions, rather, they are intended to manage existing assets in a flexible manner until retreat is achieved [11,78]. Nature based infrastructure, such as restored wetlands can enhance stormwater management and reduce stress on built systems [86], but evidence shows such ecosystems face thresholds under accelerating sea-level rise [80].

Equity considerations are central to rethinking infrastructure design for retreat. Infrastructure decisions may perpetuate spatial inequality if they are not made with deliberate consideration of accessibility and justice. For example, retreat programs in the United States have occasionally prioritized buyouts in affluent regions, resulting in historically marginalized communities having fewer options and a higher residual risk [16]. One way to make sure that infrastructure solutions are inclusive and resilient is through participatory planning, community co-design, and scenario-based stress testing which strengthen both procedural and distributive justice in retreat decisions [60,87]. Combining modular design with ecological integration and participatory governance is therefore essential to develop retreat-compatible infrastructure that is both socially just and climate resilient.

6. Environmental impact assessment in managed retreat projects

While managed retreat is commonly regarded as an environmentally friendly adaptation method, it can potentially have unanticipated ecological implications. Environmental Impact Assessments (EIAs) offer a methodical way to foresee, assess, and lessen the impact of such consequences. They are essential for ensuring that retreat projects remain ecologically sound, socially equitable, and legally compliant.

6.1. Need for EIAs in relocation planning

Managed retreat entails significant land use change, ranging from infrastructure removal and new development to ecosystem conversion and population displacement. When relocation proceeds without systematic assessment, projects can unintentionally degrade sensitive habitats, increase greenhouse gas emissions, or undermine ecosystem services, resulting in outcomes that counteract the intended resilience benefits. Evidence from U.S. buyout programs indicates that, in the absence of meticulous planning, properties frequently subjected to flooding continue to be susceptible, while new pressures on housing and land markets may arise in relocation areas [16,51].

Environmental impact assessments (EIAs) are crucial for spotting these possible consequences at the outset of planning and directing project design toward minimizing ecological disturbance. For instance, the placement of new settlements in the interior of the country may result in deforestation, habitat fragmentation, or increased pressure on agricultural land and groundwater. Research on planned relocation in Fiji also demonstrates that incomplete assessments can lead to resource conflicts and livelihood disruptions, emphasizing the significance of environmental and social safeguards [88,89]. Similarly, decommissioning coastal infrastructure must be assessed in terms of sediment flow, water quality, and shoreline dynamics [17,90].

Conducting EIAs is not only a legal requirement in many jurisdictions, but it also fosters public trust and clarifies land use tradeoffs. For example, post-Hurricane Sandy buyouts on Staten Island resulted in restored wetlands that provide long-term coastal protection, but these benefits came at the expense of reduced housing availability [48]. These examples show how EIAs can emphasize both the environmental advantages and the social costs of land-use change.

In retreat contexts, EIAs should expand beyond project level studies to assess cumulative effects, long term ecological benefits (e.g., wetland restoration), land use tradeoffs and the distribution of socioeconomic costs and benefits. By embedding EIAs into managed retreat planning, in addition to participatory and justice-oriented processes, it is possible to guarantee that relocation strategies are ecologically sustainable, socially equitable, and legally tenable.

6.2. Life cycle approaches and mitigation

Environmental assessments in managed retreats benefit greatly from life cycle techniques, which examine the retreat's complete environmental footprint, from site selection and building to maintenance and decommissioning. This viewpoint enables planners to consider not just the immediate ecological costs but also the long-term advantages, such as carbon sequestration in restored ecosystems or prevented emissions from repeating disaster reconstruction.

Mitigation strategies may include.

- Prioritizing redevelopment of abandoned land over clearing new areas.
- Use low impact building materials in rebuilt infrastructure.
- Integrating habitat restoration into decommissioned retreat areas.
- Creating multifunctional landscapes that integrate biodiversity, recreation, and flood protection.

These steps ensure retreats support broader goals like emissions reduction, protecting biodiversity, and sustainable land use.

7. Social acceptance and community engagement

Managed retreat is not only a technical and environmental intervention, but also a deeply social one. The success or failure of retreat efforts frequently depends on whether affected groups feel included, respected, and empowered. Research indicates that societal acceptance is more likely when community participation extends beyond one way information dissemination to incorporate meaningful collaboration, trust building, and long term dialogue [91]. Furthermore, recent case studies show that community land trusts and participatory planning can increase local legitimacy and lessen opposition by guaranteeing that locals actively shape relocation outcomes [92].

