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Article

Evaluating the Effectiveness of Land-Use Policies in Preventing the Risk of Coastal Flooding: Coastal Regions of Helsinki and Espoo

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Abstract: Effectively resolving environmental problems often involves not only technical solutions but also examining and potentially reforming the political and institutional frameworks that govern how societies relate to the environment. Coastal flooding due to rising sea levels, for example, poses a significant threat to waterfront areas. Land-use regulations represent an effective means of mitigating this risk. Despite the multitude of strategies developed for tackling similar problems, relatively few have concentrated on assessing the effectiveness of land-use policies in managing such issues. This study examines a framework for evaluating the effectiveness of land-use policies in preventing sea flood risks in the capital regions of Finland. While the focus of this research is on the coastal regions of the cities of Helsinki and Espoo, its implications extend internationally. By integrating Geographical Information System (GIS) and simulation tools, we simulate future land-use scenarios based on values that reflect the effects of land-use policies. This framework can be applied to other coastal regions worldwide facing similar challenges. Using land cover data and GeoSOS-FLUS software, land-use simulations of the target areas were generated. Land-use planning performance in the target areas exhibited positive changes, as fewer vulnerable land-use types were located within the sea flood risk zones in 2018 compared to 2000. This simulation also shows a strong similarity to actual land-use in 2018, confirming the framework's reliability. This paper presents a novel framework for evaluating the effectiveness of land-use policies in mitigating coastal flooding risks, focusing on the coastal regions of Helsinki and Espoo, Finland. By integrating GIS and simulation tools, the research demonstrates the utility of these tools in tracking land-use changes and analyzing policy impacts, enabling a nuanced assessment of policy effectiveness. Furthermore, the study highlights the importance of local knowledge and a localized approach to policy development, contributing to a deeper understanding of complex issues in urban planning and land-use management.

Keywords: land-use policy; land-use scenario; sea-level rise; coastal flood

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1. Introduction

We live in a complex urban world that is undergoing emerging phenomena, intertwined development processes, and shifting connections [1]. It is inevitable for planners to face the evolving version of old problems [2–4]. In the context of the modern built environment, urban planning and land-use planning face challenges that encompass both wicked environmental problems and land-use issues. Addressing these intertwined challenges necessitates a simultaneous focus on institutional and political solutions, as technical remedies alone are insufficient for such problems [5]. Therefore, these problems can be addressed by making effective policies, and an effective policy usually covers a wide range of environmental concerns as well. Several wicked environmental problems can be tracked down to land-use cover change; therefore, land-use policies need to be evaluated in order to deliver the intended results. Moreover, the impacts and functions of land-use policies must be evaluated to pave the way for improvements.

This research focuses on sea-flood risks and their impact on waterfront urban areas. 'Flood risk' refers to the probability and potential adverse consequences of a flood event for human health, the environment, cultural heritage, and economic activity [6]. Coastal floods have been addressed by local governments with varying success, leading to new challenges. For example, in Vietnam, high dikes caused productivity issues in rice-producing deltas [7]. In Finland, cities such as Porvoo and Loviisa experienced sea floods with significant damage, such as the Loviisa sea wall failure in 1986 [8] and the Marjaniemi area flooding in Helsinki during the 2005 Gudrun storm [9].

Tracking the effects of land-use policies becomes essential as a guiding tool for improving land-use policies. Evaluating land-use policies ensures that land resources are utilized sustainably and responsibly. Furthermore, it enables the identification of unintended consequences or disparities that may arise from their implementation. This process aids in minimizing negative effects on communities, such as unequal access to resources or disproportionate environmental burdens. Evaluations provide valuable insights into the effectiveness and fairness of policies, enabling policymakers to address deficiencies or biases in the decision-making process. However, few scholars have attempted to evaluate land-use policies. Some efforts to evaluate land-use policies have been hampered by either the discontinuous effects of land-use policies in terms of planning and time or difficulties in detecting causal mechanisms between either the effects of land-use policy or other factors involved in the planning implementation process. Another impediment to policy evaluation is the likelihood of predicting possible futures rather than recognizing the effects of land-use regulations [10–12]. In fact, predicting possible futures rather than recognizing the direct effects of land-use regulations has hindered policy evaluation efforts. This study tries to fill this gap.

Thus, the present study aims to evaluate the effectiveness of Finnish land-use policies in preventing the risk of sea floods in the coastal regions of Helsinki and Espoo. This paper views policy effectiveness as a quality indicating a correspondence between the intended goals and the actual outcomes of the adopted policy, which can demonstrate whether the policy is working [11]. To accomplish this aim, a framework is examined for tracking the actual effects of land-use policies by simulating land-use covers in a time period expanding from 2000 to 2018. Using this framework, it will be possible to examine the actual impact of land-use policies without considering other factors or predicting possible future outcomes.

The paper effectively integrates GIS and simulation tools (GeoSOS-FLUS V2.0 software) into policy evaluation processes. By demonstrating the utility of such tools in tracking land-use changes and analyzing policy impacts, the research pushes the boundaries of conventional policy evaluation. Through the developed framework, land-use scenarios are simulated based on specific values, which reflect the effects of a policy set. This paper utilizes GIS and the GeoSOS-FLUS model in an analytic approach combined with reviewing policy documents and other relevant institutional publications to remove difficulties in detecting causal mechanisms as much as possible.

Moreover, this paper devises a system to classify land-use changes into desirable and undesirable categories based on their alignment with policy objectives. This innovative classification system enables a nuanced and direct assessment of policy effectiveness. It also emphasizes the importance of local knowledge in improving land-use policies, highlighting the need for a more localized approach to policy development and implementation. With these contributions, our research seeks to answer the crucial question of how effective municipal land-use policies are in mitigating the risk of coastal flooding in the waterfront areas of Helsinki and Espoo.

This paper studies waterfront areas of Helsinki and Espoo municipalities. Figure 1 represents the study area which consists of 57 city districts located in waterfront areas. This region is part of the Gulf of Finland. One of the greatest flood events happened in 2005. The Gudrun flood was a significant storm and subsequent flooding event that occurred in

January 2005 in several countries in Northern Europe, particularly Sweden and Finland. Storm Gudrun, also known as Cyclone Gudrun, was an intense extratropical cyclone that brought strong winds and heavy precipitation to the region [9].

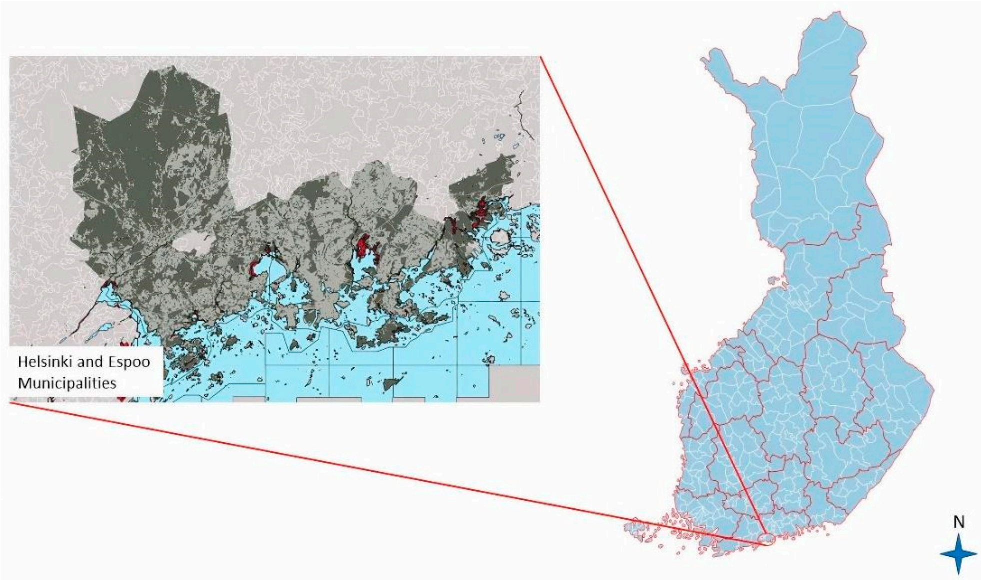

Figure 1. Coastal regions of Helsinki (60.1699° N, 24.9384° E) and Espoo (60.2055° N, 24.6559° E).