7.1. Participatory planning

Participatory planning is crucial to ensuring an equitable and effective managed retreat. It guarantees that citizens' voices, particularly those of historically marginalized groups, are heard in developing retreat methods. Involving communities in decision making brings to light local knowledge, cultural values, and place attachments that would otherwise go unnoticed by top down planning [10,93].

Research indicates that communities are more likely to endorse climate adaptation and relocation when they are perceived as active co-creators rather than passive recipients [94]. Yet relocation decisions are not limited to technical or financial factors. They are highly contextual, influenced by cultural or historic attachments, place-based livelihoods, and access to coastal assets. For instance, the loss of cultural and spiritual connections may result in long-term resistance, while disruptions to fishing, tourism, or agricultural livelihoods can undermine community support for relocation [95]. Incorporating these dimensions explicitly into planning processes increases their legitimacy and fosters trust.

Finding suitable retreat pathways, evaluating tradeoffs, and establishing local ownership of results can be accomplished through processes like community mapping, deliberative workshops, and citizen advisory boards [96,97].

Trust and social capital are also important. Transparent communication, persistent participation, and fair reward promote legitimacy while reducing skepticism. Particularly in Indigenous and tribal contexts, trust requires addressing historical injustices, upholding sovereignty and government systems [52,98].

Social acceptance cannot be reached just by consensus; it also involves an understanding of power relations, procedural justice, and the ability to respond to community feedback. Without this, retreat plans may cause backlash, exacerbate trauma, or fail to implement.

7.2. Trust, justice, and procedural inclusion

Participation isn't enough to ensure managed retreat's social acceptability; trust in institutions, outcomes, and one another is also crucial. Trust is especially important when making decisions on life, changing relocations and long-held attachments to an area.

Procedural fairness, or making sure processes are open, fair, and inclusive, is essential for retreat programs to foster trust. For communities to feel heard, they must realize that their opinions matter and can shape the outcome. Research has demonstrated that relocation initiatives that lack explicit rules, compensation fairness, or culturally appropriate approaches frequently fail to establish legitimacy [12,14].

Building trust takes time and depends on consistent engagement from the beginning rather than rushed discussions at the last minute. Restructuring programs run by governments and NGOs should prioritize relationship development, bilingualism, involvement of respected local leaders, and long-term support services.

Justice in retreat also entails realizing that not all communities suffer the same threats or have equal ability to escape. Renters, immigrants, and low income households are among the most marginalized communities, and they are frequently left out of policy-making processes and may not have the legal protections or political clout to advocate for themselves.

8. Economic rationale for retreat

Sea level rise (SLR) increases economic risks for coastal communities, particularly in terms of asset exposure, infrastructure degradation, and rising insurance costs. Managed retreat, when well-planned, offers a cost effective adaptation strategy compared to repeated post disaster recovery [99]. Assessing the economic consequences of both inaction and retreat is critical to supporting early, proactive planning.

8.1. Cost of inaction vs. planned relocation

The economic penalty of neglecting to confront rising sea levels is considerable. While earlier estimates suggested that annual global flood losses were approximately US$6 billion in 2005 to over US$1 trillion by 2050 without adaptation rising to around US$52 billion annually by 2050 due to socio economic growth alone and potentially exceeding US$1 trillion by 2050 when climate change and land subsidence were factored in Ref. [100]. More recent assessments in the IPCC AR6 Cross-Chapter Paper Cities and Settlements by the Sea [101] provide updated, higher-resolution projections, warning that without adaptation, coastal flood risks could increase by two to three orders of magnitude by 2100, with trillions of dollars in assets exposed and adaptation costs for ports alone estimated at US $223–768 billion before 2050, while between US$7 and 14 trillion of coastal assets could be exposed by the end of the century. When factoring in climate change and land subsidence, the study warns that without significant upgrades to existing flood protection annual losses could exceed US$1 trillion by 2050. Spanger Siegfried [102], in agreement with more general flood risk forecasts, define chronic flooding as 26 or more occurrences of flooding per year, a threshold that is becoming more probable in coastal areas as a result of rising sea levels. Based on this criterion, a recent Union of Concerned Scientists [103] study predicts that more than 300,000 houses and commercial structures in the contiguous United States, worth approximately $136 billion today will be at risk of chronic flooding by 2045. By 2100, that figure might increase to 2.5 million properties, which are currently worth more than $1.07 trillion. These effects have the potential to disrupt local real estate markets and create cascading financial concerns across the country, particularly in areas without proactive adaptation or withdrawal initiatives. Despite the mounting risks, these are often insufficiently reflected in mortgage lending practices, insurance markets, and land use regulatory frameworks [104,105].