2. Theoretical Background

2.1. Restraining Wickedness through Effective Land-Use Policies

Institutional and political approaches are specifically useful when dealing with complex problems [5]. This is due to some shared characteristics among diverse types of wicked problems. In this context, wickedness is used to describe the nature of these problems as vicious, aggressive, untamable, and malignant, which are in contrast with beingness, being tamable, and solvable; in other words, wicked problems are aggressive like a lion, in contrast to the docility of a lamb [2,4,13]. The nature of an urban problem evolves with urban development and growth. As a result, the ubiquity of wicked problems in socio-ecological systems has become widely recognized in the literature, and it is evident in almost every pressing issue, such as global climate change, sustainability, land-use planning, resource management, and urbanization [13].

In addressing wicked problems, scholars recommend shifting from an optimistic view of science to embracing a post-normal science approach in policy analysis. Unlike technical solutions, institutional and political approaches are necessary for complex problems [5]. Post-normal science better suits the policy context's complexity, as traditional science may fail in this regard [14]. Although wicked problems are challenging to fully comprehend and tackle within centralized frameworks, scholars propose two main approaches. These involve using methodological approaches such as scenario planning and non-deterministic participatory methods to address uncertainties and employing instruments and tools to divide the problem into sub-problems or focus on specific goals [4,15].

Land-use is one of the three areas administered by the cadastral system, a system in which the whole information of a plot of land and its fiscal and legal purposes are recorded [16]. Policy contexts are highly dependent on the administrative system of a country. Thus, this study will focus on Finland's land-use planning system and land administration to avoid unnecessary complications. One of the ultimate goals of land-use policies is to mitigate the risks and issues that urban societies face. Policies are guided by ultimate goals such as sustainability, well-being, prosperity, and socio-economic balance. According to Howlett et al. [17], a policy framework consists of three main stages: policy design, policy implementation, and policy review. This study focuses on the last stage by assessing the effects of land-use policies. The main reason for restricting the scope of this article is the importance of making effective policies when dealing with wicked problems. One way of taking a cautious approach to wicked problems is to restrain the elements of wickedness by adopting effective policies [18]. Policy improvements can be made at any stage of the policy cycle. Still, the key message is that even small policy changes will redirect processes and maintain their effects for a long time [19]. The policy effectiveness concept is depicted in Figure 2.

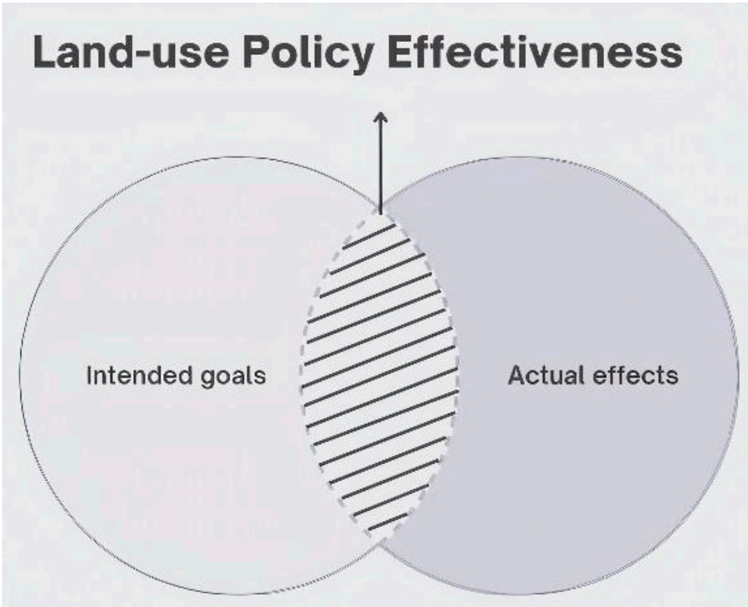

Figure 2. Land-use Policy Effectiveness.

Complex problems respond differently to political solutions depending on their attributes. Complex problems have been studied extensively over the past decades, and their characteristics have been modified by Conklin [20], Head et al. [3,20], Head [21], Ruhl and Salzman [22], Cajot et al. [23], Duckett et al. [4], and Alford and Head [24]. Among these, Ruhl and Salzman [22] investigated the attributes of massive problems based on their responsiveness to political solutions. This study considers massive problems equal to complex or wicked problems. Depending on the causal sources of the problem, causal mechanisms, and its cumulative effects, a policy can be highly effective in managing a massive problem or fail to have an influence on it. For a policy to be highly effective on a massive problem, the ideal conditions are listed in Table 1.

Table 1. The ideal conditions of causal sources, causal mechanisms, and cumulative effects for high policy effectiveness.

Source Attributes	Causal Attributes	Effect Attributes
Low number of sources	Limited scale (local and regional)	High level of detectability
Low diversity	High temporal limitation	High level of measurability
Clustered distribution		Proportional distribution over time
Large size on average (relative to effects)	Direct and proportional relationship	Proportional distribution over space
Alignment of incentives		High level of reversibility

Dealing with wicked problems is challenging for policymakers. However, since wicked problems respond to political solutions, aspects of a wicked problem can be managed by improving policies. Kirschke and Kosow [25] suggest using policy mixes for this purpose. Policy mixes are combinations of policy goals and the required instruments for achieving the intended goals [26]. According to the same study, some dimensions of wicked problems, such as complexity and uncertainty, can be addressed by improving specific aspects of policy mixes, such as adaptability, reversibility, robustness, comprehensiveness, and diversity of policy instruments.

2.2. Coastal Flooding

Sea floods are caused by a range of mostly weather-related phenomena, with climate change serving as the predominant driving force underlying the long-term change in flooding risks. It is useful to make a distinction between the long-term mean sea level and the sea level extremes, i.e., short-term variability around the mean. Both are affected by climate change. The rise in global mean sea level, caused by the thermal expansion of seawater and the melting of land-based ice, increases coastal flooding risks as the mean sea level rises. In addition, changes in sea level extremes relative to the mean may take place as the weather patterns change.

In the study area, the postglacial land uplift has so far compensated for the global sea level rise, resulting in a relatively stable mean sea level over the time period 2000–2018. Land uplift is a common process in the shoreline areas of Finland and Sweden which causes about 700 hectares of land to rise from the sea every year [27]. The rate of land uplift differs depending on the location; in Helsinki, it amounts to 3.7 mm/year [28], which is close to the current rate of global mean sea level rise [29]. In the future, global sea level rise will accelerate, overcoming the land uplift rate and causing mean sea level rise in the Helsinki region [30].

In the Baltic Sea, the astronomical tides are almost negligible, in the order of a few centimeters. Therefore, short-term sea level variations are governed by weather phenomena, mostly wind and air pressure variations. Sea levels in the Baltic Sea are relatively higher at times when westerly winds prevail because these strong wind patterns push more water into the almost enclosed basin of the Baltic Sea. In addition to water volume variations within the Baltic Sea basin, extreme sea level variations are caused by wind-induced internal redistribution of water within basins, air pressure variations, storm surges, and seiches in the various sub-basins of the sea [31]. Each of these phenomena can contribute to a sea level change of tens of centimeters on the Finnish coast: a compounding effect of several of these factors is required to produce a major coastal flood. Wind waves and, in rare cases, meteotsunamis [30] may also contribute to the height of the flood.

Climate change, on a global scale, has far-reaching and significant consequences. Research by Diez-Sierra et al. [32] indicates that the global average temperature could increase by at least 1.1 °C or up to a maximum of 6.4 °C by the year 2100. However, it is improbable that global warming will reach the most pessimistic scenario [32,33]. However, building a resilient urban environment remains essential. Urban flood events have been extensively discussed by scholars. Accordingly, ref. [34] suggests a tool for studying urban development's flooding consequences through a coupled urban growth-flood model that also considers policy, social, and physical factors influencing land cover patterns and flood impacts.

Climate change's primary impact in densely populated regions is the rise in sea levels and consequent damage from sea floods [35]. Other contributing factors include changes in salinity, ocean currents, and wind systems, influencing regional sea level fluctuations [36–39].