Coastal low lying zones have an outsized concentration of critical infrastructure, such as highways, sewage systems, power plants, and ports, which increase systemic risks. The effects of these disasters are felt throughout the local and national economies, causing disruptions in logistics, lowering property prices, and placing a strain on taxpayers with the costs of emergency response. Furthermore, the insurance sector is experiencing an increase in stress, as premiums are on the rise and coverage in flood prone regions is being reduced. This dynamic both reflects and exacerbates financial vulnerability [106].

In contrast, preemptive migration, which is a form of managed retreat, can decrease long term public expenditure by preventing recurring catastrophe recovery expenses and infrastructure losses. Although acquisition of property, relocation of infrastructure, and compensation are all upfront costs of retreat that, without proper financing, can be politically and financially challenging.

8.2. Economic rationale and strategic implementation of managed retreat

Economic studies reveal that managed retreat can yield significant returns. For example, post Hurricane Sandy buyouts, discovered that every dollar spent on retreat and hazard mitigation saved almost $6 in future losses [107].

Tools like cost benefit analysis (CBA) or life cycle cost analysis (LCCA) frequently demonstrate that managed retreat is more cost effective than repeated disaster recovery by considering the complete life-cycle costs, including initial investments and future disaster damages. A diverse body of international research highlights various analytical approaches for analyzing the economic outcomes of retreat. Hallegatte et al. [108] demonstrate via CBA that resilience measures such as strategic relocation create long-term financial gains by avoiding excessive maintenance costs, while NOAA [109] emphasized that in high risk zones, retreat may be more economical than reinforcing infrastructure. More broadly, Mechler et al. [110] present a thorough overview of climate change loss and damage estimation tools, including CBA, integrated assessment models, and insurance approaches, with applications to migration. Stroombergen and Lawrence [111] demonstrate how real options analysis may be used to assess the economic efficiency of anticipatory retreat, providing a flexible approach that takes into account uncertainty and delay in decision-making.

In addition to these formal evaluations, retreat is interwoven with larger economic and land use systems. Property prices and municipal tax bases are frequently inflated by coastal tourism and amenity values, which can encourage the continuation of development in flood-prone areas [112,113]. Likewise, local income and livelihoods are also linked to susceptible shorelines through fisheries, port activities, and extractive industries, which makes people resistant to moving even when the risks are getting worse [114]. Although these industries might temporarily stabilize local markets, they have the potential to prolong the process by which property values are adjusted to account for the impact of rising sea levels, making people more vulnerable in the long run [115]. Redevelopment plans that incorporate retreat must strike a balance between reducing hazards, keeping economic activities going, and keeping the budget in good shape.

Furthermore, the economic disruptions that frequently occur during relocation can be alleviated by implementing managed retreat in phases. Governments and communities can better adjust to changing social dynamics, allocate funds in accordance with available resources, and spread costs incrementally with a phased approach. As Kraan et al. [116] highlights that long buyout timelines generate procedural justice concerns that are associated with the design of the program and the funding structures. Phased rollouts promote better financial planning while preserving community autonomy. Although, in rapidly urbanizing regions, coastal population growth may outpace planning and infrastructure adaptation, increasing exposure unless retreat is integrated with urban development [117].

Additionally, a variety of funding mechanisms are being implemented. Green bonds, tax increment financing, and resilience-based grants are becoming more popular among municipalities. Hoboken, NJ, for instance, used a $230 million HUD Rebuild by Design funding to combine managed retreats with green infrastructure [118].

Retreat investments also provide social and ecological co-benefits, such as increased open space, water filtering, carbon sequestration, and habitat restoration which are now being monetized through social value frameworks and carbon pricing. For example, "blue carbon" ecosystems, such as mangroves and wetlands, provide not only hazard mitigation but also carbon storage and habitat services. These services are now being acknowledged and compensated for in market-based instruments and adaptation planning.

Economic assessments reveal that well-designed retreat programs frequently return benefits outweighing their initial expenses. For example, incorporating wetland restoration with coastal buyouts has increased blue carbon sequestration, decreased flood danger, and improved recreational and ecological value, among other long-term benefits [72,86]. Similarly, Moritsch et al. [119] discovered that combination of retreat and levee removal can sequester of 7.40 million Mg CO_2 by 2030 and 16.6 million Mg CO_2 by 2100, while enhancing environmental and recreational outcomes. Such benefits strengthen the economic case for retreat beyond avoided losses.

9. Illustrative global cases of retreat

9.1. Historical and contemporary examples

Restoring tidal wetlands or letting floodwaters reclaim areas protected by dikes or levees are some of the first instances of managed retreat. One notable example is the relocation of Valmeyer, Illinois, in the United States, where nearly the entire town was moved to higher ground after the catastrophic 1993 Mississippi River floods. This retreat reduced flood danger for residents by permanently removing development from the floodplain and re-establishing the area as open space and portions of it used for agriculture while retaining natural floodplain functions that improve storage and reduce downstream flood risk [120,121].

Similarly, one of the first known instances of a community-initiated withdrawal following repeated flood damage in the United States is the 1980s relocation of Soldiers Grove, Wisconsin. The new townsite was built using sustainable design principles and was intended to be robust [61]. And it has largely fulfilled that goal, remaining flood free and serving as an early model of resilient, solar powered community planning.

- In New York and New Jersey, buyout programs implemented in the aftermath of Hurricane Sandy facilitated the voluntary relocation of thousands of households, albeit with varying degrees of equity and participation [14,48].
- Early examples of planned retreat integrated with ecological restoration and community engagement initiatives include Surfers' Point in Ventura and Pacifica State Beach, two locations in California that underwent managed retreat. In these cases, public infrastructure was voluntarily moved inland to decrease erosion and flood risk [122,123].
- Internationally, Pacific Island nations such as Fiji have begun relocating vulnerable communities inland, highlighting how managed retreat intersects with cultural preservation and indigenous rights [88,124].

These instances demonstrate how context determines the success of retreats, which need long term community involvement, adequate finance, inclusive planning, and clear legal requirements [14]. To complement these historical and international cases, Table 1 presents a comparative overview of additional managed retreat efforts from around the world. These examples highlight different triggers, instruments used, and key success factors or challenges encountered. They further demonstrate how policy mechanisms, funding strategies, and sociocultural dimensions influence outcomes across diverse geographies.

9.2. Linking case studies to framework dimensions

The case studies serve not only as examples but also as evidence supporting the multidimensional managed retreat framework proposed in this study. They reveal key tradeoffs across equity, governance, infrastructural resilience, and environmental sustainability. For instance, the relocation of Valmeyer, Illinois, following the Great flood of 1993 Mississippi River catastrophe is a prime example of community-driven planning and coordinated governance in the United States. The town was successfully relocated to a higher elevation through extensive public participation and federal-state collaboration, which resulted in the integration of resilient infrastructure, updated zoning, and economic revitalization measures that alleviated long-term flood exposure [120].

In contrast, the transfer of the Isle de Jean Charles Biloxi Chitimacha Choctaw community in Louisiana demonstrates how governance misalignment and cultural marginalization limit retreat. Despite being one of the first federally funded climate induced relocation initiatives in the United States, the community encountered significant apprehensions regarding the loss of cultural heritage and the absence of tribal sovereignty in decision making [126].

Meanwhile, examples like Surfer's Point and Pacifica State Beach in California show how coastal retreats can be strategically integrated into urban design. These initiatives included environmental restoration, infrastructural setbacks, and coordinated design initiatives headed by stakeholders and local governments [122].

Fiji's Narikoso relocation is a model for participatory planning in the South Pacific. Locals helped in choosing the site, design homes, and plan livelihoods. According to Yee et al. [88] and Piggott McKellar and Vella [124], this participatory approach increased the legitimacy of the procedures and helped gain support from the community.

Together these cases affirm that managed retreat must integrate social values, ecological awareness, and inclusive governance, rather than merely as a technical intervention. Table 2 aligns each case with relevant retreat framework dimensions.

Table 2
Case study alignment with managed retreat framework dimensions.