The causal sources and mechanisms of coastal flooding are represented in Figure 3. Accordingly, extreme sea level variation is caused by wind-induced internal redistribution of water within basins, air pressure variations, storm surges, meteotsunamis, and seiches in the various sub-basins of the sea [31].

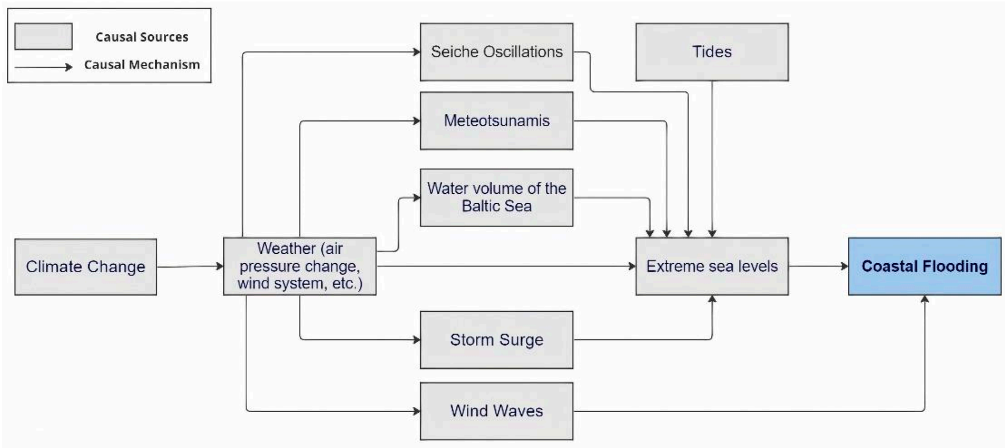

Figure 3. Causal sources and causal mechanisms of coastal flooding in the study area.

Coastal floods and wicked problems share common traits: multiple causal sources with complex relationships, ambiguous boundaries, and high uncertainty and complexity. Deep uncertainties, such as melting glaciers, further complicate sea level rise [40]. Managing sea flood risks emphasizes the significance of local knowledge [35], aligning with the "essentially unique" nature of wicked problems [2]. Sea floods are symptomatic of broader wicked problems such as ocean expansion, global warming, and climate change.

2.3. Coastal Regions of Helsinki and Espoo Municipalities

Helsinki and Espoo are in the southern part of Finland, with several densely populated districts. Since 2000, sea flood events have been more frequent in Finland as well as in other European countries. The range of sea level short-term fluctuations around the mean vary from 1.7 m in Degerby in the Archipelago Sea up to 3.1 m in Hamina in the eastern Gulf of Finland [41]. Consequently, several studies have been carried out in Helsinki and Espoo regarding the sea flood risk assessment to better understand and plan for future developments and to improve environmental protection. Additionally, some studies focused on estimating basin mass changes in order to develop effective water management strategies. A periodic rise and fall in Finnish terrestrial water storage occurs every 3.8 years, and snow plays a critical role in the annual cycle [42].

In Finland, 95% of the building codes set a minimum distance for residential or holiday buildings from the shoreline; the distance varies from 15 to 100 m and 89% of the municipalities have also defined the lowest construction height for buildings near the shoreline [9]. A minimum of 3 m above sea level was recommended for new constructions in Helsinki and Espoo [43]. The lowest recommended building height, above which structures affected by waterlogging cannot be built, is 0.5 m above the upper water line (HW50). The HW50 value is the flood height that occurs once every 50 years [44].

At a national level, the EU Floods Directive has had a great impact on the effort put into evaluating flood risks in coastal areas. The highest authority in flood risk management is the Ministry of Agriculture and Forestry and the subordinated Regional Environmental Centers. Moreover, municipal rescue authorities have an important role in flood risk management [9]. Climate adaptation policies in Helsinki are formulated by Helsinki's adaptation group (2016–2018), and these policies illustrate a climate-proof Helsinki in 2050 [45]. The "National Strategy for Adaptation to Climate Change" was adopted by the Finnish Parliament in November 2014 [46]. However, in 2006, there was no regional cooperation concerning sea flood prevention in Finland; therefore, the cooperation between city organizations only took place at the local level, especially in cases that had experienced sea flooding previously [9].

In 2007, Helsinki implemented a project (Rakennusvirasto 2007) to identify high flood-prone areas and at-risk buildings and suggested actions for risk mitigation. However, the project had limitations as it overlooked flood-prone islands and newly developing areas.

Additionally, monitoring flood-prone urban areas must be repeated regularly relative to the changes that happen in climate and mean sea levels. Currently, these aspects are covered by new measures taken, for instance, online map services (Tulvakarttapalvelu) provided by the Finnish Environment Institute (SYKE).

2.4. National and Municipal Land-Use Policies

A hierarchical system of three administrative levels organizes Finnish land-use planning [47,48]. The plans at the higher-level guide the plans at the lower level [1]. Nationally, the Ministry of the Environment and Finland's National Land-use Guidelines outline the future development of land-use. Finland's land-use and Building Act is the most important piece of legislation controlling land-use and spatial planning. The guidelines aim to ensure the appropriate actualization of national land-use solutions and to promote the implementation of international agreements and commitments [49].

The national land-use policies in Finland also consider various sector-specific policies and strategies. For example, the National Climate Change Adaptation Plan provides guidelines for addressing the impacts of climate change, including sea-level rise and coastal flooding. It emphasizes the need to integrate climate change considerations into land-use planning, risk assessments, and infrastructure development. Each municipality is responsible for preparing and maintaining a comprehensive land-use plan, which outlines the long-term vision and goals for land-use within its jurisdiction.

According to the legal consequences of land-use planning tiers in Finland, all the tiers of the land-use planning system are legally binding, and at the same time, they consider opportunities for non-binding and partially binding plans [50]. With the help of a legal-institutional role and the autonomy granted to the municipalities, land-use policies are mostly decided within municipalities. Municipalities use their autonomy in drafting local master plans. Local master plans are drafted under the supervision of municipal councils to provide long-term guidelines for land-use ordinances in the municipality [47]. However, some other factors might affect land-use controls on each level. For instance, environmental projects that monitor land-use changes by promoting climate change adaptation and environmental conservation values. FINADAPT was a project launched by the Finnish Environment Institute (SYKE) in 2003 to conduct a comprehensive research project that could help policymakers arrive at suitable policies [51].

3. Materials and Methods

3.1. Materials

To assess the effectiveness of land-use policies, two main datasets are used, which include the CORINE land-use cover dataset and the sea flood risk dataset provided by the Finnish Environment Institute (SYKE). The CORINE land cover 2000 (CLC2000) project provides information on land cover (LC) and its changes in 24 European countries, including Finland, between 1990 and 2000 [52]. This study uses CLC2000 and CLC2018 as reference material for the purpose of this study. However, the attributes of the CLC2018 dataset were improved in resolution and accuracy. CORINE land cover dataset classifies land-use data into four major classes, including artificial surfaces, agricultural areas, forests and semi-natural areas, and wetlands.

Using satellite imagery, the CLC2000 dataset was generated but has been deemed less reliable compared to newer technologies such as ESA Sentinel-2 dual date Landsat 8, which was used for CLC2018. The CLC2000 dataset exhibits low geometric accuracy (25 m) and a lower raster layer resolution. Furthermore, a generalization process was applied to aggregate small parcels into larger ones, affecting the dataset's accuracy. In response, the Finnish Environment Institute (SYKE) unified CORINE land-use cover data from 2000 to 2018 and enhanced dataset attributes to address these limitations. The improved outcomes include an increased resolution of 20 m for each layer, the unification of land-use type classifications, and the reversal of the generalization process. It is important to note that this project has not been publicly published, and access to it was granted to the researchers in response to an official request.

The Flood Risk Management Act (620/2010) of Finland demands that municipalities keep records of areas at risk of flooding. Among the different types of flood events, such as river floods, flash floods, urban floods, and floods from the sea in coastal areas, this study focuses on the last type. Due to the fact that sea level rise has accelerated the frequency of flood events in many regions, sea flooding is dependent on the mean sea level changes. This paper utilizes sea flood data provided by SYKE, which identifies the areas at risk of sea flooding and presents different probabilities of flood events. Due to the fact that flood risk zone data for 2000 is unavailable, there are limitations associated with flood risk data. The boundaries of risk zones are set based on the year 2018. The premier goal of the study was to investigate land-use changes that have happened within areas at risk of flooding. Evaluating these land-use changes leads us to recognize the effects of land-use policies that were applied to these regions.