Case Study Location & Project	Institutional and Legal	Community Engagement	Disaster Risk Reduction	Environmental Assessment	Economic Evaluation
Valmeyer, Illinois, USA	✓ Federal, state, and local coordination under FEMA's Hazard Mitigation Grant Program; relocation approved through community planning and zoning reforms [120]	✓ Extensive public meetings and citizen committees guided relocation decisions; strong local leadership ensured community buy-in	✓ Relocation of entire town (approx. 900 residents) to higher ground 400 ft above floodplain eliminated long-term flood exposure	✓ Site selection minimized environmental impacts; Former floodplain preserved as open space; portions used for agriculture while retaining natural floodplain functions that improve storage and reduce downstream flood risk	✓ Relocation cost offset by avoided repetitive losses; long-term economic revitalization through new infrastructure and housing development
Isle De Jean Charles, USA	✓ State led relocation with federal support; planning challenges due to jurisdictional fragmentation	✓ Indigenous rights, land loss, and cultural preservation central to relocation debates [126]	× Infrastructure loss due to erosion, with limited coordination	× Environmental issues secondary; focus on human displacement	**Partial** Received federal funding; high relocation costs; cultural losses not monetized
Surfer's Point, Ventura, USA	✓ Joint city agency planning and public workshops [122]	**Partial** Some community consultation occurred	✓ Road and parking relocated inland; flood prone assets moved	✓ Dune restoration and beach stabilization measures	✓ Cost sharing across agencies; long term maintenance reduced
Pacifica State Beach, CA, USA	✓ Local and state government alignment with coastal zone plans	× Justice considerations minimal but not contested	✓ Infrastructure setbacks and redesign of public amenities	✓ Dune systems rehabilitated for flood absorption	**Partial** No detailed CBA published, but project leveraged existing coastal funds
Narikoso, Fiji	✓ Community engagement throughout planning stages; government facilitation [88]	✓ Full participatory relocation; traditional land ties respected	**Partial** Housing improved, but infrastructure scalability limited	✓ Mangrove and slope stabilization measures incorporated	**Partial** International donor funding; high per household relocation cost
Soldiers Grove, Wisconsin, USA	✓ Town led buyout and rebuilding with energy efficient design principles	✓ Equitable relocation post flooding; prioritization of community cohesion [61]	✓ Town center rebuilt on higher ground	× Not primarily ecologically focused, though land repurposed for parks	✓ Cost savings from flood prevention and energy efficient rebuilding

10. Synthesis and policy implications

The necessity for proactive adaptation is underscored by the escalating severity of sea level rise, inundation, and ecological disruption. Although managed retreat is frequently perceived as controversial, it is an essential element of climate resilience, particularly when embedded in equitable, multilevel governance. Effective retreat must align with participatory, science based, and socially responsive policy.

To put retreat into action, policymakers must craft instruments that equip communities and governments with the financial, procedural, and legal resources they need for implementation. These include voluntary buyouts, rolling easements, development right transfers, setback rules, and zoning revisions, each with a distinct application based on local legal context, socioeconomic situations, and environmental dangers [10,11,14].

In the United States, voluntary buyout programs have been widely implemented to relocate residential properties from high-risk zones and convert them into buffer zones or open space. Even though buyouts are more politically acceptable and financially feasible than forced relocation, they frequently fail because of unfair access, poor and unclear communication, and procedural injustice. Research has demonstrated that these programs often favor wealthier, politically connected groups, while under-serving marginalized populations [13,48,52]. In contrast, proactive interventions such as rolling easements and zoning modifications enable natural systems to migrate inland, limiting future development. However, they often face barriers from political resistance, private property concerns, and fragmented regulatory environments [9,65].

To address these obstacles, integrated governance across institutions (federal, state, and municipal) and sectors (environment, housing, finance, and planning) is crucial. As discussed earlier, proactive retreat is significantly impeded by fragmented coastal governance, requiring realignment, better data sharing, and trust building [11,14]. International frameworks like Sendai and Paris offer guiding principles; however, the state and local levels are frequently the determining factors in their implementation. Local institutional arrangements, robust state legislation, and municipal fiscal capacity frequently determine the practical feasibility of retreat [67].

Retreating isn't just a transaction, it transforms communities, identities and landscapes. Without transparent processes and inclusive engagement, retreat policies risk provoking resistance, legal challenges, or political backlash. For long term success, it is

strategically vital to ensure participation, especially from frontline and historically marginalized communities [10,52]. Retreat also must be fully integrated into resilience, infrastructure, and land use planning cycles. For example, coordinating buyout and easement initiatives with transportation and utility planning ensures that communities are not left with "stranded infrastructure" or disconnected service provision [9,11]. Equally significant are the resource demands and capacity building requirements for implementing organizations, as well as practical limits in resource-constrained environments. These aspects will determine how the framework can be deployed in practice, hence incremental implementation across multiple settings is needed rather than assuming immediate full-scale adoption.