In total, 27,366 km^2 of Helsinki and Espoo's coastal regions are at risk of sea flood events, but its frequency varies from once every two years to once every 1000 years. Table 2 represents shares of each land-use type that is located inside the sea flood risk zones. Based on this, land-use changes over a time period of 18 years have improved the allocation of artificial surfaces and agricultural lands. The greatest land-use change has happened in artificial surfaces, with a 373 km^2 reduction in the areas at risk of flooding events.

Table 2. Shares of each land-use type that is located within the flood risk zones.

Land-Use Type at Risk of Flooding	Area in 2000 (km^2)	Area in 2018 (km^2)	Performance (km^2)
Artificial surfaces	7232	6960.4	Decreased 271.4
Agricultural areas	3234.2	2861.2	Decreased 373
Forests and semi-natural areas	11,890.9	12,208.8	Increased 317.9
Wetlands	5008.9	5335.6	Increased 326.7

The present study utilizes international guidelines for land-use planning and regulations, national legislation, regional plans, local master plans, detailed plans, and associated projects in order to review the land-use policies that applied to the coastal areas of Helsinki and Espoo. Additionally, land-use cover changes in these urban areas are impacted by other policies, including land management policies, nature conservation goals, climate adaptation plans, and economic development incentives.

3.2. Methods

This study utilizes a back-casting method to detect the effects of land-use policies that are applied to the coastal regions of the study areas. The main distinctive feature of the back-casting method compared to other multi-scenario simulation methods that tend to predict possible futures of land-use cover is that this approach helps to find causes and solutions to a problem [53,54]. Using this approach, we can identify the factors that lead to a change under the influence of policies. Thus, the direct impact of policies on land-use changes becomes distinctive [55]. In this study, the envisioned future is defined based on the land-use cover in 2018. Land-use policy effects are detected according to the way this envisioned future has been achieved. The target scenario is referred to the envisioned land-use cover. The initial scenario is based on the land-use cover in 2000.

To operationalize this method, a land-use model was simulated based on the initial scenario using GeoSOS-Future Land Use Simulation (GeoSOS-FLUS) software. This software offers a multifaceted Cellular Automata (CA) allocation model. Recent advancements in CA modeling, such as LP-CA (Landscape-driven Patch-Based Cellular Automation), have enhanced its ability to incorporate information about landscape patterns [56]. It provides a better understanding of past and future urban developments by considering both landscape similarity and cell-by-cell agreement. The GeoSOS-FLUS also utilizes an artificial neural network (ANN) to consider multiple effects and establish intricate connections between land-use patterns and various driving forces. A comparison of the FLUS model with other most widely used urban growth models shows that while some models, such as the Cellular Automata-Markov model (CA-Markov), FLUS, Land Use Scenario Dynamics model (LUSD), and Land Change Modeler (LCM) met verification criteria, Conversion of Land Use and its Effects at Small extent model (CLUE-S) and Slope, land-use, excluded layer, urban extent, transportation, hillshade (SLEUTH) had limitations [57].

This paper follows the steps taken by Wang et al. [54]. The process of tracking the effects of land-use policies has three stages, including setting up initial and target scenarios, analyzing land-use policies, and simulating land-use scenarios. The initial land-use scenario consists of land-use type allocations within the boundaries of Helsinki and Espoo municipalities in 2000. Moreover, the target scenario includes the same information as in 2018. With a backcasting technique, a longer timeframe is helpful for capturing gradual trends, assessing the long-term effects of policies, and highlighting the significance of results. The initial and target land cover data enables the comparison of land-use patterns before and after the implementation of the policies.

The results of simulating land-use models can be interpreted to reveal those land-use policies that are responsible for the land-use changes. Since this study focuses on the significant areas at risk of sea floods, the result of this attempt can shed light on how effective land-use policies can help in sea flood risk prevention.

After listing the relevant land-use policies, a value was assigned to each land-use policy (see Table 3). The aim of this stage was to indicate the intensity and direction of land-use policy effects. Policy assignments are used to structure a conversion cost matrix which is the basis of simulation models. Policy assignment Q is dependent on the intensity and direction of the effects. The intensity of land-use policy effects (symbolized as P) is either Direct (D) or Indirect (I) and Strong (S) or Weak (W). The intensities are specified based on these conditions:

$$P = \begin{cases} 9, & if\ the\ intensity\ is\ Direct\ and\ Strong \\ 5, & if\ the\ intensity\ is\ Direct\ and\ Weak\ OR\ Indirect\ and\ Strong \\ 1, & if\ the\ intensity\ is\ Indirect\ and\ Weak \end{cases}$$

The direction of the land-use policy function (symbolized as M) expresses whether the policy contributes to land-use change or prevents the change from happening. Thus, the direction would be positive (+) in the former condition or negative (−) in the latter condition. Policy assignment (Q) is calculated depending on P and M values according to the following equation.

$$Q = PM \tag{1}$$

Corresponding land-use policies with policy assignments are presented in Table 3. Table 3 also presents a short description of land-use policies.

A conversion cost matrix was created to discover a causal relationship between land-use policies and land-use changes. The value (V) of each cell in the conversion cost matrix is intended as:

$$Value = \frac{\sum k \in n_{ij}\ Q_k}{max\{\sum k \in n_{ij}\ Q_k\}} \tag{2}$$

where i represents the type of land-use transferred out; j represents the type of land-use transferred in; n_{ij} denotes a set of policy numbers for converting i-type land-use into j-type land-use; k denotes the policy number, and $1 \leq k \leq 17$; Q_k denotes the corresponding assignment of the policy number.

Table 3. Land-use policy collection and policy assignments.

Policy Name	Policy Action Mechanism Number		Policy Assignment
	Policy Number	Policy Intensity and Direction	
New residential areas are planned in Östersundom for which land elevation projects are needed to increase the height of land to prevent the risk of flooding (2012).	01-	D-S-+	9
Vegetation measures are planned in the coastal areas of Östersundom to reduce the speed of water runoff and the risk of flooding (2012).	02-	D-S-+	9
New developments include residential areas, business areas, green connections, and recreational areas, including recreational islands in Meri-Rastila-Vuosaari (2016).	03-	D-S-+	9
Residential areas and mixed land-uses are planned in Kruunuvuorenranta coastal areas (2016).	04-	D-S-+	9
Housing development in Pihlajisto with respect to natural and cultural values of Viikki old town bay and its surroundings (2015).	05-	I-S-+	5
Finnoonsatama will be a residential area; however, the recreational and conservation values of the area will be safeguarded (2015).	06-	I-S-+	5
Espoo's ecological network (EVN) is developed throughout almost all coastal areas to support biodiversity and sustainable use of cultural environments, ecological connectivity, and recreational networks (2008–2018).	07-	D-W-+	5
Developing a green network along the coastlines and naturally valuable areas, an environmental conservation plan, and supporting recreational uses for the city of Helsinki (2016).	08-	D-W-+	5
According to National land-use guidelines, municipalities must be prepaid for extreme weather events and new constructions must be located outside flood risk zone areas or otherwise ensure flood risk management (2008–2017).	09-	I-S-−	−5
Mapping flood-prone areas started in 2007 and giving instructions for flood preparation started by The European Parliament and The Councils on 23 October 2007.	10-	D-S-+	9
Construction in the shore zones is allowed only according to detailed local plans or a legally binding local master plan. This provision does not apply to (Land-use and Building Act, 2003):building required by agriculture and forestry or fishery	11-	D-S-+	9
building to serve the needs of national defense or frontier control;	12-	D-S-+	9
building required by navigation;	13-	D-S-+	9
building of an outbuilding within the curtilage of an existing residential building;	14-	D-S-+	9
repair of or limited extension of an existing residential building.	15-	D-S-+	9
Flood risks must be considered during planning and construction to ensure that new building developments are not located where they may be damaged by floods (Land-use and Building Act, 2003).	16-	D-S-+	9
Developments along the shores of the Baltic Sea should be located higher than the levels flood waters can be expected to reach once every 200 years on average, plus at least 30 cm to account for wave heights. This means the lowest recommended heights for the bases of buildings would be N60 + 2.60 m in Helsinki (2008).	17-	D-S-+	9

In this formula, $\sum k \in n_{ij}\ Q_k$ refers to the sum of the assigned values of all policies that stimulate or inhibit the conversion of land-use types. Moreover, *max* $\{\sum k \in n_{ij}\ Q_k\}$ is the maximum value of the sum of policy assignments in the table of all land-use conversions. The purpose of this step was to normalize Values to a number between 0 and 1. Since some policies were assigned negative values, it is inevitable to make $\sum k \in nij\ Qk$ negative. Therefore, the following must be applied when calculating V, so this value can take a positive number and represent different levels of land conversion costs at the same time.

$$\begin{gathered} if\ min\{Value\} \geq 0,\ V = Value\ ; \\ if\ min\{Value\} < 0,\ V = Value + min\{Value\} \end{gathered} \tag{3}$$

If V = 0, land-use change is prohibited, and if V = 1, land-use change is encouraged. Other amounts of V between 0 and 1 represent low to high costs of land-use changes. This conversion cost matrix contains the initial parameters for land-use simulations which are carried out by Geo-SOS FLUS software. The spatial variables used in simulations were demographic concentration and proximity, route proximity, Aspect and Slope maps, and distances from the city center and sub-centers of the study region. An ANN-based estimation model was created using these driving forces (see Figure 4). This estimation model demonstrates the probability of occurrence for each land-use type.

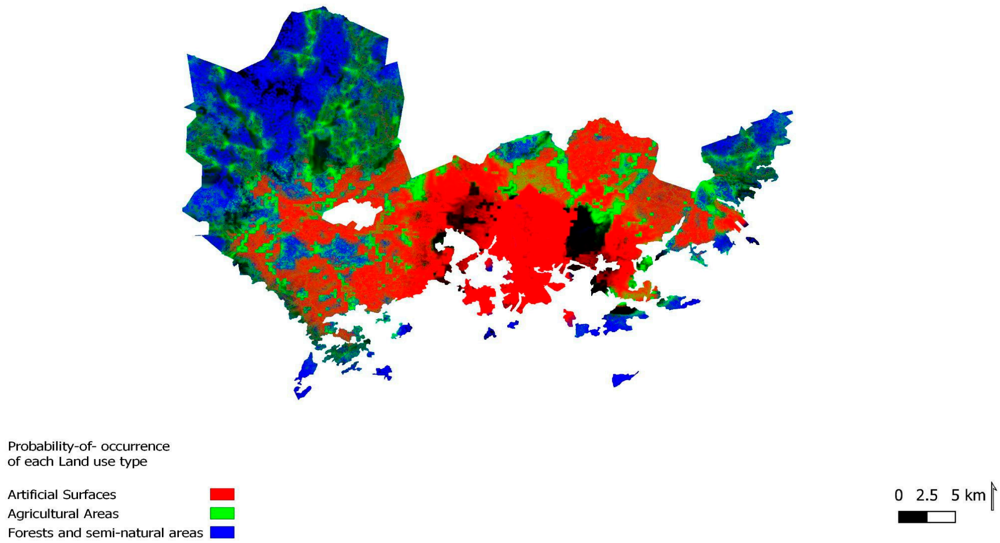

Figure 4. The ANN-based model.

To deliver a satisfying land-use scenario, multiple rounds of simulation were run, and the initial parameters of the conversion cost matrix were adjusted according to deviations in each round. Figure 5 depicts the first and last round of simulations. The adjustment criteria for land-use conversion from type A to type B, for instance, are as follows. Rule (1) states that if the simulated result of land-use type A was more than its actual amount and the simulation result of land-use type B was less than its actual amount, the corresponding value in the conversion cost matrix should be increased. Rule (2) says that if the simulated result of land-use type A is less than the actual amount and the simulation result of land-use type B is more than its actual amount, the corresponding value in the conversion cost matrix must be decreased.

GeoSOS-FLUS software enables users to check the similarity of their simulation to the actual land-use cover. The Kappa statistic tool was used to test the validity of the simulated land-use model, which indicates Kappa ecoefficiency and overall accuracy. The Kappa statistic tool measures the inter-rated reliability of variables, and the results of this test are only acceptable if they are greater than 0.4; otherwise, the model is deemed unreliable.

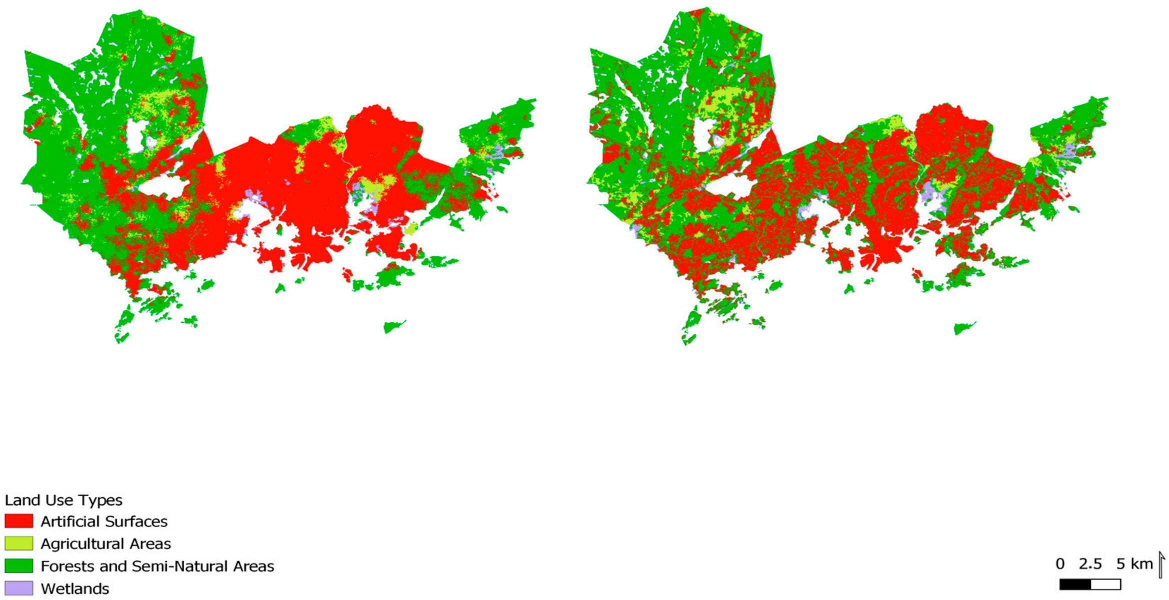

Figure 5. The first and the last round of land-use simulation.

Broadly, value A, based on expert knowledge, was assigned to each policy, indicating the intensity and direction of a land-use policy. The process continued with making a conversion cost matrix. This matrix represents the degree of change in each land-use conversion. The GeoSOS-FLUS tool considers this matrix as one of the main driving forces of land-use change. The next stage of the process consists of simulating land-use scenarios based on the conversion cost matrix and the demanded land-use areas in 2018. The initial scenario was used as a starting point. The areas of each land-use type in 2018 were inserted into the model as demanded land-use areas. Thus, the iteration rounds continued until the simulated areas reached the required areas for each land-use type. The outcome of the simulation was compared to the target scenario using the Kappa statistic tool. In case of a poor simulation result, the conversion cost matrix was adjusted. The simulation procedure was repeated until overall accuracy and Kappa ecoefficiency scores reached an acceptable rate.

4. Results

The present study aims at measuring the effects of land-use policies in the coastal regions of Helsinki and Espoo municipalities. The target area is further limited to areas at risk of sea flooding; however, land-use policies are applied to much more extensive regions and have diverse effects. Thus, selected land-use policies differ in the extent of their effects. The main results of this study are represented in Tables 4 and 5.

Table 4. The final conversion cost matrix.

Land-Use (from)	**Land-Use (to)**			
	Artificial Surfaces	**Agricultural Areas**	**Forests and Semi-Natural Areas**	**Wetlands**
Artificial Surfaces	1	0.1	0.22	0.26
Agricultural areas	0.9	1	0.32	0.4
Forests and semi-natural areas	0.99	0.16	1	0
Wetlands	0.2	0.21	0.22	1

The scale 0–1 reflects the degree of conversion. (0) indicates no conversion, and (1) complete conversion. Red indicates undesirable conversions, and green shows desirable conversions.