Although this framework provides a comprehensive framework for the implementation of managed retreat, it is crucial to acknowledge the practical constraints that numerous communities encounter when attempting to implement it independently. Community decision-makers, particularly those in small or under-resourced towns, may lack the in-house technical competence to do sea level rise modeling, vulnerability assessments, or environmental impact assessments. As a result, successful implementation generally necessitates collaboration with academic researchers, planning agencies, and technical experts. Funding agencies such as the National Science Foundation, NOAA, and HUD are increasingly encouraging collaborative and community-based research approaches. These partnerships not only give technical expertise, but also encourage inclusive planning, knowledge co-production, and long-term trust with affected communities. Increasing the importance of such cooperation may ensure that retreat strategies are scientifically sound, locally informed, and socially legitimate.

Ultimately, managed retreat provides an opportunity to rethink the way humans interact with the environment and shift our focus from reactive rebuilding to proactive adaptation. In the presence of inclusive governance and robust policy tools, retreat can facilitate the development of futures that are ecologically aligned, sustainable, and just. In conclusion, the research's policy implications are evident: advancing managed retreat requires a well-integrated suite of instruments embedded in equitable governance structures. As climate risks escalate, retreat will become not only a feasible option but a necessary one. The challenge before us is to ensure it is done right.

11. Conclusion

This research presents managed retreat as a vital yet underutilized strategy for adapting to climate risks, especially in the context of sea level rise. Although numerous documented cases to date have been implemented post-hoc, in response to imminent risks or disasters, managed retreat is increasingly being explored as a proactive strategy for long-term resilience. This transition is apparent in the emergence of policies and projects that incorporate retreat into anticipatory planning, including New Zealand's coastal hazard zoning, community buyout programs in the United States, and European experiments that connect retreat with ecosystem restoration [11,60,78]. This approach to framing retreat underscores its potential to transition from a "last resort" to a more deliberate, forward-thinking adaptation pathway in response to escalating climate risks, such as rising seas, more intense storms, and recurrent coastal hazards.

The multifaceted framework outlined here for comprehending and executing managed retreat, highlights that retreat is not merely a logistical or technical solution. Rather, it is an ecological, social, political, and legal process that needs to be governed by sustainability, equity, and participation. Successful retreat is contingent upon the implementation of integrated strategies that include infrastructure adaptation, community engagement, governance, and ecosystem restoration. While relocation may be costly, economic analysis demonstrates that planned withdrawal can reduce long-term expenditures by avoiding repeated cycles of damage and repair. Without retreat, communities often remain locked into escalating infrastructure damage, rising insurance liabilities, and recurring disaster recovery costs [78,99,133]. This emphasizes the necessity of transitioning from post-disaster recovery to anticipatory adaptive planning. Embedding retreat into land-use, infrastructure, and funding cycles before disasters allow communities to respond proactively rather than reactively [134].

The synthesis of findings presented in this work emphasizes the necessity of operationalizing managed retreat through policy instruments that are adaptable and fair, such as voluntary buyouts, zoning reforms, and rolling easements. These tools have the potential to facilitate equitable reinvestment and guide implementation, and recent initiatives show that they can help move the retreat from a reactionary to a more intentional, transformative process. For example, voluntary buyout programs in New York following Hurricane Sandy enabled wetland restoration while highlighting equity challenges in relocation [16,48], and rolling easements as outlined by the U.S. Environmental Protection Agency and acknowledged in IPCC AR6, demonstrate how legal instruments can operationalize retreat in a manner that preserves public access and ecological function while preventing costly infrastructure lock-in Refs. [78,135].

Ultimately, managed retreat must be considered as an opportunity to rethink patterns of settlement and land use, with a focus on equity, resilience, and intergenerational responsibility. It can enable communities to reduce exposure to the most vulnerable while restoring landscapes that provide long-term ecological and social benefits.

As the consequences of climate change worsen, retreat will become a practical need rather than a speculative discussion. Whether it becomes a just and effective adaptation strategy is determined by how we plan, who we include, and the values that lead the transition. Although the window for proactive preparation is narrowing, but remains open, making deliberate action both possible and urgent.

CRediT authorship contribution statement

Muhammad Sajjad Rashid: Writing – review & editing, Writing – original draft, Visualization, Methodology, Conceptualization. **Elaina J. Sutley:** Writing – review & editing, Supervision, Resources, Project administration, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

No data was used for the research described in the article.

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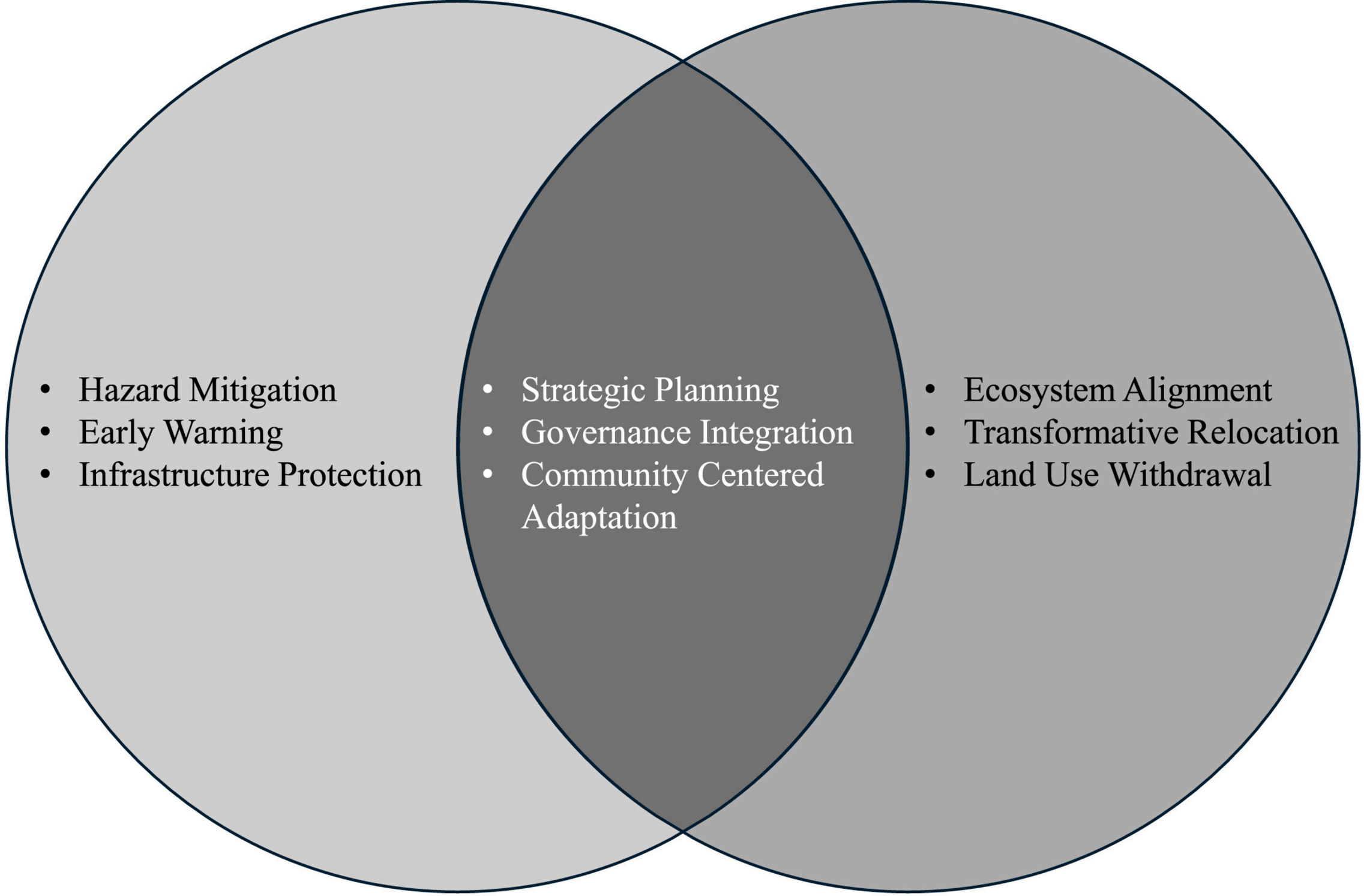
• Hazard Mitigation
• Early Warning
• Infrastructure Protection
• Strategic Planning
• Governance Integration
• Community Centered Adaptation
• Ecosystem Alignment
• Transformative Relocation
• Land Use Withdrawal
Disaster Risk Reduction (DDR)
Managed Retreat