Table 5. Effective land-use policies in preventing the risk of coastal flooding.

Desirable Land-Use Conversion	Policy Numbers	Policy Names
Artificial Surfaces Agricultural Areas	11	(02)-Vegetation measures are planned in the coastal areas of Östersundom to reduce the speed of water runoff and the risk of flooding (2012) (03)-New developments include residential areas, business areas, green connections, and recreational areas, including recreational islands in Meri-Rastila and Rastila-Vuosaari. (2016) (05)-Housing development in Pihlajisto with respect to natural and cultural values of Viikki old town bay and its surrounding (2015) (07)-Espoo's ecological network (EVN) is developed throughout almost all coastal areas to support biodiversity and sustainable use of cultural environments, ecological connectivity, and recreational networks. (2008–2018) (08)- Developing a green network along the coastlines and naturally valuable areas, an environmental conservation plan, and supporting recreational uses for the city of Helsinki (2016) (09)-According to National land-use guidelines, municipalities must be prepaid for extreme weather events and new constructions must be located outside flood risk zone areas or otherwise ensure flood risk management (2008–2017) (10)-Mapping flood-prone areas started in 2007 and giving instructions for flood preparation started by The European Parliament and The Councils on 23 October 2007. (11)-Construction in the shore zones is allowed only according to local detailed plans or a legally binding local master plan. This provision does not apply to the building required by agriculture and forestry or fishery.
Artificial Surfaces Forests and semi-natural Areas	07, 08, 11	
Artificial Surfaces Wetlands	02, 07, 08, 09, 10	
Agricultural Areas Forests and semi-natural Areas	02, 07, 08, 11	
Agricultural Areas Wetlands	02, 03, 05,07, 08, 09, 10	

The value in each cell corresponds to land-use conversions. These values are influenced by land-use policies and their assignments. To translate these values into policy effectiveness, we need to classify land-use changes into desirable and undesirable groups of change. The desirability of a land-use change is detectable by reviewing the main objectives of land-use policies. Based on the national guidelines and the Land Use and Building Act (132/1999), the following objectives are relevant to the study areas of this study:

- Environmental protection and prevention of environmental hazards.
- Functionality of communities and good building.

To succeed in these objectives, it is better to position urban infrastructures and functional land-use types, such as residential areas and main transportation routes, at a safe distance from sea-flood risk zones. Additionally, natural areas and wetlands are helpful when dealing with natural hazards such as flooding events. Forests and semi-natural areas also support environmental protection aims, and non-motorized transportation systems are encouraged as green connection networks alongside the coastal areas of Helsinki and Espoo. Therefore, the land-use conversions are divided into two groups indicated by green and red colors in the final conversion cost matrix (Table 4). This classification reflects better choices of land-use types for areas at risk of coastal flooding. Green-colored land-use conversions are aimed at reducing coastal flood risk and safeguarding the functionality of communities. Other land-use changes colored in red do not affect or make little contribution to achieving the objectives listed in the Land Use and Building Act (132/1999).

To introduce effective land-use policies, the values in each green cell in Table 4 must be translated into a set of policy numbers. Accordingly, these policies listed in Table 5 are labeled as effective at preventing the risk of coastal floods.

In order to detect the degree of effectiveness, we should pay attention to the degree of conversion in Table 5. Among the desirable land-use conversions, land-use changes from agricultural to wetlands have the greatest degree of conversion. This means the policy combination involved in this change has made a wider impact compared to the policies that are involved in land-use changes from artificial to agricultural areas. On the other hand, among the undesirable land-use changes, the highest degree of change belongs to the land-use conversion from forests and semi-natural areas to artificial surfaces. Among the policy combinations listed in Table 5, policies related to the green network connection in Helsinki and Espoo's ecological network (EVN) are the most frequently used to promote desirable land-use changes. These policies could prevent coastal areas from the risk of coastal flooding, promote non-motorized ways of transport, and preserve environmental values and natural landscapes. Fiscal incentives, however, may be undermined by using the most demanded land in coastal areas to serve public needs instead of putting them into more profit-generating uses in order to generate tax income.

Results indicate that land-use policies applied to the study area were effective in reducing the risk of coastal flooding. The majority of vulnerable land-use types, such as artificial surfaces, have been planned to be outside the flood risk zones. However, land-use changes cannot be separated by the boundaries of flood risk zones. As a result, policies that appear effective in this study might not work for other purposes. Therefore, the overall effectiveness of the land-use policies applied to the study region is satisfying in terms of safeguarding the functionality of communities and preventing the risk of environmental hazards such as coastal flooding.

5. Discussion

This paper offers a framework for evaluating land-use policy effectiveness. Evaluation of policy is a complex task, and land-use planning poses wicked problems as well. More tellingly, urban planning generates wicked problems because it attempts to manage all the issues of urban living and the environment at once, just as what sustainability science is trying to accomplish [58].

Professionals have treated wicked problems differently over the past decades. The suggested mitigations advanced from 'taming', 'handling', and 'tackling', to 'working with', 'living with', and 'embracing' [14,18], showing an increasing acceptance of wicked problems as an integrated part of socio-economic systems [13]. When facing wicked problems, one reasonable way of handling them is to break the problem down into specific aspects. Land-use policies and coastal flooding are the aspects covered by this study.

Policy evaluation is demanded by several legislations to improve decision-making and policy outcomes. However, fewer scholars have attempted to evaluate land-use policies. However, land-use planners can benefit from the literature available on the evaluation of environmental policy instruments and waste management policies [10,47]. In both studies, statistical methods are suggested to measure the effectiveness of policies, while in land-use policy evaluation, location-based information and analysis can provide useful outcomes for planners and decision-makers. For improving the effectiveness of land-use policies, local knowledge is a crucial requirement, otherwise, the policy will fail either in implementation or in delivering the intended outcomes. Another tool used in related research is GIS which has been utilized to track land-use changes and analyze the effects of these changes on various aspects of the urban environment, such as preserving natural features [12].

The implementation of land-use policies has significant legal and administrative implications that shape the spatial and socio-economic dynamics of regions and communities. Understanding the difference between the legal and administrative effects of land-use policies is crucial for effective implementation and enforcement. Legal effects of land-use policies refer to the legally binding rules and regulations that govern land-use and development within a specific area. These rules are enforceable by law and can result in penalties or legal actions if not followed. While detailed plans have explicit legal obligations, master plans play a vital role in shaping land-use policies and decisions, and their adherence is typically expected, even if not strictly legally enforceable. On the other hand, administrative effects of land-use policies refer to the non-binding guidelines, recommendations, and procedures that inform the decision-making process related to land-use and development.

This paper refers to flood risk zones as a sample of local knowledge that enriches the application of land-use policies affecting coastal areas. Using software tools enables us to conduct explanatory research regarding policy effectiveness and actual outcomes caused by land-use policies. Recently, several researchers used GIS and simulation tools to detect land-use policy effects [54,55]. Although software tools can be beneficial, researchers must be aware of their possible limitations. For instance, it is better to compare the simulated areas of each land-use type with reality to ensure the data has not been altered through different processes.

The GeoSOS-FLUS software provides validity tests to compare the simulation model with actual land-use cover. In the case of this study, the model starts with simulating according to the land-use cover in 2000, and the simulation cycle will continue (according to variables set to the model) until areas of each land-use type reach the demanded amounts in 2018. As a result, the areas of each land-use type in the actual land-use map for 2018 and in the final simulation model are equal. However, the allocation of land-use types must be compared to reality. The Kappa statistic tool was used for this purpose. This test registered excellent results for the simulated land-use cover. The overall accuracy is 0.93, and the Kappa coefficient is 0.88, both of which are excellent.

Recognizing the inherent uncertainties in predicting future land-use changes and flood events, this study has taken several steps to ensure transparency and rigor in its approach. Comprehensive information about data sources and assumptions is provided, enabling policymakers to understand the basis of our predictions and the associated limitations. In addition, scenario analysis and sensitivity analysis have been conducted to explore different outcomes and assess the model's robustness. Moreover, this study actively engages policymakers, experts, and stakeholders throughout the research process to collaboratively address challenges and make well-informed decisions. By incorporating these strategies, we aim to facilitate meaningful discussions on policy implications and contribute to effective land-use planning in flood-prone coastal regions.

6. Conclusions

This paper aimed to evaluate the effectiveness of Finnish land-use policies in preventing the risk of coastal floods in the waterfront areas of Helsinki and Espoo. Based on the results of this study, Municipal land-use policies applied to the study area were highly effective in preventing the risk of coastal flooding.

Land-use ordinances are an effective means of starting new norms and values that can maintain their effects over time and scales. Therefore, land-use planning is a beneficial tool to mitigate climate change and promote resilient living environments [45]. Land-use policies are the backbone of the land-use planning system in Finland, and evaluating these policies is mandated by the European Union and other national legislations. This study develops a framework for evaluating the effectiveness of land-use policies in preventing sea flood risks. The target application of this framework is to track the actual effects of land-use policies. Through the developed framework, land-use scenarios are simulated based on specific values, which reflect the effects of a policy set. A multi-policy analysis can be done using this framework to assess the impact of multiple policies on different land-use conversions. The framework owes this functional capability to the GeoSOS-FLUS model, as it produces simulations using ANN-based models and on the basis of CA theory.

The process of evaluating land-use policies begins with setting up initial and target land-use scenarios. The former scenario is based on the land-use cover of the study region in 2000, and the latter represents the same information for the year 2018. There are four classes of land-use (Artificial Surfaces, Agricultural areas, Forests and semi-natural areas, and Wetlands) and twelve possibilities for land-use conversions. Furthermore, a list of land-use policies that are applied to the study region has been collected. However, the boundaries of sea flood risk zones were considered when narrowing down the list of relevant land-use policies.

As demonstrated by simulation results and validation scores, the developed framework outperforms existing methods for evaluating the effects of land-use policies. The process concludes by translating the values in the final simulation scenario into policy sets, establishing a causal relationship with land-use changes. These results specify the effects of land-use policies on changes between 2000 and 2018 in the coastal regions of Helsinki and Espoo. To assess the effectiveness of selected land-use policies in mitigating coastal flood risks, changes are classified into two groups: desirable land-use changes involving conversions from Artificial Surfaces to other types or from Agricultural Areas to other types excluding Artificial Surfaces. Natural areas and wetlands are deemed less vulnerable to flooding. Depending on the framework's purpose, land-use conversions' classification may vary, presenting a valuable functional capability.

The results show that land-use planning performed well in the coastal regions of Helsinki and Espoo. Based on the results, we can conclude that vulnerable land-use types were successfully relocated outside the boundaries of sea flood risk zones. Both the simulation results and the comparison of land-use types in 2000 and 2018 support this claim.

Using a novel framework, this study assesses the effectiveness of land-use policies in mitigating coastal flooding risks in Helsinki and Espoo, Finland. By integrating GIS and simulation tools, the research demonstrates the utility of tracking land-use changes and analyzing policy impacts. This approach pushes conventional policy evaluation boundaries. This paper emphasizes the importance of local knowledge, advocates for a more localized approach to policy development, and highlights the potential of combining policy initiatives and technology to address complex issues in urban planning and land-use management. Future studies may focus on a detailed analysis of land-use types for sustainable development of waterfront areas, focusing on small-scale study areas and expanding the number of land-use classes.

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References

1. Mäntysalo, R.; Kangasoja, J.K.; Kanninen, V. The paradox of strategic spatial planning: A theoretical outline with a view on Finland. *Plan. Theory Pract.* **2015**, *16*, 169–183. [CrossRef]
2. Rittel, H.W.J.; Webber, M.M. Dilemmas in a general theory of planning. *Policy Sci.* **1973**, *4*, 155–169. [CrossRef]
3. Head, B.W. Wicked Problems in Public Policy. *Public Policy* **2022**, *3*, 101–118. [CrossRef]
4. Duckett, D.; Feliciano, D.; Martin-Ortega, J.; Munoz-Rojas, J. Tackling wicked environmental problems: The discourse and its influence on praxis in Scotland. *Landsc. Urban Plan.* **2016**, *154*, 44–56. [CrossRef]
5. Perry, J. Climate change adaptation in the world's best places: A wicked problem in need of immediate attention. *Landsc. Urban Plan.* **2015**, *133*, 1–11. [CrossRef]
6. The European Parliament and the Council. *Assessment and Management of Flood Risks*; Directive 2007/60/EC. Jun. 2007; European Parlament: Brussels, Belgium, 2007.
7. Yuen, K.W.; Hanh, T.T.; Quynh, V.D.; Switzer, A.D.; Teng, P.; Lee, J.S.H. Interacting effects of land-use change and natural hazards on rice agriculture in the Mekong and Red River deltas in Vietnam. *Nat. Hazards Earth Syst. Sci.* **2021**, *21*, 1473–1493. [CrossRef]
8. Virkki, H.; Kallio, H.; Orenius, O. *Sea Level Rise and Flood Risk Assessment in Itä-Uusimaa*; GTK: Helsinki, Finland, 2006.
9. Juuti, P. Näin Aallot Lyövät Helsingin Rantaan Tulevaisuuden Myrskyissä—Vuonna 2005 Tulva Nosti Veden Kauppatorille, Mutta Paljon Pahempaan on Varauduttava. Available online: https://yle.fi/a/3-12121601 (accessed on 13 August 2023).
10. Mickwitz, P. A Framework for Evaluating Environmental Policy Instruments. *Evaluation* **2003**, *9*, 415–436. [CrossRef]
11. Scott, E.M. Setting, and evaluating the effectiveness of, environmental policy. *Environmetrics* **2007**, *18*, 333–343. [CrossRef]

12. Taylor, J.J.; Brown, D.G.; Larsen, L. Preserving natural features: A GIS-based evaluation of a local open-space ordinance. *Landsc. Urban Plan.* **2007**, *82*, 1–16. [CrossRef]
13. Xiang, W.-N. Working with wicked problems in socio-ecological systems: Awareness, acceptance, and adaptation. *Landsc. Urban Plan.* **2013**, *110*, 1–4. [CrossRef]
14. Batie, S.S. Wicked Problems and Applied Economics. *Am. J. Agric. Econ.* **2008**, *90*, 1176–1191. [CrossRef]
15. Lazarus, R.J. Super Wicked Problems and Climate Change: Restraining the Present to Liberate the Future. 2009. Available online: https://scholarship.law.georgetown.edu/facpub/159 (accessed on 27 June 2023).
16. Enemark, S. *A Cadastral Tale*; Análisis Geográficos; Instituto Geográfico Agustin Codazzi: Bogota, Columbia, 2006; pp. 147–159.
17. Howlett, M.; Perl, A.; Ramesh, M. *Studying Public Policy*; Oxford University Press: Oxford, UK, 2009.
18. Norton, B.G. The Ways of Wickedness: Analyzing Messiness with Messy Tools. *J. Agric. Environ. Ethic.* **2011**, *25*, 447–465. [CrossRef]
19. Adams-Schoen, S. Taming the Super-Wicked Problem of Waterfront Hazard Mitigation Planning: The Role of Municipal Communication Strategies. In *Contemporary Issues in Climate Change Law and Policy: Essays Inspired by the IPCC*; SSRN: Rochester, NY, USA, 2016.
20. Conklin, J. *Dialogue Mapping: Building Shared Understanding of Wicked Problems*; John Wiley & Sons, Inc.: Hoboken, NJ, USA, 2006.
21. Head, B.W. Forty years of wicked problems literature: Forging closer links to policy studies. *Policy Soc.* **2018**, *38*, 180–197. [CrossRef]
22. Ruhl, J.B.; Salzman, J. Climate Change, Dead Zones, and Massive Problems in the Administrative State: A Guide for Whittling Away. *Calif. Law Rev.* **2010**, *98*, 59–120. [CrossRef]
23. Cajot, S.; Peter, M.; Bahu, J.-M.; Koch, A.; Maréchal, F. Energy Planning in the Urban Context: Challenges and Perspectives. *Energy Procedia* **2015**, *78*, 3366–3371. [CrossRef]
24. Alford, J.; Head, B.W. Wicked and less wicked problems: A typology and a contingency framework. *Policy Soc.* **2017**, *36*, 397–413. [CrossRef]
25. Kirschke, S.; Kosow, H. Designing policy mixes for emerging wicked problems: The case of pharmaceutical residues in freshwaters. *J. Environ. Policy Plan.* **2021**, *24*, 486–497. [CrossRef]
26. Rogge, K.S.; Reichardt, K. Policy mixes for sustainability transitions: An extended concept and framework for analysis. *Res. Policy* **2016**, *45*, 1620–1635. [CrossRef]
27. Poutanen, M.; Steffen, H. Land Uplift at Kvarken Archipelago/High Coast UNESCO World Heritage area. *Geophysica* **2015**, *50*, 49–64.
28. Pellikka, H.; Johansson, M.M.; Nordman, M.; Ruosteenoja, K. Probabilistic projections and past trends of sea level rise in Finland. *Nat. Hazards Earth Syst. Sci.* **2023**, *23*, 1613–1630. [CrossRef]
29. Intergovernmental Panel on Climate Change. Ocean, Cryosphere and Sea Level Change. In *Climate Change 2021—The Physical Science Basis*; Cambridge University Press: Cambridge, UK, 2023; pp. 1211–1362. [CrossRef]
30. Pellikka, H.; Laurila, T.K.; Boman, H.; Karjalainen, A.; Björkqvist, J.-V.; Kahma, K.K. Meteotsunami occurrence in the Gulf of Finland over the past century. *Nat. Hazards Earth Syst. Sci.* **2020**, *20*, 2535–2546. [CrossRef]
31. Pellikka, H. *Dark-Blue Horizon: Sea Level Rise and Meteotsunamis on the Finnish Coast*; Finnish Meteorological Institute: Helsinki, Finland, 2020. [CrossRef]
32. Diez-Sierra, J.; Iturbide, M.; Gutiérrez, J.M.; Fernández, J.; Milovac, J.; Cofiño, A.S.; Cimadevilla, E.; Nikulin, G.; Levavasseur, G.; Kjellström, E.; et al. The Worldwide C3S CORDEX Grand Ensemble: A Major Contribution to Assess Regional Climate Change in the IPCC AR6 Atlas. *Bull. Am. Meteorol. Soc.* **2022**, *103*, E2804–E2826. [CrossRef]
33. Hausfather, Z.; Peters, G.P. Emissions—The business as usual story is misleading. *Nature* **2020**, *577*, 618–620. [CrossRef] [PubMed]
34. Pérez-Molina, E.; Sliuzas, R.; Flacke, J.; Jetten, V. Developing a cellular automata model of urban growth to inform spatial policy for flood mitigation: A case study in Kampala, Uganda. *Comput. Environ. Urban Syst.* **2017**, *65*, 53–65. [CrossRef]
35. Crane, R.; Landis, J. Introduction to the Special Issue. *J. Am. Plan. Assoc.* **2010**, *76*, 389–401. [CrossRef]
36. Alexandra, R. Climate Change Adaptation in Metro Vancouver: Examining the Role of Managed Retreat. Master's Thesis, University of Waterloo, Waterloo, ON, Canada, 2018.
37. Biber, E. The Sting of the Long Tail: Climate Change, Backlash and the Problem of Delayed Harm. *SSRN Electron. J.* **2008**, 1292529. [CrossRef]
38. Nicholls, R.J.; Cazenave, A. Sea-Level Rise and Its Impact on Coastal Zones. *Science* **2010**, *328*, 1517–1520. [CrossRef]
39. Rizzardi, K.W. Washington and Lee Journal of Energy, Climate, and the Environment. Article 4 3-2015 Part of the Energy and Utilities Law Commons, Environmental Law Commons, and the Natural Resources Law Commons. Seas, Receding Ethics? Why Real Estate Professionals Should Seek the Moral High Ground. 2015. Available online: https://scholarlycommons.law.wlu.edu/cgi/viewcontent.cgi?article=1093&context=jece (accessed on 27 June 2023).
40. Berkes, F. Implementing ecosystem-based management: Evolution or revolution? *Fish Fish.* **2011**, *13*, 465–476. [CrossRef]
41. Jaana, J.; Kristiina, N.; Paula, T. *Climate-Proof Living Environment-Methodologies, Tools and Practical Recommendations for Climate Change Adaptation in the Kymenlaakso and Uusimaa Regions and the Helsinki Metropolitan Area*; Gaia: London, UK, 2018.
42. Zhai, Y.; Yao, Y.; Guan, Q.; Liang, X.; Li, X.; Pan, Y.; Yue, H.; Yuan, Z.; Zhou, J. Simulating urban land use change by integrating a convolutional neural network with vector-based cellular automata. *Int. J. Geogr. Inf. Sci.* **2020**, *34*, 1475–1499. [CrossRef]
43. Uudenmaanliitto. *General Flood Map of Coastal Areas of Uusimaa*; Finish Government: Helsinki, Finland, 2008.

44. Land Use and Building Act (132/1999). Construction in the Waterfront Area. 1999. Available online: https://www.kuntaliitto.fi/opas-rakennusjarjestyksen-laatimiseen/6-opas-ja-mallimaarayksia/67-rakentaminen-ranta-alueella (accessed on 28 July 2023).
45. City of Helsinki. *Helsinki-Climate-Change-Adaptation-Policies-2019–2025*; Publications of the Central Administration, no. 43, 2019; City of Helsinki Administration: Helsinki, Finland, 2019.
46. Ministry of Agriculture and Forestry. *Finland's National Climate*; Ministry of Agriculture and Forestry: Helsinki, Finland, 2014.
47. Granqvist, K.; Humer, A.; Mäntysalo, R. Tensions in city-regional spatial planning: The challenge of interpreting layered institutional rules. *Reg. Stud.* **2020**, *55*, 844–856. [CrossRef]
48. Puustinen, S.; Mäntysalo, R.; Jarenko, K. The Varying Interpretations of Public Interest: Making Sense of Finnish Urban Planners' Conceptions. *Curr. Urban Stud.* **2017**, *05*, 82–96. [CrossRef]
49. Finish Government. *Government Decision on Finland's National Land Use Guidelines*; Finish Government: Helsinki, Finland, 2017.
50. Mäntysalo, R.; Kangasoja, J.K.; Kanninen, V. *Framing 'Evidence' and Scenario Stories in Strategic Spatial Planning*; Routledge: Abingdon, UK, 2016; Volume 16, pp. 364–377.
51. Carter, T.R. *Assessing the Adaptive Capacity of the Finnish Environment and Society Under a Changing Climate—Summary for Policy Makers*; European Commission: Brussels, Belgium, 2007.
52. Feranec, J.; Jaffrain, G.; Soukup, T.; Hazeu, G. Determining changes and flows in European landscapes 1990–2000 using CORINE land cover data. *Appl. Geogr.* **2010**, *30*, 19–35. [CrossRef]
53. Robinson, J.B. Futures under glass. *Futures* **1990**, *22*, 820–842. [CrossRef]
54. Wang, Y.; Shen, J.; Yan, W.; Chen, C. Backcasting approach with multi-scenario simulation for assessing effects of land use policy using GeoSOS-FLUS software. *MethodsX* **2019**, *6*, 1384–1397. [CrossRef] [PubMed]
55. Brunner, S.H.; Huber, R.; Grêt-Regamey, A. A backcasting approach for matching regional ecosystem services supply and demand. *Environ. Model. Softw.* **2016**, *75*, 439–458. [CrossRef]
56. Lin, J.; Li, X.; Wen, Y.; He, P. Modeling urban land-use changes using a landscape-driven patch-based cellular automaton (LP-CA). *Cities* **2023**, *132*, 103906. [CrossRef]
57. Zhang, Y.; Kwan, M.-P.; Yang, J. A user-friendly assessment of six commonly used urban growth models. *Comput. Environ. Urban Syst.* **2023**, *104*, 102004. [CrossRef]
58. Mancebo, F. Sustainability Science in the Light of Urban Planning. *Chall. Sustain.* **2017**, *5*, 26–34. [CrossRef]